Yes, Standing Committee
Majority Rule in Non-Democracies*

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Abstract

The Chinese Communist Party (CCP) espouses a principle of collective leadership, in which the Politburo Standing Committee (PSC) makes important decisions by consensus. However, it is not known whether such a majority rule is employed in practice. This paper studies the appointment of party cadres into positions of power as a means of uncovering a general decision-making mechanism within the CCP. We provide reduced-form results showing that appointments are decided by the PSC, who selectively promote candidates in their social networks. This motivates a novel model of collective leadership in which PSC members play a coalition game to promote their preferred candidates. The majority rule is represented by a minimum constraint on the size of winning coalitions. Estimating our model, we show that appointments to positions above the vice-provincial minister level requires support from 75% of the PSC members on average. This cut-off varies depending on the President in power, ranging from 50% under Deng to 80% under Jiang and Hu. Estimating political factions using modularity clustering, we find that factional penalties operate in parallel to the majority rule. Our method can be useful for understanding decision-making in non-democracies more generally.

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1 Introduction

With the world's largest population and second largest economy, China is one of the most important players on the global stage. However, as a non-democracy, political power within the nation is centralized within a small group of elites, with decision-making conducted via a process that is opaque and often informal. The forces that drive policy actions in China have therefore resisted analysis.

This paper studies the appointment of party cadres into positions of power as a means of uncovering a general decision-making mechanism within the Chinese Communist Party (CCP). Given the central role of political elites in China, understanding such a mechanism is an important goal in itself. More critically, however, these appointments serve as rare examples of visible, high-level decision-making that reveals how political incumbents negotiate competing interests. They are therefore an entry point into an otherwise impenetrable process which shapes the global economic and political landscape.

We focus on the careers of Central Committee (CC) members, the highest political body in the CCP, as well as their alternates in the Alternative Committee (AC). The entire AC/CC typically meets only during the National Congress, held once every five years. In addition to their political appointment in the AC/CC, each member also holds a "daily position". These are high-level administrative roles through which the CCP governs and includes titles such as Ministers, Provincial Party Secretaries, up to General Secretary of the CCP. Position assignments, like many other important decisions within the CCP, are decided by the incumbent Politburo Standing Committee (PSC). Although the various positions are under the purview of different PSC members, such decisions are meant to be made jointly, under the banner of collective leadership. Implemented in the post-Mao era, the principle of collective leadership is intended to promote consensus-building and to avoid authoritarian rule[1]. However, deliberation occurs behind closed doors during the National Congress and decisions are presented to the public as enjoying unanimous support (Bo, 2007). It is therefore difficult to establish the extent to which each PSC member influences the process by which party cadres are assigned their daily positions.

To shed light on this process and on decision-making within the CCP more generally, we propose to model daily position assignments as the outcome of a coalitional game between members of the PSC. Our set up is intended to reflect an environment with a collective leadership mechanism, in which members of the AC/CC can be appointed to prestigious positions only if they have support from at least m members of the incumbent PSC. While the AC/CC nominally participates in the assignment of daily positions, it is well-known that political power is concentrated in the hands of the Politburo, a committee of around 20 members (see e.g. Nathan and Gilley 2003). More specifically, it is the Politburo Standing Committee (PSC), an elite group of around 8 members within the Politburo, that makes the most important decisions in China. We therefore focus on the PSC as the players of the game.

[1]One may argue that such consensus could also be reached under authoritarianism. Indeed, the Constitution of the Communist Party of China describes such mechanism as "combines centralism built on the basis of democracy with democracy under centralized guidance."

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In our model, members of the incumbent PSC prefer to appoint candidates connected to them into prestigious positions. However, not all of them are able to decide on all appointments. Instead, we assume that members of the incumbent PSC *randomly* form winning coalitions, which is one with size greater than some majority cut-off, m. Those selected to be part of the winning coalition then coordinate to choose the position of a given AC/CC member[2]. As such, the chosen candidates are the ones who are well connected to the incumbent PSC, so that their appointment benefits the entire coalition. Specifically, each AC/CC member receives a bonus in their position assignment that is proportional to their Katz-Bonacich centrality in the induced sub-network between them and the incumbent PSC. Moreover, the strength of this bonus increases as the cut-off for majority rule decrea ses. Intuitively, there is more scope for patronage when PSC members have to convince fewer of their peers to appoint a given candidate.

We present new empirical findings that support our model. To that end, we obtain biographical data for AC/CC members from the 12th to 19th National Congress. We further construct a social network for them using shared hometown province, college alumni networks and shared work experience. Our reduced-form analyses separately investigate the effect their connections with the PSC (vertical connections) and with other non-Politburo members (horizontal connections). We show vertical connections have a positive and significant effect on the career of AC/CC members, as measured by the prestige of the daily position held and the probability of promotion to the Politburo. Our results are in line with the findings of papers such as Shih et al. (2012); Jia et al. (2015) and Francois et al. (2023) and confirms the role of patronage in our setting. On the other hand, the effects of horizontal connections were less that 1/3 that of the positive effects and were not statistically different from 0 across most of the specifications we considered. Taken together, our empirical results suggest that daily position assignments are decided in a coalitional game between the incumbent PSC members only, in line with our model.

To uncover the precise decision mechanism that determines daily position assignment, we estimate our model structurally. Our results suggest that the incumbent PSC follows a majority rule with an average cut-off of 75%. In other words, AC/CC members are preferentially assigned prestigious positions only when at least 75% of the incumbent PSC support their candidacy. Comparing the cut-off across different Presidents, we find that it is the lowest for Deng, at 50%. Under Jiang and Hu, the cut-off is close to 80%, in line with their image as consensus-builders. Finally, it falls to around 67% under Xi. Our results therefore point to the existence of a collective leadership mechanism, but with strength that varies depending on the President in power.

An important alternative theory views position assignments and promotions as the outcome of factional competition (see Shih et al. (2012) and Francois et al. (2023) among others). However, work in this vein has been hampered by the difficulty of observing faction membership: since the PSC is scrupulous in maintaining a united front, there is no public dissent from which to

[2]The decision-making hierarchy and majority rule in our model is motivated by the Constitution of the CCP. The Constitution outlines the collective leadership as "Individual Party members defer to Party organizations, the minority defers to the majority, lower-level Party organizations defer to higher-level Party organizations, and all organizations and members of the Party defer to the National Congress and the Central Committee of the Party..." This collective leadership mechanism is designed to be both the party's fundamental organizational principle and the application of the mass line in the party's everyday activities after the Cultural Revolution.

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infer allegiances. We explore the role of factions in our setting by estimating membership using modularity clustering. Our recovered clusters appear consistent with conventional wisdom on alliances within the CCP and have out-of-sample predictive power. As an example, for the 19th term of the National Congress, we estimated 3 out of 23 Politburo members to be in Xi's faction. All 3 members we re-appointed in the 20th term, whereas of the remaining 20 members, only 2 were re-appointed. This is without using any data on the 20th term of the National Congress.

Using our estimated clusters, we find that conditional on total connections, candidates in the same faction as members of the incumbent PSC were assigned less prestigious daily positions and were less likely to be promoted to the Politburo. Furthermore, controlling for links between members of the same factions led to more positive estimates on the effect of non-factional connection to the incumbent PSC. Our results suggest that even as the PSC promoted their connections into positions of power, they are constrained by norms of anti-factionalism, which has a long history in the CCP.[3] This leads us towards a more nuanced understanding of position assignment as the outcome of multiple competing forces.

The results in this paper relate directly to the selection of political elites in China. However, we believe that it offers broader lessons for understanding how policy decisions are made in non-democracies. Our analysis reveals that position assignments and promotion are decided by a system in which individuals maximize their personal gains under the explicit constraints of a majority rule, as well as the implicit constraints arising from competing interest groups. It stands to reason that a similar collective leadership decision mechanism is at work in driving other major policy actions of the CCP. Studying position assignments and promotions, via a model-based empirical approach, therefore offers insight into a system that is otherwise opaque and impenetrable.

Our paper speaks to a large literature that studies the internal organization of political elites in China. Recent quantitative work has focused on the role of social connections, including factional alliances, in the selection of political elites. Since connections between politicians are unobserved, these papers construct social networks for politicians based on some combination of shared work experience, hometown and college connections. Using this approach, Jia et al. (2015) and Shih et al. (2012) document career benefits arising from connections with the officials at the level of the PSC, arguing for the role of patronage in driving promotions. On the other hand, Fisman et al. (2020) finds a penalty to being connected with the Politburo, which the authors interpret as evidence of anti-factionalism. These contradictory results find some reconciliation in the work of Francois et al. (2023), in which the authors identified members of four putative factions based on popular accounts. Using a structural model of factional competition, they find evidence that two of the four conjectured factions indeed behaved in a faction-like manner, having selectively promoted their own members. Meanwhile, they engaged in competition with the other, so that in equilibrium, prestigious positions are divided across factions.

Our paper contributes to this literature by separately considering the effects of vertical connections with superiors and horizontal connection with peers, documenting important heterogeneity.

[3]Anti-factionalism is an ideology that is opposes any faction from banding together and, forming "parties within the party", as a way of advancing their agenda and position, to the detriment of the CCP. Anti-factionalism was written into the Communist Party's constitution during the Seventh National Congress in June 11, 1945.

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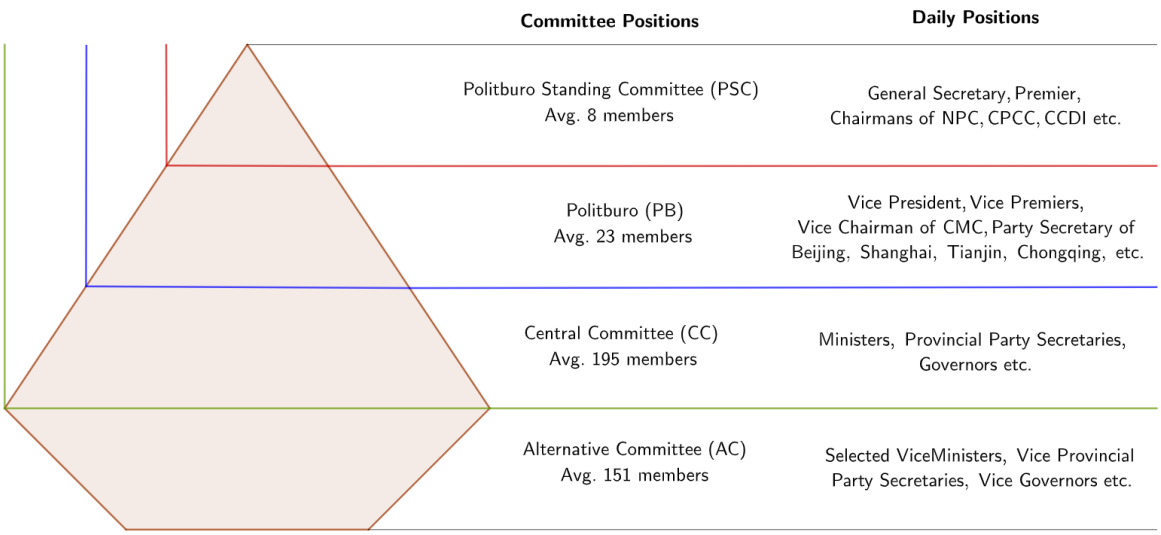


Figure 1: Position assignments structure inside the Central Committee

To our knowledge, we are also the first to estimate factions within the CCP, in contrast to earlier papers which have identified them in a more ad-hoc manner. Using our estimated factions, we find that patronage and anti-factionalism operate simultaneously. This suggests that the seeming contradiction between Fisman et al. (2020) and Jia et al. (2015) and Shih et al. (2012) can potentially be understood as a measurement issue that can be resolved with more accurate observations of faction memberships.

Conceptually, we locate our paper within the literature on collective action and decision-making in non-democracies. Olson Jr (1965)'s seminal work underscores the challenges of coordinating group efforts in the face of diverse interests, which are often exacerbated in non-transparent environments. Austen-Smith and Banks (1996), which studies informational aggregation in voting, suggests that the way information is processed and decisions are made can significantly affect the quality of outcomes. In non-transparent committees, such as the PSC of the CCP, the flow of information is often restricted, which can impede effective decision-making. While theoretical analysis raises concerns about the practice of collective decision-making in China, the issue has resisted quantitative analysis since these processes are largely hidden from public view. Our contribution here is to propose an approach by which observed decisions (e.g. position assignments) can be combined with revealed incentives (e.g. in-group favoritism as proxied by social networks) to infer a decision-making mechanism. We believe that the approach can be applied to uncover the workings of the CCP on other issues, as well as on other non-democracies more generally.

The remainder of this paper is organized as follows: Section 2 presents the relevant institutional details. Section 3 presents data and reduced form estimation results. Section 4 presents the model of position assignment behavior and the coalitional game when proposing the candidates' appointment. Section 5 defines the econometric specification of the model, discusses the estimation method and results. Section 6 presents the factions obtained via modularity clustering and the associated empirical results. Section 7 concludes.

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2 Institutional Background

Hierarchy in the Central Committee

The Central Committee is the highest organ of the Chinese Communist Party, tasked with setting the course of government policies. The committee has a clear hierarchical structure, which is presened in Figure 1. While its exact composition has fluctuated over time, the Central Committee has had on average over 220 full members and 150 alternate members. Throughout this paper, we refer to them as CC and AC members respectively. AC members serve as the pool from which replacements are drawn when CC members leave their positions during the term, whether due to corruption allegations, health, or other reasons. AC members participate fully in the proceedings of the committee, with the exception that they lack voting rights. The AC/CC members are led by the Politburo (PB), a select group numbering around 25. Within the PB is the Politburo Standing Committee (PSC), an even more elite group of around 8 members. Whereas the power of the PSC has waxed and waned over the course of history, it has retained its position as the supreme decision-making body of the CCP since the 1980s.

In addition to their committee positions, each AC/CC member also holds a *daily position* in one of four bureaucratic domains: (1) the CCP, (2) the People's Liberation Army, (3) the Central Government, or (4) the Local Government (Jia and Xu, 2019). For example, the PSC members work as the General Secretary, Premier, and Chairman of National People's Congress (NPC), Chinese People's Political Consultative Conference (CPPCC), and Central Commission for Discipline Inspection (CCDI) when the National Congress is not in session. Daily positions are therefore powerful administrative roles through which actual governance takes place.

Promotions and Appointments

According to the Constitution of the CCP, AC/CC members are elected by the National Congress. Convened once every five years, the National Congress is a body of over 2000 CCP members, selected to represent workers from a broad range of careers, including politicians, commanders, scholars, and entrepreneurs. To be elected as an AC/CC member, a candidate must be nominated by the Politburo. A confirmation vote then takes place during the National Congress, in which attendees can vote for, against or abstain on each candidate. Similarly, to be elected into the Politburo or the PSC, a candidate has to be nominated by the incumbent PSC committee. Whereas there are approximately 10% more nominees than there are seats for the CC, there are exactly as many nominees as there are seats in the Politburo and the PSC. As such, passing the nomination process controlled by the incumbent PSC is the main hurdle for promotion to the Politburo and the PSC.

Whereas the PSC had de facto but not de jure control over promotion to the Politburo, the Constitution of the CCP gives it direct control over the daily positions. In principle, each member of the PSC has specific positions under their purview, depending on their role within the committee.

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For example, the Constitution stipulates that the Congress chooses Vice Premiers, State Councilors and Ministers based on the recommendations of the Premier. Similarly, the Chairperson of the Central Military Commission is responsible for nominating the other members of the Central Military Commission. Note that the Chairman of the National People's Congress, the Premier and the Chairperson of the Central Military Commission are members of the PSC. In practice, however, these decisions are likely the outcomes of negotiations between the entire PSC (Shirk, 1993).

Decision-Making within the PSC

Nominally, decision-making within the CCP follows the principle of *collective leadership*. Implemented by Deng Xiaoping as a response to the cult-of-personality that surrounded Mao Zedong, collective leadership requires the PSC to make decisions by consensus (see e.g. McGregor 2010). Under such a system, the opinions of all incumbent PSC members would carry equal weight in assigning daily positions or Politburo membership. Indeed, when the previous CCP General Secretary (1989-2002), Jiang Zemin, was accused by CBS journalist Mike Wallace of being a dictator, he replied that the "Politburo has a Standing Committee, [of] which I am a member. No decisions are made unless all members agree." In practice, however, the real decision-making mechanism is unobserved. The Politburo is believed to meet weekly to discuss major issues, but deliberations are kept private. Any major decisions are announced to the public as enjoying unanimous support so that it is difficult to infer the existence of dissent within the PSC. Given the opaque nature of the deliberations process, it is therefore difficult to know the extent to which a majority rule is actually applied (Shirk, 1993).

3 Data and Reduced-Form Results

We collect biographical data for all AC/CC members after the Cultural Revolution (from the 12th Congress in 1982 to the 19th Congress 2017). The data includes information on the political elites' gender, birth province, year of birth, ethnicity, education level, college, college major, graduate school, graduate school major, princeling status. We also obtain the career paths of these elites as recorded on the CVs (including both committee and daily positions), as well as their private-sector experience and military experience. This data comes from the career code book created by Shih et al. (2012), which we have updated, following Lu and Ma (2017), to the 19th Congress.

We measure the prestige of a committee members' daily position using the Position Rank, `posRank+` of Jia and Xu (2019).[4] Based on the the idea that most AC/CC members move up in their career paths over time, `posRank+` applies a machine learning algorithm to the career trajectories of 1,598 CC members to learn the vertical ordering of 4,183 positions across 4 different bureaucratic domains in the CCP. Positions are ranked from 0 to 16 with larger numbers representing more prestigious positions with better promotion opportunity to top leadership roles.

[4]The data is presented in Table A.1. of Jia and Xu (2019). Given it measures the provincial-ministerial above-level positions, we truncate the rest of members' position as the bottom tier.

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To construct the network, G, we define two AC/CC members i and j to be linked – that is, $G_{ij} = 1$ – if they either: (1) graduated from the same college within 5 years of each other (alumni connection); (2) were born in the same province (hometown connection), or; (3) worked in the same province or ministry in the same year prior to their appointment to the AC/CC (overlapping work experience). Our definitions for the types of connections are similar to that of Fisman et al. (2020), except their hometown connection is defined at the city level, whereas ours is at the state level. Furthermore, We exclude the Central Party School and the National Defense University in constructing alumni connections. This is because candidates are usually (endogenously) admitted in these schools in anticipation of future promotion. To better reflect promotion pathways for under a military career, we also treat the Vice Chairmen of the Central Military Commission as PSC members. Figure 3 plots the network of AC/CC members in various terms. Candidates who were promoted to the PSC are highlighted in red. Looking at their networks, we see that Politburo members who are most likely to be promoted are not necessarily well-connected throughout the entire Congress, but are very well-connected among the incumbent PSC.

In the rest of this section, for an election happening in Congress t, a candidate is a politician who is an AC or CC member in Congress $t-1$. The incumbent PSC members are members of the PSC in Congress $t-1$. By this definition, for example, Xi only served as the incumbent General Secretary during the 19th Congress even though he was General Secretary in both the 18th and 19th Congress. Summary statistics for key variables are presented in Table 1.

In Congress t, we define the vertical network of candidate i to be the network comprising all members of the incumbent PSC together with i. Denote the corresponding adjacency matrix G^V_{it}. Similarly, define the horizontal network of candidate i to be the network comprising all other AC/CC members, excluding those in the Politburo and above. Denote the corresponding adjacency matrix G^H_{it}.

We use a within-group identification strategy to estimate the impact of vertical and horizontal social connections on job assignments. That is, we estimate

$$R_{itcp} = \Phi \cdot \zeta(G^V_{it}) + \phi \cdot \zeta(G^H_{it}) + \beta' \mathbf{X}_{itcp} + \gamma_t + \gamma_c + \gamma_p + \epsilon_{itcp} \tag{1}$$

where R_{itcp} is some career outcome for candidate i in Congress t, from college c and who was born in province p. For specifications on Promotion to Politburo, R_{itcp} is a dummy variable which equals one if the candidate is promoted to the PB. For specifications on Daily Positions, R_{itcp} is rank of a candidate's daily position assignment, as measured by `posRank+`. The function $\zeta(\cdot)$ denotes a centrality measure, including degree, closeness, betweenness, and eigenvector centralities. $\mathbf{X}_{itcp}$ is a vector of individual controls, including gender, age at Congress t, education level, and dummy variables for princeling status, provincial party secretaries, governors and military leaders. γ_t, γ_c and γ_p are Congress, college, and birth province fixed effects respectively which capture unobservables for the specific groups. For example, college fixed effects could capture the candidates' intelligence, while hometown fixed effects could capture the hometown-favoritism, which is commonly noted in the literature. Finally, ϵ_{itcp} is the error term.

Table 2 presents the effects of a candidate's eigenvector centrality – as defined using their vertical and horizontal networks – on their promotion probability and daily position assignment. Columns

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(1) to (4) show that eigenvector centrality in the vertical network has a positive and significant effect on the probability of promotion to the Politburo. Changing from a linear probability model to a Probit does not affect the result. On the other hand, the effect of horizontal connection is not statistically different from 0 under the OLS specification in column (2), although it is negative and significant under the Probit specification in column (4). Columns (5) to (8) show that vertical eigenvector centrality has a significant positive effect on the daily position of a candidate, whereas horizontal connections are not statistically different from 0 across specifications. Tables 3 and 4 show that they are similarly robust to the choice of centrality measure.

Our results on the benefits of vertical connections concord with Shih et al. (2012), Jia et al. (2015) and Francois et al. (2023). In contrast, Fisman et al. (2020) finds that that connections to the Politburo lowers the probability of a candidate's promotion. The authors suggest several explanations for the connection penalty, one of which being intra-group competition. Here, members of the Politburo oppose the promotion of candidates with similar backgrounds to themselves to avoid inadvertently grooming their own replacements. In our specifications, connections are defined with respect to the PSC, while the candidates are at a level strictly below that of the Politburo. The difference in seniority between the candidates and the PSC implies that they are unlikely to have to compete for the same positions. We therefore attribute at least part of the difference in results to our specifications being better at isolating the patronage channel. Fisman et al. (2020) also argue that the negative effects is due to anti-factionalism within the CCP. We investigate this theory in Section 6. Turning to horizontal connections, our estimates suggest that they are not relevant for determining daily position and promotion. In particular, horizontal connections have effects that are not statistically different from 0 across all specifications, except in column (4) of Table 2. We therefore interpret the latter as the statistical fluke. Taken together, the results in this section motivate a coalitional game for understanding daily position assignments, in which the key players are members of the PSC.

4 A Model of Collective Leadership

This section presents a coalitional game by which members of the PSC decide the appointments of the AC/CC members.

4.1 Setup

Suppose there are $|N|$ politicians in a Congress and let their indices be $N = \{1, \dots, |N|\}$. Call the incumbent PSC members Tier I agents and denote their indices by N^{I}. Analogously, call the appointed AC/CC members Tier II agents and denote their indices by N^{II} agents. Then $N = N^{\mathrm{I}} \cup N^{\mathrm{II}}$ and $N^{\mathrm{I}} \cap N^{\mathrm{II}} = \emptyset$. We will refer to social connections between agents of the same tier as horizontal connections, and those between agents of different tiers as vertical connections.

Consider a two-stage model that proceeds as follows. In the first stage, Tier I agents choose

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Figure 2: Timeline of the model

the position assignments of the Tier II agents. This is decided in a coalition game. In the second stage, both Tier I and II agents then choose effort to maximize their own prestige. The timeline can be found in Figure 2. We first describe the structure of prestige, before discussing stages 2 and 1 respectively.

Prestige

The prestige of agent i, R_i, refers to their career potential. The greater the probability that i has of obtaining a top leadership positions in the CCP, the greater their prestige. We assume that R_i is an increasing function of the effort directly exerted by i, denoted E_i, as well as their social connection, denoted S_i. In particular, suppose it takes the form of a Cobb-Douglas function:

$$R_i = \varphi S_i^{\alpha} E_i^{1-\alpha} + \xi_i \ . \tag{2}$$

Furthermore, let S_i be:

$$S_i = \begin{cases} \eta \cdot \sum_{j \in N^{\mathrm{I}}} G_{ij} \cdot R_j \quad + \quad \sum_{j \in N^{\mathrm{II}}} G_{ij} \cdot R_j & \text{if } i \in N^{\mathrm{I}} \\ \sum_{j \in N^{\mathrm{I}}} G_{ij} \cdot R_j \quad + \quad \eta \cdot \sum_{j \in N^{\mathrm{II}}} G_{ij} \cdot R_j, & \text{if } i \in N^{\mathrm{II}} \end{cases} . \tag{3}$$

Recall that G_{ij} is the exogenous social connection between agents i and j. We standardize $\sum_{j \neq i}^{|N|} G_{ij} = 1$ and set $G_{ii} = 0$, so that the social connection of an agent is the weighted average of their friends' job prestige. η reflects the potentially heterogeneous contributions from vertical and horizontal connections.

All other characteristics of an agent that may affect R_i is subsumed under the ξ_i, which is assumed to take the form:

$$\xi_i = \beta' \mathbf{X}_i + D_i \mathbb{1}\{i \in N^{\mathrm{II}}\} \ .$$

Here $\mathbf{X}_i$ is a vector of i's fixed characteristics, such as gender, age and education attainment. They enter R_i independently of E_i and S_i.

Importantly, for Tier II agents, ξ_i also includes the position assignment D_i, which is the result of deliberation by Tier I agent. A high position assignment boosts the prestige of each Tier II agents, all else constant. This reflects the idea that Tier I agents can help fast-track the careers of Tier II agents by appointing them to positions of prominence and influence.

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Stage 2: Effort Choice

At the start of stage 2, each agent $i \in N$ takes S_i and ξ_i as given and chooses effort to solve:

$$\max_{E_i \geq 0} R_i - cE_i \ , \tag{4}$$

where c is unit cost of effort. Agents make their decisions simultaneously. We model social connections and effort as being complements. That is, agents with better connections have higher returns to effort in terms of career outcomes. This may be because they are less likely to be ousted by political opponents (e.g. in Jia et al. 2015), or because their performance are more likely to be noticed and rewarded.

Stage 1: Position Assignments

Tier I agents are forward-looking. Given the game in Stage 2, they choose the Tier II candidates' position assignments in order to maximize the utility of their coalition. Assigning a Tier II agent to a prestigious position yields more benefits to the coalition when they are well-connected. We therefore assume that Tier I agents choose D_i by solving the following coalitional game:

$$D_i^* = \arg\max_{D_i} \sum_{\substack{\tilde{N} \subseteq N^{\mathrm{I}}, \\ |\tilde{N}| \geq m}} \left[\frac{|\tilde{N}|!(|N^{\mathrm{I}}| - |\tilde{N}|)!}{|N^{\mathrm{I}}|!} (T(\tilde{N} \cup i) - T(\tilde{N})) \right] - \frac{D_i^2}{2} \tag{5}$$

Here, $\tilde{N}$ is a wining coalition that contains at least m Tier I agents. This reflects the idea members of the PSC can assign a prestigious position to an AC/CC member only if at least m of their peers agree. Such a majority rule is the defining feature of our model. We assume that the winning coalitions are formed *randomly*, so that the probability of a given $\tilde{N}$ is given by $P(\tilde{N}) = \frac{|\tilde{N}|!(|N^{\mathrm{I}}|-|\tilde{N}|)!}{|N^{\mathrm{I}}|!}$. Note that $P(\tilde{N})$ is constant across agents within the same congress, because the incumbent PSC members N^{I} and majority rule m, are fixed across all candidates within each Congress. The cost to an incumbent member of increasing their support for promoting candidate i is quadratic. We have assumed the coefficient for D_i^2 above is $\frac{1}{2}$. As will become clear in the discussion after equation (9), parameters in this model are identified up to scale. This normalization is therefore without loss of generality.

The function $T(\cdot)$ is the sum of the utility of all members inside a given coalition. Specifically, $T(\tilde{N} \cup i) = \sum_{j \in \tilde{N}} R_j(\tilde{N} \cup i)$ and $T(\tilde{N}) = \sum_{j \in \tilde{N}} R_j(\tilde{N})$, where $R_j(\tilde{N} \cup i)$ and $R_j(\tilde{N})$ indicates whether candidate i is included in the $\tilde{N}$ coalition through network connections. Recall that the group decision, D_i, is an element of ξ_i inside R_i, and R_i enters the function R_j through social connection S_j. This representation captures both direct and indirect connection benefits through the network.

The game characterized by equation (5) is distinguished from classical coalitional games involving Shapley values by two main features. Firstly, the only players in our game are Tier I agents. A Tier II candidate i enters the game through the Tier I players' utility function without any strategic

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behavior. Our model therefore captures the power hierarchy within the CCP in the sense that the lower-tiered agents do not enter the decision process for their own promotion.

More importantly, the classical games typically do not require a minimum coalition size, so that even a single player could be a coalition. Following the idea of Shapley and Shubik (1954), our model, on the other hand, imposes a majority rule, in which decisions require the cooperation of at least m members. This is important for understanding position assignments and promotions since majority rule is a key organizing principle within the CCP, at least in name. Indeed, following the Cultural Revolution, Deng's program of "Boluan Fanzheng" is meant to promote consensus building within the PSC, expressly forbidding the cults of personalities that characterized the Mao-Era. This is formalized in the Constitution of the CCP, which requires that "the minority defers to the majority". However, the extent to which high-level decisions are taken by consensus is unclear since the process of deliberation is completely hidden from public view. A model which explicity features a majority rule is therefore important for empirically unpacking the decision-making process, as will become clear in Section 5.

4.2 Equilibrium analysis

In this subsection, we use backward induction to solve the model. Starting with stage 2, we have the following proposition:

Proposition 1. For $[\frac{\varphi}{c}(1-\alpha)]^{\frac{1}{\alpha}} > 0$, the optimal working effort $E^* = (E_i^*)_{i\in N}$ is proportional to agents' social connection $S = (S_i)_{i\in N}$.

The proposition follows straightforwardly from solving the Stage 2 maximization problem in (4). The optimal working effort $E_i^* = [\frac{\varphi}{c}(1-\alpha)]^{\frac{1}{\alpha}} S_i$. Under standard assumptions about the Cobb-Douglas parameters, $[\frac{\varphi}{c}(1-\alpha)]^{\frac{1}{\alpha}} > 0$. Optimal working effort is therefore proportional to agents' connectedness. This coincides with the empirical evidence in Jia et al. (2015) which shows that connections and performance in office are complements in the Chinese political selection process.

Next, let the benefit coefficient of horizontal connections, $\phi_v = \varphi^{\frac{1}{\alpha}}[\frac{(1-\alpha)}{c}]^{\frac{1-\alpha}{\alpha}}$, and the benefit coefficient of vertical connections, $\phi_h = \eta\phi_v$. Given Proposition 1, we can rewrite R_i as

$$R_i = \begin{cases} \phi_h \sum_{j\in N^{\mathrm{I}}} G_{ij}\cdot R_j + \phi_v \sum_{j\in N^{\mathrm{II}}} G_{ij}\cdot R_j + \xi_i & \text{if } i \in N^{\mathrm{I}} \\ \phi_v \sum_{j\in N^{\mathrm{I}}} G_{ij}\cdot R_j + \phi_h \sum_{j\in N^{\mathrm{II}}} G_{ij}\cdot R_j + \xi_i, & \text{if } i \in N^{\mathrm{II}} \end{cases} \tag{6}$$

We now return to stage 1. Given characterizations of R_i above, the aggregate utility of winning

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coalition $\tilde{N}$ is

$$\begin{aligned} T(\tilde{N} \cup i) &= \sum\nolimits_{j \in \tilde{N}} R_j(\tilde{N} \cup i) \\ &= \sum\nolimits_{j \in \tilde{N}} [\phi_h \cdot \sum\nolimits_{i' \in N^{\mathrm{I}}} G_{i'j} \cdot R_{i'} + \phi_v \cdot G_{ij} \cdot R_i + \xi_j] \qquad (7) \\ T(\tilde{N}) &= \sum\nolimits_{j \in \tilde{N}} R_j(\tilde{N}) \\ &= \sum\nolimits_{j \in \tilde{N}} [\phi_h \cdot \sum\nolimits_{i' \in N^{\mathrm{I}}} G_{i'j} \cdot R_{i'} + \xi_j] \qquad (8) \end{aligned}$$

Note that the utility for the winning coalition has two parts. The first is the contribution from members of $\tilde{N}$ itself. This depends only on the horizontal connections among the coalition members $\phi_h \cdot \sum_{i' \in N^{\mathrm{I}}} G_{i'j} \cdot R_{i'}$ plus their characteristics, $\xi_j = \beta' \mathbf{X}_j$. It does not depend on the candidate i. The second term, which is the Tier II agent's marginal contribution to a winning coalition simply their vertical connections to such a coalition, weighted by their position assignment R_i with benefit coefficient ϕ_v.

Given equations (6), (7) and (8), we can rewrite the collective optimization problem for Tier I agents in (4), as:

$$D_i^* = arg \max_{D_i} \sum\nolimits_{\tilde{N} \subseteq N^{\mathrm{I}}, |\tilde{N}| \geq m} P(\tilde{N}) \left[\sum\nolimits_{j \in \tilde{N}} \phi_v \cdot G_{ij} \cdot R_i \right] - \frac{D_i^2}{2} \qquad (9)$$

Denote the weakest vertical connections $\underline{G}^V = min_{i \in N^{\mathrm{II}}} \sum_{j \in N^{\mathrm{I}}} (G_{ij})$, the highest deliberated position assignment $\overline{D} = max_{i \in N^{\mathrm{II}}} D_i$, and overall coalition formation probability $\gamma = \sum_{\tilde{N} \subseteq N^{\mathrm{I}}, |\tilde{N}| \geq m} P(\tilde{N})$[5]. We further assume that the deliberated position assignments is bound above at $\overline{D} < \gamma \phi_v \underline{G}$. Observe that ϕ_v pre-multiplies the first term in the equation above. A model with quadratic cost $cD_i^2/2$ will therefore have the same D_i^* once we re-scale ϕ_v. That is, our parameters are identified only up to scale. It is therefore without loss of generality to set $c = 1$ and to interpret ϕ_v as the value of vertical connections relative to the cost of position assignments.

Solving for the optimal collective decision yields:

$$\begin{aligned} D_i^* &= \sum\nolimits_{\tilde{N} \subseteq N^{\mathrm{I}}, |\tilde{N}| \geq m} P(\tilde{N}) [\sum\nolimits_{j \in \tilde{N}} \phi_v \cdot G_{ij}] \qquad (10) \\ &= \gamma \cdot \phi_v \cdot |G_i^V| \,, \qquad (11) \end{aligned}$$

where the above display is the first-order condition characterizing the unique solution to (9). We collect the above discussion into the following result:

Proposition 2. For any majority rule $\frac{|N^{\mathrm{I}}|}{2} \leq m < |N^{\mathrm{I}}|$, there is a unique equilibrium in which the Central Committee member's prestige is equal to

$$R_i^*(\phi_v, \phi_h, G_i, \xi_i) = (\mathbf{I} - \phi_v G_i^V - \phi_h G_i^H)^{-1} \xi_i \,,$$

[5]Following the binominal coefficient of the Pascal's triangle, we can rewrite γ as:

$$\gamma = \sum\nolimits_{\tilde{N} \subseteq N^{\mathrm{I}}, |\tilde{N}| \geq m} P(\tilde{N}) = \frac{\sum_{|\tilde{N}|=m}^{|N^{\mathrm{I}}|} [|\tilde{N}|!(|N^{\mathrm{I}}| - |\tilde{N}|)!]^{-1}}{\sum_{|\tilde{N}|=1}^{|N^{\mathrm{I}}|} [|\tilde{N}|!(|N^{\mathrm{I}}| - |\tilde{N}|)!]^{-1}}$$

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which is the weighted Katz-Bonacich centrality of politican i in network G_i with discount factor ϕ_v, ϕ_h and weights $\xi_i^* = (\xi_1, ..., \xi_{|N|})'$. $\xi_i^* = \beta' \mathbf{X}_i + D_i \mathbb{1}\{i \in N^{\text{II}}\}$ and the optimal position assignments are $D^* = (D_i^*)_{i \in N^{\text{II}}}$.

Proof: See discussion above. ■

Our model has the novel and distinguishing feature that AC/CC members choose their optimal working effort E_i taking given rational expectations aboutthe other agents' effort and positions assignments. In turn, Tier I agents choose position assignments taking optimal working effort E_i as given. Our approach is similar to that in general equilibrium theory, where consumers choose their optimal consumption taking prices as given: here AC/CC members choose their levels of effort taking the position assignments and effort as given. The equilibrium levels of prestige are endogenous since they must satisfy the externality equation in (2) given the optimal effort levels – just as general equilibrium models have endogenous prices that must adjust to clear the market. This equilibrium concept is formally defined as a network competitive equilibrium in Battaglini et al. (2019).

Corollary 1. As the majority rule $m > \frac{|N^{\text{I}}|}{2}$ increases to $|N^I|$ (unanimity), the marginal connection benefits to an additional incumbent PSC decreases (competition among PSC on promoting their own faction members increases).

Proof: Let us consider $D_i^* = \gamma \cdot \phi_v \cdot |G_i^V|$ as the connection benefits of being nominated by the incumbent PSC and ϕ_h as treat constant. As the majority cut-off m increases $|N^I|/2$ to $|N^I|$, the probability that any given incumbent PSC will be included in the randomly formed winning coalition increases. Consequently, the expected overall benefits of connections increase. That is, γ is a monotonic increasing function of m. However, the marginal connection benefits to an additional incumbent PSC decreases. It can be shown that, after m surpasses half of the incumbent PSC, the marginal connection benefits, denoted $\Delta\gamma(m) = \gamma(m+1) - \gamma(m)$, shrinks. ■

Since its implementation in the post-Mao era, the collective leadership mechanism has encouraged the PSC to rule by consensus. Intuitively, under a dictatorship, m is small. The benefit of being connected to a PSC member other than the dictator is low since such connections are marginal to decision making. On the other hand, if m is close to $|N^I|$ (such as a collective leadership mechanism with a unanimous decision rule), connection to an additional PSC member yields less benefit since the additional member is less likely to be pivotal in the coalition game.

5 Structural estimation

This section presents results from structural estimation based on the model in Section 4.

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For a given Congress t, we write equation (6) in matrix form:

$$\begin{aligned} \mathbf{R}_t &= (\phi_v \psi G_t^V + \phi_h \psi G_t^H)\mathbf{R}_t + \xi_t \\ \Rightarrow \mathbf{R}_t &= (1 - \phi_v \psi G_t^V - \phi_h \psi G_t^H)^{-1} \xi_t \end{aligned} \tag{12}$$

Here, $\mathbf{R}_t$ is the prestige of the AC/CC members' daily position assignments, as measured by `posRank+`. G_t^V is the vertical adjacency matrix and G_t^H is the horizontal adjacency matrix[6]. $\xi_t = \mathbf{X}_t\beta + \epsilon_t$, where $\epsilon_t = D_i \mathbb{1}\{i \in N^{\text{II}}\} + \epsilon_t'$ contains the incumbent SC's deliberation result D_i for Tier II candidate i. $\mathbf{X}_t$ is the matrix with individual controls including gender, age at the time of Congress$_t$, education level, and dummy variables for princelings, provincial party sectaries, governors and military leaders, plus a set of fixed effects. Other candidate characteristics that have an impact on the promotion, which are observed by the politicians but not by the econometrician, are captured by ϵ_t'.

We propose two ways to estimate equation (12) above. The first uses dense-network asymptotics to justify OLS. The second implements non-linear least squares to deal with the endogeneity that arises when networks are sparse.

Suppose networks are dense, so that the degrees of all agents are of order n. As Table 8 shows, mean degrees are approximately 10% of Congress sizes across all t's, so that such an assumption is plausible. This yields the orthogonality condition $\mathbb{E}[(\sum_{j\neq i} G_{ijt} R_{jt})\epsilon_{it}] = 0$ so that we can estimate the following equation by naive OLS:

$$\mathbf{R}_t = \phi_v G_t^V \mathbf{R}_t + \phi_h G_t^H \mathbf{R}_t + \mathbf{X}_t\beta + \epsilon_t \tag{13}$$

Results are presented in Columns (1) - (5) of Table 5. Columns (1) and (2) show there are connection benefits inside the Central Committee in general when pooling across vertical and horizontal networks. When separately considering their effects, Columns (3) and (4) show that the connection benefits to incumbent members of the PSC are roughly three times higher than those of peer connections. Column (5) suggests limited heterogeneity among connection benefits for Tier I or Tier II agents, i.e., the heterogeneous coefficients ϕ_h and ϕ_v for Tier I and II agents are statistically insignificant. Interestingly, the horizontal network connection benefits are positive, which we do not capture using the centrality measures in Section 3.

However, we might be concerned about the reliability of the dense network approximation. When networks are sparse, the condition that $\mathbb{E}[(\sum_{j\neq i} G_{ijt} R_{jt})\epsilon_{it}] = 0$ may not hold. This is because R_{it} contains ϵ_{it}, which is itself an element of R_{jt}. Under large network asymptotics, each ϵ_{it} is a vanishing fraction of R_{jt}, so that violation of the moment condition is asymptotically negligible. Under sparse network asymptotics, however, the violation can be large even in the limit, so that OLS is invalid. Instead, we turn to NLLSE (or MLE) to estimate equation (3). Assuming

[6]Specifically, in Congress t, the full adjacency matrix is G_t:

$$G_t = \begin{pmatrix} G_t^{|N^{\text{I}}|\times|N^{\text{I}}|} & G_t^{|N^{\text{I}}|\times|N^{\text{II}}|} \\ G_t^{|N^{\text{II}}|\times|N^{\text{I}}|} & G_t^{|N^{\text{II}}|\times|N^{\text{II}}|} \end{pmatrix} = \begin{pmatrix} \mathbf{0}_t^{|N^{\text{I}}|\times|N^{\text{I}}|} & G_t^{|N^{\text{I}}|\times|N^{\text{II}}|} \\ G_t^{|N^{\text{II}}|\times|N^{\text{I}}|} & \mathbf{0}_t^{|N^{\text{II}}|\times|N^{\text{II}}|} \end{pmatrix} + \begin{pmatrix} G_t^{|N^{\text{I}}|\times|N^{\text{I}}|} & \mathbf{0}_t^{|N^{\text{I}}|\times|N^{\text{II}}|} \\ \mathbf{0}_t^{|N^{\text{II}}|\times|N^{\text{I}}|} & G_t^{|N^{\text{II}}|\times|N^{\text{II}}|} \end{pmatrix} = G_t^V + G_t^H$$

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$\xi_t = \mathbf{X}_t\beta + \epsilon_t$, $\epsilon_t \sim N(0, \sigma^2_{\epsilon t})$ is i.i.d., we can write equation (3) as

$$\mathbf{R}_t = (\mathbf{I} - \phi_v G^V_t - \phi_h G^H_t)^{-1}(\mathbf{X}_t\beta + \epsilon_t) \tag{14}$$

Now, $\mathbf{b}_t(\phi_v, \phi_h, G^V_t, G^H_t) = (\mathbf{I} - \phi_v G^V_t - \phi_h G^H_t)^{-1}(\mathbf{X}_t\beta + \epsilon_t)$ is the Katz-Bonacich centrality of the agents with vertical and horizontal connections. Results using the NLLS estimation approach are presented in columns (6) - (7) of Table 5.[7] Comparing columns (1) and (6), we see the general connection benefit shrink but remain positive and significant. Comparing columns (3), (4) and (6) we see that estimates under naive OLS and NLLSE are very close, in terms of both magnitude and significance. This suggests that large network asymptotics may be appropriate in this context. Both sets of estimates find that the vertical connection benefit with PSC incumbents is roughly three times higher than the horizontal connection benefit to peer CC and AC members.

Table 6 presents the estimation results for Katz-Bonacich centrality on daily position assignments for each presidency since 1982. The returns from vertical connections consistently remain positive and significant across the seven congresses. However, the returns from horizontal connections are variable, with a negative sign or statistical insignificance during Deng and Jiang's era. This suggests that the horizontal connection with the peer Central Committee members could jeopardize a candidate's appointment to a prestigious daily position. The gap between vertical and horizontal connection benefits has widened in the most recent congressional terms under Hu and Xi's presidencies.

We showed in equation (10) that the optimal position assignment is $D^*_i = \gamma \cdot \phi_v \cdot |G^V_i|$. Substituting this expression into the Tier II candidate i's residual term, we have that

$$\begin{aligned} \epsilon^{\text{II}}_i &= D_i + \epsilon'^{\text{II}}_i \\ &= \Theta|G^V_t| + \epsilon^{\text{II}\prime}_t \end{aligned} \tag{15}$$

where $\Theta = \gamma \cdot \phi_v$. Given our estimates ϕ_v, the size of incumbent Standing Committee $|N^{\text{I}}|$, as well as the 1:1 relationship between the majority rule m and probability coefficient γ, we are able to estimate the closest majority rule cutoff m and obtain its confidence interval using the above equation.

Table 7 presents the estimated majority cutoff in deliberating the daily position appointments of the AC/CC members. The square brackets in the last column presents the estimated cut-off evaluated at one standard deviation of ϕ_v and Θ. Our results suggest that since the post-Mao era, the members of the PSC have employed a majority rule with an increasing cut-off when deciding the appointments at the level of vice-provincial-minister and above. The estimated cut-offs are relatively lower during Deng's presidency (at about 50%), when the country had only just implemented the collective leadership mechanism. The cut-off increased to 80% during Jiang and Hu's presidency, consistent with their image as consensus-builders. However, it has fallen back to 67% during Xi's

[7] Our NLLS estimation specifically uses the Levenberg-Marquardt algorithm implemented by Box et al. (1969) in the R package `minpack.lm` developed by Elzhov et al. (2022), and the R package `econet` developed by Battaglini et al. (2022). NLLS estimation yields the estimated residual term $u_t = (\mathbf{I} - \phi_v G^V_t - \phi_h G^H_t)^{-1}\epsilon_t$. We construct ϵ_t by using this expression and the estimated parameters.

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first term as the incumbent General Secretary, which is below the average of the entire sample period of 75%.

Taken together, our results shows that the CCP in fact makes decision via collective leadership, though the degree to which it is implemented varies according to the president in power. Intuitively, we were able to infer the majority rule cut-off by examining how the networks of AC/CC members varied with their probability of receiving a prestigious daily positions. At a high-level, our approach connects observed decisions (e.g. position assignments) with revealed incentives (e.g. in-group favoritism as proxied by social networks) to infer a decision-making mechanism. We believe that the approach can be applied to uncover the workings of the CCP on other issues, as well as on other non-democracies more generally.

6 Factional Politics

Our reduced-form and structural estimation results show that connections to the Politburo Standing Committee are beneficial for promotion and daily position assignments. This stands in apparent contrast to the existing literature which finds strong evidence of anti-factionalism (see e.g. Fisman et al. 2020; Francois et al. 2023). In this section, we investigate the role of factional politics in affecting promotion. Section 6.1 discusses the use of modularity clustering for estimating faction. Section 6.2 presents empirical results.

6.1 Estimating Faction

Factional politics is widely considered to play a pivotal role in the selection of political elites in China. However, little is known about their membership structure, due in part to strong norms against perceived factionalism that began with Mao. Papers such as Francois et al. (2023) therefore study conjectured factions with memberships that are defined based on historical or narrative evidence. Using our network data, we instead attempt to construct factions based on modularity clustering.

Modularity clustering estimates faction memberships in a degree-corrected stochastic block model (DCSBM). A formal discussion of the relevant statistical theory can be found in Appendix B.1. Intuitively, agents in a DCSBM have two characteristics: faction membership and gregariousness. Agents are more likely to form links with others in same faction. On the other hand, gregarious agents form more links with all other agents, regardless of their factions. Modularity clustering is known to recover factional membership in a DCSBM as long as the network is not too sparse. Minimizing the modularity clustering objective function is NP-hard. Instead, we turn to the Leiden Algorithm of Traag et al. (2019), which is known to perform well in practice. Details of the algorithm are presented in Appendix B.2.

We apply the Leiden Algorithm to cross-sectional network data to estimate faction membership

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in each term. As such, factional alliances are allowed to shift as the composition of the AC and CC changes. This allows, for example, for a faction member to be replaced when a new member that is better connected joins the AC or CC.

Summary statistics for the estimated factions are presented in Table 8. First note that the networks are relatively dense. Mean degree is around 10% of the total number of individuals in each term. There are also no more than 2 isolated individuals in any term. As such, we expect modularity clustering to have good performance. When we run the Leiden Algorithm, we recover between 8 to 11 factions in each term, with reasonable faction sizes.

The recovered factions also appear reasonable. Table 9 lists Politburo members who were estimated to be in the same factions as with Deng, Jiang, Hu and Xi across the various terms. We observe that the estimated factions are fairly stable across terms, even though they are estimated separately. The estimate factions capture well-known relationships such as the enmity between Jiang and Hu, as well as the allyship between Hu and Wen. Li Keqiang is widely seen to be Hu's protege and the two are consistently estimated to be in the same faction. Interestingly, Xi joins the faction of Hu and Li in the 18th term, but their alliance is broken by the 19th, foreshadowing recent developments. Finally, all 3 members estimated to be in Xi's faction from the 19th term were re-elected in the 20th. Of the remaining 20 PB members not in Xi's faction, 2 were re-elected.

6.2 Empirical Results

For each AC and CC member, we define factional connection to be the number of PBSC members who belong to the same faction. We then investigate the relationship between career success and factional connection via linear regression. Our findings, presented in Table 10, show that factional connections lead to career penalties as measured daily position, and to a lesser extent, likelihood of promotion to the Politburo.

First consider Daily Position. Column (1) presents the regression on factional connection and no other measures of social connection. The effect is negative but not statistically significant. Columns (2) repeats the same regression, but with controls for vertical and horizontal connections as measured by degree. This makes the estimated effect of factional connection substantially negative, and renders it statistically significant at the 5% level. More specifically, connection to a PBSC member increases the job power of a given AC or CC member by 0.164. However, this bonus is reduced by 0.087 – nearly halved – if the two belong to the same faction. Column (3) finds similar results when we repeat the regression measuring connections by eigenvector centrality.

Columns (4) to (6) repeat columns (1) to (3) but with promotion to Politburo as the outcome of interest. We continue to find that factional connection lead to negative effects, although the estimates are noisier. Politburo members are 20 most powerful people in China. Their selection plausibly entails many other factors, leading to noticeably lower R^2 in our regression and noisier estimates for the effects of factional connection.

In sum, AC and CC members receive less career benefits from connections to PBSC members

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of the same faction, than those of differing factions. This suggests that connections affect the career prospects of political cadres through at least two channels. Firstly, the collective leadership mechanism means that connections to the top-decision making body should lead to career advantage. However, connections to PBSC members of the same faction are less valuable, due to a second anti-factionalism effect. The analyses in this paper therefore enriches current understanding on the effect of social connections for the selection of political elites in China.

7 Conclusion

This paper studies the appointment of party cadres into positions of power as a means of uncovering a general decision-making mechanism within the Chinese Communist Party. Our reduced form results show that these decisions lie in the hands of the Politburo Standing Committee, who selectively promote candidates to whom they are socially connected. Motivated by these empirical findings, we develop a model of collective leadership in which PSC members seek to promote candidates in their social networks, but have to win support of others to do so. Formally, they play a coalition game with a constraint on the minimum coalition size – the cut-off in majority rule. Estimating our model structurally, we show that the CCP has generally operated on a policy of collective leadership. However, the amount of agreement required decision making varies, ranging from 50 to 75% depending on the President in power. Estimating political factions using modularity clustering, we find that intra-factional competition/anti-faction norms interacts with the majority, leading to rich predictions about promotion decisions. Our method, which uses known private incentives to unpack the influence on individuals on collective decisions, can be applied to understand decision-making in non-democracies more generally.

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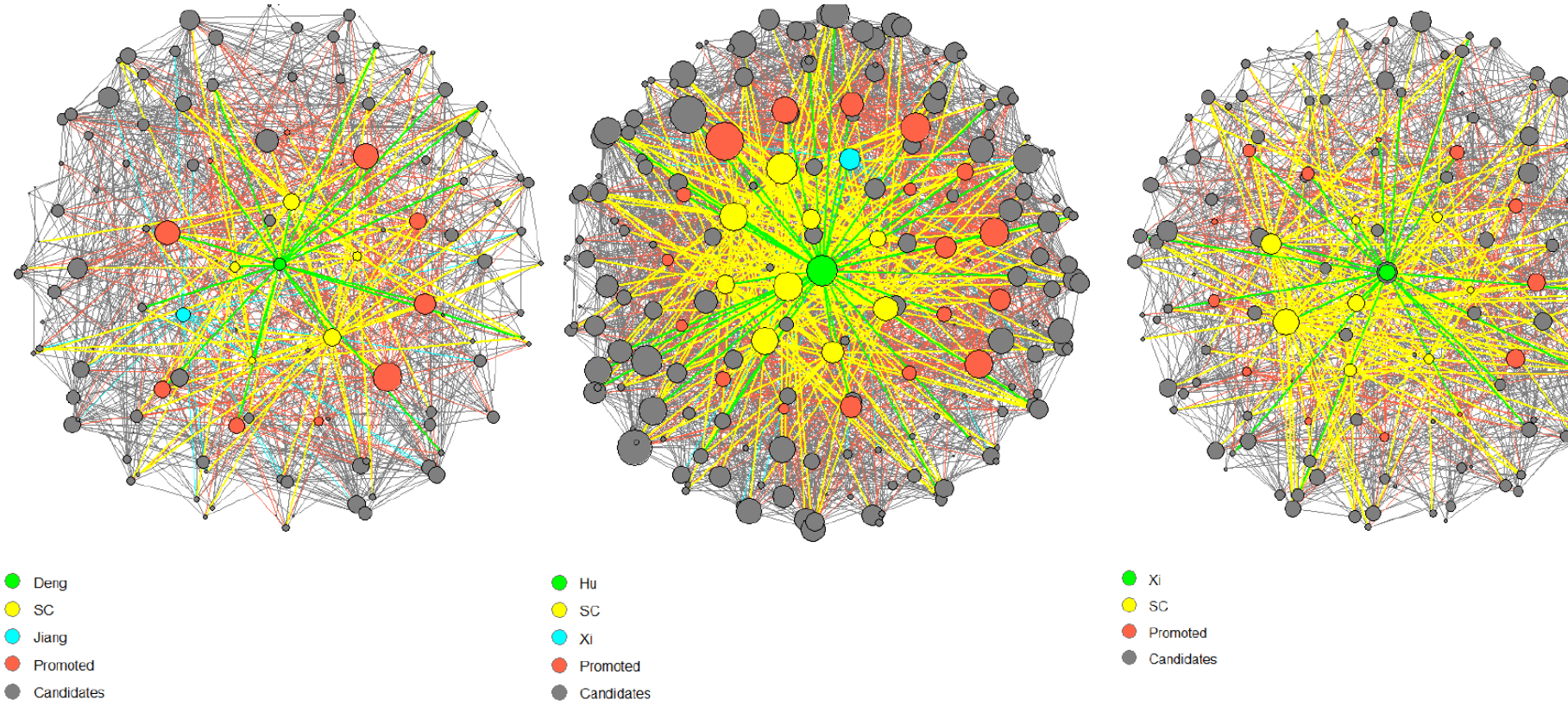


Figure 3: Networks in 13th, 17th and 19th CCP National Congress

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Appendix

A Tables and Figures

Table 1: Summary Statistics

	All	SC	PB	CC	AC
Degree-SC	0.185	0.426	0.369	0.210	0.107
	(0.216)	(0.296)	(0.268)	(0.226)	(0.155)
Degree-AC&CC	0.392	0.537	0.510	0.417	0.361
	(0.213)	(0.208)	(0.203)	(0.210)	(0.212)
Closeness-SC	0.501	0.672	0.641	0.525	0.423
	(0.218)	(0.229)	(0.213)	(0.217)	(0.201)
Closeness-AC&CC	0.859	0.918	0.909	0.871	0.843
	(0.094)	(0.063)	(0.063)	(0.079)	(0.109)
Betweenness-SC	0.035	0.180	0.109	0.042	0.015
	(0.131)	(0.296)	(0.238)	(0.142)	(0.088)
Betweenness-AC&CC	0.157	0.388	0.322	0.185	0.122
	(0.163)	(0.270)	(0.224)	(0.171)	(0.144)
Eigenvector-SC	0.187	0.434	0.396	0.216	0.095
	(0.242)	(0.319)	(0.305)	(0.255)	(0.162)
Eigenvector-AC&CC	0.211	0.190	0.236	0.223	0.196
	(0.303)	(0.172)	(0.282)	(0.308)	(0.295)
DailyPosn	1.495	4.185	3.599	1.78	1.05
	(1.109)	(2.007)	(1.819)	(1.242)	(0.313)
log (Age)	4.034	4.168	4.134	4.078	3.970
	(0.104)	(0.098)	(0.093)	(0.082)	(0.088)
Gender	0.920	1	0.969	0.981	0.878
	(0.271)	(0)	(0.173)	(0.216)	(0.327)
College	0.935	0.954	0.932	0.913	0.963
	(0.247)	(0.211)	(0.252)	(0.281)	(0.189)
GradSch	0.395	0.185	0.259	0.333	0.486
	(0.489)	(0.391)	(0.440)	(0.741)	(0.500)
Military	0.179	0.292	0.148	0.207	0.140
	(0.383)	(0.458)	(0.356)	(0.405)	(0.347)
Princeling	0.043	0.138	0.130	0.057	0.024
	(0.204)	(0.348)	(0.337)	(0.231)	(0.152)
Observations	2446	162	1361	1053	711

Note: *Degree-SC* (*Degree-AC&CC*) measures the standarized *Degree* centrality of the candidate's vertical (horizontal) network. *Closeness-SC* (*Closeness-AC&CC*) measures the closeness centrality of the candidate's vertical (horizontal) network. *Betweenness-SC* (*Betweenness-AC&CC*) measures the Betweenness centrality of the candidate's vertical (horizontal) network. *Eigenvector-SC* (*Eigenvector-AC&CC*) measures the eigenvector centrality of the candidate's vertical (horizontal) network. DailyPosn is an integer variable following Table A.1. of Jia and Xu (2019) that measures the quality of a politician's assigned daily position. *log* (Age) indicates the logged age. Gender, College, GradSch, Military, Princeling are dummy variables that equals to 1 if the agent is male, has a college degree, has a graduate degree, is a military leader, is a princeling, respectively. The mean values are reported and the standard derivatives are shown in the parentheses.

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Table 2: Eigenvector Centrality on Promotion

	Promotion to Politburo				Daily Position			
	OLS		Probit		OLS		Rank-Logit	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EV-SC	0.126**	0.144***	1.011***	1.229***	0.960***	0.982***	0.949***	0.947***
	(0.057)	(0.058)	(0.405)	(0.419)	(0.194)	(0.196)	(0.239)	(0.240)
EV-AC&CC		-0.094		−0.965**		-0.172		0.229
		(0.141)		(0.045)		(0.215)		(0.180)
$i \in PB$					1.347***	1.335***	1.233***	1.233***
					(0.136)	(0.137)	(0.164)	(0.166)
Term FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
College FE	Yes	Yes	Yes	Yes	Yes	Yes	-	-
Hometown FE	Yes	Yes	Yes	Yes	Yes	Yes	-	-
i Control	Yes	Yes	Yes	Yes	Yes	Yes	-	-
Observations	711	710	551	550	711	711	801	800
$R-square$	0.209	0.213			0.396	0.396		
LogLikelihood			-150.8	-145.7			-787.2	-784.6

Note: *EV-SC* (*EV-AC&CC*) measures the eigenvector centrality of the candidate's vertical (horizontal) network. $i \in l$ is a dummy variable indicates the candidate was a politiburo or not at the election. Individual i Controls include gender, age, education level, and dummy variables for princelings and military leader. Term, college and hometown fixed effects are controlled. The missing observations in column (3) and (4) are because too many fixed effects are controlled under Probit model. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

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Table 3: Vertical and Horizontal Centrality on Promotion to PB

	Promotion to Politburo							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Degree-SC	0.131**	0.136**						
	(0.067)	(0.068)						
Degree-AC&CC		0.047						
		(0.125)						
Closeness-SC			0.057	0.052				
			(0.067)	(0.068)				
Closeness-AC&CC				0.307				
				(0.280)				
Betweenness-SC					0.111	0.114		
					(0.096)	(0.096)		
Betweenness-AC&CC						0.077		
						(0.088)		
Eigenvector-SC							0.126**	0.144***
							(0.058)	(0.058)
Eigenvector-AC&CC								-0.094
								(0.064)
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Term FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BirthProvence FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
College FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	713	712	711	710	711	710	711	710
$PR-square$	0.205	0.207	0.204	0.201	0.204	0.206	0.201	0.213

Note: *Degree-SC* (*Degree-AC&CC*) measures the standarized *Degree* centrality of the candidate's vertical (horizontal) network. *Closeness-SC* (*Closeness-AC&CC*) measures the closeness centrality of the candidate's vertical (horizontal) network. *Betweenness-SC* (*Betweenness-AC&CC*) measures the Betweenness centrality of the candidate's vertical (horizontal) network. *Eigenvector-SC* (*Eigenvector-AC&CC*) measures the eigenvector centrality of the candidate's vertical (horizontal) network. *Individual Controls* include gender, logged age, education level, the candidate's ranking percentile in Alternative Committee, and dummy variables for princelings and military leader. *Term FE*, *BirthProvence FE*, *College FE* are congress, college, and birth province fixed effects respectively. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

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Table 4: Vertical and Horizontal Centrality on Daily Position Assignments

	Daily Position Assignment (R_i)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Degree-SC	1.129**	1.110***						
	(0.224)	(0.230)						
Degree-AC&CC		0.205						
		(0.421)						
Closeness-SC			0.955***	0.907***				
			(0.225)	(0.231)				
Closeness-AC&CC				0.985				
				(0.944)				
Betweenness-SC					0.630**	0.608*		
					(0.327)	(0.328)		
Betweenness-AC&CC						0.364		
						(0.300)		
Eigenvector-SC							0.960***	0.982***
							(0.194)	(0.196)
Eigenvector-AC&CC								-0.173
								(0.215)
$i \in PB$	1.328***	1.320***	1.385***	1.374***	1.393***	1.386***	1.347***	1.335***
	(0.224)	(0.137)	(0.136)	(0.137)	(0.137)	(0.139)	(0.136)	(0.137)
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Term FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BirthProvence FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
College FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	713	712	711	710	711	710	711	710
$PR-square$	0.390	0.389	0.390	0.390	0.375	0.376	0.396	0.396

Note: *Degree-SC* (*Degree-AC&CC*) measures the standarized *Degree* centrality of the candidate's vertical (horizontal) network. *Closeness-SC* (*Closeness-AC&CC*) measures the closeness centrality of the candidate's vertical (horizontal) network. *Betweenness-SC* (*Betweenness-AC&CC*) measures the Betweenness centrality of the candidate's vertical (horizontal) network. *Eigenvector-SC* (*Eigenvector-AC&CC*) measures the eigenvector centrality of the candidate's vertical (horizontal) network. $i \in PB$ is a dummy variable equals to 1 if the candidate is promoted to Politburo. *Individual Controls* include gender, logged age, education level, the candidate's ranking percentile in Alternative Committee, and dummy variables for princelings and military leader. *Term FE*, *BirthProvence FE*, *College FE* are congress, college, and birth province fixed effects respectively. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

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Table 5: Katz-Bonacich Centrality on Daily Position Assignments

	Daily Position Assignment R_i						
	OLS (Assumption: $E[(\sum G_{ij}R_j)\epsilon_i] = 0$)					NLLSE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ϕ	0.745***	0.691***				0.754***	
	(0.056)	(0.0720)				(0.052)	
ϕ_v			1.084***	1.126***			1.032***
			(0.074)	(0.092)			(0.100)
ϕ_h			0.472***	0.339***			0.354***
			(0.068)	(0.085)			(0.160)
ϕ_v^{II}					0.746***		
					(0.108)		
$\phi_v^{\mathrm{I}} - \phi_v^{\mathrm{II}}$					0.534		
					(0.717)		
ϕ_h^{II}					0.551***		
					(0.091)		
$\phi_h^{\mathrm{I}} - \phi_h^{\mathrm{II}}$					0.665		
					(0.861)		
$IndividualCon.$	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$TermFE$		Yes		Yes	Yes	Yes	Yes
$HometownFE$		Yes		Yes	Yes		
$CollegeFE$		Yes		Yes	Yes		
$Observations$	2,407	2,151	2,407	2,151	2,151	2,446	2,446
$Adj - R^2$	0.255	0.278	0.270	0.297	0.312		

Note: ϕ is the coefficient of connection benefits when $\eta = 1$. ϕ_v (ϕ_h) is the coefficient of vertical (horizontal) connection benefits. ϕ_v^{I} and ϕ_v^{II} specifies the heterogenous vertical connection benefits for Tier I and Tier II agents, analogically for ϕ_h^{I} and ϕ_h^{II}. $IndividualCon.$ include gender, logged age, education level, the candidate's ranking percentile in Alternative Committee, and dummy variables for princelings and military leader. $TermFE$, $HometownFE$, $CollegeFE$ are congress, college, and birth province fixed effects respectively. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

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Table 6: Katz-Bonacich Centrality on Daily Position Assignments for Each Presidency (NLLS)

	Job Assignment R_{it}				
	All	*Deng*	*Jiang*	*Hu*	*Xi*
	(1)	(2)	(3)	(4)	(5)
ϕ_v	1.032***	0.604***	1.320***	1.160***	1.652***
	(0.100)	(0.195)	(0.236)	(0.173)	(0.441)
ϕ_h	0.354**	−0.212*	-0.626	0.468**	0.495***
	(0.160)	(0.518)	(0.531)	(0.234)	(0.564)
IndividualCon.	Yes	Yes	Yes	Yes	Yes
TermFE	Yes	Yes	Yes	Yes	
Observations	2,446	604	708	757	377
AIC	6781.03	1814.98	1977.07	1920.58	1000.57
logLik	-3381.52	-898.49	-979.53	-951.29	-491.28

Note: ϕ_v (ϕ_h) is the coefficient of vertical (horizontal) connection benefits. *IndividualCon.* include gender, logged age, education level, and dummy variables for isolated dot and PSC members. *TermFE* is congress fixed effect. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

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Table 7: Estimated Majority Rule in Deliberating the Daily Position Appointments

	(1)	(2)	(3)	(4)	(5)	(6)
			Without FE		*Home-Col FE*	
Incumbent GS	$\lvert\bar{N^{\mathrm{I}}}\rvert$	ϕ_v	Θ	$\hat{m}$	Θ	$\hat{m}$
All	8	1.032***	0.102***	6	0.079***	6
		(0.100)	(0.019)	[4, 7]	(0.021)	[6, 7]
Deng	6	0.604***	0.271***	4	0.413***	3
		(0.195)	(0.048)	[3, 4]	(0.072)	[1, 4]
Jiang	7.5	1.320***	0.171***	6	0.290***	6
		(0.236)	(0.032)	[6, 6]	(0.044)	[5, 6]
Hu	10	1.160***	0.077***	8	0.156***	8
		(0.173)	(0.021)	[8, 8]	(0.033)	[7, 8]
Xi	9	1.652***	0.114***	7	0.276***	6
		(0.441)	(0.045)	[7, 8]	(0.081)	[6, 7]

Note: ϕ_v is the estimated coefficient of vertical connection benefits in Katz-Bonacich Centrality. Θ is the estimated coefficient of vertical connection benefits in the coalition game. $\lvert\bar{N^{\mathrm{I}}}\rvert$ is the average number of incumbent Standing Committee members within one incumbent presidency. $\hat{m}$ is the calculated majority rule during one incumbent presidency. *Deng, Jiang, Hu* and *Xi* represent the incumbent presidency of Deng Xiaoping (13-14th), Jiang Zemin (15-16th), Hu Jintao (17-18th) and Xi Jinping (19th). The square bracket indicates the calculated majority rule with one standard deviation of ϕ_v and Θ. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table 8: Summary Statistics for Estimated Factions

Term	Observations	Mean Degree	No. of Isolates	No. of Factions	Size of Smallest Faction	Size of Largest Faction
13	286	24.56	1	11	5	58
14	318	28.48	0	9	13	59
15	346	31.48	0	10	18	85
16	362	32.85	2	10	19	72
17	374	32.53	1	10	20	62
18	383	41.51	0	8	19	101
19	377	32.58	1	9	19	65

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Table 9: Allies of Deng, Jiang, Hu and Xi

Deng		Jiang		Hu		Xi	
13	Li Peng	14	Ding Guangen	13	Hu Yaobang	15	Li Peng
	Yang Rudai		Li Lanqing		Li Tieying		Li Tieying
	Yang Shangkun	15	Ding Guangen		Qin Jiwei		Qian Qichen
14	Chen Xitong		Li Lanqing		Wu Xueqian		Wu Guanzheng
	Li Peng	16	Liu Qi		Yao Yilin		Xie Fei
	Liu Huaqing		Zhou Yongkang	14	Li Tieying		Zhu Rongji
	Qian Qichen	17	Li Yuanchao		Wu Bangguo	16	Guo Boxiong
	Tan Shaowen		Liu Qi		Zhang Zhen		Liu Yunshan
	Xie Fei		Liu Yandong		Zhu Rongji		Wen Jiabao
	Yang Baibing		Zhou Yongkang	15	Wu Bangguo	17	Guo Boxiong
	Zou Jiahua			16	Hui Liangyu		He Guoqiang
15	Li Peng				Wu Bangguo	18	Hu Chunhua
	Li Tieying			17	Hui Liangyu		Li Keqiang
	Qian Qichen				Li Keqiang		Liu Qibao
	Wu Guanzheng				Wang Gang		Ma Kai
	Xie Fei				Wang Yang		Wang Yang
	Zhu Rongji				Wen Jiabao		Zhao Leji
					Wu Bangguo	19	Li Xi
				18	Hu Chunhua		Zhang Youxia
					Li Keqiang		Zhao Leji
					Liu Qibao		
					Ma Kai		
					Wang Yang		
					Xi Jinping		
					Zhao Leji		

Note: Each column lists Politburo members who are estimated to be in the same faction as the respective leader.

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Table 10: Effect of Factional Ties on Daily Position and Promotion to Politburo

	Daily Positions			Promotion to Politburo		
	(1)	(2)	(3)	(4)	(5)	(6)
Degree-SC		0.164***			0.021*	
		(0.045)			(0.012)	
Degree-AC&CC		−0.006			0.0001	
		(0.004)			(0.001)	
EV-SC			0.751***			0.071
			(0.234)			(0.048)
EV-SC&CC			−0.304			−0.003
			(0.228)			(0.045)
Faction-SC	−0.026	−0.087**	−0.071*	−0.005	−0.013*	−0.010
	(0.029)	(0.041)	(0.037)	(0.006)	(0.007)	(0.007)
Individual Controls	Yes	Yes	Yes	Yes	Yes	Yes
Term FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth Province FE	Yes	Yes	Yes	Yes	Yes	Yes
College FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	821	821	821	821	821	821
R^2	0.229	0.256	0.253	0.162	0.170	0.165
Adjusted R^2	0.044	0.059	0.055	0.054	0.041	0.036

Note: Faction-SC is the number of Politburo Standing Committee members that are estimated to be in the same faction as a given AC or CC member. Individual controls include gender, age, princeling status, education level and military affliation. Standard errors in parentheses are clustered at the faction-term level. (*p<0.1; **p<0.05; ***p<0.01)

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B Modularity Clustering

In this section, we discuss the theory and implementation of modularity clustering. Section B.1 discusses the relevant statistical theory, drawing primarily from Zhao et al. (2012). Section B.2 discusses implementation via the Leiden Algorithm of Traag et al. (2019).

B.1 Statistical Theory

Proposed by Newman and Girvan (2004), modularity clustering recovers faction memberships when networks are generated by a degree-corrected stochastic block model (DCSBM):

Assumption 1 (Degree-Corrected Stochastic Block Model)**.** Suppose each individual is independently and identically assigned cluster membership and gregariousness, which are respectively $c_i \in \{1, ...K\}$ and $\theta_i \in \{x_1, ..., x_M\}$.

Suppose further that c_i follows a multinomial distribution $\pi = (\pi_1, ..., \pi_K)$ and $E[\theta_i] = 1$. Given $\mathbf{c}$ and π, the network is the $n \times n$ matrix G where

$$P\left(G_{ij} = 1 \mid \mathbf{c}, \boldsymbol{\theta}\right) = \rho_n \cdot \theta_i \theta_j B_{c_i c_j} \ . \tag{16}$$

Here, B is a symmetric $K \times K$ matrix satisfying

$$x_M^2 \rho_n \max_{i,j} B_{i,j} \leq 1 \ . \tag{17}$$

Under the DCSBM, each individual belongs to one of K factions. They are also endowed with a level of gregariousness, θ_i, that is assumed to be discretely support scalar random variable.[8] Conditional on θ_i and θ_j, the probability that i and j are linked depends only on their faction memberships, c_i and c_j. Two individuals are therefore more likely to be friends if they belong to factions that are friendly with each other and vice versa. θ_i is the gregariousness parameter. Conditional on faction membership, individuals with higher θ_i's are more likely form links with any given counterpart. It therefore allows the model to fit data in which some individuals have many more links than others, an important feature of network data. When the θ_i's are constant at 1, the DCSBM reduces to the standard Stochastic Block Model (Holland et al., 1983), the workhorse model in network statistics. ρ_n is a parameter that controls the density of the observed network: by allowing $\rho_n \to 0$, the model is able to generate networks with few links even in the limit as $n \to \infty$.

The remaining conditions in Assumption 1 are technical. $E[\theta_i] = 1$ is a normalization that is needed for identification. The condition in Equation (17) ensures that the right-hand-side of Equation (16) is smaller than 1. The discrete support of θ_i is used by Zhao et al. (2012) to establish consistent cluster recovery under the DCSBM. However, the support need not be specified, and simulation results suggests that estimation is not sensitive to the discreteness assumption. Finally,

[8] Zhao et al. (2012) provides simulation evidence that consistency of modularity clustering is not sensitive to the discrete support assumption.

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the we note that K is a tuning parameter that is assumed to be known, though in practice it will be automatically chosen by the clustering algorithm.

Additionally, we make the following assumption:

Assumption 2. Let the joint distribution of (c_i, θ_i) be represented by the $K \times M$ matrix Π. That is,

$$P\left(c_i = k, \theta_i = x_m\right) = \Pi_{km} \ .$$

Furthermore, let $\tilde{\pi}_k = \sum_m x_m \Pi_{km}$ and define

$$\tilde{W}_{kl} = \frac{\tilde{\pi}_k \tilde{\pi}_l B_{kl}}{\sum_{k',l'} \tilde{\pi}_{k'} \tilde{\pi}_{l'} B_{k'l'}} \quad ,$$

Let $\tilde{\mathcal{E}}$ be $\tilde{W} - \left(\tilde{W}\mathbf{1}\right)\left(\tilde{W}\mathbf{1}\right)^T$. We assume that

$$\tilde{\mathcal{E}}_{kk} > 0 \quad \text{and} \quad \tilde{\mathcal{E}}_{kl} > 0 \text{ for all } k \neq l \ .$$

The above assumption essentially imposes that there should be more links within than across factions. To see this, observe that when $K = 2$, it simplifies to

$$B_{11} B_{22} > B_{12}^2 \ .$$

The most general DCSBM groups individuals who form links in a similar way into the same faction. This can include parametrizations in which individuals in the same faction have no connections to each other, as long as they have similar types of friends. Such models are not reasonable in our setting, since our intuitive notion of factions is one in which members help each other to secure more prestigious positions.

Assumption 2 motivates clustering by maximizing the following criterion function:

$$\mathbf{Q}(\mathbf{c}) = \sum_{i,j} \left(G_{ij} - \theta_i \theta_j \rho_n B\right) \mathbf{1}\{c_i = c_j\}$$

In a DCSBM where all individuals belong to the same faction, the probability for two individuals to be linked is $\theta_i \theta_j \rho_n B$, where B is a scalar since $K = 1$. This is also known as the configurations model. Call this the null model. If we can maximize the above criterion, we would find faction memberships that lead to more within cluster links than is expected under the null model. It is intuitive that these correspond to good clusters. Arguably, we might also want to specify that factions should have low link probabilities across them. This turns out not to be necessary for estimating faction membership (see Theorem 1), though the algorithm that we apply will lead to well-separated factions (see Appendix B.2).

Let $d_i = \sum_j G_{ij}$ be the degree of i. Under the null model, we expect d_i/n to be close to

$$E\left[\theta_i \theta_j \rho_n B \,|\, \theta_i\right] = \theta_i \rho_n B \ .$$

Similarly, we expect $L/n^2 \approx \rho_n B$. Consider estimating $\theta_i \theta_j \rho_n B$ using $d_i d_j / L$. With some algebra, we obtain the popular Newman-Girvan modularity:

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Definition 1 (Newman-Girvan Modularity)**.** Given an adjacency matrix G, the Newman-Girvan modularity of a given faction membership $\mathbf{c}$ is:

$$\mathbf{Q}(\mathbf{c}) = \sum_k \left(O_{kk} - \frac{O_k^2}{L} \right)$$

where

$$O_{kl} = \sum_{i,j} G_{ij} \mathbf{1}\{c_i = k, c_j = l\} \quad , \quad O_k = \sum_l O_{kl} \quad , \quad L = \sum_{i,j} G_{ij} \, .$$

Let $\hat{\mathbf{c}} = \arg\max \mathbf{Q}(\mathbf{c})$.

It turns out that maximizing Newman-Girvan modularity leads to consistent estimation of faction membership:

Theorem 1 (Theorem 3.1 in Zhao et al. (2012))**.** Suppose Assumptions 1 and 2 hold and that K is known. As $n \to \infty$,

(a) If $\rho_n \gg \frac{\log n}{n}$, then $P(\hat{\mathbf{c}} = \mathbf{c}) \to 1$.

(b) If $\rho_n \gg \frac{1}{n}$, then for all $\varepsilon > 0$,

$$P\left(\frac{1}{n} \sum_{i=1}^{n} \mathbf{1}\{\hat{c}_i \neq c_i\} < \varepsilon \right) \to 1$$

Clearly, the quality of the estimated membership depends on the density of the network, ρ_n. Intuitively, observing a link reveals information about the factions of the individuals involved. If most links are 0, then it is difficult to learn cluster membership.

In case (a), $\hat{\mathbf{c}}$ is said to be strongly consistent. Under strong consistency, it is immediate that we can use $\hat{\mathbf{c}}$ in place of $\mathbf{c}$ in any estimator without affecting its asymptotic properties. That is, using the generated regressor $\hat{\mathbf{c}}$ does not change its asymptotic distribution and does not require different variance estimators. Because the networks to which we apply modularity clustering have no more than 1 to 2 isolates, the rule-of-thumb in Cai (2023) suggests that we can proceed as if $\hat{\mathbf{c}}$ is strongly consistent.

B.2 Implementation

From Theorem 1, we know that maximizing modularity leads to consistent estimates of faction membership. However, this optimization problem is NP-hard given the exponential number of possible faction assignments. Instead, we will rely on the Leiden Algorithm of Traag et al. (2019), which has quickly become the standard approach to modularity clustering.

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We now provide a high level description of the Leiden Algorithm. It initializes with every single individual assigned to a faction of their own. The following three steps are then repeated. Note that the algorithms acts on factions, rather than individuals.

1. The algorithm processes factions in a random sequence, iteratively merging them into other factions that leads to the largest increase in modularity. The output is a conjectured partition of factions, $\mathcal{P}$.

2. In the refinement step, the first step is repeated but only within the conjectured faction in $\mathcal{P}$. Call the output $\mathcal{P}_{\text{refined}}$. Even if factions were merged in Step 1, they may not be merged in Step 2. $\mathcal{P}_{\text{refined}}$ is therefore a finer partition than $\mathcal{P}$.

3. New factions are defined according to $\mathcal{P}_{\text{refined}}$.

Steps 1 to 3 are repeated a fixed number of times, or until a stable partition is obtained. This defines the final faction membership. In this way, the iterative procedure implicitly chooses the number of factions. The refinement step, in which the merged factions in Step 1 are potentially split, is an important innovation in the Leiden Algorithm. It guarantees that factions are well-connected as the algorithm progresses, whereas earlier algorithms for maximizing modularity, particularly the Louvain Algorithm of Blondel et al. (2008), could lead to disconnected factions. Furthermore, the factions that are returned by the Leiden algorithm are also guaranteed to be well-separated. Since it merges factions whenever doing increases modularity, the final unmerged factions must be sufficiently separated. Otherwise the algorithm will continue to merge them. Traag et al. (2019) provides theoretical guarantees that factions will be well-connected within and well-separated across in a suitable sense.

The Leiden Algorithm performs local merging of factions and is not guaranteed to recover the globally optimal faction memberships. Nonetheless, it appears to perform well in practice and has been widely adopted since its introduction. We apply the version of the Leiden Algorithm as implemented in the `R` version of the `igraph` package. Since the algorithm is random, we run each clustering 100 times on each network, retaining the faction memberships with the highest modularity.

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