



## Essays on conflicts, networks and information

Giulio Iacobelli

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**Essays on Conflicts, Networks and Information**

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*Per i miei genitori,  
che mi hanno portato quassù sul palmo delle loro mani.*



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*Fa' la punta alla matita,  
corri a scrivere la tua vita.  
Scrivi parole diritte e chiare:  
Amore, lottare, lavorare.*

— Gianni Rodari

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# Summary

Weakly institutionalized environments represent a fertile ground for conflicts and for the suboptimal exploitation of resources. This dissertation explores these themes using a combination of theory and field experiments. Chapter 1, joint with Francis Bloch, studies the phenomenon of information distortion with a simple model of communication in networks. Agents can influence the probability that the information they send is transmitted without distortion, by exerting a costly and continuous effort. We characterize the equilibria of the game in function of the timing of agents' decisions and of communication costs. Chapter 2, joint with Juni Singh, looks into the endogenous demand of peer-monitoring institutions in rural Nepal and studies its effect on contributions to a public good. Socially sparse groups are more likely to elect a highly influential monitor compared to socially dense ones. Monitoring institutions that are democratically elected by groups increase cooperation compared to those that are externally imposed, but only in socially sparse groups. Chapter 3 offers a model of conflict delegation with adverse selection, where states employ local groups to fight on their behalf. In a setting with incomplete information, militias receive transfers that are smaller than in complete information but are left with higher political autonomy. Chapter 4 extends this framework investigating the tradeoffs of delegating conflict and studies the effect of competition between different sponsors willing to hire the same local group. The delegation of conflict is the unique equilibrium when local groups enjoy weak local support. When there is competition between two sponsors, the delegate can carve out higher rents compared to a situation of monopoly contracting.

**Key words:** conflicts, institutions, networks, rent-seeking, communication.



# Résumé

Les environnements peu institutionnalisés représentent un terrain fertile pour les conflits et pour l'exploitation sous-optimale des ressources. Cette thèse explore ces thèmes en utilisant une combinaison de théorie et d'expériences de terrain. Le chapitre 1, écrit en collaboration avec Francis Bloch, étudie le phénomène de la distorsion de l'information avec un modèle simple de communication en réseau. Les agents peuvent influencer la probabilité que les informations qu'ils envoient soient transmises sans distorsion, en exerçant un effort coûteux et continu. Nous caractérisons les équilibres du jeu en fonction de la structure temporelle des décisions des agents et du coût de la communication. Le chapitre 2, écrit en collaboration avec Juni Singh, examine la demande endogène pour des institutions de surveillance dans les régions rurales du Népal et étudie son effet sur les contributions à un bien public. Les groupes avec des liens sociaux lâches sont beaucoup plus susceptibles d'élire un surveillant très influent que les groupes avec des liens sociaux denses. Les institutions de contrôle démocratiquement élues par les groupes renforcent plus la coopération que celles qui sont imposées de l'extérieur, mais uniquement dans les groupes socialement clairsemés. Le chapitre 3 propose un modèle de délégation de conflit avec sélection adverse, où les États emploient des groupes locaux pour lutter en leur nom. Dans un contexte d'information incomplète, les milices reçoivent des transferts moins importants qu'avec de l'information complète mais se retrouvent avec une plus grande autonomie politique. Le chapitre 4 étend ce cadre en examinant le problème de la délégation stratégique du conflit et étudie l'effet de la concurrence entre différents sponsors désireux d'embaucher le même groupe local. La délégation du conflit est l'équilibre unique lorsque les groupes locaux bénéficient d'un faible soutien local. Lorsqu'il y a concurrence entre deux sponsors, le délégué peut percevoir des avantages plus élevés par rapport à une situation de monopole.

**Mots-clés:** conflits, institutions, réseaux, recherche de rente, communication.



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# General Introduction

The welfare of human societies is continuously affected by several challenges, old and new ones. The spread of misinformation<sup>1</sup>, the quality of institutions and patterns of conflicts affect our everyday behavior and our economies, creating or exasperating social cleavages. This thesis deepens our knowledge of these themes. The diversity of the subjects is reflected in the diversity of the methods, which includes insights from the economics of networks and conflicts, behavioral economics, and the theory of contracts. In many ways, the research questions tackled in this doctoral thesis are personal and have been cultivated throughout the years in a continuous exchange with some brilliant colleagues and mentors.

**Chapter 1**, joint with Francis Bloch, considers a simple model of communication in networks. This work has been deeply inspired by Dawkins (1976), an evolutionary biologist who thought that pieces of information could *spread* and *mutate* through communication. Hence the word “meme” to designate ideas or messages that evolve similarly to genes during multiple steps of communication. How and why these mutations happen in communication? Can a game-theoretical model of networked communication explain this phenomenon? These questions motivated us to analyze this problem with a formal model.

In our setting, one agent observes the state of the world and creates a message that is relayed from agent to agent until it reaches a decision maker, who takes the payoff relevant action for the whole population. At every step of the communication chain agents can influence the probability that the next in the line receives the correct message, by

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1. Misinformation is false or inaccurate information that is communicated regardless of an intention to deceive. On the contrary, disinformation is communicated with a deliberate intention to deceive.

exerting a continuous and costly effort. To highlight as much as possible the role of the network, we assume that there is no conflict of interest, e.g. there are no agents willing to intentionally distort the truth. We can think of this situation as a case of communication in organizations. An analyst in charge of analyzing data formulates a report or a presentation for his supervisor. The content of the analysis is then transmitted from the supervisor to the decision maker through a series of middle managers. We can also think of this model as describing online communication on social media. [Adamic et al. \(2016\)](#) and [Simmons et al. \(2011\)](#) have documented how message distortion occurs when messages are relayed from user to user. The phenomenon on online messaging platforms is pervasive, and its effects are far-reaching.

We adopt a stylized model where we code the state of the world and messages as either being in favor of an action or against it. The successful transmission from the source to the decision maker, whom we call the “sink”, faces two threats. First, messages can involuntarily mutate at every step of the communication chain because of agents’ insufficient investment in information accuracy. Second, we consider the possibility of the breakdown of communication channels. Studies in management science ([Carley and Lin \(1997\)](#)) highlight that the complete breakdown of communication channels is a serious threat in organizations, where employees could be unavailable or ignoring the necessity of communication. We model the possibility of channel breakdown by introducing two types of agents, communicative agents and blockers. While communicative agents strategically choose how much to invest in accuracy<sup>2</sup>, blockers represent the total breakdown of a channel, i.e. they do not retransmit any message.

This uncertainty is at the heart of our results. We consider two timings of the game: a simultaneous and a sequential game. In the former setting, we show that when the cost parameter is small enough there exist two interior equilibria. In this case, equilibrium probabilities of correct transmission monotonically increase with the distance from the source, as agents face decreasing uncertainty about the possibility of the message being lost in the steps ahead of them. As the cost parameter increases, the interior equilibria progressively disappear and we are left with an equilibrium where all communicative

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2. They can also exert a zero effort, in which case they send a random message.

agents send random messages. In the limit of cheap communication, there exist two corner equilibria. In this case communication is characterized either by a sequence of random messages or by a set of deterministic transmissions. In sequential games, we are able to write the precision of communication in closed form. Interestingly, we find that the probability of correct transmission can either increase or decrease along the line, depending on the cost of communication and the probability of channel breakdown. Finally, we find conditions for which the source prefers to exploit two parallel and symmetric channels to the sink rather than just one.

**Chapter 2**, joint with Juni Singh, is born from the observation that Nepal is experiencing a surge in the number of community based organizations for the management of common pool resources, such as forests or rivers. In a setting where formal institutions are weak or absent, the community is responsible for creating and enforcing informal agreements for the management of these public goods. In this context, mechanisms based on peer effects and social ties can sustain cooperation in community resource management, as highlighted by the seminal work by [Ostrom \(1990\)](#). Exploiting methods and insights from the study of social networks, we present a lab in the field experiment in rural Nepal to study in a controlled environment the demand of such monitoring institutions by different social groups. Moreover, we ask whether the *political process* whereby monitoring institutions are assigned matters for cooperative behavior. We shed some light on these issues collecting a novel data set on the social networks of 19 villages in rural Nepal and combining it with an innovative experimental design.

We conduct a network survey to elicit the social structure of 19 Nepali villages, inspired by the work of [Banerjee et al. \(2013\)](#) and of [Breza and Chandrashekar \(2018\)](#). A link between two individuals is established if any one of them nominates the other. Thus, we are able to map the social network of villages along a number of dimensions of interactions, such as trust and friendship. We can extract a number of precious statistics that we use in our experimental design. We identify the most and least influential individuals in the network according to their Bonacich centrality index<sup>3</sup> and we assign to these two

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3. It is a measure of relative “prestige” of each node of a network. It based on the idea that the prestige of a node is related to the prestige of her neighbors in the network ([Bonacich \(1972\)](#))

individuals the role of monitor candidates. The rest of the village is divided into groups of three individuals. As highlighted by [Jackson et al. \(2012\)](#), focusing on groups of three allows to maximize the behavioral contrast between groups that sustain high cooperation levels and those that do not. Groups are formed according to the social distance among their members, and can be of either one of two types: socially dense or sparse groups. Dense groups are composed of people who are socially close-knit, i.e. the average path length among them is less than 2, whereas sparse groups are composed of individuals who are far away in the social network, i.e. the average path length among them is more than 4.

Experimental sessions are based on a two-stage game. In the first stage and for every group composition, participants secretly vote for their preferred monitoring institutions out of three options: a high central monitor, a low central one or no monitor at all. In the second stage, they play a public good game where they decide how much of an initial endowment to put in a common pot and how much to keep for themselves. The amount of the common pot is increased by 50% and redistributed among all group members regardless of individual contribution. Monitors observe everyone’s private contributions, but cannot impose fines in the lab. Rather, we exploit their capacity to put pressure on individuals’ behavior through the possible damage to the reputation of participants during everyday village interactions outside the laboratory. The public good game is played twice for every group configuration, once with the monitoring institutions chosen by the group through majority voting and once with a monitoring institution randomly assigned. Summing up, every participant plays four rounds of the public good game, two in a dense group and two in a sparse group. In each group composition, every participant plays twice, one with the endogenous institution and once with the exogenously assigned one. Thus, we are able to extract fixed effects at the individual level and considerably alleviate the problem of the endogeneity of the network when studying the impact of various treatments. The order of all treatments is randomized.

We investigate whether dense or sparse groups significantly elect different third party institutions. We find that closely knit groups are about 40% points less likely to elect a central monitor, while sparse groups tend to prefer a monitor who is highly central in the network. Also, participants’ contribution is 23% higher in dense groups than in



sparse ones and the presence of a high central monitor that is externally imposed increases contribution by around 15% in sparse groups. This supports the idea that contractual incompleteness can be mitigated by social density, but socially distant individuals need third party institutions to enforce social norms and increase efficiency. Most importantly, we find that the political process whereby monitoring institutions are assigned matters for contribution. The democratic selection of monitoring improves cooperation by up to 22% compared to its exogenous assignment but only in sparse groups. Finally, we observe that in sparse groups the positive effect of the endogenous treatment is so strong that can spill-over to rounds played under the exogenous assignment.

We ground our empirical findings on a theoretical framework of a signaling model. Each individual can be of either one of two types depending on the group she plays in. In the spirit of [Rabin \(1993\)](#), types represent the level of altruism towards other group members. Players have a common prior on the types of their fellow group members and everyone believes that in dense groups there is a higher probability of facing altruistic individuals than in sparse groups. We show that in sparse groups there exists a separating equilibrium where high types vote for no monitor and low types vote for a monitor. Moreover, the outcome of the endogenous selection of the monitoring institution is perceived as a signal of the altruism level of group members and affects contribution.

**Chapter 3** and **Chapter 4**, which are single-authored, look at the economics of conflicts from a new perspective. Modern economics has overlooked the issue of outright conflict as a way of allocating goods. Yet, conflicts represent a real alternative to standard “market” transactions, especially in contexts where property rights are not perfectly specified or cannot be enforced. While strong states tend to monopolize violence within their own borders ([Powell \(2013\)](#)), they often employ local groups to extend their influence in weak polities. These contexts are characterized by low service delivery as well as by low bureaucratic, military and financial capacity ([Berman et al. \(2011\)](#)).

Only during the past half century, internal wars have affected a third of all nations ([Blattman and Miguel \(2010\)](#)). At the heart of this phenomenon is the fact that states competing for influence over natural or geopolitical resources often act as patrons to

foreign armed groups by according financial assistance in return for access to material and political resources. Conflict is thus outsourced to third parties that act as delegates of their foreign sponsors. Two puzzling facts emerge from qualitative evidence ([Ahram \(2011\)](#)). Governments often support groups that are initially weak, and contracted militias retain considerable political autonomy from their sponsors. These two chapters of the dissertation shed some light on the issue of the delegation of war to local groups, drawing methods from the theory of contracts.

In **Chapter 3**, I present a principal-agent model of proxy war with two principals and two agents. Two governments compete to exert influence in a given territory, in the form of extracting resources at a low price or having preferential access to its markets for domestic firms. The contested territory is a fragile state where institutions are captured by two groups. Instead of fighting each other directly, each sponsor offers a contract to one militia to fight on its behalf. The offered contracts are made up of two elements, a transfer of resources and a share of influence over the militia's political autonomy. Transferred resources can be strategically split between recruiting fighters and buy weapons or can be invested in productive activities. In return, militias pledge allegiance to the external sponsor and give away a portion of their political independence. Militias can either turn down the offer and remain neutral, or accept the contract and fight each other. A Tullock contest function determines who wins the contest, and the total prize is divided between the winning militia and her sponsor.

The model is structured as a two-stage game, where in the first stage governments set their proposed contracts and in the second stage armed groups strategically choose their optimal fighting effort and their investment in productive activities. Crucially, militias are positioned along a continuum of types representing their ideological misalignment vis-à-vis the sponsors. Information asymmetries in the patron-client relation arise naturally in this context, and deeply drive our results. Governments face adverse selection when contracting local armed groups since these groups often lack a fixed ideological structure and frequently change leadership and inspiration ([Salehyan \(2010\)](#)).

Solving this framework analytically allows me to make several propositions. The equilib-

rium of the baseline model with complete information can be characterized in a simple way and hinges fundamentally on the relative ideological misalignments between the two parties. The government most ideologically aligned transfers more resources and has a strictly higher probability of winning. When the militias' marginal cost of recruiting fighters increases, e.g. due to an improvement in local labor market conditions, the optimal transfers are not affected while fighting efforts decrease. Similarly, an increase in the cost of transferring funds results in a decrease in total transfers and in less aggregate violence. When governments hold incomplete information on their militias' ideologies, they can design contracts that are incentive-compatible. Since governments transfer more resources to groups ideologically closer, armed groups seek to exploit their informational advantage to receive higher transfers. Governments can offset the militias' incentives to declare to be more ideologically aligned than they are. At equilibrium, offers are characterized by transfers that are lower than those in complete information but militias are left with more political independence.

**Chapter 4** moves a step further and extends the framework in two directions. First, it studies a game of strategic delegation of conflict in a setting of complete information. This approach is inspired by [Fershtman et al. \(1991\)](#), who show that the principals of a delegation game can strategically use agents to play on their behalf by offering contracts that are common knowledge. Delegating or not delegating conflict is an important decision for governments, and it carries its own tradeoffs. In particular when there is no international legitimacy for direct intervention, hiring a proxy offers the possibility of achieving strategic goals more economically, with fewer political costs. While sponsors have to spend resources to finance local armed groups, they enjoy the plausible deniability of having direct ties and do not suffer the typical domestic war weariness and discontent. Direct involvement is instead a costly strategy, as the state burns resources and lives are lost, but avoids the negative consequences of being associated to a group that is ideologically misaligned and that might commit atrocities. Moreover, the long term strategic objectives of sponsors and delegates diverge.

Second, this chapter introduces the possibility of competition between two governments trying to hire the same armed group, inspired by [Bernheim and Whinston \(1986\)](#). When

local groups first form, the choice of which support to accept is a crucial decision. Militias demand resources that can augment the groups' military and political capabilities, while giving up some degree of political autonomy. External sponsors often compete to hire local combatants, and groups receive several offers. I model this situation with a common agency game where two governments compete to hire a common militia.

This chapter contributes to the literature by characterizing the equilibria of the delegation game. The analysis shows that the equilibria hinge on the level of support that armed groups receive from local populations. When militias enjoy weak local support, the delegation of conflict is the unique equilibrium. Militias that lack local support are at the fringe of society, and are easily hired by principals. When militias benefit from strong local support, for governments it is politically and financially too expensive to hire informal armed groups. The unique equilibrium, in this case, is characterized by both governments entering directly into conflict. When the ideological misalignments of the two parties are identical, multiple equilibria could arise for intermediate levels of local support.

When two governments compete to hire the same militia, the equilibria of the common agency game can be characterized by the ideological misalignments, the value of the prize and the outside option of neutrality. The competition triggers a sequence of undercutting á la Bertrand over the control of the militia's autonomy. The analysis shows that the armed group is generally able to carve out a contract where it keeps all its political independence. When the two sponsors are in tight ideological competition or when the stakes are very high, governments compete on the offered transfers. The principal that is most aligned offers slightly more than its competitor and gets the group's allegiance.



# Introduction générale

Le bien-être des sociétés humaines est continuellement affecté par plusieurs défis, anciens et nouveaux. La propagation de la mésinformation<sup>4</sup>, la qualité des institutions et les conflits affectent au quotidien nos comportements et nos économies, créant ou accentuant des clivages sociaux. Cette thèse approfondit nos connaissances sur ces thèmes. La diversité des sujets se reflète dans la diversité des méthodes, qui va de l'économie des réseaux et des conflits, à l'économie comportementale et à la théorie des contrats. De plusieurs façons, les questions de recherche abordées dans cette thèse de doctorat sont personnelles et ont été cultivées au fil des années dans un échange continu avec de brillants collègues et mentors.

Le **chapitre 1**, écrit en collaboration avec Francis Bloch, considère un modèle simple de communication en réseaux. Ce travail a été profondément inspiré par Dawkins (1976), un biologiste évolutionniste qui pensait que les informations pourraient *se propager* et *muter* par la communication. D'où le mot «meme» pour désigner des idées ou des messages qui évoluent de manière similaire aux gènes au cours de multiples étapes de communication. Comment et pourquoi ces mutations se produisent-elles dans la communication ? Un modèle de théorie des jeux de communication en réseau peut-il expliquer ce phénomène ? Nous analysons ces questions à l'aide d'un modèle formel.

Dans notre contexte, un agent observe l'état du monde et crée un message qui est relayé

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<sup>4</sup>. La mésinformation est une information fausse ou inexacte qui est communiquée indépendamment de l'intention de tromper. Au contraire, la désinformation est communiquée avec une intention délibérée de tromper.

d’agent en agent jusqu’à atteindre un décideur. Celui-ci prend une décision qui détermine le gain de l’ensemble de la population. À chaque étape de la chaîne de communication, les agents peuvent influencer la probabilité que le suivant reçoive le message correct, en exerçant un effort continu et coûteux. Afin d’analyser le rôle du réseau, nous supposons qu’il n’y a pas de conflits d’intérêts et qu’aucun agent ne souhaite déformer intentionnellement la vérité. Cette situation modélise le cas de communication dans les organisations: un analyste analyse des données et formule un rapport ou une présentation pour son superviseur. Le contenu de l’analyse est ensuite transmis jusqu’au décideur *via* une série de cadres intermédiaires. On peut également considérer ce modèle comme décrivant la communication sur les réseaux sociaux. [Adamic et al. \(2016\)](#) et [Simmons et al. \(2011\)](#) ont documenté comment la distorsion des messages se produit lorsque les messages sont relayés d’un utilisateur à l’autre. Le phénomène est omniprésent sur les réseaux sociaux et ses effets sont considérables.

Nous adoptons un modèle stylisé où nous codons l’état du monde et les messages comme étant soit en faveur de l’action, soit contre elle. La réussite de la transmission de la source au décideur, que nous appelons le “puits”, fait face à deux menaces. Premièrement, les messages peuvent muter involontairement à chaque étape de la chaîne de communication en raison de l’investissement insuffisant des agents dans l’exactitude des informations. Deuxièmement, nous considérons la possibilité d’une panne des canaux de communication. Des études en sciences de la gestion ([Carley and Lin \(1997\)](#)) soulignent que la panne complète des canaux de communication est une menace sérieuse dans les organisations, où les employés pourraient être indisponibles ou ignorer la nécessité de la communication. Nous modélisons la possibilité d’une panne de canal en introduisant deux types d’agents, les agents communicatifs et les bloqueurs. Alors que les agents communicatifs choisissent stratégiquement combien investir dans la précision <sup>5</sup>, les bloqueurs représentent la rupture totale d’un canal, c’est-à-dire qu’ils ne retransmettent aucun message.

Cette incertitude est au coeur de nos résultats. Nous considérons deux structures temporelles du jeu: un jeu simultané et un jeu séquentiel. Dans le premier cas, nous montrons que lorsque le coût est suffisamment faible, il existe deux équilibres intérieurs. Dans ce cas,

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5. Ils peuvent également exercer un effort nul, auquel cas ils envoient un message aléatoire.

les probabilités d'équilibre d'une transmission correcte augmentent de manière monotone avec la distance de la source, car les agents font face à une incertitude décroissante quant à la possibilité que le message soit perdu dans les étapes suivantes. Au fur et à mesure que le coût augmente, les équilibres intérieurs disparaissent progressivement et, dans le seul équilibre restant, tous les agents communicatifs envoient des messages aléatoires. Dans la limite de la communication *cheap*, deux équilibres en coin existent. Dans ce cas, la communication est caractérisée soit par une séquence de messages aléatoires, soit par un ensemble de transmissions déterministes. Dans les jeux séquentiels, nous sommes capables d'écrire la précision de la communication sous forme analytique. Nous constatons alors que la probabilité d'une transmission correcte peut augmenter ou diminuer le long de la ligne, en fonction du coût et de la probabilité de rupture de canal. Enfin, nous trouvons des conditions pour lesquelles la source préfère exploiter deux canaux parallèles et symétriques vers le puits plutôt qu'un seul.

Le **chapitre 2**, écrit en collaboration avec Juni Singh, est né du constat que le Népal connaît une augmentation du nombre d'organisations locales pour la gestion des ressources communes, telles que les forêts ou les rivières. Dans un contexte où les institutions formelles sont faibles ou absentes, la communauté est responsable de la création et de l'application des accords informels pour la gestion de ces biens publics. Dans ce contexte, des mécanismes basés sur les liens sociaux peuvent soutenir la coopération dans la gestion des ressources locales, comme le souligne le travail fondateur de [Ostrom \(1990\)](#). En exploitant les méthodes et les connaissances issues de l'étude des réseaux sociaux, nous présentons une expérience de terrain en milieu rural au Népal pour étudier dans un environnement contrôlé la demande de telles institutions de gestion par différents groupes sociaux. De plus, nous nous demandons si le *processus politique* par lequel les institutions de contrôle sont assignées a un impact sur le comportement coopératif. Nous avons étudié ces problèmes en collectant un nouvel ensemble de données sur les réseaux sociaux de 19 villages ruraux du Népal et en l'associant à une conception expérimentale innovante.

Nous menons une enquête de réseau pour obtenir la structure sociale de 19 villages népalais, inspirée par le travail de [Banerjee et al. \(2013\)](#) et de [Breza and Chandrashekhara \(2018\)](#). Un lien entre deux individus est établi si l'un des deux nomme l'autre. Ainsi,



nous sommes en mesure de cartographier le réseau social des villages selon un certain nombre de dimensions d’interactions, telles que la confiance et l’amitié. Nous pouvons extraire un certain nombre de statistiques précieuses que nous utilisons dans notre conception expérimentale. Nous identifions les individus les plus et les moins influents du réseau en fonction de leur indice de centralité de Bonacich<sup>6</sup> et nous attribuons à ces deux individus le rôle de candidats surveillants. Le reste du village est divisé en groupes de trois individus. Comme le souligne [Jackson et al. \(2012\)](#), se concentrer sur des groupes de trois permet de maximiser le contraste de comportement entre les groupes qui soutiennent des niveaux de coopération élevés et ceux qui ne le font pas. Les groupes sont formés en fonction de la distance sociale entre leurs membres et peuvent être de l’un des deux types: groupes socialement denses ou clairsemés. Les groupes denses sont composés de personnes socialement proches, c’est-à-dire que la longueur moyenne du chemin parmi eux est inférieure à 2, tandis que les groupes clairsemés sont composés d’individus éloignés dans le réseau social, c’est-à-dire que la longueur moyenne du chemin entre elles est supérieur à 4.

Les sessions expérimentales sont basées sur un jeu en deux étapes. Dans la première étape et pour chaque composition de groupe, les participants votent secrètement pour leur institution de surveillance préférée parmi trois options: un surveillant avec centralité élevée, un surveillant avec centralité faible ou aucun surveillant. Dans la deuxième étape, ils jouent un jeu de bien public où ils décident de la part de dotation initiale à mettre dans un pot commun et de la quantité à garder pour eux-mêmes. Le montant du pot commun est augmenté de 50% et redistribué entre tous les membres du groupe indépendamment de la contribution individuelle. Les surveillants observent les contributions privées de chacun, mais ne peuvent pas imposer d’amendes dans le laboratoire. Au contraire, nous exploitons leur capacité de faire pression sur le comportement des individus en endommageant la réputation des participants en dehors du laboratoire dans les interactions quotidiennes du village. Le jeu du bien public est joué deux fois pour chaque configuration de groupe, une fois avec les institutions de contrôle choisies par le groupe par vote à la majorité et une fois avec une institution de contrôle assignée au hasard. Chaque participant joue donc quatre tours du jeu du bien public, deux dans un groupe dense et deux dans un groupe clairsemé. Dans chaque composition de groupe, chaque participant

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6. Il s’agit d’une mesure du “prestige” relatif de chaque noeud d’un réseau. Il repose sur l’idée que le prestige d’un noeud est lié au prestige de ses voisins dans le réseau ([Bonacich \(1972\)](#)).

joue deux fois, une avec l'institution endogène et une avec l'institution affectée de manière exogène. Ainsi, nous sommes en mesure d'extraire des effets fixes au niveau individuel et d'atténuer considérablement le problème de l'endogénéité du réseau lors de l'étude de l'impact de différents traitements. L'ordre de tous les traitements est aléatoire.

Nous cherchons à savoir si des groupes denses ou clairsemés élisent des institutions tierces différentes. Nous constatons que les groupes étroitement unis ont environ 40% moins de chances d'élire un surveillant central, tandis que les groupes clairsemés ont tendance à préférer un surveillant qui est très central dans le réseau. En outre, la contribution des participants est 23% plus élevée dans les groupes denses que dans les groupes clairsemés et la présence d'un surveillant avec une centralité élevée imposé de façon exogène augmente la contribution d'environ 15% dans les groupes clairsemés. Cela soutient l'idée que l'incomplétude contractuelle peut être atténuée par la densité sociale, mais les individus socialement éloignés ont besoin d'institutions tierces pour faire appliquer les normes sociales et accroître l'efficacité. Plus important encore, nous constatons que le processus politique par lequel les institutions de contrôle sont attribuées a un impact sur les contributions au bien public. La sélection démocratique du contrôle améliore la coopération jusqu'à 22% par rapport à son affectation exogène, mais seulement dans des groupes clairsemés. Enfin, nous observons que dans les groupes clairsemés, l'effet positif du traitement endogène est si fort qu'il peut se répercuter sur les tours joués dans le cadre de l'assignation exogène.

Nous fondons nos résultats empiriques sur un cadre théorique d'un modèle de signal. Chaque individu peut être d'un type parmi deux selon le groupe dans lequel il joue. Dans l'esprit de [Rabin \(1993\)](#), les types représentent le niveau d'altruisme envers les autres membres du groupe. Les joueurs ont une croyance a priori commune sur les types de leurs camarades du groupe et tout le monde pense que dans les groupes denses il y a une probabilité plus élevée d'affronter des individus altruistes que dans des groupes clairsemés. Nous montrons que dans les groupes clairsemés il existe un équilibre de séparation où les types élevés ne votent pour aucun surveillant et les types bas votent pour un surveillant. De plus, le résultat de la sélection endogène de l'institution de contrôle est perçu comme un signal du niveau d'altruisme des membres du groupe et affecte la contribution.

Les **chapitres 3** et **4** examinent l'économie des conflits sous un nouvel angle. L'économie moderne a négligé la question du conflit pur et simple comme moyen d'attribution des biens. Pourtant, les conflits représentent une réelle alternative aux transactions classiques de marché, en particulier dans les contextes où les droits de propriété ne sont pas parfaitement spécifiés ou ne peuvent pas être appliqués. Alors que les États forts ont tendance à monopoliser la violence à l'intérieur de leurs propres frontières ([Powell \(2013\)](#)), ils emploient souvent des groupes locaux pour étendre leur influence dans les régimes politiques faibles. Ces contextes sont caractérisés par une faible prestation de services ainsi que par une faible capacité bureaucratique, militaire et financière ([Berman et al. \(2011\)](#)).

Au cours du dernier demi-siècle, les guerres civiles ont touché un tiers de toutes les nations ([Blattman and Miguel \(2010\)](#)). Les États en compétition pour l'influence sur les ressources naturelles ou géopolitiques agissent souvent en tant que patrons de groupes armés étrangers en accordant une aide financière en échange d'un accès aux ressources matérielles et politiques. Le conflit est ainsi sous-traité à des tiers qui agissent en tant que délégués de leurs sponsors étrangers. Deux faits déroutants ressortent des études qualitatives ([Ahram \(2011\)](#)). Les gouvernements soutiennent souvent des groupes initialement faibles et les milices sous contrat conservent une autonomie politique considérable vis-à-vis leurs sponsors. Ces deux chapitres de la thèse éclairent la question de la délégation de la guerre aux groupes locaux, en utilisant des méthodes de la théorie des contrats.

Dans le **chapitre 3**, je présente un modèle principal-agent de guerre par procuration avec deux principaux et deux agents. Deux gouvernements se font concurrence pour exercer une influence sur un territoire donné, sous la forme d'extraction de ressources à prix bas ou d'accès préférentiel à ses marchés pour les entreprises nationales. Le territoire contesté est un État fragile dont les institutions sont capturées par deux groupes. Au lieu de se battre directement, chaque sponsor offre un contrat à une milice pour combattre en son nom. Les contrats proposés se composent de deux éléments, un transfert de ressources et une influence sur l'autonomie politique de la milice. Les ressources transférées peuvent être réparties stratégiquement par les milices entre le recrutement de combattants et l'achat d'armes ou peuvent être investies dans des activités productives. En retour, les groupes armés locaux prêtent allégeance au sponsor extérieur et cèdent une partie de

leur indépendance politique. Les milices peuvent soit rejeter l'offre et rester neutres, soit accepter le contrat et se battre. Une fonction de concours Tullock détermine qui gagne la guerre, et la récompense est divisée entre la milice gagnante et son sponsor.

Le modèle est structuré suivant un jeu en deux étapes. Dans la première, les gouvernements définissent leurs contrats et dans la seconde les groupes armés choisissent stratégiquement leur effort de combat optimal et leur investissement dans des activités productives. Les milices sont positionnées le long d'un continuum de types représentant leur désalignement idéologique vis-à-vis les sponsors. Les asymétries d'information entre le patron et le client surgissent naturellement dans ce contexte et déterminent nos résultats. Les gouvernements sont souvent confrontés à une sélection adverse lorsqu'ils engagent des groupes armés locaux, car ces groupes n'ont pas de structure idéologique fixe et changent fréquemment de *leadership* et d'inspiration ([Salehyan \(2010\)](#)).

La résolution analytique de ce modèle me permet de faire plusieurs propositions. L'équilibre du modèle de base dans un cadre d'information complète peut être caractérisé de manière simple et dépend fondamentalement des désalignements idéologiques relatifs entre les deux parties. Le gouvernement le plus aligné sur le plan idéologique transfère plus de ressources et a une probabilité strictement plus élevée de gagner. Lorsque le coût marginal des milices pour recruter des combattants augmente, par exemple en raison d'une amélioration des conditions du marché du travail local, les transferts optimaux ne sont pas affectés tandis que les efforts de combat diminuent. Une augmentation du coût de transfert de fonds entraîne une diminution du total des transferts et une diminution de la violence globale. Lorsque les gouvernements détiennent des informations incomplètes sur les idéologies de leurs milices, ils peuvent concevoir des contrats compatibles avec les incitations. Puisque les gouvernements transfèrent plus de ressources à des groupes idéologiquement plus proches, les groupes armés cherchent à exploiter leur avantage informationnel pour recevoir des transferts plus importants. Les gouvernements peuvent contrebalancer les incitations des milices à se déclarer plus idéologiquement alignées qu'elles ne le sont. À l'équilibre, les offres sont caractérisées par des transferts plus faibles qu'en information complète, mais les milices se retrouvent avec plus d'indépendance politique.

Le **chapitre 4** étend ce cadre dans deux directions. Premièrement, il étudie un jeu de délégation stratégique de conflit dans un cadre d'information complète. Cette approche est inspirée de [Fershtman et al. \(1991\)](#), qui montre que les principaux d'un jeu de délégation peuvent stratégiquement utiliser des agents pour jouer en leur nom en proposant des contrats publics. Déléguer ou ne pas déléguer les conflits est une décision importante pour les gouvernements, et elle comporte ses propres compromis. En particulier en absence de légitimité internationale pour une intervention directe, l'embauche d'un mandataire offre la possibilité d'atteindre des objectifs stratégiques avec des coûts économiques et politiques moindres. Alors que les sponsors doivent dépenser des ressources pour financer les groupes armés locaux, ils valorisent la possibilité de nier les liens directs et ne souffrent pas de la lassitude et du mécontentement typiques de la guerre nationale. L'implication directe est au contraire une stratégie coûteuse, car l'État utilise des ressources humaines et économiques, mais évite les conséquences négatives d'être associé à un groupe qui est idéologiquement désaligné et qui pourrait commettre des atrocités. En plus, les objectifs stratégiques à long terme des sponsors et des délégués divergent.

Deuxièmement, ce chapitre introduit la possibilité d'une concurrence entre deux gouvernements essayant d'embaucher le même groupe armé, inspiré par [Bernheim and Whinston \(1986\)](#). Lors de la formation initiale des groupes locaux, le choix du soutien à accepter est une décision cruciale. Les milices exigent des ressources qui peuvent augmenter leurs capacités militaires et politiques, tout en renonçant à un certain degré d'autonomie politique. Les sponsors externes se font souvent concurrence pour embaucher des combattants locaux et les groupes reçoivent plusieurs offres. Je modélise cette situation avec un jeu d'agence commun où deux gouvernements se font concurrence pour embaucher une unique milice.

Ce chapitre contribue à la littérature en caractérisant les équilibres du jeu de délégation. L'analyse montre que les équilibres dépendent du niveau de soutien que les groupes armés reçoivent des populations locales. Lorsque les milices bénéficient d'un faible soutien local, la délégation du conflit est l'équilibre unique. Les milices manquant de soutien local sont en marge de la société et sont facilement engagées par les principaux. Quand les milices bénéficient d'un fort soutien local, pour les gouvernements il est politiquement et finan-

cièrement trop coûteux d'embaucher des groupes armés informels. L'équilibre unique, dans ce cas, est caractérisé par le fait que les deux gouvernements entrent directement en conflit. Lorsque les désalignements idéologiques des deux parties sont identiques, des équilibres multiples peuvent apparaître pour les niveaux intermédiaires de soutien local.

Lorsque deux gouvernements se font concurrence pour embaucher la même milice, les équilibres du jeu d'agence commune peuvent être caractérisés par les désalignements idéologiques, la valeur des enjeux et de l'option extérieure de la neutralité. La compétition déclenche une séquence de sous-cotation à la Bertrand sur le contrôle de l'autonomie de la milice. L'analyse montre que le groupe armé est généralement en mesure de conclure un contrat où il conserve toute son indépendance politique. Lorsque les deux sponsors sont en concurrence idéologique serrée ou lorsque les enjeux sont très importants, les gouvernements se font concurrence sur les transferts proposés. Le mandant le plus aligné offre un peu plus que son concurrent et obtient l'allégeance du groupe.



# Chapter 1

## Whispers in Networks

### Abstract <sup>1</sup>

We study a simple model of communication in networks, where agents can influence the precision of the information they report to their neighbors by exerting a costly and continuous effort. The message is originated by a source and it is relayed until it reaches the destination, the “sink”. The population shares the objective of having the sink receive the message originated by the source. We characterize the equilibria in a game where all agents choose simultaneously the accuracy of their messages. Depending on the cost structure, different equilibria can emerge. In the simultaneous game, communication precision increases along the path to the sink. When agents play sequentially, we are able to find a closed-form expression of each player’s communication precision. The accuracy of messages is dependent on each player’s position in the network and can either decrease or increase along the chain depending on the parameters of the game. Finally, we find conditions under which players in a simple network with a symmetric cycle have an incentive to send messages along two channels instead than along just one.

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<sup>1</sup>. This chapter is coauthored with Francis Bloch. We thank Simon Gleyze, Gabrielle Demange, Emanuela Migliaccio, Thibaut Piquard, Agnieszka Rusinowska, Lennart Stern and Karine Van der Straten for precious comments. We thank the support of the EUR grant ANR-17-EURE-0001.



## 1.1 Introduction

Our place in society is in part defined by what information we receive, by how we process it and transmit it to our peers ([Castells \(2004\)](#), [Castells et al. \(2005\)](#)). The spread of information, both online and offline, is a noisy process whereby messages are easily altered, distorted or misinterpreted when they are passed on from person to person. Well before the digital revolution, R. Dawkins thought that pieces of information could spread and “mutate” through communication ([Dawkins \(1976\)](#)). He coined the word “meme” to designate ideas or messages that spread and evolve analogously to genes through communication, through mutations and distortions. This phenomenon is also at the center of the internationally popular children’s game “broken telephone”<sup>2</sup>. The alteration of a message can be amplified through its sequential retransmission from individual to individual, resulting in the harmful diffusion of incorrect information. Even the accuracy of reporting by major news outlets depends on the level of acquaintanceship between journalists and people witnessing facts ([Blankenburg \(1970\)](#)). This process of information distortion, widely documented and investigated in communication studies ([Entman \(1993\)](#)), can have serious consequences. Governments and organizations have acknowledged the potential harm of information distortion and have strengthened their regulatory frameworks to contain the phenomenon.

Organizations often suffer from information distortion. As the literature in management science points out (e.g. [Carley and Lin \(1997\)](#)), in hierarchical organizations information is channeled up and down the management chain through a series of retransmissions. It is common practice that analysts tasked with gathering and analyzing data transmit the outcome of the analysis to their supervisors, who in turn transmit it to their managers. Thus, information gets iteratively passed on from employee to employee, through a set of intermediaries up until a manager who takes a decision that affects the whole organization. Errors are likely to build up along the chain of communication. The decision maker, after this series of retransmissions, often receives information that is different from what was initially observed by the analyst. Hence, the decision maker could be unintentionally misled to take a sub-optimal action. Mistakes in information transmission occur in a variety of settings and can lead to dreadful consequences. For instance, contact was

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2. This game is also called “telephone”, “chinese whispers”, “telephone arabe”, etc.

permanently lost with the Mars Global Surveyor probe due to a sequence of errors in the entry of flight-critical data which built up through multiple rounds of transmission (NASA, 1999). Similarly, miscommunication in military operations has caused numerous unintended deaths in contemporary<sup>3</sup> and historical conflicts. A famous historical instance can be found in Victorian history. During the Crimean War in 1854, the Royal Light Brigade rode unprepared directly into a heavy artillery battle scene due to a chain of communication errors, causing heavy losses.

Information distortion also pervades online communication. Bill Gates has been accused of being plotting to use COVID-19 testing and a future vaccine to track people with microchips, following a forum he attended in March 2020 on Reddit, where he answered a question about maintaining businesses during the pandemic. While he said “Eventually we will have some digital certificates to show who has recovered or been tested recently or when we have a vaccine who has received it” the online community misunderstood this statement and linked it to a research conducted at MIT about a technology that can keep a vaccination record on a patient’s skin. The research project received funding from the Gates Foundation. The story has been shared 18,000 times on Facebook, and its related YouTube videos have received 1.8 million views in few days. As the Gates Foundation later clarified, the information which emerged from social media was a mash-up of two unrelated things and Bill Gates was referring to digital certificates<sup>4</sup> as part of an effort to create a digital platform that would expand home-based, self-administered testing for COVID-19.

Similarly, Simmons et al. (2011) analyzes how one twit “Street style shooting in Oxford Circus for ASOS and Diet Coke. Let me know if you’re around!!” prompted others to tweet “Shooting in progress in Oxford Circus? What?”. Originally an invitation for people to join the crowd for a commercial being filmed in London, after few minutes this meme mutated and got readily retweeted as “Shooting in progress in Oxford Circus, stay safe people”. Even though the Metropolitan Police declared no shooting took place, the quick

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3. See for instance <https://www.nytimes.com/2014/09/05/world/asia/miscommunication-blamed-for-mistaken-us-airstrike-in-afghanistan.html>

4. Digital certificates are used to send encrypted information over the internet, as in the common case of electronic signatures which are used to verify identity. They were officially defined by what is now called the Telecommunication Standardization Sector in 1988 and have always been virtual, not physical.

diffusion of these messages sparked panic across London<sup>5</sup>. [Adamic et al. \(2016\)](#) analyzes the mutations of a #noone meme regarding the right to universal health care in the US. The meme was reposted more than 470,000 times, with a mutation rate of around 11 percent and more than 100,000 variants.

Even in a context characterized by the absence of conflict of interest between individuals, information distortion can occur because of two distinct reasons: imprecise retransmission or breakdowns of communication channels ([Carley and Lin \(1997\)](#), [Adamic et al. \(2016\)](#)). First, as pointed out by these studies, not every individual who receives an online message can retransmit it to his peers nor every middle manager always reports to his supervisor. Hence, the possibility of the breakdown of communication channels due the failure of communication technology. In online messaging, some users might experience connection errors or device problems. In organizations, employees could be unavailable or ignoring the necessity of communication ([Carley and Lin \(1997\)](#)). Second, communication is costly and at every step of the transmission chain individuals can distort information by exerting little effort in passing on messages. We study precisely how these two factors of communication distortion interact with individuals' positions in a network and how people strategically exert effort in the accuracy of information they transmit.

This paper asks three main set of questions. How can we characterize the equilibria of a game where all agents choose simultaneously their investments in communication precision? What are the different equilibrium characteristics of a setting where players choose sequentially according to their order in the chain? If the source can reach the sink through two symmetric channels, under what conditions will she do so?

In our model the transmission of information is costly and every individual can choose a continuous effort that affects the probability that the message gets transmitted without distortions. We denote this probability as the “precision” or “accuracy” of communication. Messages are subject to mutations and alterations, and people’s efforts affect the probability that a message is transmitted correctly to their peers. Society is represented by a network populated by two types of individuals. We call “communicative” those that are willing to listen to messages and pass them on, while we denote by “blockers” those that do

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<sup>5</sup>. The Metropolitan Police of London later communicated that it appeared as if some information about a routine police training exercise being held on that day had inadvertently got into the public domain.

not retransmit the messages received, and interrupt the communication chain altogether. Communicative agents pass on a message only if they received it. On the other hand, they stay silent if they do not receive anything from their predecessor in the chain, i.e. the predecessor has also not received any message or he is a “blocker”. Communicative agents can influence the probability that the message they transmit matches the message they received. If they exert no effort in accuracy, the message they send is random, and the precision increases with the costly effort. In line with previous studies in management and computer science (Carley and Lin (1997), Adamic et al. (2016)), we distinguish between blockers and communicative agents exerting zero effort in communication. While blockers represent the total breakdown of a communication channel, i.e. no message is retransmitted due the failure of the communication technology, communicative agents exerting zero effort send a random message.

One agent, whom we call the *source*, perfectly observes the state of the world. We code the state of the world and messages as either being in favor of an action, e.g.  $m_{source} = 1$ , or against it, e.g.  $m_{source} = 0$ . Once the source has observed the state of the world, she creates a message and transmits it to her peers, who in turn pass it along the communication path until it reaches a final individual who takes the payoff relevant action for the whole population. We call this final receiver the *sink*. The sink selects the action he thinks matches the state of the world. To highlight the inner mechanisms of message distortion, we consider a population where all communicative agents are honest and their common goal is to have the sink receiving the right message. There are no malicious intents to deliberately distort the truth. In particular, when an individual exerts no effort in communication precision, the player next to him receives a random message. As the investment in accuracy increases, so does the probability that the message is correctly transmitted. In the limit, the message becomes deterministic. Incentives for communication accuracy are dependent only on the network position of agents, as the model creates a tradeoff between the goal of successful transmission to the sink and the cost of exerting effort, given everyone’s position in the communication chain. We mostly focus on tree networks, as Liben-Nowell and Kleinberg (2008) finds that online messages mostly proceed in a narrow and very deep tree-like pattern, and Iribarren and Moro (2009) shows that the cascades of a recommendation letter are almost tree-liked shaped. We also study the case of a simple symmetric cycle, where the source can reach the sink through two symmetric channels. In case both channels are used, the sink might receive contradicting

messages and has to update his belief accordingly.

The first main contribution is to show that at most two interior equilibria can exist in the simultaneous game. The technology of information transmission creates non-linearities in the best responses of players, and we are not able to write the strategic communication precisions in closed form. However, we are able to characterize the existence of equilibria in function of the cost of accuracy. When the cost is high, there cannot exist interior equilibria due to a strong complementarity effect, and the only equilibrium is characterized by everyone exerting zero effort. The resulting chain is a sequence of random messages. As the marginal cost of accuracy decreases, the benefit of positive effort increases due to complementarities of everyone's investments and an interior equilibrium exists. When the marginal cost further decreases, there exist two interior equilibria, one characterized by high message accuracies and one by low accuracies. When there is no cost of communication precision, all agents are better off by exerting the maximum effort. The resulting chain is a deterministic sequence of messages. We also find that in the simultaneous game the precision of messages increases along the chain, i.e. the probability that a mutation of the message occurs is higher up in the communication sequence. This is caused by decreasing probability that the flow of information will be interrupted by blockers in the following steps.

The second main contribution is to characterize the equilibrium precisions of the sequential game, which we are able to write in closed form. Optimal accuracies depend crucially on the length of the chain, the proportion of blockers, and the distance from the source. Every players' accuracy is positive only if the cost is smaller than a threshold that is agent specific and that decreases along the chain. Thus, all agents along the communication path are active only if the cost is smaller than the threshold defined by the last agent before the sink. Otherwise, previous agents know that their communication efforts will surely be nullified by a node after them, and at equilibrium no one exerts effort. In this case, communication is a sequence of random messages. The precision of messages can both increase or decrease along the chain, depending on the fundamental parameters of the cost technology and the proportion of communicative agents. The third contribution lies in the study of a simple cycle, where the source can reach the sink through two symmetric channels. Through an illustrative example, we find that there are cases when the source prefers using both channels, depending on the cost technology and on the proportion of

blockers in the population.

### 1.1.1 Related Literature

Relative to previous literature, the innovation of this paper lies in introducing the strategic decision of message accuracy in a setting where communication is costly and the message can mutate in a chain of directed retransmissions. A number of recent papers focus on the centralization of information in fixed ([Hagenbach \(2011\)](#)) or endogenous ([Mauleon et al. \(2020\)](#)) networks, where each individual holds an information item and chooses whether to hold it or pass it on. Our paper focuses instead on a situation where only one agent observes the state of the world, and creates a message that is passed along until it reaches the decision maker. While players in these class of models face a binary decision – whether to hold or to transmit a message – in our model players strategically exert a costly effort of message accuracy influencing the probability of correct retransmission.

The paper closest to ours is [Jackson et al. \(2019\)](#), which studies the tradeoff between the length of communication chains and the number of parallel paths to the sink. They relate their investigation to the learning dynamics of the population and differs from ours in one fundamental respect. In their model, the transmission of messages is mechanical and agents are not strategic in their decisions of how much to invest in message accuracy, while this is precisely the focus of our paper. The probability that the message mutates is a completely exogenous parameter, while we model this probability as the main decision variable of the game. Our work relates naturally to the emerging literature on the economics of rumors, pioneered by [Banerjee \(1993\)](#). In a network setting, [Bloch et al. \(2018\)](#) studies a network populated by unbiased and biased agents, where one agent possibly learns the underlying state and chooses whether to send a true or false message to her friends and neighbors, who then decide whether or not to transmit it further. They find that the social network can serve as a filter, so that sufficiently credible information circulates. Our setting differs from theirs as we do not consider a context characterized by conflict of interests among players, which is the main focus of their investigation. Furthermore, we depart from their setting by introducing the strategic precision of messages with its associated costs.

This paper also relates to a large literature that studies Bayesian learning in networks (Gale and Kariv (2003), Venkatesh and Goyal (1998), Acemoglu et al. (2011)), characterizing the convergence or not to common opinions. In this paper, instead, we have only one source of information and only one agent takes the payoff relevant action. The message flows through a set of retransmissions from the source to the sink. Perhaps closer to our setting is Niehaus (2011), which studies a setting where costs of communication are modeled explicitly. Agents are endowed with discrete units of knowledge and must weigh the costs and benefits of communicating each unit. We differ from his setting by introducing message precision as a probabilistic decision variable, which is continuous in the effort. While we also study a simultaneous game, Niehaus (2011) only focuses on a setting where agents move sequentially. Moreover, we introduce the possibility of having some nodes blocking the transmission altogether. Finally, this paper also relates to a literature that studies network reliability (Bala and Goyal (2000)), the credibility of messages in social networks (Chatterjee and Dutta (2016)), and to the one that studies the noise of information in a Bayesian setting (Sethi and Yildiz (2016)). We differ from all these strands as we model explicitly the cost of message precision and do not consider the process of endogenous network formation.

The paper unfolds as follows: Section 2 describes the baseline model in the case of tree networks. Section 3 presents the results of a game where all agents simultaneously choose their optimal communication accuracies, while Section 4 looks at a game where actions are taken sequentially. Section 5 studies the case of a simple cycle. The Conclusion summarizes the findings and outlines directions for future research.

## 1.2 The Baseline Model

### 1.2.1 Players, payoffs and communication technology

We study a setting where a population of  $|N| = n$  agents are embedded into an exogenously given network  $G$ . The network is represented by an adjacency matrix  $\mathbf{G}$  that keeps track of all the direct connection between agents, where  $g_{ij} = 1$  if agent  $i$  is connected to agent  $j$  and  $g_{ij} = 0$  otherwise. Links are not reciprocal  $g_{ij} \neq g_{ji}$  and we focus

only on directed networks. Let us denote the set of individual  $i$ 's direct connections as  $N_i(\mathbf{G}) = \{j \neq i | g_{ij} = 1\}$ . We study the problem of how a message created from one agent – the *source* – will spread into the network and eventually reach the designed receiver of the message – the *sink*. The identity and position of the *source* and that of the *sink* are publicly known from all agents. The message created by the source is passed on from agent to agent and it is relayed from the source to the sink via word of mouth. The successful transmission from the source to the sink faces two threats. Messages can involuntarily be altered and can mutate at every step of the communication chain, resulting into the possible spread of the wrong message. Second, there exist two types of agents and the set of possible types is  $T = (\theta_c, \theta_b)$ . An agent is of type  $\theta_c$  with probability  $\phi$  and is willing to retransmit the message he receives. Agents of type  $\theta_c$  have the choice to communicate when on the path from the source to the sink. We call them “communicative” agents. Respectively, with probability  $1 - \phi$  any given agent is of type  $\theta_b$  and blocks the transmission of messages to its peers. We call them “blockers”. As highlighted by existing research (Carley and Lin (1997); Adamic et al. (2016)), the complete breakdown of channels is a serious threat to successful communication. While in organizations employees could be unavailable or ignoring the necessity of communication, in online messaging some users might experience connection errors or device problems. We want to study how the risk of channel breakdown influences players’ strategic investments in communication precision. The breakdown of a channel differs fundamentally from communicative agents not investing in communication precision, i.e. a middle manager sending a completely ambiguous report to his manager. In the latter case, the message is passed on from  $i$  to  $j$ , but the probability that the transmitted message matches the information item previously received by  $i$  is  $1/2$ .

There is complete information about the network architecture, but agents do not know how the two types of agents are located in the network. More specifically, each agent ignores the types of his neighbors in the network and the population shares a common prior belief on the distribution of agents’ types  $(\phi, 1 - \phi)$ . The source perfectly observes the underlying state of the world and generates a message describing the underlying state. We code the state of the world and messages as either being in favor of an action (“1”) or against it (“0”). We denote the set of possible states of the world by  $S = \{s_0, s_1\}$  and the set of messages as  $M = \{w_0, w_1\}$ . We assume without loss of generality that the source observes the state  $s_0$  and generates the word  $w_0$ . This message is passed from the source



on to her neighbors, who in turn will pass it to their neighbors and so forth, until the message reaches the sink who takes the payoff relevant decision for all the players in the network, picking an action in  $A_{sink} = \{w_0, w_1, \emptyset\}$ .

There is no conflict of interest and all individuals seek the truth, i.e. everyone wants the sink to receive the true message and learn the underlying state. Agents are Bayesian and share a common prior belief  $\pi = \frac{1}{2}$  on the original message being generated by the source. Each agent decides how much to invest in the precision of the message she sends. The precision of communication is a costly effort and reflects real costs of communicating: primarily the time and effort involved (Dewatripont and Tirole (2005), Niehaus (2011)). The cost of communication is born by agents only when they speak and not when they listen. This is a simplifying assumption reflecting the fact listening and speaking are perfect complements and that it is sufficient to study strategic investments in one activity to capture the main workings of the model. The cost agent  $i$  endogenously chooses to pay for communicating with agent  $j \in N_i$  is

$$c(x_{ij}) = c x_{ij}$$

where  $x_{ij} \in \mathbb{R}_0^+$  represents the time and effort agent  $i$  invests in communicating with agent  $j$ . The effort  $x_{ij}$  determines univocally the *precision*  $B_{ij}$  of the message sent from  $i$  to  $j$ <sup>6</sup>. We define the “precision”, or “accuracy”, of the transmission as a quantity represented by

$$B_{ij}(x_{ij}) = 1 - e^{-x_{ij}}$$

We see that the precision of communication between  $i$  and  $j$  is a monotone and increasing function of  $x_{ij}$  such that  $B: \mathbb{R}_0^+ \rightarrow [0, 1)$ . With this representation, we also assume that, as the investment in communication increases, the marginal precision decreases. This is a reasonable assumption, as the quality of communication increases disproportionately when the baseline effort is low, compared to when communication is already clear and the message already has a high probability of being correctly transmitted. We can rewrite the cost function of agent  $i$  in terms of the precision of the message she transmits and,

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6. Sometimes we denote the precision  $B_{ij}$  also as *accuracy*

since there exists a unique correspondence between effort  $x_{ij}$  and the precision of the message  $B_{ij}$ , we will consider the precision  $B_{ij}$  itself as  $i$ 's choice variable. The effort of communication can be written as

$$x_{ij} = -\ln(1 - B_{ij})$$

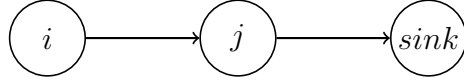
Moreover, we strongly believe that convexity is the right assumption to make when one discusses investments in communication links. The formation of any network involves a fixed cost component. Whenever agents need to invest a fixed initial amount in a communication link, the quality of the communication link is likely to be a convex function of investments. In fact, the literature on discrete link formation assumes an extreme form of convexity. We can think of the precision of communication as the degree of articulation of words and the clarity of expression in verbal communication or as the degree of accurateness of a report sent from an analyst to his supervisor. The precision  $B_{ij}$  consequently defines the technology of information transmission. With probability

$$\frac{1 + B_{ij}}{2}$$

the correct message  $w_0$  is transmitted from  $i$  to  $j$  and with complementary probability  $\frac{1-B_{ij}}{2}$  the wrong message  $w_1$  is communicated to agent  $j$ . From this simple formulation we see how zero precision  $B_{ij} = 0$  (we can think about this as an individual mumbling words) results in a random message while an extremely precise message,  $B_{ij} = 1$  means that communication is deterministic and the message is passed on without distortions or alterations. We include the possibility that, by a double mutation, the original message is retrieved by mistake. More precisely, once the original message, say  $w_0$ , is lost in the communication between agent  $i$  and  $j$  and  $w_1$  is transmitted, there is the possibility that  $w_0$  is retrieved in the following communication steps. Let us take the word "game" for instance. When not well pronounced, it could be understood as "fame" or "blame" and, by retransmitting the message multiple times, it is possible that the word "game" will be pronounced again in the communication chain. Without loss of generality we study a case where the messages set consists of two words, but the underlying working of the model can be extended to a larger message set, given that the possibility of message retrieval

my multiple mistakes holds. To illustrate better this mechanism, consider the following example of a line network of three agents.

**Figure 1.1** – Line network of three agents



In this example, agent  $i$ , whom we consider to be the source, perfectly observes state of the world  $s_0$ . She creates the message  $w_0$  and transmits it to individual  $j$  who in turn communicates it to the sink. For the sake of exposition, we assume in this instance that both agents  $i$  and  $j$  are communicative. In this example the total probability  $p(w_0|w_s = w_0)$  that, once  $w_0$  is created by the source, the sink also hears  $w_0$  is

$$\begin{aligned} p(w_0|w_s = w_0) &= \frac{1 + B_{ij}}{2} \frac{1 + B_{jsink}}{2} + \frac{1 - B_{ij}}{2} \frac{1 - B_{jsink}}{2} \\ &= \frac{1 + B_{ij}B_{jsink}}{2} \end{aligned}$$

The first term of  $p(w_0|w_s = w_0)$  gives the probability that  $w_0$  is transmitted in both communication steps, while the second term takes into account the possibility that in the communication between  $i$  and  $j$  the word  $w_1$  is transmitted instead of  $w_0$  – this event having probability  $\frac{1-B_{ij}}{2}$  – and that in the following step also  $j$  makes a mistake and instead of  $w_1$  he sends  $w_0$ . Interestingly, in this setting we see how the investments in communication precision  $B_{ij}$  and  $B_{jsink}$  are perfect complements. The perfect complementarity of precisions is the core of our results. When anyone on the communication path exerts no effort and sends a completely unintelligible message, the resulting probability that the correct information gets to the sink without mutations is  $1/2$  and the overall transmission is random, no matter how much other agents invested in communication. All agents want the sink to take the action that matches the original message. The action set of the sink is  $A_{sink} = \{w_0, w_1, \emptyset\}$  and one element is denoted by  $a_{sink}$ . Assuming that the underlying state is  $w_0$ , the payoff of a generic individual  $i$  writes

$$\begin{cases} u_i(a_{sink} = w_0) &= 1 + c \ln(1 - B_i) \\ u_i(a_{sink} = \emptyset) &= 0 + c \ln(1 - B_i) \\ u_i(a_{sink} = w_1) &= -1 + c \ln(1 - B_i) \end{cases}$$

The sink chooses  $a_{sink} = \emptyset$  when he hears no message, and chooses  $a_{sink} = w_0$  or  $a_{sink} = w_1$  according to which one he believes is the original message created by the source. In both settings, the information flow originating in the source and ending in the sink partitions the set of nodes in two subsets: one containing the nodes through which information can reach the sink and another that does not. We restrict our attention to those nodes that can potentially be in the communication chain between the source and the sink because strategic agents do not have interest to invest in communication precision on links that do not lead to the sink. Moreover, in both sections we study two settings: one where agents take decisions simultaneously and one where they act sequentially.

### 1.2.2 Conversation in Trees

We mostly focus on tree networks, as the literature in computer science shows that communication on social media flows in a tree-shaped fashion ([Liben-Nowell and Kleinberg \(2008\)](#), [Iribarren and Moro \(2009\)](#)). In trees there exists a unique path connecting the source and sink and we restrict our attention to these nodes and disregard the others. We denote the path from the source to the sink as  $s(\mathbf{G})$ . When writing the probability that the sink receives the original message created by the source we have to take into account all the possible combinations of successful message transmission and mistakes, such that the message heard by the sink is indeed the original one. Iterating the computation of the total probability of successful transmission of the message created by the source  $w_s$  to the sink, the successful transmission over  $m$  agents writes

$$p(w_0|w_s = w_0) = \frac{1 + B_{ij}B_{jk}\dots B_{lsink}}{2}$$

We see that in this case, as in the previous example, it suffices that only one agent along the line connecting the source with the sink invests zero precision in communication to

have a random message. Also, since all agents in the network are Bayesian but have a common prior  $\pi = \frac{1}{2}$  on the underlying state, they believe to whatever message they receive and try to retransmit it to the next agent in the line. Considering again the example of the line with three agents and introducing now the possibility that any given agent might be a blocker with probability  $1 - \phi$ , the expected utility of the source writes

$$\begin{aligned}\mathbb{E}u_i &= \phi\{p(w_0|w_s = w_0)u_i(a_{sink} = w_0) + (1 - p(w_0|w_s = w_0))u_i(a_{sink} = w_1)\} \\ &\quad + (1 - \phi)u_i(a_{sink} = \emptyset) \\ &= \phi B_i B_j + c \ln(1 - B_i)\end{aligned}$$

Since the source does not know whether the next agent in the line is a blocker or communicative, she expects that with probability  $1 - \phi$  her message will be blocked the sink does not receive anything from his predecessor. Assuming agent  $j$  receives a message, his expected utility instead writes

$$\begin{aligned}\mathbb{E}u_j &= p(w_0|w_s = w_0)u_i(a_{sink} = w_0) + (1 - p(w_0|w_s = w_0))u_i(a_{sink} = w_1)\} \\ &= B_i B_j + c \ln(1 - B_j)\end{aligned}$$

We see from this example how the network distance of each individual from the sink enters the utility function discounting the benefit term by a factor  $\phi$ . Individual  $j$  is the last in the line and has no uncertainty on the probability of the message reaching the sink. The source is at distance two from the sink and with probability  $\phi$  the next in line will be a “blocker”, resulting in no message reaching the sink. We easily generalize the form of the expected utility such that for any individual  $k$  at distance  $d_k$  from the sink the expected utility writes

$$\mathbb{E}u_k = \phi^{d_k-1} \prod_{j \in s(\mathbf{G})} B_j + c \log(1 - B_k)$$

As the distance to the sink decreases, the smaller is agent  $k$ 's uncertainty about the successful transmission of the message in the subsequent steps, due to a smaller likelihood that any agent in front of  $k$  is a blocker. This lower uncertainty translates in a higher

expected benefit of those down the line compared to those closer to the source. On the other hand, the effect of precisions' complementarity is the same across the chain. We analyze two different timings of the game. First, we focus on simultaneous games, where every individual decides how much to invest in communication precision before the communication chain starts and without observing the actions of other players. Second, we consider a setting where the accuracies of communication are chosen sequentially from the source to the sink, and every agent  $k$  observes the message precision of his predecessor  $B_{k-1}$  before optimally choosing his own  $B_k$ .

### 1.3 Conversation in a simultaneous game

Let us consider an illustrative example with just two agents and the sink, as in Figure 1. Agents  $i$  and  $j$  maximize their expected utilities without observing each others' investments, and their first order conditions write

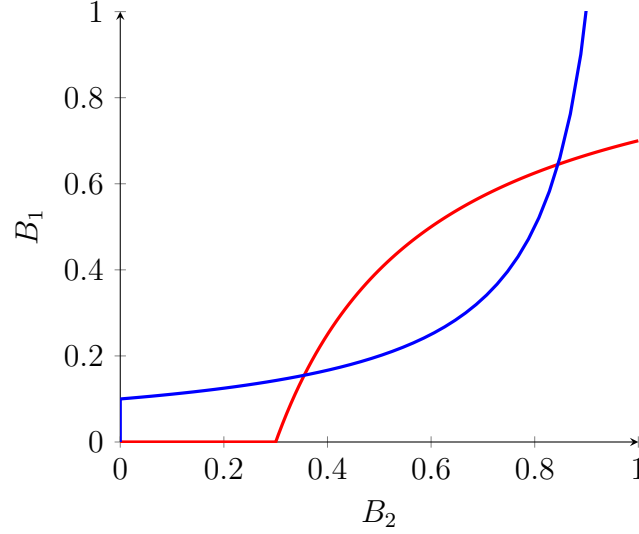
$$\begin{cases} \frac{\partial \mathbb{E}u_i}{\partial B_i} = \phi B_j - \frac{c}{1 - B_i} = 0 \\ \frac{\partial \mathbb{E}u_j}{\partial B_j} = B_i - \frac{c}{1 - B_j} = 0 \end{cases}$$

Writing the best responses to one another, we obtain that

$$\begin{cases} B_i^*(B_j) = 1 - \frac{c}{\phi B_j} \\ B_j^*(B_i) = 1 - \frac{c}{1 - B_i} \end{cases}$$

Plotting these two best responses

**Figure 1.2** – Best responses for 2-agents line. In red is  $B_1(B_2)$  and in blue is  $B_2(B_1)$ .



Solving the system we find that the solutions write

$$\begin{cases} B_i = \frac{c\phi + \phi - c \pm \sqrt{\Delta_1}}{2\phi} \\ B_j = \frac{-c\phi + \phi + c \pm \sqrt{\Delta_1}}{2\phi} \end{cases}$$

where  $\Delta_1 = (c\phi - \phi - c)^2 - 4c\phi$ . Obviously, the profile of actions  $(0,0)$  is always an equilibrium of the communication game due to the perfect complementarity of precisions. Interestingly we see that the second individual in the line invests strictly more in precision,  $B_j > B_i$ , for any values of the parameters and this is due to the fact that individual  $j$  faces no uncertainty about the probability of the sink receiving a message, since he is the last in the line before the sink. The number of solutions of this coordination problem depends on the value of the discriminant  $\Delta_1$  and it is ultimately pinned down by the fundamental parameters of the game, i.e. the cost of communication  $c$  and the probability of nodes being communicative  $\phi$ .

$$\left\{ \begin{array}{ll} \Delta_1 > 0 \iff c < \frac{\phi}{(1 + \sqrt{\phi})^2} \Rightarrow & 2 \text{ solutions} \\ \Delta_1 = 0 \iff c = \frac{\phi}{(1 + \sqrt{\phi})^2} \Rightarrow & 1 \text{ solution} \\ \Delta_1 < 0 \iff c > \frac{\phi}{(1 + \sqrt{\phi})^2} \Rightarrow & 0 \text{ solutions} \end{array} \right.$$

It is also see to notice that, when they exist, both solutions are positive. We would like to study the features of this system: how does the system behave and how what are the characteristics of the equilibrium precision? Are these solutions stable? We can see these equilibrium outcomes as the result of a dynamic process of adjustments of agents' investments towards certain values. Denoting by  $\mathbf{B}^*$  the equilibrium precisions, we can introduce a definition.

**Definition 1.1** (Tatônnement stability).

*Let  $\phi_i$  be the best response of player  $i$ . Then, a Nash equilibrium  $\mathbf{B}^*$  will be globally stable if for any initial position the system converges to  $\mathbf{B}^*$ . Also, a Nash equilibrium  $\mathbf{B}^*$  is locally stable if there exists a neighborhood of  $\mathbf{B}^*$  such that stability holds.*

The intuition behind this formulation of stability lies in the idea that agents take turns in adjusting their investments, each agent reacting optimally to the others' best responses. This induces a tatônnement process to reach equilibrium. [Moulin \(1984\)](#) introduces a criterion to characterize the stability of equilibria for games with continuous best response functions. Adapting their result to our setting we know that  $\mathbf{B}^*$  is locally stable if and only if the spectral radius of the Jacobian of the best response function  $\mathbf{J} [\Phi(\mathbf{B}^*)]$  is no more than one. An alternative graphical explanation says that an strategy is stable if, at equilibrium point, the best-response curve intersects the forty-five degree line from above (the symmetric applies for unstable equilibrium points). In the case of a 2-player game with one-dimensional strategy space, the above condition for a local stable equilibrium reduces to having



$$\left| \frac{\partial^2 \mathbb{E}u_i}{\partial B_i^2} \frac{\partial^2 \mathbb{E}u_j}{\partial B_j^2} \right| > \left| \frac{\partial^2 \mathbb{E}u_i}{\partial B_i \partial B_j} \frac{\partial^2 \mathbb{E}u_j}{\partial B_i \partial B_j} \right|$$

at equilibrium. Evaluating the condition above at the higher equilibrium we find this happens if

$$\frac{4c\phi^2}{c - \phi + c\phi + \sqrt{\Delta_1}} > 1$$

which is always true for  $c < \frac{\phi}{(1+\sqrt{\phi})^2}$ . Symmetrically, at the lower equilibrium the inequality is reversed and we obtain a stable high equilibrium and an unstable low equilibrium, where a small movement away from it causes a big change in the best responses eventually taking the game out of equilibrium. When only equilibrium exists, it is easy to verify that it is unstable. The next Proposition characterizes the equilibria for networks with  $m$  agents on the communication path, and finds conditions for the existence of different equilibrium configurations. In the chain of retransmissions,  $m$  agents decide simultaneously about their investments in communication precision. We can see that the fundamental mechanism analyzed in the two-agents example is reproduced with more general chains.

**Proposition 1.1.**

*In networks where  $m$  agents on the path to the sink choose their message precisions simultaneously, there always exists a value  $\tilde{c} = \tilde{c}(n, \phi)$  such that for  $0 < c < \tilde{c}$  there exist two interior equilibria of the communication game. If  $c = \tilde{c}$  there exist only one interior equilibrium, and if  $c > \tilde{c}$  there exist no interior equilibrium. Moreover, in the limit of cheap communication  $c \rightarrow 0$  there only exist the two corner equilibria  $B_k = 0$  and  $B_k = 1$  for all agents  $k = 1, \dots, n$ .*

As in the two-players example, the equilibrium characterized by all agents exerting zero communication effort always exist, irrespective of the values of the parameters  $c$  and  $\phi$ . The number of equilibria does not depend explicitly on the number of agents along the chain. We are able to prove the Proposition using the fact that it is possible to write

the best responses of every agent in function of that of the last agent before the sink – the only one that face no uncertainty on the possibility of sending the message to a blocker. Substituting the best responses of every agent in the first order condition of the very last individual, we obtain that one equation of degree  $m$  regulates the whole problem. Unfortunately we are not able to study the stability of equilibria in this more complex case, since we cannot explicitly write down the equilibrium precisions. Interestingly, although we are not able to write a closed form expression for the investments of  $m$ -players game for the simultaneous game, we can characterize the trend of message precisions along the chain.

**Proposition 1.2.**

*When  $m$  agents play a simultaneous game of endogenous communication precision, if  $\phi < 1$  the equilibrium investments monotonically increase with the distance from the source*

$$B_{i+1} > B_i$$

*If  $\phi = 1$ , all players invest equally in communication precision.*

The previous proposition tells us that in a setting where investments in message precision are decided simultaneously, when moving from the source towards the sink, agents face decreasing uncertainty about the possibility of the message being lost in communication steps ahead of them, thus resulting in increasing incentives to invest in communication precision. The mechanism relies only on this parameter and on the simultaneity of the game. Investments in precisions are decided at the same instant, assuming to receive a message from the predecessor. Another way of looking at the simultaneous game is a situation where, once the message is generated by the source, it is passed on sequentially but it is not possible to observe their predecessors accuracies. The fact of receiving the message carries information per se, and agents who receive it know that there were no blockers among their predecessor. Thus, they optimize only worrying whether the message they pass on is going to reach the sink or not. In the case agent  $i$  does not receive any message, the game stops there and everyone gets a normalized payoff of zero.

## 1.4 Conversation in a sequential game

When agents take decisions sequentially we solve the game by backward induction, starting from the last agent before the sink. Now, the strategic problem of optimizing the accuracy of information transmission is quite different. Every agent  $i$  optimizes his effort in message precision knowing that his follower in the chain  $i+1$  is going to observe the precision  $B_{i,i+1}$  and will condition on it his own investment. The following proposition characterizes the communication precisions for all agents  $m$  on the path from the source to the sink. We can see that the precision of communication is always less than one at equilibrium and that it decreases uniformly with the total number of agents along the path. The more overall steps there are between the source and the sink, the higher the probability that the message arrives to a node turning out to be a blocker. Also, the message relay is not random, i.e.  $B_m > 0$ , only if the cost parameter is lower than an agent-specific threshold. This results in the fact that in order to have all agents investing in communication precision, it is must the case that the cost parameter is smaller than the threshold imposed by the last agent in the chain. Proposition 3 characterizes the optimal  $B_m$  and the threshold for non random communication.

### Proposition 1.3.

*In trees networks, when  $n$  agents play a sequential communication game, the precision of communication can be written in closed form as*

$$B_m = 1 - \frac{c\phi^{d_m}(1-\phi)}{(1-\phi)\phi^{n-1} - c(1-\phi^{d_m})}$$

*Moreover, there exists an interior equilibrium characterized by  $B_m$  if and only if*

$$c < c_m = \frac{\phi^{n-1}(1-\phi)}{\phi^{d_m}(1-\phi) + 1 - \phi^{d_m}}$$

*for every  $m=1,\dots,n$  on the communication path. If  $c > c_m$  for some  $m$ , then the unique equilibrium is characterized by  $B_m = 0$ , for all  $m$ .*

We see that in this setting, even in a situation where there is no conflict of interests, the further away agents are from the source the smaller is the threshold on the cost to have them invest positively in communication precision. If we name  $c_i$  and  $c_j$  the cost thresholds for two agents  $i$  and  $j$  who are at distance  $d_i$  and  $d_j$  from the source and  $d_i < d_j$ , this implies that when  $c_i > c > c_j$ , agent  $j$  will not invest at all in communication precision and agent  $i$ , anticipating  $j$ 's behavior, will not invest as well - even though he would have normally invested in precision given that  $c < c_i$ . This argument can be repeated up the communication chain, resulting in random message transmission occurring in the network. The following proposition characterizes the trend of communication precisions along the communication path in relation to the cost parameter  $c$  and  $\phi$ . The trend is determined by the global characteristic of the game, i.e. the total number of agents in the network  $n$ , the cost and the proportion of blockers. Proposition 4 also shows that if there are no blockers in the population,  $\phi = 1$ , communication precisions can only decrease as the information moves down the chain since  $c$  is bound to be positive, in a trend that is opposite to the case of the simultaneous game.

**Proposition 1.4.**

*In the sequential game with  $n$  players, the investments in communication precisions increase and decrease along the communication path depending on the relative values of  $c$  and  $\phi$ . Formally,*

$$\begin{cases} B_i > B_{i+1} & \text{if } c > \phi^{n-1} - \phi^n \\ B_i < B_{i+1} & \text{if } c < \phi^{n-1} - \phi^n \end{cases}$$

where  $i + 1$  denotes the player right after player  $i$  on the communication path and  $n$  denotes the number of agents that are on the communication path. In the extreme situation in which agents are all “communicative”  $\phi = 1$ , investments in communication are always decreasing from the source, as there is no risk of the message being blocked in the subsequent steps. The source transmits a message of precision one, minus the cost parameter of accuracy. All subsequent agents internalize the accuracy of all previous retransmissions and produce messages of accuracy one minus a cost which is normalized

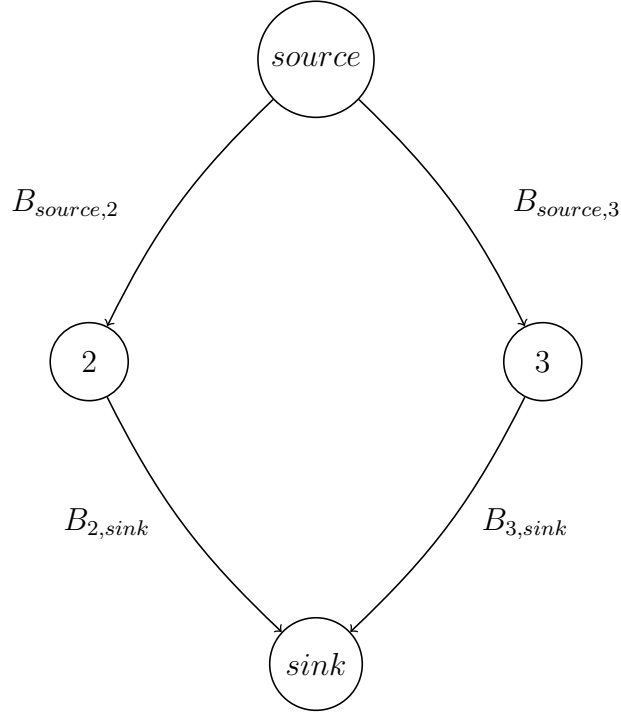
by a factor representing the number of previous retransmissions. As soon as  $\phi$  becomes different from this corner value and if the cost  $c$  is low enough, then for any agent  $i$  the decreasing probability of having the message lost in the steps ahead of him overcomes the cost of his own effort, thus incentivizing him to invest in message precision more than his predecessor in the line. Also, we can see that the threshold that distinguishes the two regimes is not monotonic in  $\phi$ . When the proportion of active players is large enough with respect to the whole population,  $1 > \phi > (n-1)/n$ , the threshold decreases and the interval of the parameter  $c$  for which communication precision increases along the path becomes smaller. On the contrary, when the proportion of active players is smaller,  $(n-1)/n > \phi > 0$ , the threshold increases and the interval of the parameter  $c$  for which communication precision decreases becomes smaller. The maximum threshold with respect to  $c$  is found exactly when the proportion of blockers  $1 - \phi$  equals  $1/n$ , in other words when  $\phi = (n-1)/n$ .

## 1.5 Cycles

### 1.5.1 Two Channels

We turn now to study cycles. Let us suppose that the source can reach the *sink* through two different channels: through agent 2 on the left of the network below and through agent 3 on the right. Since the two channels are symmetric, when the source uses both channels the precision of these messages is going to be same and  $B_{source,2} = B_{source,3} = B$ . When the cycle is symmetric, agents 2 and 3 face the same uncertainty on the possible position of blockers and have identical incentives to invest in communication precision, since they are equidistant from the source and the sink, and they play simultaneously to the source. Their best responses are identically symmetric and depend only on the source's communication accuracy and on the structure of the cycle through its dependence on the distribution of blockers  $(\phi, 1 - \phi)$ . The source has no incentive to deviate from investing symmetrically in both channels, taking into account the symmetric best responses of agents 2 and 3 and the equal probability that any of the two channels breaks down. Hence, the source has no incentive to deviate from investing equally in communication precision. When the source sends the message through agents 2 and 3, she pays

twice the cost of communication precision, but can diversify the risk of the message being blocked in the subsequent steps. However, using two channels entails the possibility that the sink hears contradicting messages coming from the two intermediate agents.



We assume that the *sink* is Bayesian and his prior is  $\pi = \frac{1}{2}$ . He chooses  $a_{sink} = w_0$  if his posterior belief is  $\mu(w_0|\cdot) > \frac{1}{2}$ , he chooses  $a_{sink} = w_1$  if  $\mu(w_0|\cdot) < \frac{1}{2}$  and he stays silent,  $a_{sink} = \emptyset$ , if he receives no message. Also, he randomizes with equal weights between actions  $a_{sink} = w_0$  and  $a_{sink} = w_1$  when his posterior belief is exactly at  $\mu(w_0|\cdot) = \frac{1}{2}$ .

Now, the sink can receive seven possible set of messages from agents 2 and 3, which we denote with  $(m_2, m_3)$ : either  $(w_0, w_0)$ ,  $(w_1, w_1)$ ,  $(w_0, w_1)$ ,  $(w_1, w_0)$ ,  $(\emptyset, w_0)$ ,  $(\emptyset, w_1)$ ,  $(w_0, \emptyset)$ ,  $(w_1, \emptyset)$ ,  $(\emptyset, \emptyset)$ . The first element of the set corresponds to the message coming from agent 2 and the second element of the vector to the message coming from the other channel, agent 3. The first column contains all possible set of messages if both agents 2 and 3 are not blockers, which happens with probability  $\phi^2$ . The second and third columns contain all possible set of messages in case only one among agents 2 and 3 is a blocker  $\theta_b$  and the other is a communicative  $\theta_c$ , which occurs with probability  $\phi(1 - \phi)$ . The third column

looks at the case where both agents are blockers  $\theta_b$ , and no message goes through with probability  $(1 - \phi)^2$ . Summing up,

**Table 1.1** – Set of possible messages received by the sink

Types	$(\theta_2 = \theta_c, \theta_3 = \theta_c)$	$(\theta_2 = \theta_c, \theta_3 = \theta_b)$	$(\theta_2 = \theta_b, \theta_3 = \theta_c)$	$(\theta_2 = \theta_b, \theta_3 = \theta_b)$
<b>MESSAGES</b>	$(w_0, w_0)$	$(w_0, \emptyset)$	$(\emptyset, w_0)$	$(\emptyset, \emptyset)$
	$(w_1, w_1)$	$(w_1, \emptyset)$	$(\emptyset, w_1)$	
	$(w_0, w_1)$			
	$(w_1, w_0)$			

When the sink hears two messages because both agents 2 and 3 are of type  $\theta_c$ , the probability of each pair of messages reaching the sink is

$$\begin{cases} p(w_0, w_0) = \frac{(1 + BB_2)(1 + BB_3)}{4} \\ p(w_1, w_1) = \frac{(1 - BB_2)(1 - BB_3)}{4} \\ p(w_0, w_1) = \frac{(1 + BB_2)(1 - BB_3)}{4} \\ p(w_1, w_0) = \frac{(1 - BB_2)(1 + BB_3)}{4} \end{cases}$$

which correspond the following posteriors of the sink

$$\begin{cases} \mu(w_0|w_0, w_0) = \frac{(1 + BB_2)(1 + BB_3)}{(1 + BB_2)(1 + BB_3) + (1 - BB_2)(1 - BB_3)} \\ \mu(w_0|w_1, w_1) = \frac{(1 - BB_2)(1 - BB_3)}{(1 + BB_2)(1 + BB_3) + (1 - BB_2)(1 - BB_3)} \\ \mu(w_0|w_0, w_1) = \frac{(1 + BB_2)(1 - BB_3)}{(1 + BB_2)(1 - BB_3) + (1 - BB_2)(1 + BB_3)} \\ \mu(w_0|w_1, w_0) = \frac{(1 - BB_2)(1 + BB_3)}{(1 + BB_2)(1 - BB_3) + (1 - BB_2)(1 + BB_3)} \end{cases}$$

Let us now analyze the posteriors of the sink for all different set of messages he receives.

When the sink receives  $w_0$  from both channels, his posterior belief can be written as

$$\mu(w_0|w_0, w_0) = \frac{(1 + BB_2)(1 + BB_3)}{(1 + BB_2)(1 + BB_3) + (1 - BB_2)(1 - BB_3)} > \frac{1}{2}$$

for every  $B > 0$ . Consequently, whenever the sink receives the set  $(w_0, w_0)$  he will choose  $a_{sink} = w_0$ . Symmetrically, when the sink receives  $w_1$  from both agents his posterior is

$$\mu(w_0|w_1, w_1) = \frac{(1 - BB_2)(1 - BB_3)}{(1 + BB_2)(1 + BB_3) + (1 - BB_2)(1 - BB_3)} < \frac{1}{2}$$

for every positive  $B$  and  $a_{sink} = w_1$ . When the sink instead receives contradicting messages  $(w_0, w_1)$  or  $(w_1, w_0)$ , his posterior will not be different from his prior and he chooses with equal probability  $a_{sink} = w_0$  and  $a_{sink} = w_1$ , since we expect that in equilibrium the two intermediate agents 2 and 3 communicate messages of the same precision  $B_2^* = B_3^*$ <sup>7</sup>. The analysis is even simpler when one agent among 2 and 3 turns out to be of type  $\theta_b$ . In that case, the sink hears just one message coming from either channel and we are back to the case of a line network. The sink chooses the action matching the message he receives. After some algebra<sup>8</sup>, the expected utilities of the source and of the two intermediaries above write

$$\begin{aligned}\mathbb{E}u_s^{2ch} &= \phi B(B_2 + B_3)\left(1 - \frac{\phi}{2}\right) + 2c \log(1 - B) \\ \mathbb{E}u_2 &= \frac{\phi}{2}B(B_3 - B_2) + BB_2 + c \log(1 - B_2) \\ \mathbb{E}u_3 &= \frac{\phi}{2}B(B_2 - B_3) + BB_3 + c \log(1 - B_3)\end{aligned}$$

We now proceed to finding the equilibrium of this game and, by comparing it with the equilibrium of a game where the source exploits only one channel, study the incentives of the source to use one or both channels. The three first order conditions write

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<sup>7</sup>. In the case of an asymmetric channel that would not be the case, since the total probability that the message transmission gets interrupted by a blocker is higher in the longer channel. Consequently, that would also modify the equilibrium precisions.

<sup>8</sup>. The proof in the Appendix shows how we obtain the utilities above.



$$\begin{cases} \phi(B_2 + B_3)(1 - \frac{\phi}{2}) = \frac{2c}{1 - B} \\ B(1 - \frac{\phi}{2}) = \frac{c}{1 - B_2} \\ B(1 - \frac{\phi}{2}) = \frac{c}{1 - B_3} \end{cases}$$

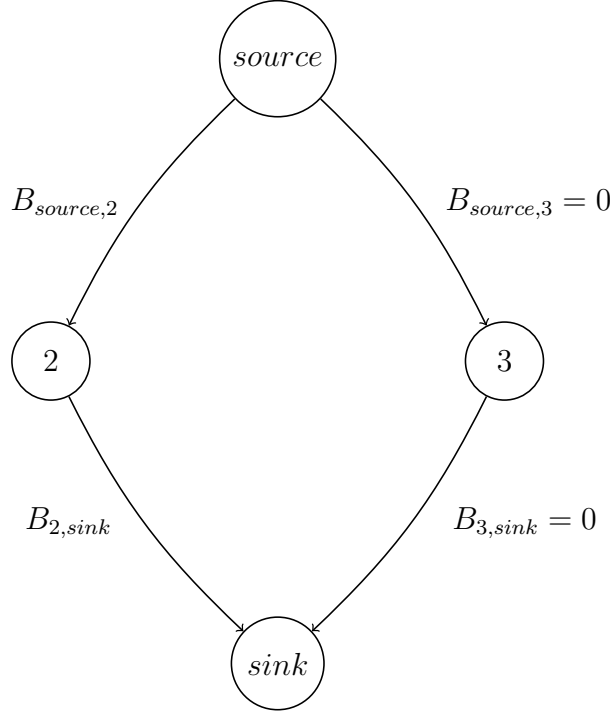
From the last two equations we know, as expected, that in equilibrium  $B_2^* = B_3^*$ . When the source send messages along both channels, we denote the equilibrium communication precisions of agents 2 and 3 as  $B_2^* = B_3^* = B_m^*$ . The equilibrium precision of the message transmitted by the source is denoted by  $B^{**}$ . Solving the system we find that

$$\begin{cases} B^{**} = \frac{(2 - \phi)\phi - 2c(1 - \phi) \pm \sqrt{\Delta_2}}{2(2 - \phi)\phi} \\ B_m^{**} = \frac{(2 - \phi)\phi + 2c(1 - \phi) \pm \sqrt{\Delta_2}}{2(2 - \phi)\phi} \end{cases}$$

where  $\Delta_2 = (2c(1 - \phi) + \phi(2 - \phi))^2 - 8c(2 - \phi)\phi$ . In what follows we focus on the highest, stable equilibria. As expected from Proposition 2,  $B_m^{**} > B^{**}$ .

### 1.5.2 Unique Channel

We study now a situation where the source exerts communication precision only in communicating with agent 2 and sends a random message to agent 3, i.e.  $B_{source,3}=0$ . We assume that, since the source is always of type  $\theta_c$ , she does not block communication with any agent. Instead, when she exploits *actively* only one channel, the other remains open. However, the source does not exert any accuracy in message transmission and the message is random on that channel, no matter how much agent three invests in precision.



We rewrite the probabilities of the different message sets getting to the *sink*. As highlighted above, the message is completely random along the inactive channel. No matter how much agent 3 invests in accuracy, from that side the sink hears either message  $w_0$  or  $w_1$  with probability  $1/2$ .

$$\left\{ \begin{array}{l} p(w_0, w_0) = \frac{(1 + BB_2)}{4} \\ p(w_1, w_1) = \frac{(1 - BB_2)}{4} \\ p(w_0, w_1) = \frac{(1 + BB_2)}{4} \\ p(w_1, w_0) = \frac{(1 - BB_2)}{4} \end{array} \right.$$

which induce the following posterior beliefs

$$\left\{ \begin{array}{l} \mu(w_0|w_0, w_0) = \frac{1 + BB_2}{2} \\ \mu(w_0|w_1, w_1) = \frac{1 - BB_2}{2} \\ \mu(w_0|w_0, w_1) = \frac{1 + BB_2}{2} \\ \mu(w_0|w_1, w_0) = \frac{1 - BB_2}{2} \end{array} \right.$$

Now, the posterior of the sink depends only on the communication accuracies exerted by the source and by agent 2, since the channel going through agent 3 carries no real information but only noise. The message received by agent 3 does not impact the posterior belief and the utilities of agents on the active channel resemble those we analyzed in Section 3 when we looked at the case of communication in a simple line. The uncertainty on agent's 3 type does not directly affect the utilities and the utilities write

$$\begin{aligned} \mathbb{E}u_s^{1ch.} &= \phi BB_2 + c \log(1 - B) \\ \mathbb{E}u_2 &= BB_2 + c \log(1 - B) \end{aligned}$$

The first order conditions write

$$\left\{ \begin{array}{l} B_2 \phi = \frac{c}{1 - B} \\ B = \frac{c}{1 - B_2} \end{array} \right.$$

Solving the system we find

$$\left\{ \begin{array}{l} B_{source}^* = \frac{\phi + c\phi - c \pm \sqrt{\Delta_1}}{2\phi} \\ B_2^* = \frac{\phi - c\phi + c \pm \sqrt{\Delta_1}}{2\phi} \end{array} \right.$$

where  $\Delta_1 = (c\phi - \phi - c)^2 - 4c\phi$ . Again,  $B_2^* > B_{source}^*$  for any  $\phi < 1$ , as highlighted prece-  
dently. We define the difference in the source's expected utilities at the equilibria obtained  
in the two different scenarios, i.e. when active communication occurs along both channels  
and when it occurs only along one channel  $\delta = \mathbb{E}_{source}^{2ch.}(\mathbf{B}^{**}) - \mathbb{E}_{source}^{2ch.}(\mathbf{B}^*)$ . Proposition  
5 finds conditions on the parameters of the game such that active communication along  
two symmetric channels is a payoff maximizing strategy for the source.

**Proposition 1.5.**

*In networks where the source can reach the sink through two symmetric channels*

- *If  $\phi < 1$  there always exists  $\bar{c}$  such that for  $c \in [0, \bar{c})$ ,  $\delta > 0$  and the source sends information along both channels. If  $\phi = 1$ , for any value of the cost parameter  $c$ , the source prefers to use only one channel.*
- *In the limit of cheap communication,  $c \rightarrow 0$ , the incentive to use both channels is maximal when there is the highest uncertainty on agents' types,  $\phi = \frac{1}{2}$ .*

When there is complete information about agents' types and there are no blockers in the population, i.e.  $\phi = 1$ , it is optimal for the source to use only one channel as to minimize the cost of communication precision, knowing the sink will eventually listen to the message coming from that particular channel. The potential benefits of risk diversification are not at play in this scenario, because all agents are communicative and the source can maximize the probability of having the sink receive the right message by using only one channel and minimizing the costs. On the other hand, when there is incomplete information about agents' types and there exists the possibility that the message will be blocked along the communication chain, there exists an opportunity of risk diversification and the source will optimally choose to use both channels when the cost is low enough. As the cost increases, the negative impact on the source's utility is disproportionately larger in the scenario where she uses both channels, compared to the scenario where she uses only one. In other words, the benefit of risk diversification decreases as the cost parameter increases. In particular, the equilibrium precision when the source exploits only one channel is larger than the precisions of messages sent when two channels are exploited. However, the precision of messages sent along the two channels is large enough to result in a negative

indirect effect of the cost increase through the best responses that is larger compared to the scenario where the source uses only one channel. Similarly, the direct negative effect of a change in the cost parameter are larger when the source uses two channels because the total costs of sending two messages of precision  $B^{**}$  are larger than the costs of sending one message only of precision  $B^*$ . For every value of  $\phi$ , when communication is cheap, for the source it is payoff maximizing to use both channels since she bears no cost of communication precision. The source sends two messages along the two channels, both of maximal precision and the message is deterministic. Agents 2 and 3 also communicate at no cost and the sink receives two messages, both reflecting the underlying state with probability 1. As the probability of nodes being “communicative” increases, the relative advantage of risk diversification given by the exploitation of both channels decreases relative to the use of only one channel. Finally, when  $\phi = 1$  and communication is cheap, the source is indifferent between using one of both channels.

## 1.6 Conclusion

This paper studies how agents invest effort in the accuracy of the information they transmit. The state of the world is perfectly observed by one agent, the source, who creates a message representing the underlying state. The message is then passed on from agent to agent, until it reaches a final decision maker, the sink, that takes the payoff relevant action for the whole population. There is no conflict of interest among agents. However, the successful transmission of the message from the source to the sink faces two threats. First, the message can mutate and can be distorted at every step with an endogenous probability. The more effort agents invest in communicating accurately, the higher is the probability that the message is passed on correctly. Second, there exist two types of agents. Those that are ready to invest in communication precision and those that block any message they receive and retransmit only an empty message. Agents ignore the types of their neighbors, but know their probability distribution. Since the accuracy of information is a costly effort, this creates a tradeoff between everyone’s position in the network and the cost-benefit to have the correct message arrive to the sink.

We consider two scenarios. In the simultaneous game, agents decide simultaneously how

much to invest in the precision of their retransmissions. Multiple equilibria can exist, which are underpinned by the structure of the communication costs. In particular, when costs are low enough, there always exist two interior equilibria. The precision exerted by agents increases along the chain because the probability that the message is blocked in the subsequent steps decreases as the proximity to the sink increases. In the sequential game, we are able to write the communication accuracies of every agent in closed form. The optimal accuracies depend crucially on the total length of the chain, the proportion of blockers, and the distance from the source. Every players' accuracy is positive only if the cost is smaller than a threshold that is agent specific and that decreases along the chain. Finally, we study a simple cycle where the source can reach the sink through two symmetric channels and find conditions for which it is optimal to send two messages along both channels instead that using only one. Future research would further consider a more general setting. It would be interesting to study the case of general networks, where there can be multiple sources of information as in [Jackson et al. \(2019\)](#). Also, the discussion on the accuracy of information transmission would be greatly enriched by integrating the possibility of having several non-symmetric cycles and of introducing agents with conflicting interests in this setting, as in [Bloch et al. \(2018\)](#). Finally, integrating a process of endogenous network formation with our setting would significantly contribute to understanding the spread of misinformation in social networks. Those are difficult but important avenues for future research.

## 1.7 Appendix: Proofs

### 1.7.1 Proof of Proposition 1.1

We start by writing the first order conditions for all the agents on the communication path where the index  $d_k$  is an indicator of the distance of the players from the sink. We set  $k = 1$  to be the source. With this indexing, the source is at distance  $d_1 = n$  from sink, the second agent on the communication path is at distance  $d_2 = n - 1$  from the sink and so on. When there are  $n$  players on the communication path, they simultaneously maximize the following system of first order conditions

$$\begin{aligned} \phi^{n-1} B_j \dots B_k - \frac{c}{1 - B_i} &= 0 \\ \phi^{n-2} B_i B_{j+1} \dots B_k - \frac{c}{1 - B_j} &= 0 \\ \dots & \\ \dots & \\ \phi^{n-k} B_i B_j \dots B_{k-1} - \frac{c}{1 - B_k} &= 0 \end{aligned}$$

which can be written iteratively in compact form as

$$\frac{\partial u_k}{\partial B_k} = \phi^{n-k} \prod_{j \neq k} B_j - \frac{c}{1 - B_k} = 0$$

All the equations of this system can be put equal to the parameter  $c$

$$\phi^{n-1} B_j \dots B_k (1 - B_i) = \phi^{n-2} B_i B_{j+1} (1 - B_j) = \dots = \phi^{n-k} B_i B_j \dots B_{k-1} (1 - B_k) = c$$

At this point we can express the communication efforts of all agents in function of that of the last agent, agent  $k$ , on the communication path. Since agent  $k$  is the last one on the path, he holds no uncertainty over the probability of message transmission to the next in the line. This yields

$$\begin{aligned} B_i &= \frac{\phi^{n-1} B_k}{1 - B_k(1 - \phi^{n-1})} \\ B_j &= \frac{\phi^{n-2} B_k}{1 - B_k(1 - \phi^{n-2})} \\ &\dots \\ &\dots \\ B_{k-1} &= \frac{\phi^{n-k+1} B_{k-1}}{1 - B_{k-1}(1 - \phi^{n-k+1})} \end{aligned}$$

Now, it is sufficient to substitute all these best responses of the  $k - 1$  players in  $k$ 's first order condition. Even though this is a non-linear system, we can are able to find that one equation regulates the the whole system, that is

$$\phi^{n(n-1) - \sum_{m=1}^{n-1} m} \frac{B_k^{n-1} (1 - B_k)}{\prod_{m=i}^{n-1} (1 - B_k(1 - \phi^m))} = c$$

The polynomial is always positive, and it is easy to show that

$$\frac{\partial}{\partial \phi} \phi^{n(n-1) - \sum_{m=1}^{n-1} m} \frac{B_k^{n-1} (1 - B_k)}{\prod_{m=i}^{n-1} (1 - B_k(1 - \phi^m))} > 0$$

We can see that it equals zero when  $B_k = 0$  and when  $B_k = 1$  and the derivative with respect to  $B_k$  is null when evaluated  $B_k = 0$ . It follows that it always possible to find a positive  $c = c(n, \phi)$  such that the polynomial has at least two zeros, since it always



positive and equals 0 at the corners of the interval. Now, it is sufficient to show that in the interval  $(0, 1)$  its derivative changes sign only once to show that it can have no more than two solutions. Neglecting the multiplying factor, the first derivative writes

$$\begin{aligned}
\frac{\partial}{\partial B_k} \frac{B_k^{n-1}(1 - B_k)}{\prod_{m=i}^{n-1} (1 - B_k(1 - \phi^m))} &= \\
&= \frac{\left( (1 - B_k)(n - 1)B_k^{n-2} - B_k^{n-1} \right) \prod_{m=i}^{n-1} (1 - B_k(1 - \phi^m))}{\left( \prod_{m=i}^{n-1} (1 - B_k(1 - \phi^m)) \right)^2} + \\
&\quad + \frac{(1 - B_k)B_k^{n-1} \sum_{m=1}^{n-1} \frac{1 - \phi^m}{(1 - B_k(1 - \phi^m))} \prod_{m=i}^{n-1} (1 - B_k(1 - \phi^m))}{\left( \prod_{m=i}^{n-1} (1 - B_k(1 - \phi^m)) \right)^2} \\
&= 0
\end{aligned}$$

Neglecting the denominator, which is always positive, we want to show that the numerator has a unique zero in for  $B_k \in (0, 1)$ . The numerator can be rewritten, by simplifying the product operator, as

$$\begin{aligned}
& (1 - B_k)(n - 1)B_k^{n-2} - B_k^{n-1} + (1 - B_k)B_k^{n-1} \sum_{m=1}^{n-1} \frac{1 - \phi^m}{(1 - B_k(1 - \phi^m))} \\
&= (1 - B_k)(n - 1) - B_k + (1 - B_k)B_k \sum_{m=1}^{n-1} \frac{1 - \phi^m}{(1 - B_k(1 - \phi^m))} \\
&= (1 - B_k)(n - 1) - B_k + (1 - B_k) \sum_{m=1}^{n-1} \frac{B_k(1 - \phi^m) - 1}{1 - B_k(1 - \phi^m)} + \frac{1}{1 - B_k(1 - \phi^m)} \\
&= (1 - B_k)(n - 1) - B_k + (1 - B_k) \sum_{m=1}^{n-1} \frac{1}{1 - B_k(1 - \phi^m)} - n \\
&= \left( - (1 - B_k) - B_k \right) + (1 - B_k) \sum_{m=1}^{n-1} \frac{1}{1 - B_k(1 - \phi^m)}
\end{aligned}$$

Thus, the problem is to show that there is a unique solution on  $(0,1)$  to

$$\begin{aligned}
& -1 + (1 - B_k) \sum_{m=1}^{n-1} \frac{1}{1 - B_k(1 - \phi^m)} \\
&= \sum_{m=1}^{n-1} \frac{1 - B_k}{1 - B_k(1 - \phi^m)} - 1 \\
&= 0
\end{aligned}$$

Since each of the terms is strictly decreasing on  $(0,1)$ , starting at 1 and ending at 0, there is a unique solution in that same interval. This completes the proof.  $\square$

### 1.7.2 Proof of Proposition 1.2

Let us take two agents in the line of communication. Without loss of generality, let us take the first two agents, agents  $i$  and  $j$ . As we have found from the proof of Proposition

2, the best responses of every player can be written in function of the communication effort of the very last agent on the communication path, agent  $k$ . We can simplify the expression of the best responses such that

$$B_i = \frac{\phi^{n-1} B_k}{1 - B_k(1 - \phi^{n-1})} = 1 - \frac{1 - B_k}{1 - B_k(1 - \phi^{n-1})}$$

and

$$B_j = \frac{\phi^{n-2} B_k}{1 - B_k(1 - \phi^{n-2})} = 1 - \frac{1 - B_k}{1 - B_k(1 - \phi^{n-2})}$$

Now it is easy to show that  $B_j > B_i$  since this happens if

$$\frac{1 - B_k}{1 - B_k(1 - \phi^{n-1})} > \frac{1 - B_k}{1 - B_k(1 - \phi^{n-2})}$$

which simplifies to

$$\phi^{n-2} > \phi^{n-1} \iff \phi < 1$$

This completes the proof.

□

### 1.7.3 Proof of Proposition 1.3

We prove Proposition 4 by induction. We first solve for a communication line of three agents and find their optimal communication investments, then for a line of four agents. Following this procedure we are able to write a closed form expression for  $m$  agents in a tree network. When there are three active agents, say  $i$ ,  $j$ ,  $k$ , and one sink, the third

player's utility writes

$$\mathbb{E}u_k = B_i B_j B_k + c \log(1 - B_k)$$

and his best response is

$$B_k^*(B_i, B_j) = 1 - \frac{c}{B_i B_j}$$

Substituting this expression into the expected utility of agent  $j$  his utility writes

$$\mathbb{E}u_j = \phi B_i B_j - c\phi + c \log(1 - B_j)$$

and his best response is then

$$B_j^*(B_i) = 1 - \frac{c}{B_i \phi}$$

and substituting back in the utility of the source – player  $i$  – and maximizing his utility we obtain that

$$\begin{aligned} B_i^* &= 1 - \frac{c}{\phi^2} \\ B_j^* &= 1 - \frac{c\phi}{\phi^2 - c} \\ B_k^* &= 1 - \frac{c\phi^2}{\phi^2 - c(1 + \phi)} \end{aligned}$$

Following the same procedure for a communication chain of  $n$  agents, where agent  $i$  is the source,  $j$  is the second in line and so on, we obtain

$$\begin{aligned}
B_i &= 1 - \frac{c}{\phi^{n-1}} \\
B_j &= 1 - \frac{c\phi}{\phi^{n-1} - c} \\
B_k &= 1 - \frac{c\phi^2}{\phi^{n-1} - c(1 + \phi)} \\
B_l &= 1 - \frac{c\phi^3}{\phi^{n-1} - c(1 + \phi + \phi^2)} \\
&\dots \\
B_m &= 1 - \frac{c\phi^{d_m}}{\phi^{n-1} - c(1 + \phi + \phi^2 + \phi^3 + \dots + \phi^{m-2})} = \\
&= 1 - \frac{c\phi^{d_m}}{\phi^{n-1} - c(1 + \phi + \phi^2 + \phi^3 + \dots + \phi^{n-2})} \\
&= 1 - \frac{c\phi^{d_m}}{\phi^{n-1} - c \left( \sum_{l=0}^{d_m-1} \phi^l \right)} \\
&= 1 - \frac{c\phi^{d_m}(1 - \phi)}{(1 - \phi)\phi^{n-1} - c(1 - \phi^{d_m})}
\end{aligned}$$

where  $d_m$  is the distance of player  $m$  from the source,  $n$  is the total number of players on the communication path and we substituted

$$\sum_{l=0}^{d_m-1} \phi^l = \frac{1 - \phi^{d_m}}{1 - \phi}$$

We see that the communication precision of a generic player  $m$  is positive only if

$$\begin{aligned}
c < c_m &= \frac{\phi^{n-1}}{\phi^{d_m} + \left( \sum_{l=0}^{d_m-1} \phi^l \right)} \\
&= \frac{\phi^{n-1}(1 - \phi)}{\phi^{d_m}(1 - \phi) + 1 - \phi^{d_m}}
\end{aligned}$$

It is easy to see that the threshold on the cost parameter  $c_m$  is decreasing in the distance from the source  $d_m$  since, after some algebra,

$$\frac{\partial c_m}{\partial d_m} = \log(\phi) \frac{\phi^{1+d_m}}{(1 - \phi^{1+d_m})^2} < 0$$

since  $0 < \phi < 1$ . It is sufficient that  $c_{m+1} < c < c_m$  for agent  $m + 1$  to exert zero communication precision and to trigger the best responses of all previous players on the communication path that would also exert zero effort. The only equilibrium in this scenario is  $B_i = B_j = \dots = B_{m+1} = 0$  and the message is random. This completes the proof. □

#### 1.7.4 Proof of Proposition 1.4

We start by writing the communication precision of a generic player  $m$ ,  $B_m$  and we compare it to that of the following player on the communication path, agent  $m + 1$ . The precision exerted by agent  $m$  is

$$B_m = 1 - \frac{c\phi^{d_m}(1 - \phi)}{(1 - \phi)\phi^{n-1} - c(1 - \phi^{d_m})}$$

and that exerted by agent  $m + 1$  writes

$$B_{m+1} = 1 - \frac{c\phi^{d_{m+1}}(1 - \phi)}{(1 - \phi)\phi^{n-1} - c(1 - \phi^{d_{m+1}})}$$

Then it is easy to show that the precisions decrease along the path if

$$\begin{aligned}
B_m > B_{m+1} &\iff \frac{c\phi^{d_m}(1-\phi)}{(1-\phi)\phi^{n-1} - c(1-\phi^{d_m})} < \frac{c\phi^{d_{m+1}}(1-\phi)}{(1-\phi)\phi^{n-1} - c(1-\phi^{d_{m+1}})} \\
&\iff (1-\phi)\phi^{n-1} - c(1-\phi^{d_{m+1}}) < \phi(1-\phi)\phi^{n-1} - c\phi(1-\phi^{d_m}) \\
&\iff (1-\phi)\phi^{n-1}(1-\phi) < c(1-\phi) \\
&\iff (1-\phi)\phi^{n-1} < c \\
&\iff \phi^{n-1} - \phi^n < c
\end{aligned}$$

□

### 1.7.5 Proof of Proposition 1.5

We divide the proof in four steps. First, we show how to derive the expected utility of the source when she uses two channels. Second, we write her utility when she actively communicates only along one channel. Third, we analyze the difference between the source's expected utilities. Fourth, we prove the last part of the proposition about the limit case of cheap communication.

1. Writing down the expected utility of the source when he exploits both communication channels by sending two messages of equal precision we get

$$\begin{aligned}
\mathbb{E}u_{source}^{2ch.} = & \phi^2 \left\{ p(w_0, w_0)(1 + 2c \log(1 - B)) + p(w_1, w_1)(-1 + 2c \log(1 - B)) + \right. \\
& \left. 2p(w_0, w_1) \left[ \frac{1}{2}(1 + 2c \log(1 - B)) + \frac{1}{2}(-1 + 2c \log(1 - B)) \right] \right\} + \\
& \phi(1 - \phi) \left\{ p(w_0, \emptyset)(1 + 2c \log(1 - B)) + p(w_1, \emptyset)(-1 + 2c \log(1 - B)) \right\} + \\
& (1 - \phi)\phi \left\{ p(\emptyset, w_0)(1 + 2c \log(1 - B)) + p(\emptyset, w_1)(-1 + 2c \log(1 - B)) \right\} + \\
& (1 - \phi)^2 \left\{ 2c \log(1 - B) \right\}
\end{aligned}$$

where the terms that are multiplied by  $\phi(1 - \phi)$  consider the case when communication takes place along a line because either agent 2 or 3 are blockers. Substituting and rearranging we write

$$\mathbb{E}u_s^{2ch} = \phi B(B_2 + B_3)(1 - \frac{\phi}{2}) + 2c \log(1 - B)$$

Similarly, we can obtain the expected utilities of agents 2 and 3. Once solved for their optimal precisions, the source's expected utility computed at equilibrium writes

$$\mathbb{E}_{source}(\mathbf{B}^{**}) = \frac{1}{2} \left\{ (2 - \phi)\phi + \sqrt{\Delta_2} - 2c \left( 1 + \phi + \log(4) - 2 \log \frac{2c(1 - \phi) + (2 - \phi)\phi + \sqrt{\Delta_2}}{(2 - \phi)\phi} \right) \right\}$$

2. Writing the expected utility of the source in the setting where only one channel is exploited we obtain

$$\begin{aligned} \mathbb{E}u_{source}^{1ch.} = & \phi^2 \left\{ p(w_0, w_0)(1 + c \log(1 - B)) + p(w_1, w_1)(-1 + c \log(1 - B)) + \right. \\ & \left. p(w_0, w_1)(1 + c \log(1 - B)) + p(w_1, w_0)(-1 + c \log(1 - B)) \right\} + \\ & \phi(1 - \phi) \left\{ p(w_0, \emptyset)(1 + c \log(1 - B)) + p(w_1, \emptyset)(-1 + c \log(1 - B)) \right\} + \\ & (1 - \phi)\phi \left\{ \frac{1}{2}(1 + c \log(1 - B)) + \frac{1}{2}(-1 + c \log(1 - B)) \right\} + \\ & (1 - \phi)^2 \left\{ c \log(1 - B) \right\} \end{aligned}$$

and by substituting the expressions of the probabilities we obtain

$$\mathbb{E}u_{source}^{1ch.} = BB_2\phi + c \log(1 - B)$$

which is analogous to the form of the utility in the case of tree networks. For agent 2 we



can similarly write

$$\mathbb{E}u_2^{1ch.} = BB_2 + c \log(1 - B_2)$$

At equilibrium the expected utility of the source is

$$\mathbb{E}_{source}^{1ch.}(\mathbf{B}^*) = \frac{1}{2} \left\{ \phi + \sqrt{\Delta_1} - c \left( 1 + \phi + \log(4) - 2 \log \left( \frac{c + \phi - c\phi - \sqrt{\Delta_1}}{\phi} \right) \right) \right\}$$

3. The difference between the two expected utilities is denoted by  $\delta = \mathbb{E}_{source}^{2ch.}(\mathbf{B}^{**}) - \mathbb{E}_{source}^{1ch.}(\mathbf{B}^*)$ , where  $\mathbf{B}^{**} = (B_{source}^{**}, B_2^{**}, B_3^{**})$  represents the vector of optimal communication precisions when the source uses two channels, and  $\mathbf{B}^* = (B_{source}^*, B_2^*)$  represents the vector of optimal communication precisions when the source uses only the channel passing through agent 2. First, we will show that

$$\frac{\partial \delta}{\partial c} < 0$$

for any  $\phi \in (0, 1]$ . Then, we show that when there is complete information and there are no blockers, i.e.  $\phi = 1$ , we obtain  $\delta(c = 0) = 0$ . In this case, the source is indifferent between transmitting information along two channels or along one. Then, we show that when we introduce incomplete information about agents' types,  $\phi = 1 - \epsilon$ , the difference  $\delta > 0$  if  $c$  is small. The continuity of  $\delta$  concludes the argument. Substituting the expressions of the optimal communication precisions and simplifying we find

$$\begin{aligned} \delta = \frac{1}{2} \left\{ (1 - \phi)\phi + \sqrt{\Delta_2} - \sqrt{\Delta_1} + -c \left[ 1 + \phi + 2 \log \left( \frac{c + \phi - c\phi - \sqrt{\Delta_1}}{\phi} \right) \right. \right. \\ \left. \left. - 4 \log \left( \frac{2c(1 - \phi) + (2 - \phi)\phi - \sqrt{\Delta_2}}{(2 - \phi)\phi} \right) \right] \right\} \end{aligned}$$

but showing that

$$\frac{\partial \delta}{\partial c} < 0$$

is equivalent, by the definition of  $\delta$ , to showing that

$$\frac{\partial \mathbb{E}_{source}^{2ch.}(\mathbf{B}^{**})}{\partial c} < \frac{\partial \mathbb{E}_{source}^{1ch.}(\mathbf{B}^*)}{\partial c}$$

Using the envelope theorem and substituting the equilibrium values for  $\mathbf{B}^*$  and  $\mathbf{B}^{**}$  the condition above writes

$$-\frac{\phi^2(2-\phi)}{\sqrt{\Delta_2}}B_{source}^{**} + 2\log(1 - B_{source}^{**}) < -\frac{\phi^2}{\sqrt{\Delta_1}}B_{source}^* + \log(1 - B_{source}^*)$$

where the first terms of both sides represent the indirect effects of a change in  $c$  through the best responses and the second terms represent the direct effects. Comparing the first terms of both sides of the inequality

$$\begin{aligned} -\frac{\phi^2(2-\phi)}{\sqrt{\Delta_2}}B_{source}^{**} < -\frac{\phi^2}{\sqrt{\Delta_1}}B_{source}^* &\implies \frac{(2-\phi)}{\sqrt{\Delta_2}}B_{source}^{**} > \frac{B_{source}^*}{\sqrt{\Delta_1}} \\ &\implies \frac{(2-\phi)}{\sqrt{\Delta_2}}B_{source}^{**} - \frac{B_{source}^*}{\sqrt{\Delta_1}} > 0 \\ &\implies \frac{1}{2\phi} \left\{ (1-\phi)c(2\Delta_1 - \Delta_2) + \phi(\Delta_1(2-\phi) - \Delta_2) \right\} > 0 \end{aligned}$$

since  $\Delta_1 > \Delta_2$ . As for the second terms on both sides, since the logarithm is monotonic, it is sufficient to study their arguments.

$$\begin{aligned}
2\log(1 - B_{source}^{**}) < \log(1 - B_{source}^*) &\iff B_{source}^* < (2 - B_{source}^{**})B_{source}^{**} \\
&\iff \frac{B_{source}^*}{B_{source}^{**}} < 2 - B_{source}^{**}
\end{aligned}$$

It can be easily verified that when  $\phi < 1$  the last inequality is always satisfied for the allowed range of the cost parameter.

4. Finally, when  $\phi = 1$  the difference  $\delta$  above reduces to

$$\delta(\phi = 1) = \frac{1}{2} \left\{ \sqrt{1 - 8c} - \sqrt{1 - 4c} + 4c \log(1 - \sqrt{1 - 8c}) - 2c(1 + \log(2 - 2\sqrt{1 - 4c})) \right\}$$

which is negative for any value of  $c \neq 0$  and equals zero when  $c = 0$ . Finally, the limit for  $c \rightarrow 0$  when  $\phi = 1 - \epsilon$ , is

$$\begin{aligned}
\lim_{c \rightarrow 0} \delta(\phi = 1 - \epsilon) &= \frac{1}{2} ((1 - \epsilon^2) - (1 - \epsilon)^2 + \epsilon - \epsilon^2) \\
&= \frac{3}{2} \epsilon (1 - \epsilon) > 0
\end{aligned}$$

which completes the proof of the first statement of the proposition. Now, we turn to studying the limit case of cheap communication. We write the limit of  $\delta$  for  $c \rightarrow 0$

$$\lim_{c \rightarrow 0} \delta = \frac{\phi - \phi^2 - \sqrt{\phi^2} + \sqrt{\phi^2(-2 + \phi)^2}}{2} = \phi - \phi^2$$

First, we observe that in the limit of cheap communication  $\delta$  is always positive, i.e. the source is always better off using two channels rather than only one. Moreover, taking the first derivative with respect to  $\phi$ , we can see that the benefit of exploiting both communication channels is maximized when

$$\phi = \arg \max_{\phi} \lim_{c \rightarrow 0} \delta = \frac{1}{2}.$$



## Chapter 2

# Endogenous Institutions: a network experiment in Nepal

### Abstract <sup>1</sup>

In developing countries where formal institutions are often weak, peer monitoring represents a natural mechanism for the enforcement of agreements. This paper studies the demand for monitoring and its effectiveness in sustaining cooperation across social groups. Mapping the social networks of 19 Nepali villages, we conduct an experiment to explore the role of the endogenous choice of monitors on cooperation. The paper shows that closely knit groups are 40% points less likely to choose a central monitor, while sparse groups tend to prefer a monitor who is highly central in the network. The democratic selection of monitoring improves cooperation by up to 22% compared to an exogenous assignment, but only in sparse groups. Further, we observe that in sparse groups the positive effect of endogenous monitoring can spill-over to games played under exogenous assignment.

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## 2.1 Introduction

Peer based monitoring has applications from credit markets to labor outcomes ([Besley and Coate \(1995\)](#)). However, its effectiveness for public good provision and community resource management has been understudied. In a seminal study, [Ostrom \(1990\)](#) suggests how such mechanisms based on peer effects and social ties sustain cooperation in community resource management rather than mere punishment.<sup>2</sup> One plausible channel for the effectiveness of peer based monitoring is represented by the fact that individuals care about their reputation. [Breza and Chandrashekhara \(2018\)](#) establishes that reputation concerns act as a plausible channel through which peer monitoring works. We extend this further in two main directions in the context of community based institutions and public good provision. First, we study the demand for peer monitors across different social groups. Second, we show that the impact of allowing people to choose their monitor is heterogeneous across different group compositions<sup>3</sup>. We focus on the role of social networks in the choice of these institutions and their impact on cooperation.

In developing countries where formal institutions are often weak or non-existent, the enforcement of local agreements is based on the community. Its individuals coordinate to select a monitoring institution to oversee the functioning of the agreement. This is also the case in Nepal where in the recent past we have seen an upsurge in the number of community based organizations for the management of common pool resources (e.g. FUGs, Forest Users Groups or WUAs, Water Users Associations). The striking power of such peer based institutions is to self-impose behaviors that bring about increased welfare through community-based responsibility and authority. Departing from this real-case study we want to generalize and deepen our understanding of how a group of people decide whom to elect as their own monitor and how this choice in turn impacts cooperative behavior.

We conduct a lab in the field experiment in 19 villages in rural Nepal to understand third party monitoring in the context of common-pool contributions. Villagers play a coopera-

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2. There exists a rich literature that studies the effect of punishment on public good games. For more details see [Charness and Jimenez \(2008\)](#); [Glockner et al. \(2018\)](#); [Kosfeld and Rustagi \(2015\)](#); [Fonseca and Peters \(2018\)](#) and [Fehr and Sutter \(2019\)](#)

3. See [Olken \(2007\)](#); [Bjorkman and Svensson \(2009\)](#) and [Gelade, 2018](#). Unlike direct reporting in these papers, our experiment relies on reputational concerns affected via gossip by the chosen monitor.

tion game and can choose to elect a monitor through majority voting. This monitor can impose higher cooperation through reputational concerns. Concerns of social image are important drivers of cooperative behavior since people fear bad reputation. Third party monitoring can substitute for social density by emphasizing these very reputational concerns (Greif (2006); Bowles (2008); Andreoni and Sanchez (2020)). Further, the impact of the monitor may depend on their position in the social network<sup>4</sup> and on the political process whereby it is assigned to groups. We explore the effects of monitoring induced by reputation concerns<sup>5</sup> rather than by material punishment. Two main pieces of evidence emerge from previous research. First, dense groups are able to sustain more cooperation than socially distant groups. Second, monitors have the power to relax the inefficiencies arising from contractual incompleteness in the context of socially distant groups (Breza and Chandrashekhar (2018); Breza et al. (2016); Chandrashekhar et al. (2018)). These studies focus on the impact of exogenously assigned monitors on cooperation in groups.

The aim of this paper is to bring the literature forward by allowing individuals to endogenously elect their preferred monitor and by studying the induced cooperative behavior. We estimate the demand for monitoring, relate it to the network structure and study its impact on cooperation by tackling three subsequent questions. First, do individuals change their demand for monitoring as a function of the social composition of the group they interact with? Second, do monitors who are endogenously chosen spur cooperative behavior compared to those assigned exogenously? If that is the case, does the effect of endogenous monitors spill-over to cases where monitors are externally imposed? To answer these questions, we conduct a lab in the field experiment in rural Nepal and build a theoretical model supporting our experimental findings.

First, we ask whether groups with different social proximity elect different third party institutions. In line with the literature, we offer three monitoring options, according to a measure of social prominence. We present strong evidence that socially distant groups are more likely than closely-knit groups to elect a high central monitor. We find that individuals are 40% less likely to elect a monitor with their close peers compared to when

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4. Central individuals in the network are shown to be particularly effective in monitoring due to their higher ability of spreading information in the form of gossip (Ballester et al. (2006) and Banerjee et al. (2019a))

5. Individuals rely on local connections for risk sharing, public good provision and information delivery. Social image and trust therefore become more important. See Kranton (1996); Leider et al. (2009)

they are in groups with socially distant members. This supports the idea that contractual incompleteness can be mitigated by social density, but socially distant individuals need third party institutions to enforce social norms and increase efficiency<sup>6</sup>.

Secondly, we investigate whether the political process by which the institution is chosen matters for cooperative behavior. We present the first evidence of the heterogeneous impact of asymmetric information in different social groups. Interestingly, we find that a monitoring institution that is democratically elected has strong positive effects on cooperation compared to an institution assigned randomly. Previous experimental evidence in economics (Sutter et al. (2010); Tyran and Feld (2006); Dal Bo and Putterman (2010)) and sociology (Grossman and Baldassarri (2012)) shows that cooperation is higher when players are given the opportunity to choose the institution rather than having an externally imposed one. We further investigate this dimension, and we offer evidence that the positive impact of endogenous institutions is limited to socially distant groups. More precisely, the magnitude of the increase in contribution ranges from 8.6% when a socially prominent monitor is chosen to 21.9% when no monitor is chosen. In socially close groups, the point estimate is negative and not significant. The possible mechanism underlying this “democracy premium” can be explained by the fact that individuals perceive the election outcome as a signal of their group members’ altruism level which in turn affects their willingness to contribute to the public good<sup>7</sup>.

Third, we present evidence that the signalling effects of the endogenous selection of monitors can spill-over to cases when the monitoring “technology” is exogenously assigned. The theoretical literature of principal-agent models (Herold (2010)) shows that the proposal of a complete contract can signal distrust. On this basis, we explore whether the effect of endogenous monitors can be strong enough to persist in games played under exogenous monitors. We find that individuals interpret the outcome of the vote as a strong signal of trust when no monitor is chosen and that the positive effect spills over to the exogenous treatment. This entails a significant increase in average contribution by 17.7% in sparse groups, when the endogenous treatment is played before the exogenous one. On the

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6. In line with this reasoning Glaeser et al. (2000) establish that groups with shorter social distance have higher trust. In the same spirit, experiments in the lab (Hoffman and Smith (1996); Leider et al. (2009); Goeree et al. (2010)) and in the field (Etang and Knowles (2011); Grossman and Baldassarri (2012)) show that cooperation increases with decreasing social distance.

7. Other possible explanations can be found in an increased sense of agency and control, increased sense of authority (Greif (2006)) and stronger worthiness of authority (Zelditch (2001)).



contrary, a negative point estimate suggests that dense groups perceive the election of a high central monitor as a signal of mistrust leading to a possible decrease in contribution. This finding sheds light on the heterogeneity of the effects of signaling when we take into account the social structure of agents.

We build these results on novel network data and we ground our empirical findings in a theoretical framework. Network data is collected through an intensive network survey inspired by [Banerjee et al. \(2013\)](#)). We ask questions about advice, trust, friendship and financial relationships such as “whom do you spend your free time with”, “in case of an emergency, whom would you rely on” and “whom do you borrow money from”. Based on data from the survey, we build an undirected social network where a connection between two people is established if any one of them names the other. Next, we identify the persons in the network with the highest and lowest eigenvector centrality. In other words, we identify the most influential and least influential individuals in the village. The rest of the village is divided into groups of three with varying network distance. Groups of three are an optimal choice to study questions of mutual trust inasmuch it is possible to maximize the behavioral contrast between groups which can sustain high levels of cooperation and those which cannot ([Jackson et al. \(2012\)](#)). Players interact both in a closely knit group and in a group with socially distant individuals.

We refer to the closely knit group as “dense” and to the group with weak acquaintances as “sparse”. The term “dense” implies each individual is at most at distance 2 (average path length  $< 1.6$ ) and “sparse” implies each individual is at least at distance 4 (average path length  $> 4$ ). We allow individuals to either vote for no monitor, or to choose one from two monitor candidates belonging to their village: a high central monitor (very prominent individual) or a low central monitor (less prominent). Players play a contribution game both with a monitor chosen by the group (endogenous treatment) and an externally assigned monitor (exogenous treatment). The monitor does not materially punish but only observes the contributions of each player, which would otherwise be private information. Players have an initial endowment and need to decide between how much to contribute to a common pot and how much to keep for themselves. The total contribution in the common pot is augmented by 50 percent and divided equally among the three players irrespective of initial contribution. Each individual therefore plays both in a dense and in a sparse group, and in each group both with exogenous and endogenous monitoring institutions.

We vary both the social composition of groups and how monitors are assigned to study the demand for monitoring and cooperation. The order of all treatments is randomized.

### 2.1.1 Related Literature

This paper is at the intersection of multiple strands of literature. First, it relates to the vast literature on public good games and peer monitoring. Starting with [Fehr and Gächter \(2000\)](#), the threat of punishment from an external monitor is seen to increase contributions to the public good ([Charness and Jimenez \(2008\)](#); [Fiedler and Haruvy \(2017\)](#)). In particular, [Fiedler and Haruvy \(2017\)](#) establishes that simple monitoring without punishment enforces higher contribution. [DeAngelo and Geeb \(2020\)](#) similarly establish that peer monitoring is better for public good provision. In [Shreedhar et al. \(2020\)](#) network topology is seen to be an important factor driving effectiveness of peer monitoring in the lab. To our knowledge, none of these papers studies the impact of network position on public good games with endogenous monitoring. We believe that the identity of players is an important factor in contribution games and that network position can explain behavior in public good games.

Another relevant strand of literature focuses on how altruism might drive contribution behavior in communities ([Bénabou and Tirole \(2006\)](#); [Bourlès et al. \(2018\)](#); [Acemoglu and Wolitzky \(2020\)](#); [Ali and Miller \(2016\)](#)). Thirdly, our paper is closely connected to the literature on reputation concern. Gossips and social image concern as an effective channel for peer minoring has been established (See [Wu et al. \(2015\)](#) and [Wu et al. \(2016\)](#); [Beersma and Van Kleef \(2011\)](#); [Sommerfeld et al. \(2007a\)](#); [Galbiati and Vertova \(2008\)](#)). This paper is also intimately related to a growing literature of experiments on networks, where a number of papers have looked into how position in the network affects behavior in real life. Our work is closely related to field experiments by [Breza and Chandrashekhara \(2018\)](#) which shows that an exogenous central monitor improves cooperation in sparse groups but crowds out contributions in close groups. In a similar vein, [Breza et al. \(2016\)](#) establishes that the capacity for cooperation, in the absence of contract enforcement, depends on players' network position. Our field experiment differs from these settings by allowing groups of players to choose the monitor overseeing the contribution game. We study how network position not only impacts cooperation but also the institutional

choice that ensures cooperation. The institution options are based on the centrality of the monitors (Banerjee et al. (2013), Banerjee et al. (2014) for details on the role of centrality).

Finally, our work bridges experiments on public goods and networks with a strand in the literature that studies the impact of institutional choice on cooperation. Papers in the laboratory as Sutter et al. (2010), Fehr and Gächter (2000), Dal Bo and Putterman (2010) and in the field as Grossman and Baldassarri (2012) show that cooperation is higher when players are given an opportunity to choose the form of the institution rather than having an externally imposed one. We advance this literature by exploring the heterogeneity of this impact through network structure. We investigate how different informal institutions – monitors – emerge endogenously from group decisions and how it affects cooperation.

The rest of this paper is organized as follows: Section 2 describes the experimental protocol and the data collection process. Section 3 presents the theoretical framework. Section 4 describes the results of the experiment and the econometric specifications. We discuss the results and conclude in Section 5.

## 2.2 Experiment

### 2.2.1 Networks and Data

We start by mapping the social network of villages, with a special focus on relations of trust. Given the location of these villages<sup>8</sup>, mutual trust fundamentally shapes social interactions and the contribution to local public goods. As a first step, we assigned a unique identification code to each woman in the census. We started interviewing very few individuals, who would give us names of their closest friends and we administered the network questionnaire to those women who were nominated in the first round. This process was repeated iteratively until either all women were covered or no new individual was nominated – the elicited network is “closed”. This technique has the advantage to be faster than the standard network elicitation method and simplifies considerably the issue

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<sup>8</sup>. The villages are situated at 1200m above sea level in the mid hills of Nepal. They are a four hours drive away from Kathmandu

of homonyms. Each woman was asked at least three connections for each question. The questionnaire consisted of a set of questions designed to elicit social networks, inspired by [Banerjee et al. \(2013\)](#). These questions are meant to elicit ties of friendship and trust and span along various dimensions of social interactions. A link between two individuals  $i$  and  $j$  is established when either  $i$  nominates  $j$  or vice versa in any of the questions. We then aggregate and collapse the networks obtained from different questions into one, undirected network. Once a network is fully mapped, it is possible to visualize it and extract important statistics that are central in our experimental design. Figure 2.2 in the Appendix is a snapshot of the network of a village where we conducted the experiment.

The network we obtain is thus a good representation of the social structure of the community and it is an essential variable of our study. More precisely, we use the network to create groups of contrasting social density for every participant and interact it with variations along two dimensions: monitoring centrality and the political process by which monitors are assigned, either democratically elected or exogenously given. We focus on networks of only women due to the high emigration rate of men either to Kathmandu or abroad, as shown by our pilot experiment conducted in the spring 2018. In the districts we worked in, social networks are often gender specific and women play a preponderant role: they are responsible for households' finances, for agricultural production and for their children.

We look at how social density influences the demand for monitors and how it ultimately affects individual contribution to public goods. Groups are formed in order to maximize the number of participants who play in both dense groups, i.e. groups of average path length less than 1.6, and in sparse groups, i.e. with average path length higher than 4<sup>9</sup>. In other words, being in a dense group implies that the members of the group are at no more than 2 steps away from each other whereas in the sparse group they are at least 4 steps away. The cutoffs defining dense and sparse have been carefully chosen in order to amplify the respective contrast in trust and reputation while maximizing the number of observations. The starker is the difference between dense and sparse groups, the more different will be the behavioral response in the different treatments. Figure 2.9 in Appendix B shows the distribution of average path length of all groups we formed.

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9. The dense groups would correspond to topography that is a triangle (average path=1), line (average path=1.3)

We over sampled dense groups to make a reliable comparison with sparse ones. Players in the dense groups often belong to the same caste and have similar characteristics. We end up with 503 women who played in both sparse and dense groups, as defined by our thresholds. The summary statistics are presented in Table 2.9. In total, we have four observations for each participant, for a total of 2012 observations.

### 2.2.2 Monitors and Game Overview

We choose monitors candidates with respect to their Bonacich centrality and their assignment to groups can be determined by either democratic election or random exogenous assignment. Underlying the framework is the assumption that participants' behavior in the experiment will likely affect market and non-market interaction outside the laboratory in real-life interactions, such as access to jobs, informal loans or other opportunities. In this context, we assume that monitors have the power to spur cooperative behavior through their capacity to report outside the laboratory bad behavior occurred within our experiment. In 2019, to provide support for our framework we conducted a survey to more than 300 random women. We shared with them a vignette of our experiment and asked several questions about the reputational power of monitors. The purpose of this survey was to capture their perceptions of the role of monitors and possible motivations behind voting for one of them. We described our study and asked subjects about whether information about misbehavior in the experiment would spread, how that would depend on the identity of the monitor, and what could be the motivations for voting to have a monitor. We find that on average respondents believe that high central monitors are able to spread information to almost 60% of the village population, while low central or average central monitors would reach less than 40% of the village population. Similarly, more than 80% of respondents declared that they would vote for a monitor in order to keep in check other group members through the threat of reputation. We present the main results in Figure 2.8.

We pick monitors in function of their Bonacich centrality. For every given village, we compute the eigenvector Bonacich centrality of all women and select for the role of monitors those with a centrality score greater than the 95th percentile or smaller than the 5th percentile. We choose eigenvector centrality because it captures how much informa-

tion emanating from a monitor should spread in the network reaching also individuals who are not directly connected to the monitor. Our choice of basing our experiment on eigenvector centrality, and not on other centrality measures, derives from the literature (Banerjee et al. (2014); Banerjee et al. (2019a); Breza and Chandrashekhar (2018)). These works show that an individual's eigenvector centrality can explain his capacity to spread information in the larger network and that villagers are able to accurately identify central members of the community. In order to check in our context the robustness of this choice against alternative measures of centrality, we compute correlations between three centrality measures for the whole undirected network sample: degree, betweenness and (eigenvector) Bonacich centrality. While degree simply measures how many links a node has, betweenness quantifies the number of times a node acts as a bridge along the shortest path between any two other nodes. The results shown in Table 2.1 give us reason to think that, in our sample, attributing the roles of monitors according a measure of eigenvector centrality is robust to different centrality measures. The correlations in Table 2.1 are very strong and the coefficient between degree and Bonacich centrality is almost 0.92 while the coefficient between the latter and betweenness is almost 0.87. Computing the same coefficients on the subset of monitors, we obtain even stronger correlations between different measures. These figures give us reason to believe that the centrality of monitors is an intrinsic network characteristic of individuals that underlies different possible measures.

In order to neatly disentangle the different possible channels that might drive behavior, we set up an experiment where groups of three individuals are asked to privately vote for their preferred monitor and then play twice a standard public good game. The experimental session is sequenced as follows: first, players are assigned to a group formed either by their closest friends or by socially distant peers. The order of assignment to these two group compositions is randomized. Secondly, after being assigned their groups, players privately vote for their preferred monitor. Third, the choice of monitor is immediately followed by a contribution game. Each individual plays 2 rounds of a public good game within each group, once played with the elected monitor and once with a randomly picked monitor option, where we randomize the order of the two treatments. Groups are then reshuffled so that the same player is then placed in a different group composition (dense or sparse) and the game unfolds again as explained above. In total, each individual plays 4 rounds in two different groups (dense and sparse). We are able to exploit this design to get extract individual fixed effects and get partially rid of the endogeneity of networks

when evaluating the impact of treatments. After participants play in the experimental sessions and receive payment for their performance in the games, we administer a second questionnaire meant to capture caste, wealth, religion, membership to community based organizations and a set of other individual level characteristics. Participants are quite homogeneous in terms of wealth and networks are highly homogenous in terms of caste.

### 2.2.3 Experimental Context

Nepali villages are often too remote to be reached easily or too sparse to ask their members to participate to group sessions in a fixed location. We decided to conduct our experiments in the mid-hills of Nepal in the district of Makwanpur, which is around four hours drive from Kathmandu. The municipalities we chose – Palung, Bajrabarahi, and Chitlang – present an economy almost uniquely focused on agriculture and the exploitation of natural resources. Dozens of community based organizations are active in the region and people are generally involved in at least one. They are familiar with issues of coordination and with the risks of free-riding. Villages are on average composed of 70 households, for an average of 120 women per village. We covered 19 villages with more than 2000 women between 18-60 years answering our network survey. We have a census of all inhabitants living in each village and we made sure to administer the network questionnaire to every woman.

In partnership with a local research company based in Kathmandu, we hired a team of local enumerators. All enumerators were women, in order not to add any confounding factor in the network elicitation and in the experimental sessions. In each village, women who answered our network survey were invited via a phone call to take part in the experiment. We invited around 75% of interviewed women in each village and, based on a measure of (eigenvector) network centrality, we divided people into either players or monitor candidates. The individuals belonging to the top and bottom 5% of the centrality distribution were assigned the role of monitor candidates, while the others were assigned the role of players. Among those who were assigned the role of players, we oversampled groups in the periphery so as to avoid picking high centrality individuals in order to maximize the contrast between dense and sparse groups. This gives more power to the information transmission role of the monitor. As an incentive to participate, every player was given

100 Nrs (1 euro) along with the possibility to obtain additional money up to 200 Rs, as a function of their performance in the games. On average, the total gain was around 220 Rs. per individual which is half day's wage. Monitors were given a fixed sum of 250 Rs. for their participation.

The experiments were typically conducted early in the morning in schools close to each village. Women, as they arrived to schools, were assigned to either sparse or dense groups for the experiment. They were progressively sent to one of the classrooms to play the games. Once played, they got out of the room to be assigned to another group and to play again with a different group composition. The order of the dense and sparse groups was randomized. Typically, three sessions were run in parallel in separate classrooms with one session lasting for around 15 min. Two enumerators were in charge of each session: they read the instructions, conducted the game and noted down the choices of participants.

## 2.2.4 Design

In our experiment, we have three treatments variables. First, group composition. Groups can be composed either by close friends or by people socially distant in the network. Second, centrality of monitors. In our experiment, we offer three monitoring options: high central monitors, low central monitors and no monitors. Third, the process whereby monitoring institutions are assigned: either democratically elected by the group or exogenously imposed. After assigning the role of high central and low central monitors, which remains fixed throughout the experiment, we divide the rest of the individuals into groups of three with varying group composition, either dense or sparse. Individuals play in groups of three in both dense and sparse treatment in a randomized order. In Figure 2.2, we show two possible groups for the player circled in green. She plays both with her closest friends – circled in red – and with individuals far in the social network circled in blue. By always reshuffling groups in such a way that every individual plays exactly in two different groups, we are able to extract individual fixed effects. This part of the design is of paramount importance because of the intrinsically endogenous nature of networks: the network position of player  $i$  is endogenous to her observable characteristics which are in turn affecting her contribution. This design allows a neat disentanglement of the endogenous position in the network from the contribution, through the extraction of fixed



effects at the individual level.

At the start of each session, group players are gathered in a room where they can see each other, but no communication is allowed. Each member of the group receives 10 tokens of a different color, where the value of 1 token is marked at Rs 10. Each session is divided in two stages. In the first stage, each player privately casts a vote on her preferred monitoring option.<sup>10</sup> In Figure 2.3, step 1 represents the setting of the game. Players are given the option to choose between high central monitor (H), a low central monitor (L) or no monitor at all (NM). Note that this monitor is a fourth individual that remains the same for all groups within a village. The cost of choosing the monitor is 20 Rs.<sup>11</sup> This cost makes always choosing a monitor a non-dominated strategy. The cost is paid by participants who vote to have a monitor (either high central or low central), irrespective of the voting outcome of the group.<sup>12</sup> The monitor is elected by a majority rule and the result of the vote is not immediately revealed. As seen in Step 2 of Figure 2.3, the group is then randomly assigned to either the endogenous treatment or the exogenous one. The randomization is implemented by picking one out of two balls: if the ball drawn is green, the endogenous treatment is played first and the exogenous follows. If the ball drawn is pink then exogenous is played first followed by endogenous. The result of voting is only revealed just before playing the endogenous treatment. In the exogenous treatment, the group is randomly assigned either to a high central, low central or to no monitor treatment.

In the second stage of the experiment, the group plays a public good game where each player decides how many tokens out of the 10 is to be contributed to the public pot. They are informed that the money in the public pot would be increased by 50% and then divided equally among them. As seen from Step 3 of Figure 2.3, once the contributions are made, the monitor – either elected or assigned – is called into the room to see how much each player contributed in the public pot. The monitor can distinguish the contributions belonging to each player by the different colors of the tokens they were endowed with.

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<sup>10</sup>. In case of a tie, the monitor choice was determined by a random draw. Ties represent around 6% of cases.

<sup>11</sup>. In line with the public good literature, the cost of the option was around 7% of the average earnings across all games. Also, the fee player  $i$  pays when choosing a monitor is directly detracted from the realized payoff of that specific round and does not directly affect the payoff of other players nor of monitors.

<sup>12</sup>. If  $x$  votes for a monitor but no monitor is elected by the group,  $x$  stills pays the cost of voting for a monitor.

13. Breza et al. (2016) do not find a significant difference between information and punishment treatments

```
graph TD; Start(( )) --> RandomizeGroups[Randomize groups<br/>-Closely knit (Dense)<br/>-Socially distant (Sparse)]; RandomizeGroups --> Voting[Voting<br/>- No monitor (NM)<br/>- High central (H)<br/>- Low central (L)]; Voting --> RandomizeOrder[Randomize order<br/>- Group choice (ENDO)<br/>- Externally assign (EXO)]; RandomizeOrder --> CG1[Contribution game<br/>(Round I)]; CG1 --> CG2[Contribution game<br/>(Round II)]; CG2 -.-> RandomizeGroups; CG1 --> Info[Identity of the monitor<br/>chosen by the group is<br/>revealed]; RandomizeOrder -- Ex. --> RoundI[Round I: Exogenous treatment]; RandomizeOrder --> RoundII[Round II: Endogenous treatment];
```

The flowchart illustrates the experimental design for the contribution game. It begins with a participant (represented by a stick figure) entering the experiment. The process follows a circular path through four main stages: 1. **Randomize groups**: Groups are randomized into two types: 'Closely knit (Dense)' and 'Socially distant (Sparse)'. 2. **Voting**: Participants vote on whether to have a monitor (NM) and on the central node (H or L). 3. **Randomize order**: The order of play is randomized, either by group choice (ENDO) or external assignment (EXO). This stage branches into two rounds: Round I (Exogenous treatment) and Round II (Endogenous treatment). 4. **Contribution game**: The game is played in Round I and Round II. The identity of the monitor chosen by the group is revealed after Round I. The process then loops back from Round II to the Randomize groups stage.

13. Breza et al. (2016) do not find a significant difference between information and punishment treatments

## 2.3 The Framework

In this section we present a theoretical framework that can guide the interpretation of our empirical results. One way to think about the difference between sparse and dense groups is the level of altruism. This is in line with the literature on altruism where individuals contribute and cooperate more in closely knit dense groups (Leider et al. (2009) and Goeree et al. (2010)). This is also consistent with what we observe in our data. Following our conversation with the women, one possible mechanism driving behavior in the field is reputation concerns. Monitors can effectively spread information and enforce social norms. As shown by the results of our end-line survey in Figure 2.8, monitors are perceived as capable of spreading information thus affecting reputation. We build a model of altruism and reputation concerns that provides a framework for our results.

### 2.3.1 Types

Agents are embedded into a fixed network of relations. We model the contribution behavior of individuals with an *altruism* parameter  $\alpha$ . We think of this parameter as representing how much an individual cares about the material utility of others and as determining the propensity of higher contribution. As people become more altruistic, i.e the value of  $\alpha$  increases, individuals care more about the material utility of others and are more likely to contribute a higher amount.

Each individual  $i$  has a level of altruism  $\alpha_i$  that depends on the group she plays in, where  $\alpha_i \in \{\alpha_l, \alpha_h\}$  and  $\alpha_h > \alpha_l$ . Player  $i$  knows her own level of altruism  $\alpha_i$  and has a prior  $\mu_{0i}(\alpha_j)$  on the level of altruism of the other player  $j$ . The prior  $\mu_{0i}(\alpha_j)$  is distributed uniformly in  $(0, 1)$  and it is homogeneous across agents. Let us assume that agent's  $i$  ex-ante subjective probability of  $j$  being a high type  $\mu_{0i}(\alpha_j = \alpha_h)$  depends on how close they are in the network. Agents  $i$  and  $j$  can form a group of type  $G(ij) = G(ji) = \{d, s\}$ , i.e. they can form either a dense group or a sparse group. In this context,  $i$ 's prior about  $j$  being type  $\alpha_h$  is higher in dense rather than in sparse groups.

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<sup>13</sup>. We present here a simplified model with two agents for the sake of exposition, but we extend the main results to three agents in the Appendix to match the experimental design

$$\mu_{0i}(\alpha_j = \alpha_h)_{G(ij)=d} > \mu_{0i}(\alpha_j = \alpha_h)_{G(ij)=s}$$

Even though we do not model network interactions explicitly, the effects of social interactions are introduced in the mechanics of the model through the different initial priors and through the power of the monitor, as explained in the next paragraph. This mimics the fact that in dense groups people perceive their neighbors to be more altruistic than those to whom they are not directly connected.

### 2.3.2 Timing, Actions and Payoffs

Agents play a two-stage game. In the second stage, agents play a voluntary contribution game which can be either overseen by a third-party monitor or by no one. The third party monitor can be assigned either through a random lottery or can be elected through a democratic vote, which happens in the first stage. More precisely, the game unfolds as follows. First, agents simultaneously vote for their preferred monitor  $m_i \in \{0, 1\}$ , where  $m_i = 0$  implies no monitor is chosen by individual  $i$  and  $m_i = 1$  means  $i$  votes for having the monitor. Once participants cast their votes, a monitoring technology is assigned to the group according to the following voting rule

$$m^* = \begin{cases} 1 & \text{if } m_i = m_j = 1 \\ 0 & \text{if otherwise} \end{cases}$$

where  $m^*$  denotes the outcome of the vote. Second, agents make their contribution decision  $c_i \in \mathbb{R}_+$ . The action profile of agent  $i$  is then  $(m_i, c_i)$ . The total contribution of all players is increased by 50 % and divided equally among the group members, implying that the rate of return for the contribution game with two players is  $\frac{3}{4}$ . The utility of player  $i$  is a function of both  $c_i$  and  $c_j$ , the level of altruism  $\alpha_i$  and the rate of return of the contribution game. We assume a convex cost of contributing to represent the behavioral burden of contributing and to ensure the existence of an interior solution. Further, we believe that in this context belief-dependant motivations deeply affect players' actions

and, in the spirit of psychological games<sup>14</sup>, we assume that how much player  $i$  values the utility of player  $j$  depends on  $i$ 's belief about the altruism of player  $j$ ,  $\mu_{0i}(\alpha_j)$ . In this regard, we take inspiration by [Rabin \(1993\)](#) which models the reciprocity of one agent as a function of beliefs about the other agent. The payoff of player  $i$  in the contribution game without a monitor is then

$$U(\alpha_i | m^* = 0) = W - c_i - c_i^2 + \frac{3}{4}(c_i + c_j) + \alpha_i \cdot \mu_{0i}(\alpha_j) \left( W - c_j - c_j^2 + \frac{3}{4}(c_i + c_j) \right)$$

In the case where a monitor is elected, we add two terms to the above utility function: a cost of monitor election  $mc$  and a reputation cost  $-\delta P(c_i < \theta)$ . Voting for the monitor is costly and  $i$  pays  $mc$  if she votes for the monitor, irrespective of whether the monitor is elected or not. If elected, the monitor can impose a reputation cost on the players. The parameter  $\delta > 1$  represents the penalty from a contribution lower than the social norm  $\theta$  in the presence of the monitor. As corroborated by qualitative evidence presented in [Table 2.8](#) and for the sake of exposition, we use a fixed value of  $\delta$ . However, we could incorporate a varying power of monitors depending on their centrality by allowing  $\delta \in \{\delta_H, \delta_L\}$ , where  $\delta_H > \delta_L$ , i.e. high central monitors are more effective in spreading information and can inflict stronger reputational penalties. The social norm is a stochastic parameter representing the fact that different groups would have different norms about what is considered an acceptable cooperative behavior<sup>15</sup>. It is assumed to be uniformly distributed between  $[0, \bar{\theta}]$  where  $\bar{\theta}$  is the highest possible contribution. It can also be interpreted as a reference point that varies with each monitor ([Kahneman and Tversky \(1979\)](#)), i.e. it hinges on the distribution of  $\theta$ . The probability of one's contribution to be higher than the norm is then simply  $\frac{c_i}{\bar{\theta}}$  and the probability of contributing below the acceptable social norm – as perceived by the monitor – can thus be represented as

$$P(c_i < \theta) = \begin{cases} 1 - \frac{c_i}{\bar{\theta}} & \text{if } c_i < \bar{\theta} \\ 0 & \text{otherwise} \end{cases}$$

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<sup>14</sup>. For a review on psychological game refer to [Dufwenberg \(2008\)](#) and [Attanasii and Nagel \(2008\)](#).

<sup>15</sup>. This would vary across dense and sparse groups. In dense groups individuals would be supposed to contribute more than in sparse ones.

The utility of agent  $i$  when a monitor is elected ( $m^* = 1$ ) can be written as

$$U_i(\alpha_i | m^* = 1) = W - \hat{c}_i - \hat{c}_i^2 + \frac{3}{4}(\hat{c}_i + \hat{c}_j) - mc - \delta P(\hat{c}_i < \theta) + \\ \alpha_i \cdot \mu_{0i}(\alpha_j) + \left( W - \hat{c}_j - \hat{c}_j^2 + \frac{3}{4}(\hat{c}_i + \hat{c}_j) - mc - \delta P(\hat{c}_j < \theta) \right)$$

Moreover, players are Bayesian and  $i$  updates her prior about  $j$ 's type  $\mu_{0i}(\alpha_j)$  to  $\mu_{1i}(\alpha_j)$  depending on the outcome of the voting,  $m^*$ . When players do not observe the outcome of the group vote, e.g. when third-party monitoring is exogenously assigned,  $i$  does not receive a signal on  $j$ 's type and cannot update her prior.

### 2.3.3 Equilibrium

We assume that the altruism parameter  $\alpha_i$  of individual  $i$  fully determines her demand for peer monitoring. More formally, we consider an equilibrium of the form below. An (altruistic) player  $i$  of type  $\alpha_h$  cares strongly about the utility of the other player irrespective of  $j$ 's type. She would therefore prefer not to elect a monitor<sup>16</sup> in order to avoid the other player being punished through the spread of bad reputation in case of low contribution. For a player  $i$  of type  $\alpha_l$ , however, the cost of electing a monitor and the negative reputation effects for both herself and  $j$  is outweighed by the increase in group contribution driven by the presence of the monitor. Thus, agents would contribute differently depending on their type  $\alpha_i$ , the outcome of the vote  $m^*$  and the updated belief  $\mu_{1i}$  about player  $j$ , once the outcome of the vote is revealed. The separating equilibrium would then be

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<sup>16</sup>. Given that dense groups have higher subjective probability of being altruists, the demand of peer monitoring should be lower than that in sparse as seen in Fig 2.4.

$$\sigma_i(\alpha_i) = \begin{cases} m_i = 0 & \text{if } \alpha_i = \alpha_h \\ m_i = 1 & \text{if } \alpha_i = \alpha_l \end{cases}$$

Given the equilibrium above, when  $\alpha_i = \alpha_l$ , agent  $i$  would always vote for a monitor. Given the voting rule  $m^*$  defined above, she is able to perfectly infer the voting choice of player  $j$ . In this case,  $i$  updates her prior to  $\mu_{1i}(\alpha_j = \alpha_h) = 1$  if  $m^* = 0$  and  $\mu_{1i}(\alpha_j = \alpha_h) = 0$  if  $m^* = 1$ . On the other hand, type  $\alpha_h$  always votes for  $m_i = 0$  and no monitor is elected ( $m^* = 0$ ) irrespective of the vote of the other player. In this case player  $i$  cannot infer anything about  $j$ 's type and she keeps the original prior  $\mu_{1i}(\alpha_j) = \mu_{0i}(\alpha_j)$ . First, we solve the above set of equations and calculate the value of optimal contributions across the different scenarios. Secondly, given  $c_i$ , we study when the above separating equilibrium holds true. We find that for type  $\alpha_l$ , voting for the monitor is an optimal strategy for certain values of initial prior  $\mu_{0i}(\alpha_j) < \overline{\mu_{0i}}(\alpha_j)$ . On the other hand, for type  $\alpha_h$  it is always a dominant strategy to vote for no monitor. Therefore, in order to have a separating equilibrium people should have a low prior on the proportion of altruists, which by construction occurs in sparse groups. In what follows, we present our theoretical results in the same order of the empirical ones to match and guide progressively the experimental findings.

**Proposition 2.1.**

*Let us assume that  $\delta$  is large and  $\theta$  is small enough. Then, there exists a value of the initial prior  $\overline{\mu_{0i}}$  such that for  $0 < \mu_{0i} < \overline{\mu_{0i}}$ , the separating equilibrium  $\sigma$  exists, where low types  $\alpha_l$  vote for the monitor and high types  $\alpha_h$  vote for no monitor.*

Proposition 1 just says that the separating equilibrium  $\sigma$  holds only in sparse groups, while in dense groups both types pool their actions and do not vote for the monitor. We believe that the assumption of large  $\delta$  is quite natural, given that in our context formal institutions are weak, and reputation concerns drive most of the social interactions. This assumption is also supported by the experimental evidence that low central monitors are very rarely chosen by participants. Similarly, the ex-ante level of cooperative behavior of

these villages is quite modest, hence justifying the assumption of low values of  $\theta$ . The mechanism underlying this proposition lies in the fact that high type players  $\alpha_h$  always vote for no monitor, irrespective of the group they are in. Moreover, Proposition 1 gives us reason to believe that a story of reciprocal altruism well describes the voting behavior we see in the experimental data, i.e. players vote more often for having a monitor in sparse groups (low  $\mu_{0i}$ ) rather than in dense ones. This Proposition also gives theoretical support to our experimental results presented in Table 2.4.

**Proposition 2.2.**

*In the game with exogenous monitors, high-type players  $\alpha_h$  contribute always more than low-type ones  $\alpha_l$ . Moreover, at equilibrium the contributions of both players' types are higher in the presence of the monitor than without,*

$$\hat{c}_i^{exo} > c_i^{exo}$$

*for  $i = h, l$ . Moreover, the increase in contributions caused by the monitor is stronger for high central monitors and in sparse groups.*

where  $\hat{c}_i^{exo}$  indicates the optimal contribution when the contribution game is played in presence of a monitor and  $c_i^{exo}$  when there is no monitor overseeing the game. The result is simply driven by the reputation effect of the monitor, which can entail the penalty  $\delta$  in case of contributions lower than the social norm  $\theta$ . The second part of Proposition 2 derives simply by the fact that high central monitors have a stronger capacity of imposing reputational penalties compared to low central monitors, i.e.  $\delta_H > \delta_L$ . Similarly, the impact of the monitor is stronger in sparse groups since we assume that the social norm of contribution is higher in dense groups rather than in sparse ones. These results match our empirical results presented in Table 2.5.

We now study the optimal contributions in the setting with the endogenous election of the monitor. In this case, the elected monitor serves as a signal of each other's types. Players are Bayesian and update their prior beliefs about the opponent's type, knowing their own vote in the election stage. In Proposition 3 below we study the effect on contribution of



having a monitor who is endogenously chosen by the group.

**Proposition 2.3.**

*In sparse groups, endogenously chosen monitoring increases average contribution for all election outcomes, while in dense groups it decreases contribution.*

Having a monitor chosen by the group has a positive effect for  $\mu_{0i} < \overline{\mu_{0i}} = \frac{5\alpha_l + 2\alpha_h}{6(\alpha_l + \alpha_h)}$ , i.e. for sparse groups, while in dense groups the effect is negative. The election of monitors – or the lack thereof – serves as a signal for agents who can infer other players' types as the game unfolds. In the case of exogenously assigned monitors,  $i$ 's benefit of contribution increases linearly with the prior belief of  $j$ 's being of high type, which is higher in dense groups. On the other hand, in the case of endogenous monitors the outcome of the election is internalized in the agents' optimization problem and the benefit of contributing is not anymore uncertain as agents update their beliefs accordingly and their priors are pushed either up or down. Given that in sparse (dense) groups there are more low (high) types than high (low) types, low type agents  $\alpha_l$  drive the result in sparse groups while high type agents  $\alpha_h$  drive those for dense groups. When an agent  $i$  is of type  $\alpha_l$  and observes that the group decided not to have any monitor, it received a perfectly informative signal about the fact that both his group members are of type  $\alpha_h$ . After the revelation of the vote outcome, there is no uncertainty and contribution increases since  $\mu_{1i} = 1$ . When an agent  $i$  of type  $\alpha_l$  observes that the group elected the monitor, she knows that with probability  $2/3$  one of the two group members is of high type and at least one group member is of type  $\alpha_l$ . Consequently, her posterior is higher than the prior if the former is smaller than  $2/3$ , i.e. in sparse groups. In dense groups, the prior is already high and the signal affects negatively contribution. Symmetric arguments can be done for  $\alpha_h$  types in dense groups. This result guides our experimental analysis and gives support to the findings shown in Table 2.6 and Table 2.7.

## 2.4 Results

The hypothesis is that the individual demand for peer-monitoring varies depending on the composition of groups, i.e. across dense and sparse groups. In particular, we expect individuals in dense groups not to choose a monitor and to enforce co-operation on their own in the second stage of the game. This result would not hold for socially sparse groups where the ex-ante level of contribution is lower, given the lower level of reciprocal trust. Thus, socially sparse groups might have a stronger incentive to pay the fixed cost of electing a monitor that is able to strengthen the reputation channel and spur cooperative behavior. The presence of a monitor – even more so for a high central one – increases the possibility of being reported on outside the lab in case of “defection”. On the other hand, we expect socially close groups to be more cooperative than sparse groups, irrespective of the treatments<sup>17</sup>. Finally, we also expect to find a different impact between the endogenous and the exogenous assignment monitors: the group’s choice about the preferred monitor is revealed only in the endogenous treatment, and it can affect contributions by carrying additional information about the group’s altruism level.

### 2.4.1 Preliminary Findings and Possible Limitations

We start the analysis by looking at the individual level variation in the choice of the monitor. In Table 2.2, the numbers along the diagonal represent the percentage of individuals that always choose the same voting strategy irrespective of group composition. The largest proportion being 34.95% that always chooses to have no monitor, followed by 19.68% that always vote to have a high central monitor. The voting result shows substantial variation in voting strategy. Looking at the aggregate demand for peer monitoring, both dense and sparse groups vote more often to not have a monitor. Figure 2.4 shows that in dense groups, around 32% of players vote for a high central monitor, while in sparse groups more than 39% of players do so. Low central monitor is seldom chosen accounting for around 13% in both dense and sparse groups. For contribution, exogenous monitoring increases contribution only in sparse groups as seen from Table 2.3. We want to study how this differs when individuals play under the monitor that has

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17. Socially close or distant is characterized by the average social distance (path length) in a group

been endogenously chosen by the group. To begin with, we compare the outcomes under endogenous and exogenous institutions, clubbing all three monitor treatments together for the later in Figure 2.5. The political process whereby the monitoring institution is obtained matters only for sparse groups where endogenous monitoring in blue increases contribution compared to the exogenous one.

Before presenting the results, we highlight two possible threats to our results and point to possible solutions. First, a number of recent studies have focused on the role that group inequality could play in contribution games (e.g. Nishi et al. (2015); Fehr and Schmidt (1999); Bolton and Ockenfels (2006)). We build three variables in order to capture inequality along dimensions that are particularly relevant to our context: wealth, caste and education. The inequality indices are simply the group variance of the indices we constructed with our questionnaire on individual level characteristics. We observe that the 19 villages where we conduct our experimental sessions display very high degrees of homogeneity along these three dimensions. We control for these variables in all regressions under the label “Group Characteristics”, which embed also a set of socio-economic characteristics at the individual level. None of these variables has a significant impact on cooperative behavior and our results are robust to their inclusion among the regressors.

Second, our result could be sensitive to the process of network elicitation. We ask for at least three “nominations” of friends. In most interviews, women named an average of 4 women which may not be fully exhaustive and may lead to have networks that are sparser than they actually are. This could imply an overestimation of social distance, i.e. individuals are actually socially closer than what they appear to be, which in turn may bias our results. However, it does not represent a threat to the validity of our results. On the contrary, it implies that the estimated effects of our treatments represent a lower bound of the real effect.

## 2.4.2 Statistical Estimation

### 2.4.2.1 Impact of Group Composition on Monitor Voting

As suggested by the preliminary results shown in Figure 2.4, we conduct a Mann-Whitney test to understand whether the proportion of participants choosing a given monitor is significantly different across group compositions. We find that no monitor is chosen significantly more often in dense groups rather than in sparse groups (p-value 0.07) and that high central monitors are chosen more often in sparse rather than in dense groups (p-value 0.002). In order to estimate how the demand for monitor varies depending on the group composition, we use a multinomial logistic regression with individual and round fixed effects. Since players vote once in a dense and once in a sparse group in a random order, we can include both individual and round fixed effects, therefore exploiting a “within” design and getting rid of the confounding effect deriving from the intrinsic endogeneity of real networks. The fixed effect multi logit model is therefore defined by the logistic probability of choice of monitor  $y_{jt}$ , where  $y_{jt}=0$  represents no monitor is chosen,  $y_{jt}=1$  that a low central monitor is chosen and  $y_{jt}=2$  represents a high central monitor. We take  $y_{jt}=0$  as the base category and can write the fixed effect logit as

$$Pr(y_{jt} = 1) = \frac{1}{1 + e^{-(\alpha + \beta_1 G_{jt} + \beta_2 X_g + \rho_j + \nu_t + \epsilon_{jt})}}$$

$$Pr(y_{jt} = 2) = \frac{1}{1 + e^{-(\alpha + \beta_2 G_{jt} + \beta_3 X_g + \rho_j + \nu_t + \epsilon_{jt})}}$$

where  $y_{jt}$  is the chosen level of monitoring,  $G_{jt}$ : dummy for group composition equal to 1 if the treatment is for dense groups,  $X_g$ : group characteristics  $\nu_t$ : round fixed effect and  $\rho_j$ : individual fixed effects.

We present in Table 2.4 the results of the multinomial fixed effect regression of individual monitor choice (voting) on the social composition of the group (dense/sparse). In the first column, we find that dense groups are less likely to elect a high central monitor by 40% points compared to sparse groups. In the second column, we see that this is also true when we control for individual level characteristics, such as age, caste, education, wealth and

others<sup>18</sup>. Importantly, we also include three indicators of group inequality that span three dimensions: wealth inequality, as well as differences in caste and education. The inclusion of such controls do not undermine our result as shown in Table 2.4. More details on voting as a function of individual characteristics is presented in Appendix C. This result is in line with our theoretical result of Proposition 1, whereby dense groups would prefer not to have monitoring whereas individuals in sparse groups would want a high level of monitoring.

### 2.4.2.2 Impact of Different Exogenous Monitoring

For contribution, we start with the baseline case where monitors are assigned exogenously and study the difference in contribution between sparse and dense groups. As seen from Table 2.5, in sparse groups, average contributions increase significantly (p-value 0.014) by Rs 7.4<sup>19</sup> (15.8% of the mean) in the presence of a high central monitor (H) as compared to no monitor (NM). In dense groups, there is a Rs 4.5 increase (8.3% of the mean) but the difference is not significant. This result is in line with the literature that suggests presence of a central monitor increases cooperation only in sparse groups (Breza et al. (2016)). Further, the cost of the monitor being 8% of the average payoff, it is optimal for sparse groups to vote for a monitor but not dense. Taking only the exogenous monitor treatment, we run a linear regression with fixed effects on the contribution with respect to the type of monitor that was assigned and the group composition. It takes the following form:

$$c_{jt} = \alpha + \beta_1 \cdot Dense + \beta_2 \cdot H + \beta_3 \cdot L + \beta_4 \cdot H \times Dense + \beta_5 \cdot L \times Dense + \rho_j + \nu_t + \epsilon_{jt}$$

where  $c_{jt}$ : contribution of individual  $j$  in round  $t$ ,  $Dense$ : dummy equal to 1 if the group is dense,  $H$ : dummy equal to 1 if a high central monitor is assigned,  $L$ : dummy equal to 1 if a low central monitor is assigned,  $\rho_j$ : individual fixed effect and  $\nu_t$ : round fixed effects. We

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<sup>18</sup>. The number of individuals in the sample drops from 503 to 459 because we do not have data on individual level characteristics for all women. The same applies also for all other regressions of the paper

<sup>19</sup>. Note that the value of 1 token is Rs 10. The regression is in terms of tokens but all the results are expressed in terms of Rs.

also check the robustness of our empirical results against the inclusion of three variables measuring wealth, education and caste inequality. Finally we check also the robustness of our results to the application of individual level fixed effects and individual characteristics.

We are particularly interested in the coefficient  $\beta_2$  that shows the effect of being assigned a high central monitor and in the coefficient  $\beta_4$  that shows the difference in the effect across dense and sparse groups. In Table 2.5, the dependant variable is the individual level contribution. We see that individuals in dense groups generally contribute Rs 13.7 higher (23% of the mean) than sparse ones. Next, contribution increases by Rs 7.25 (11% of the mean) in the presence of a High central monitor (H). As seen from the interaction term<sup>20</sup>, the effect is starker in sparse groups. The effects are robust, and even stronger, when including for groups characteristics and individual-level fixed effects. In all four specifications we control for the monitor choice of the individual. Without individual fixed-effects, the regression shows that monitor choice and contribution are indeed strongly correlated, but with our “within” design we show that individual fixed effects completely absorb away that effect. Finally, this evidence is line with our theoretical results of Proposition 2, whereby the presence of monitors increases contribution due to the threat of reputational penalty  $\delta$  and that its effect is stronger for high central monitors and in groups where social norms are lower, i.e. in sparse groups.

#### 2.4.2.3 Impact of Endogenous v/s Exogenous Monitoring

The process whereby the monitoring institution is chosen can impact cooperative behavior, and we investigate this possibility in two steps. First, we run a linear regression on the whole set of observations, similar to that we used in the previous section. Now we include the variable “Endogenous” which takes value 1 when participants play in the endogenous treatment, i.e. when they play with the monitor chosen by the group. The specification we use is

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<sup>20.</sup>  $H \times Dense$  being an interaction term represents  $[(H = 1) - (H = 0)|Dense] - [(H = 1) - (H = 0)|Sparse]$

$$c_{jt} = \alpha + \beta_0 \cdot \text{Endogenous} + \beta_1 \cdot \text{Dense} + \beta_2 \cdot H + \beta_3 \cdot L + \beta_4 \cdot H \times \text{Dense} + \beta_5 \cdot L \times \text{Dense} + \\ \beta_6 \cdot \text{Endogenous} \times \text{Dense} + \beta_7 \cdot \text{Endogenous} \times \text{Dense} \times L + \beta_8 \cdot \text{Endogenous} \times \text{Dense} \times H + \\ \rho_j + \nu_t + \epsilon_{jt}$$

where the main coefficient of interest is  $\beta_0$ , which captures the effect of the endogenous treatment. The results are presented in Table 2.6. The effect of the endogenous treatment is very strong, highly significant and robust to the inclusion/exclusion of group characteristics (wealth, caste and education inequality), individual characteristics and individual level fixed effects. Moreover, we observe that this effect is at work mostly in sparse groups. Secondly, we estimate a linear fixed effect regression that takes care of participants' self-selection into the monitoring "technology"<sup>21</sup>. In the endogenous treatment, individuals select into an institution that in turn drives their contribution behavior. In order to overcome this selection problem, we keep monitoring fixed and compare groups which play both exogenous and endogenous treatment under the same monitor. Our identification strategy is to overcome selection by comparing the same group, with the same monitor treatment, differing only on how this monitor was obtained. Inspired by Dal Bo and Putterman (2010), an individual  $i$ 's action in the game may depend on the group density  $G \in \{\text{dense}, \text{sparse}\}$ , on the elected monitor  $M \in \{NM, H, L\}$ , and on the mechanism that selected the monitor  $I \in \{\text{Endo}, \text{Exo}\}$  and her type  $\alpha_i$ . The probability of cooperation is therefore determined by

$$P_i = f(M, G, I, \alpha_i)$$

We fix the group  $G$  and monitor  $M$  to determine the effect of the mechanism by which the monitor is elected. More formally,

$$E(P_i | G = \text{dense}, M = NM, \alpha_i, \text{Endo}) - E(P_i | G = \text{dense}, M = NM, \alpha_i, \text{Exo})$$

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<sup>21</sup>. We are able to extract fixed effects at the individual level even in this case, since each participant plays twice – once in the endogenous and once in the exogenous treatments – in the same group composition

By doing so, we eliminate the threat of self-selection and we are able to disentangle the effect of the exogenous vs endogenous treatments. In terms of regression, it translates into the following fixed effect equations.

$$\begin{aligned} c_{jt} &= \alpha + \beta_1 \cdot (Endo \mid G = S, M = H) + \rho_j + \nu_t + \epsilon_{jt} \\ c_{jt} &= \alpha + \beta_1 \cdot (Endo \mid G = D, M = H) + \rho_j + \nu_t + \epsilon_{jt} \\ c_{jt} &= \alpha + \beta_1 \cdot (Endo \mid G = S, M = NM) + \rho_j + \nu_t + \epsilon_{jt} \\ c_{jt} &= \alpha + \beta_1 \cdot (Endo \mid G = D, M = NM) + \rho_j + \nu_t + \epsilon_{jt} \end{aligned}$$

where  $c_{jt}$ : contribution of individual  $j$  in round  $t$ ,  $Endo$ : is a dummy variable that takes value 1 if monitor is endogenously chosen, given group  $G : \{D = dense, S = sparse\}$  and monitor choice  $M : \{NM = No\ monitor, H = High\ central\ monitor\}$ <sup>22</sup>,  $\rho_j$ : individual fixed effect and  $\nu_t$ : round fixed effect. We are primarily interested in the coefficient  $\beta_1$  that captures the effect of having an endogenous monitor as compared to being assigned exogenously.

Figure 2.6 shows the average contributions for sub-samples that are free from selection effect. We see that for a sparse group contribution increases under an endogenous monitoring setting as seen from the red bars. In particular, with endogenous no monitor, contribution increases significantly (p-value 0.009) by Rs 9.1 while with a high central monitor it increases by Rs 5 but not significantly. The change in dense groups across endogenous and exogenous monitoring institutions is not significantly different. We find in sparse groups that giving individuals opportunity to chose their own monitoring institution leads to better outcomes than externally imposing a third party monitor.

The first four columns in Table 2.7 report results for individuals who self-selected into high monitoring institution in sparse groups followed by dense groups in the third and fourth column. The next four columns report the same but for the case where groups self selected into no monitoring. We see that a sparse group electing a high central monitor

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<sup>22</sup>. We also tried to do individual level analysis by looking at variation in monitor choice within groups. We find that 50% of the groups vote unanimously for the same monitor option hence not much power to study this effect.



(H) endogenously increases contribution by Rs 5 (8.6% of the mean) whereas there is no effect for the dense group. Similarly, sparse group electing no monitor (NM) endogenously increases contribution by Rs. 9.13 (21.9% of mean) with no effect in the dense groups. As we have done previously, we check the robustness of our results to the introduction of individual fixed effects as well as to group and individual characteristics. Consistent to our theoretical framework and to Proposition 3, we observe that contribution in the endogenous treatment increases in sparse groups, where the effect is strong and highly significant. In dense groups, even if the effect is not statistically significant, we observe that the point estimates are negative. The fact that the effect is stronger and more significant when no monitor is chosen is in line with the fact that in sparse groups, where trust and reciprocal altruism is lower, the election of no monitor by the groups sends a very strong signal of trust to group members<sup>23</sup>. This result presents evidence to believe that there exists a sort of endogeneity premium in socially sparse groups: individuals facing the same monitoring institution behave differently depending on whether the institution is chosen by the group itself or imposed.

#### 2.4.2.4 Impact of Order of Endogenous/Exogenous

In order to further investigate the impact of the endogenous treatment, we study whether the order whereby endogenous and exogenous treatments are played affects the average contribution in a given social group, conditioning on the monitoring technology. That would be equivalent to studying whether the effect of the endogenous treatment spills over to the exogenous treatment, in case the former is played before the latter. In presenting this comparison, we plot the average contribution in treatments across the two rounds. Since the order of endogenous and exogenous is randomized, we compare cases where Endogenous was played first to where it was played second. The result of the vote is only revealed in the endogenous case. Hence, if Endogenous is played first, the information

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<sup>23</sup>. This explanation is also in line with the separating equilibrium  $\sigma$  we presented in the theoretical section, where in sparse groups there are more agents of type  $\alpha_l$  than  $\alpha_h$ . Consequently, low types agents in sparse group observing that no monitor was chosen by the group infer that group members are surely high types, while observing that a monitor was chosen they infer that it is likely that at least one of the other two group members is of high type. Hence, the weaker effect for sparse groups electing a high central monitor

revealed through the vote outcome<sup>24</sup> could affect contribution in both rounds. We focus on cases where participants play with No Monitor and High central monitors because of the very few observations we have for Low central monitor. We can see in Figure 2.7 an evidence of a possible significant effect of the order, especially in sparse groups. The election of a high central monitor in dense groups decreases contribution by Rs 8.1. When no monitor is elected, contribution increases by Rs. 9.6 in sparse groups (p-value 0.06) and Rs 8.9 in dense groups. We run OLS regressions controlling for individual level characteristics to further investigate this effect. Our variable of interest takes value 1 if the endogenous round is played first and 0 otherwise. The dependent variable is represented by the average contribution across the endogenous and exogenous treatments<sup>25</sup>. We use the following econometric specification

$$\begin{aligned} c_{jg} &= \alpha + \beta_1 \cdot (Order \mid G = S, M = H) + \beta_2 \cdot X + \epsilon_{jt} \\ c_{jg} &= \alpha + \beta_1 \cdot (Order \mid G = D, M = H) + \beta_2 \cdot X + \epsilon_{jt} \\ c_{jg} &= \alpha + \beta_1 \cdot (Order \mid G = S, M = NM) + \beta_2 \cdot X + \epsilon_{jt} \\ c_{jg} &= \alpha + \beta_1 \cdot (Order \mid G = D, M = NM) + \beta_2 \cdot X + \epsilon_{jt} \end{aligned}$$

where  $c_{jt}$ : average contribution of individual  $j$  in group  $g$ ,  $Order$ : is a dummy variable that takes value 1 if endogenous treatment is played first, given group  $G : \{D = dense, S = sparse\}$  and monitor choice  $M : \{NM = No\ monitor, H = High\ central\ monitor\}$ ,  $X$ : individual characteristics (caste, wealth, age and education). We are primarily interested in the coefficient  $\beta_1$  that captures the effect of having played an endogenous monitor round first followed by the exogenous one.

In Table 2.8, we see that in sparse groups where No monitor was chosen, the effect of revealing the group's choice has such a strong positive effect that it spills over to the exogenous round, thus increasing average contribution when endogenous is played before the exogenous treatment. Average contribution increases significantly by Rs. 11.6 (17.7 %

<sup>24</sup>. We hypothesize that this information could act as a signal of the level of trust in the group vis à vis each other.

<sup>25</sup>. We are not able to extract fixed effects at the individual level because we take the average of contributions across endogenous and exogenous treatments and condition on the monitoring technology

of mean) for sparse groups when groups played endogenous first and elected No monitor (NM). On the contrary, average contribution decreases slightly by Rs. 3.05 (6.3 % of mean) in dense groups that played endogenous first and elected a high central monitor (H). This result is also in line with our theoretical framework and our previous empirical findings. At the center of this evidence is the story that signaling is stronger in sparse groups, where individuals mostly differentiate their actions according to their types and have a lower prior about the altruism level in their group.

## 2.5 Conclusion

By using original network data and a novel design, we try to understand how the varying demand of peer monitoring depends on group density and how this in turn affects cooperation. We divide the network into groups of three individuals with varying network distance, where dense implies each individual is at most at distance 2 and sparse implies each individual is at least at distance 4. To begin with, we show that dense groups prefer to not have a monitor whereas sparse groups choose to have a central one, reflecting variation in trust. Low central monitors are seldom chosen. In line with previous literature, when individuals are socially close (dense), they can sustain a higher level of cooperation without outside intervention. Dense groups contribute higher than the sparse group in the contribution game. Next, we show that “how” an institution is assigned matters for cooperation. The endogenous choice of monitoring increases cooperation only in sparse groups. Looking at the order of the monitor treatment, the outcome of the vote being revealed in endogenous treatment carries an additional information regarding individual preferences and hence, when revealed, acts as a signal to the group. When endogenous treatment is played first and no monitor is chosen by the group, individuals tend to contribute higher in both groups. However, when endogenous treatment is played first and a monitor is chosen, contribution decreases only in dense groups due to a stronger prior about the level of altruism. This is an interesting finding that suggests monitoring should be catered to the needs of the community. It is also in line with the argument that repeated interactions in dense groups imply higher concern for reputation.

Given the increased popularity of community-based interventions and focus on peer monitoring, it is important to understand the role social networks play in small scale societies. We propose here a theoretical framework followed by a simple experiment that show that the effect of a monitor can be very different depending on the density of the network. Our work opens avenues for further research. We would like to understand the choice of the monitors further by presenting individuals with a panel of monitor options rather than just the high and low central ones.

## 2.6 Appendix

### 2.6.1 Figures

Figure 2.2 – Example of formation of groups

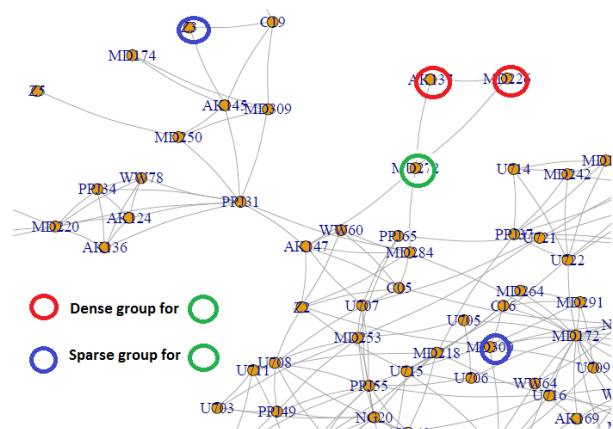
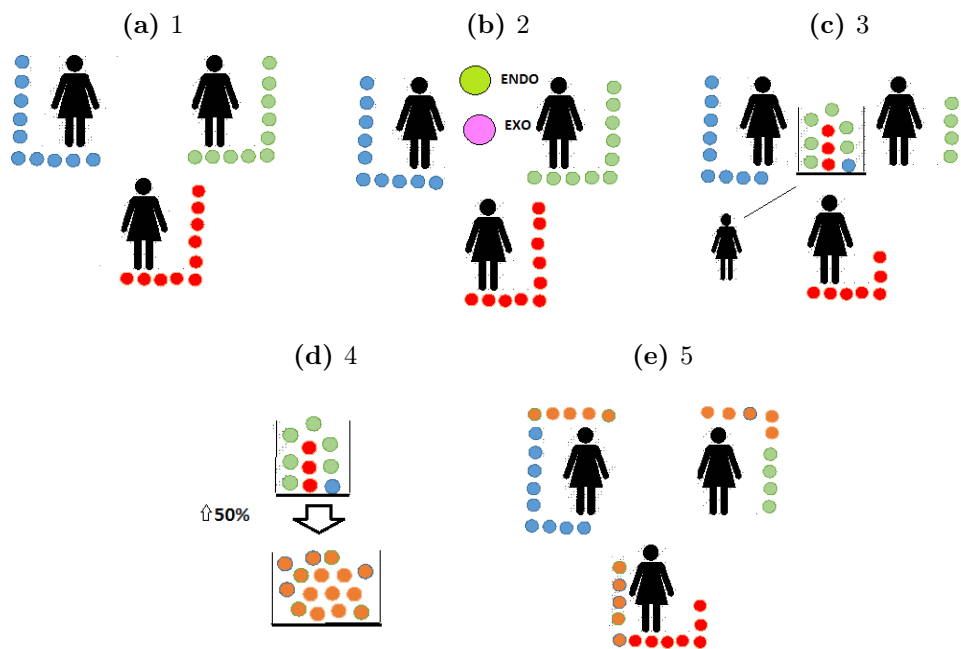
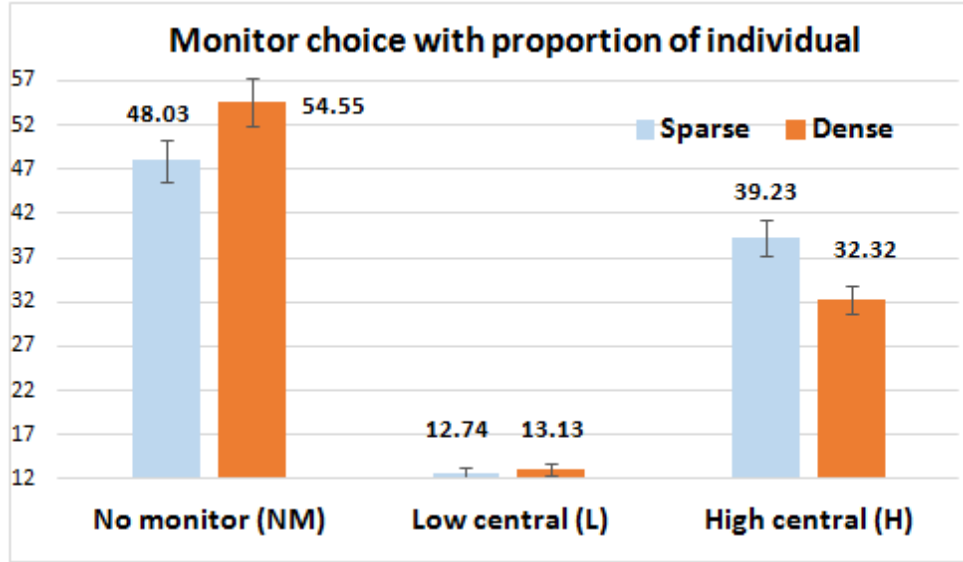
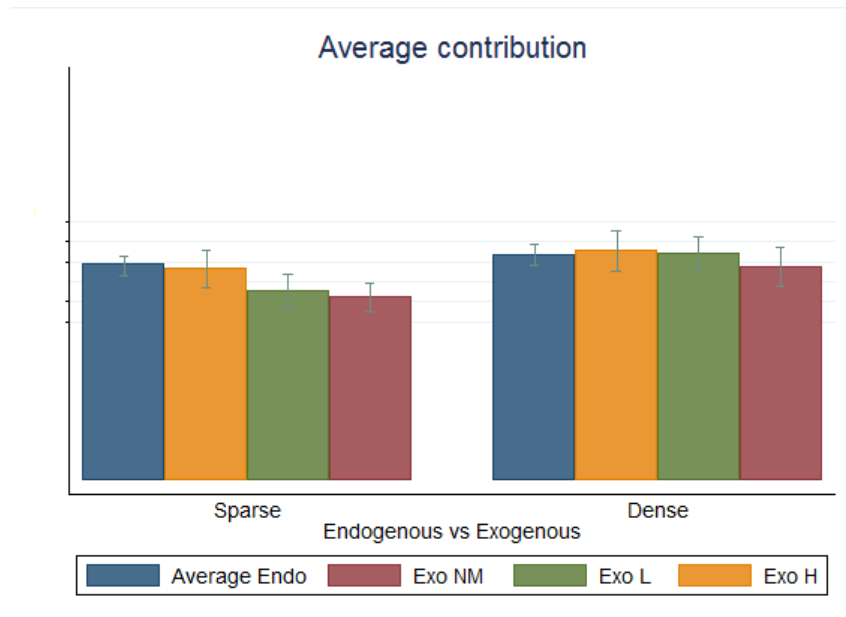
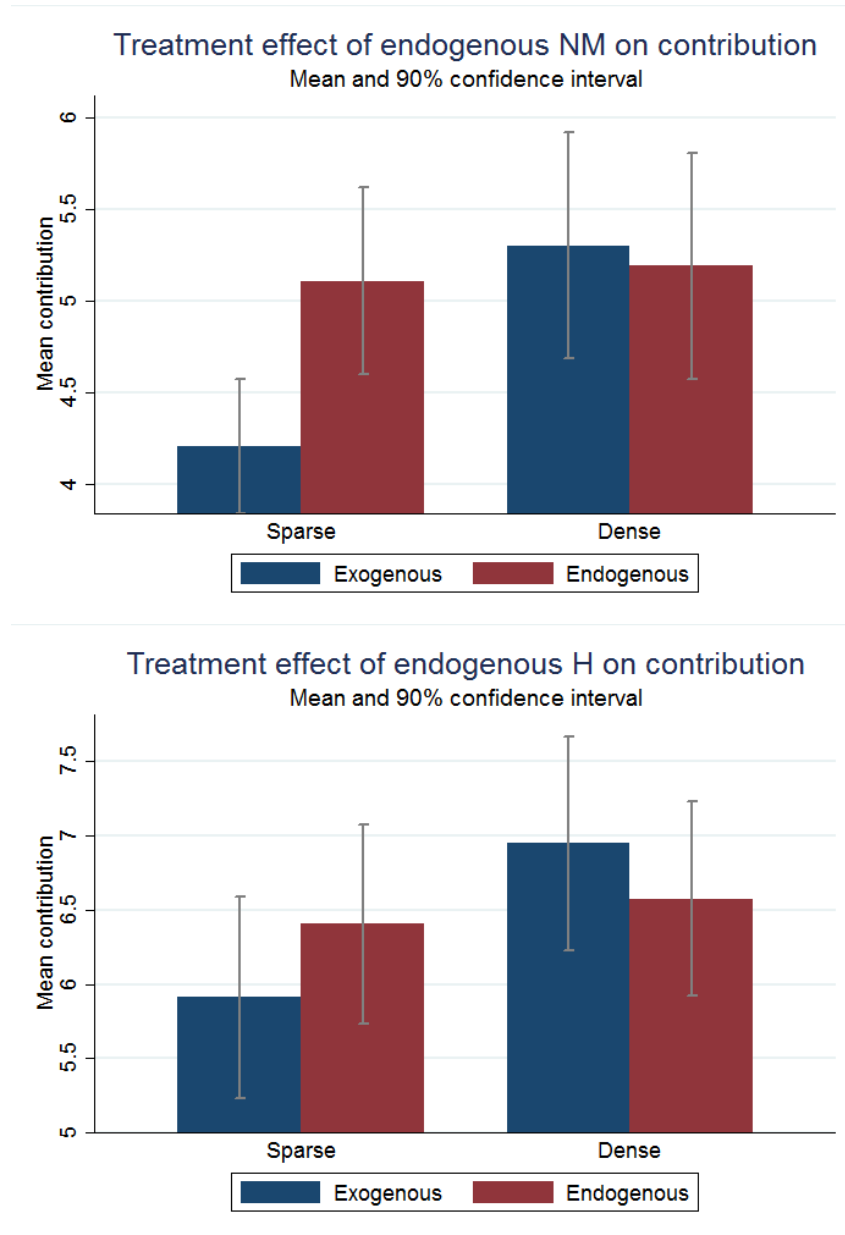


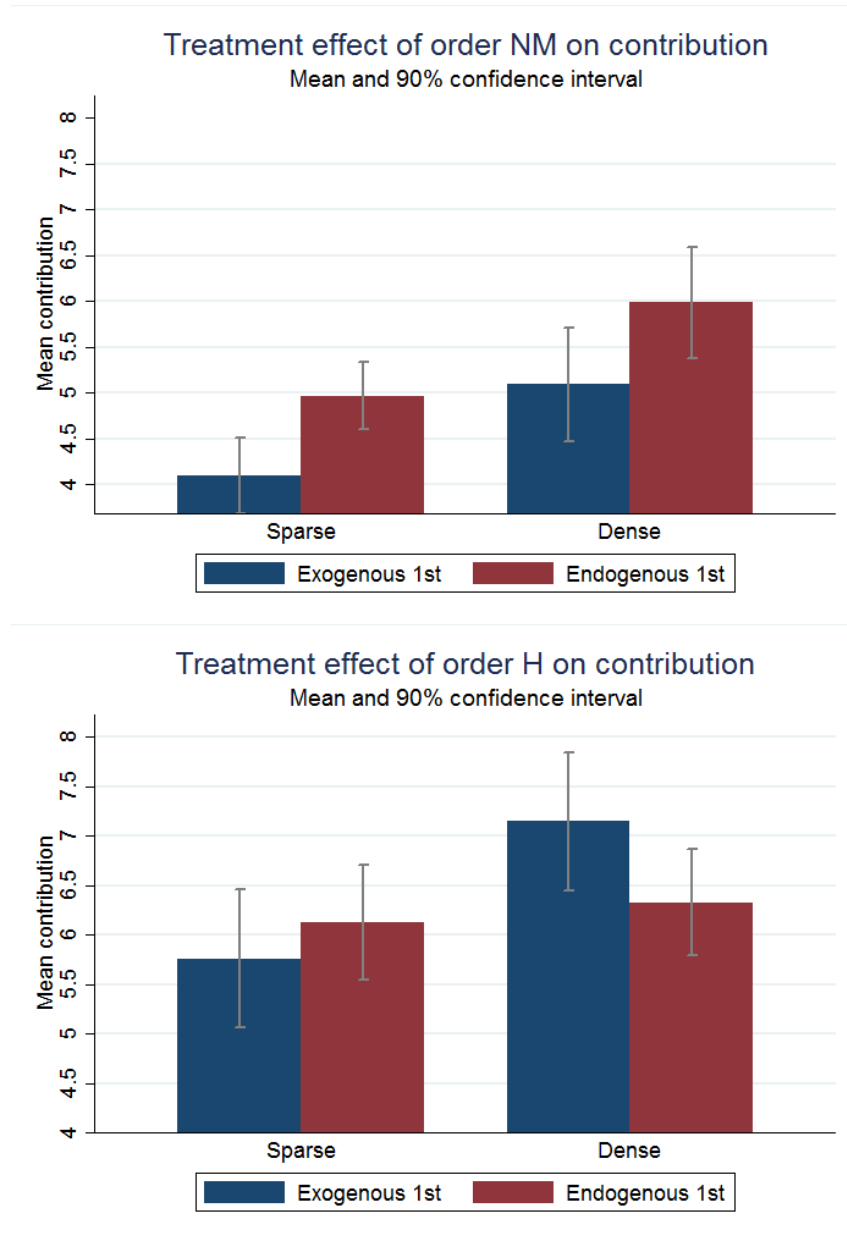
Figure 2.3 – Experimental Design



**Figure 2.4** – Percentage of individuals voting in Sparse and Dense groups**Figure 2.5** – Average contribution endogenous v/s exogenous monitors with selection

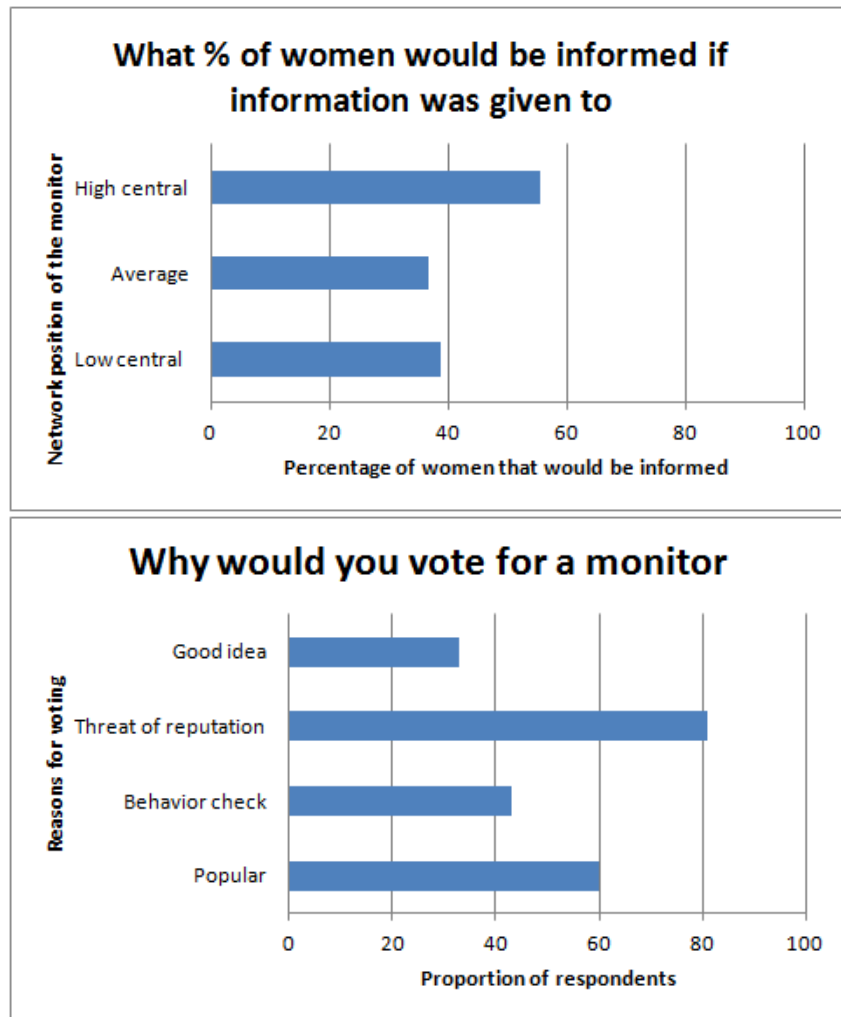
**Figure 2.6** – Contribution with Endogenous and Exogenous Monitors

Notes: Contribution with endogenous v/s exogenous monitors without selection. In the bar graph, x-axis represents group composition and y-axis represents average contribution. We focus on a sub sample where the same group plays under the same monitoring condition both exogenously and endogenously.

**Figure 2.7** – The Order of Endogenous and Exogenous Monitor Treatment

Notes: Order of endogenous and exogenous monitors. In the bar graph, x-axis represents group composition and y-axis represents average contribution. We focus on a sub sample where the same group plays under the same monitoring condition both exogenously and endogenously. The blue bar represents monitoring institutions being assigned exogenously as compared to the red bar where monitor is assigned endogenously.



**Figure 2.8** – Supplemental Survey Evidence

## 2.6.2 Tables

**Table 2.1** – Correlations between Different Centrality Measures

	<i>Degree</i>	<i>Betweenness</i>	<i>Bonacich Centrality</i>
<i>Degree</i>	1	0.7844	0.9161
<i>Betweenness</i>	0.7844	1	0.8686
<i>Bonacich Centrality</i>	0.9161	0.8686	1

**Table 2.2** – Variation in Voting within Individual across Different Groups

		<b>Dense group</b>		
		<i>No monitor</i>	<i>Low central</i>	<i>High central</i>
<b>Sparse group</b>	<i>No monitor</i>	34.95%	4.57%	9.34%
	<i>Low central</i>	5.17%	4.37%	2.98%
	<i>High central</i>	14.71%	4.17%	19.68%

**Table 2.3** – Average Contribution in the Exogenous Treatment

	<b>NM</b>	<b>L</b>	<b>H</b>
<b>DENSE</b>	5.39	5.71	5.84
<b>SPARSE</b>	4.67	4.76	5.41

Note: dense group contribute more than the sparse ones. In the presence of a high central monitor, contribution increases significantly in sparse groups.

**Table 2.4** – Multilogit Regression on Monitor Choice

	Monitor choice	Monitor choice	Monitor choice	Monitor choice
Low central				
Dense	0.02 (0.20)	0.015 (0.21)	-0.062 (0.24)	0.062 (0.20)
High central				
Dense	-0.31 (0.14)	-0.39*** (0.14)	-0.407*** (0.18)	-0.466** (0.20)
N	503	459	503	459
Group characteristics	No	Yes	No	Yes
Individual Fixed Effects	No	No	Yes	Yes

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: No monitor is the base outcome. Monitor choice refers to the individual choice out of: No monitor, High central monitor and Low central monitor. Elected monitor is choice at the level of the group. Dense is a dummy variable that takes value 1 if the group is dense (average path length  $< 2$ ) and 0 otherwise. Group characteristics include: measures of group-differences in wealth, education and caste as well as individual level characteristics.

**Table 2.5** – Contribution under Exogenous Monitors

	contribution	contribution	contribution	contribution
Dense	0.859** (0.38)	0.893*** (0.39)	1.407*** (0.31)	1.614*** (0.33)
H	0.617 (0.4)	1.309*** (0.41)	0.760** (0.36)	0.939** (0.38)
H $\times$ Dense	-0.117 (0.41)	-0.134 (0.41)	-0.933** (0.43)	-1.088** (0.44)
L	0.02 (0.62)	0.47 (0.61)	0.646* (0.38)	0.748* (0.39)
L $\times$ Dense	-0.55 (.11)	-0.49 (0.50)	-0.972** (0.42)	-1.170*** (0.45)
Choice	0.615*** (0.14)	0.632*** (0.14)	0.082 (0.14)	0.111 (0.14)
N	503	459	503	459
Group characteristics	No	Yes	No	Yes
Individual Fixed Effects	No	No	Yes	Yes

\* p<0.10, \*\* p<0.05, \*\*\* p<0.01

Note: Dense is a dummy variable that takes value 1 if the group is dense (average path length  $< 2$ ) and 0 otherwise. H is a dummy variable which is 1 if a High central monitor is elected and L is a dummy which is 1 if a Low central monitor is elected. We include also group characteristics and fixed effects at the individual level. Group characteristics include: an index of wealth inequality among group members, an index of education inequality and a variable representing whether group members belong to the same caste

**Table 2.6** – Endogenous v/s Exogenous Contribution

	contribution	contribution	contribution	contribution
Endogenous	0.611** (0.30)	0.597* (0.30)	0.574*** (0.20)	0.571*** (0.20)
Dense	0.868** (0.35)	0.886** (0.35)	1.235*** (0.23)	1.285*** (0.23)
L	0.152 (0.33)	0.124 (0.33)	0.419* (0.23)	0.399* (0.23)
H	0.780** (0.33)	0.763** (0.34)	0.851*** (0.23)	0.855*** (0.23)
Endogenous $\times$ L	-0.571 (0.56)	-0.505 (0.56)	-0.116 (0.38)	-0.085 (0.38)
Endogenous $\times$ H	-0.066 (0.45)	-0.060 (0.45)	0.046 (0.31)	0.033 (0.31)
Endogenous $\times$ Dense	-0.162 (0.44)	-0.160 (0.44)	-0.583** (0.29)	-0.591** (0.29)
Dense $\times$ L	0.134 (0.47)	0.143 (0.47)	-0.623* (0.33)	-0.623* (0.33)
Dense $\times$ H	-0.312 (0.49)	-0.297 (0.49)	-0.796** (0.33)	-0.815** (0.34)
Endogenous $\times$ Dense $\times$ L	-0.650 (0.78)	-0.699 (0.78)	0.014 (0.53)	-0.005 (0.53)
Endogenous $\times$ Dense $\times$ H	-0.477 (0.64)	-0.470 (0.64)	-0.036 (0.44)	-0.008 (0.44)
N	503	459	503	459
Group characteristics	No	Yes	No	Yes
Individual Fixed Effects	No	No	Yes	Yes
Monitor Choice	Yes	Yes	Yes	Yes

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Table 2.7** – Endogenous v/s Exogenous Contribution without Self-Selection: Fixed Effects

	Sparse(H)	Sparse(H)	Dense(H)	Dense(H)	Sparse(NM)	Sparse(NM)	Dense(NM)	Dense(NM)
Endogenous	0.517 (0.59)	0.519** (0.26)	-0.368 (0.59)	-0.365 (0.23)	0.904** (0.40)	0.907*** (0.22)	-0.089 (0.55)	-0.092 (0.21)
N	104	104	104	104	172	172	130	130
Group Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes

\* p<0.10, \*\* p<0.05, \*\*\* p<0.01

Note: Contribution is the amount given by individuals under each sub group. Sparse (H) refers to sparse groups (average path length > 4) who played both endogenous and exogenous treatment under a High central monitor (H). Dense NM refers to dense groups (average path length < 2) who played both endogenous and exogenous treatment under no monitor. Endogenous is a dummy that takes value 1 if contribution was made with choice of the group. We control for individual and round fixed effects.

**Table 2.8** – Effect of Order on average contribution across endogenous and exogenous round

	Sparse(H)	Dense(H)	Sparse(NM)	Dense(NM)
Order	0.779 (0.62)	-0.305 (0.55)	1.160** (0.51)	0.987 (0.79)
N	170	106	130	104
Group Characteristics	Yes	Yes	Yes	Yes

\* p<0.10, \*\* p<0.05, \*\*\* p<0.01

Note: Order is a dummy that takes value 1 if endogenous treatment was played first. Contribution is the amount given by individuals under each sub group. Sparse (H) refers to sparse groups (average path length > 4) who played both endogenous and exogenous treatment under a High central monitor (H). Dense NM refers to dense groups (average path length < 2) who played both endogenous and exogenous treatment under no monitor.

### 2.6.3 Experiment Instructions

#### Important Clarification

*The text in italic is not meant to be read aloud to experiment participants. It has the explanation of what experimenters should do. The remaining text that is not in italics is meant to be read aloud to experiment participants.*

#### Experiment

*Divide the research team into two groups: team A and team B. As participants enter the venue, team A must welcome them and locate their ID number based on their name from the individual identification list. The research team must then provide the participants with the consent forms, read the forms aloud, explain to them the contents of the forms and that the participants are free to leave at their discretion, answer any questions participants may have, and obtain their consent. [Go to Consent Form]*

*Then, team B should be ready to enter data on contributions.*

#### Experiment begins

Thanks for coming today! We are researchers from Rooster Logic. You are participating in a study on daily decision-making. Today you will play a series of short games. The information gathered here will be confidential and used for research purposes only.

## **Overview**

Today, we will ask you to play a game with two different groups of people for two rounds each. You will randomly be placed in groups of three for the game, whose identity will be known. In each game, you and your group members will make some decisions. The result of these decisions will determine how much money you will earn today.

The games will represent situations and decisions you make every day in your life. You earn some money, you keep some money for yourself, you might give some money to your neighbors or friend, use the money to fund a common project etc.

## **Explanation of Payment**

Let us now discuss how you will make money today. First, you will receive 100 Rs. for simply participating in our games. Second, you will make money from the decisions made during the game.

You will play the same game with two different groups. In the beginning of each game, you will get some income in the form of tokens in a bag we call an 'INCOME POT'. The game is easy and all that you need to do is decide how many tokens you want to keep for yourself and how many tokens you want to contribute to the 'PUBLIC POT'. The total amount collected in the 'PUBLIC POT' will be increased in value by 50%. In both games, the experimenter will collect the tokens that you want to contribute in two different 'PUBLIC POT'.

At the end of the experiment, we will pick one 'PUBLIC POT' out of the 4 and the total amount with the additional 50% increase will be equally divided among the four players in your corresponding group. You will receive equal share, irrespective of how much you put in the 'PUBLIC POT', Respectively, the tokens you decided to keep for yourself in



the ‘INCOME POT’ corresponding to that game will be yours.

*Demonstrate: The experimenter should explain that they will be playing four rounds during the day with two different groups of people. Please show them the graphical image and explain how the contribution game works and how they would earn.*

See then that the decisions you make in all rounds count but you will only be paid the amount in one randomly chosen game. Before I explain the game you will play today in detail, are there any questions?

Answer any questions that they may have.

### **Explanation of the Game**

The game I will explain to you is a very simple one. In this game, you will be matched randomly with 3 more people who you will interact with. You are not allowed to talk to each other throughout this game. At the beginning of the game, you and your partners will get some money that you can either keep for yourself or contribute to a common pot.

There are two stages in this game: First you will be given the choice to elect a monitor to oversee the contribution game that we just briefly explained. The monitor vote will be followed by the contribution task. Let me explain in detail what the contribution task is.

At the beginning of each game, each of you will be given an initial income of Rs 100. All earnings during the games will be represented by tokens, each with a value of Rs 10. Then, each of you will be provided with 10 tokens that are worth Rs 100 in total. This cup will be known as ‘INCOME POT’.

*Demonstrate procedure, the objective you should have in mind is that individuals acquire a sense of the physicality of the game.*

Now, we will explain how you can use your income in the game. You can either keep the

tokens for yourself in the INCOME POT or you can contribute to the PUBLIC POT. The money that you decided to keep in the INCOME POT will be yours. The tokens that you will put in the PUBLIC POT will be added to the tokens that rest of your group put in the PUBLIC POT. The total amount contributed by the group will then increase in value by 50%.

The amount you contribute to the PUBLIC POT will not be revealed to the rest of the members of your group. To contribute to the PUBLIC POT, you will give the number of tokens you want to contribute to the experimenter in the PUBLIC POT. Remember that 1 token is worth 10 Rs.

*Demonstrate the procedure via the chart again. Explain to them that 2 tokens= 20 Rs*

In the first stage, you will be given a chance to elect a monitor to oversee this contribution task. The monitor will observe the amount contributed by each individual to the PUBLIC POT which is otherwise not known. In order to choose a monitor, you will put a tick next to one of the two choices: either having a monitor or not having a monitor. If you decided to have a monitor by putting a tick on the square, you will choose the name of the person you want to elect in the same sheet. If you decide to vote for having a monitor, you will be charged 10 Rs from the money you have been given for participation in the game.

*Demonstrate the voting sheet to participants.*

We will consider the choices of everyone in your group. The option that gets the highest number of votes will be chosen. Now, to see whether the majority choice will be implemented or an external option will be randomly assigned, we will pick a ball from this box without looking. In the box which we will call the CHOICE BOX.

We have two balls, 1 Pink and the other Green. We will pick a ball from the box, if a green ball is chosen, then the option chosen by the group will be implemented. If a pink ball is chosen instead, we will randomly assign one of the 3 options to your group.

*Demonstrate the voting procedure to the participants with four enumerators. Make sure they understand the use of the CHOICE BOX*

Do we have any questions at this point? Have you understood the two stages of the game? Now, we will demonstrate the complete game.

*Five members of the team of experimenters should do the demonstration. Four of them should take the role contributors. The fifth person should represent himself and we will refer to him/her as the experimenter.*

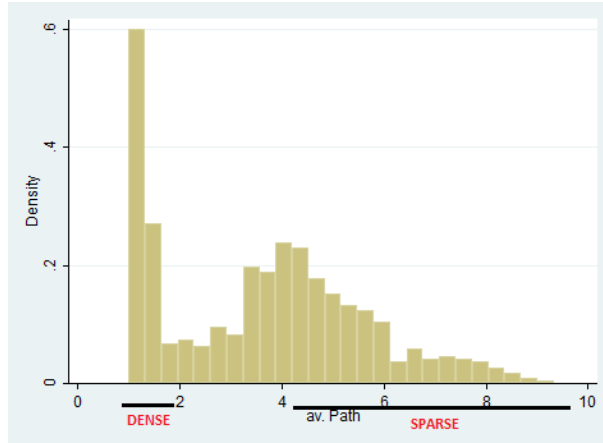
Do you have any questions?

Now, we will practice the game. Note that this will only be practice rounds and that you will not actually play with your actual partner. You will play the actual games with your actual partners after we explain the contribution game, practice them and we answer any question you might have about the games.

*Participants play three rounds of the game and information is recorded exactly as if the game was actually being played.*

### 2.6.4 Summary Statistics

**Figure 2.9** – Distribution of Groups' Average Path Length



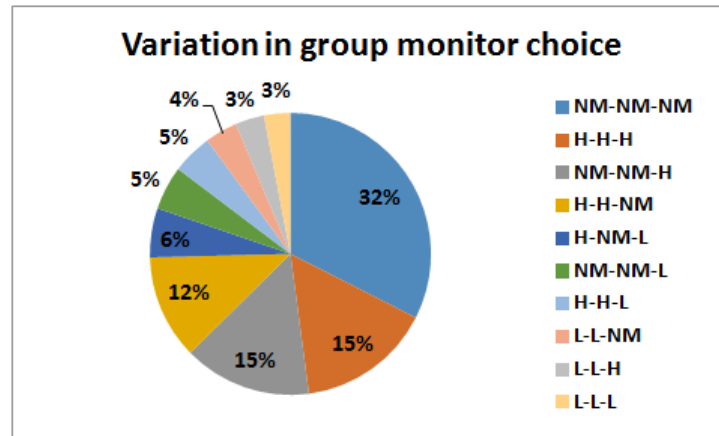
Notes: This is the distribution of average path length in the 1006 groups we formed. Average path length is defined as the average number of steps along the shortest paths for all possible pairs of the group. We over sampled closely knit groups with average path length  $< 2$  (dense). Sparse group is defined as groups with average path length  $> 4$ .

**Table 2.9** – Summary Statistics

	Mean	Std.dev	N
<i>Individual Characteristics</i>			
age	35.8	11.43	503
education	3.06	3.85	503
no, of links	11.38	4.46	503
centrality	0.052	0.071	503
wealth index	-0.253	1.503	503
<i>Group Characteristics</i>			
Same caste	0.74	0.438	503
Same education	0.3801	0.485	503

### 2.6.5 Monitor Choice

**Figure 2.10** – Variation in Individual Choice within a Group



Notes: It shows the variation in individual choice within a group. NM: no monitor being chosen, L: low central monitor and H: high central monitor is chosen. In most groups, all three members vote for NM followed by all three group members voting for H.

**Table 2.10** – OLS Regression for Monitor Choice Behavior

	Monitor	
	Dense	Sparse
Age	-0.0004 (0.002)	-0.003* (0.001)
Caste	0.021 (0.02)	0.090*** (0.02)
Education	-0.030** (0.01)	-0.052*** (0.01)
Wealth	0.014 (0.01)	0.050*** (0.01)
Favor return strangers	0.002 (0.01)	-0.048*** (0.01)
Help friends	-0.009 (0.01)	0.038*** (0.01)
Centrality	0.181 (0.30)	0.566** (0.29)
Distance to H	-0.001 (0.01)	0.032*** (0.01)
Distance to L	0.005 (0.01)	0.010* (0.01)
N	842	842

\* p<0.10, \*\* p<0.05, \*\*\* p<0.01

Note: Monitor is a dummy that takes value 0 if no monitor is elected and 1 if either a high or low monitor is elected. The first column (Dense) regresses individual characteristics with outcome of the vote and the second column does the same but for sparse groups.

## 2.6.6 Model with Three Agents

We expand the two agent model presented in the main body of the paper to three agents, for it to be more representative of the interaction we observe in the experiment.

### 2.6.6.1 Proof of Proposition 2.1

We divide the proof in three steps. First, we compute the optimal contributions for both  $\alpha_l$  and  $\alpha_h$  types when the monitoring technology is exogenously assigned. Second, we

compute the optimal contributions when the monitoring technology is endogenously chosen and the election of a monitor acts as a signal to group members. Third, we compute the equilibrium utilities and find conditions for which the separating equilibrium  $\sigma$  exists.

1. Let us first consider the exogenous case with no signalling. Since the monitoring technology is randomly assigned and not chosen by the group, there is no update of the prior  $\mu_{0i}$ . The voting rule  $m^*$  is slightly different with no tie possible. For types  $\alpha_h$  the utilities when the monitor is elected ( $m^* = 1$ ) or not elected ( $m^* = 0$ ) write

$$\begin{aligned} U(m^* = 1) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(\hat{c}_h^{exo}, \hat{c}_h^{exo}, \hat{c}_l^{exo}) + U(\hat{c}_h^{exo}, \hat{c}_l^{exo}, \hat{c}_h^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(\hat{c}_h^{exo}, \hat{c}_h^{exo}, \hat{c}_h^{exo}) + U(\hat{c}_h^{exo}, \hat{c}_l^{exo}, \hat{c}_l^{exo})] \\ U(m^* = 0) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(c_h^{exo}, c_h^{exo}, c_l^{exo}) + U(c_h^{exo}, c_l^{exo}, c_h^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(c_h^{exo}, c_h^{exo}, c_h^{exo}) + U(c_h^{exo}, c_l^{exo}, c_l^{exo})] \end{aligned}$$

while for types  $\alpha_l$  they write

$$\begin{aligned} U(m^* = 1) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(\hat{c}_l^{exo}, \hat{c}_h^{exo}, \hat{c}_l^{exo}) + U(\hat{c}_l^{exo}, \hat{c}_l^{exo}, \hat{c}_h^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(\hat{c}_l^{exo}, \hat{c}_h^{exo}, \hat{c}_h^{exo}) + U(\hat{c}_l^{exo}, \hat{c}_l^{exo}, \hat{c}_l^{exo})] \\ U(m^* = 0) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(c_l^{exo}, c_h^{exo}, c_l^{exo}) + U(c_l^{exo}, c_l^{exo}, c_l^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(c_l^{exo}, c_h^{exo}, c_h^{exo}) + U(c_l^{exo}, c_l^{exo}, c_l^{exo})] \end{aligned}$$

where  $\hat{c}_i^{exo}$  denotes the contribution of player  $i$  when there is the monitor and  $c_i^{exo}$  when there is no monitor. Solving for each contribution level  $c_l^{exo}$ ,  $c_h^{exo}$ ,  $\hat{c}_l^{exo}$ ,  $\hat{c}_h^{exo}$  we get, for the exogenous assignment of monitoring technology, that the optimal contributions are

$$\begin{aligned}\hat{c}_l^{exo} &= \frac{2\alpha_l \mu_{0i} - 1}{4} + \frac{\delta}{2\theta} & c_l^{exo} &= \frac{2\alpha_l \mu_{0i} - 1}{4} \\ \hat{c}_h^{exo} &= \frac{2\alpha_h \mu_{0i} - 1}{4} + \frac{\delta}{2\theta} & c_h^{exo} &= \frac{2\alpha_h \mu_{0i} - 1}{4}\end{aligned}$$

2. In the endogenous case we have to take into account the election rule and now the monitor outcome ( $m^*$ ) becomes a signal according to which players update their belief about other players' types. Given the updated priors, we can write the utility function for type  $\alpha_h$ , considering the fact that the election of the monitor is perceived as a perfectly informative signal whereby an agent  $\alpha_h$  can infer that with probability one the other two group members are types  $\alpha_l$ . On the contrary, when no monitor is elected, the beliefs are updated to reflect that with probability  $2/3$  one of the other two players in group is of low type. The utilities write

$$\begin{aligned}U(\alpha_i = \alpha_h, \cdot, m^* = 1) &= U(\hat{c}_h^{end}, \hat{c}_l^{end}, \hat{c}_l^{end}) \\ U(\alpha_i = \alpha_h, \cdot, m^* = 0) &= \mu_{0i}(1 - \mu_{0i})[U(c_h^{end}, c_h^{end}, c_l^{end}) + U(c_h^{end}, c_l^{end}, c_h^{end})] + \mu_{0i}^2 U(c_h^{end}, c_h^{end}, c_h^{end})\end{aligned}$$

Following a symmetric argument for type  $\alpha_l$ , we can write

$$\begin{aligned}U(\alpha_i = \alpha_l, \cdot, m^* = 0) &= U(\hat{c}_l^{end}, \hat{c}_h^{end}, \hat{c}_h^{end}) \\ U(\alpha_i = \alpha_h, \cdot, m^* = 0) &= \mu_{0i}(1 - \mu_{0i})[U(c_l^{end}, c_h^{end}, c_l^{end}) + U(c_h^{end}, c_l^{end}, c_h^{end})] + \mu_{0i}^2 U(c_l^{end}, c_l^{end}, c_l^{end})\end{aligned}$$

Solving for each contribution level  $c_l^{end}$ ,  $c_h^{end}$ ,  $\hat{c}_l^{end}$ ,  $\hat{c}_h^{end}$  we get,



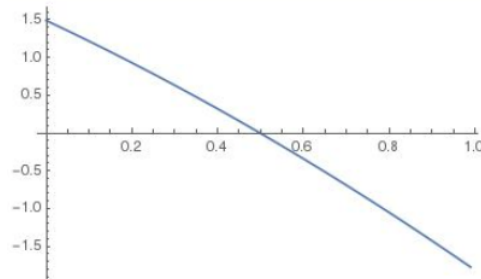
$$\begin{aligned} \hat{c}_l^{end} &= \frac{4\alpha_l - 3}{12} + \frac{\delta}{2\theta} & c_l^{end} &= \frac{2\alpha_l - 1}{4} \\ \hat{c}_h^{end} &= -\frac{1}{4} + \frac{\delta}{2\theta} & c_h^{end} &= \frac{4\alpha_h - 3}{12} \end{aligned}$$

3. In order to show the existence of the separating equilibrium, we evaluate the utilities of players at the optimal contributions computed in steps 1 and 2 and compare them with respect to the two possible actions of voting for the monitor or not. For players of type  $\alpha_i = \alpha_l$  we can write

$$\begin{aligned} U(m_i = 1) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(\hat{c}_l^{exo}, \hat{c}_h^{exo}, \hat{c}_l^{exo}) + U(\hat{c}_l^{exo}, \hat{c}_l^{exo}, \hat{c}_h^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(c_l^{exo}, c_h^{exo}, c_h^{exo}) + U(\hat{c}_l^{exo}, \hat{c}_l^{exo}, \hat{c}_l^{exo})] \\ U(m_i = 0) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(c_l^{exo}, c_h^{exo}, c_l^{exo}) + U(c_l^{exo}, c_l^{exo}, c_h^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(c_l^{exo}, c_h^{exo}, c_h^{exo}) + U(\hat{c}_l^{exo}, \hat{c}_l^{exo}, \hat{c}_l^{exo})] \end{aligned}$$

It is easy to show that when  $\delta$  is large enough there exists a  $\bar{\mu}_{0i=\alpha_l}$  st. for  $\mu_{0i} < \bar{\mu}_{0i=\alpha_l}$ , agent  $i$  of type  $\alpha_l$  is better off voting for the monitor rather than not, i.e. the difference  $U(\alpha_i = \alpha_l | m_i = 1) - U(\alpha_i = \alpha_l | m_i = 0)$  is positive.

**Figure 2.11** –  $\Delta U = U(m_i=1) - U(m_i=0)$  in function of  $\mu_{0i}$



Similarly, we can write for type  $\alpha_i = \alpha_h$

$$\begin{aligned} U(m_i = 1) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(\hat{c}_h^{exo}, \hat{c}_h^{exo}, \hat{c}_l^{exo}) + U(\hat{c}_h^{exo}, \hat{c}_l^{exo}, \hat{c}_h^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(c_h^{exo}, c_h^{exo}, c_h^{exo}) + U(\hat{c}_h^{exo}, \hat{c}_l^{exo}, \hat{c}_l^{exo})] \\ U(m_i = 0) &= \mu_{0i}(1 - \mu_{0i}) \cdot [U(c_h^{exo}, c_h^{exo}, c_l^{exo}) + U(c_h^{exo}, c_l^{exo}, c_h^{exo})] + \\ &\quad \mu_{0i}^2 \cdot [U(c_h^{exo}, c_h^{exo}, c_h^{exo}) + U(\hat{c}_h^{exo}, \hat{c}_l^{exo}, \hat{c}_l^{exo})] \end{aligned}$$

In calculating the difference, it easy to see that for any value of the prior  $\mu_{0i}$   $U(\alpha_h|m_i = 1) - U(\alpha_h|m_i = 0) < 0$ , and a high type would always vote for no monitor, irrespective of the group he plays in. Combining the two results above, there exists an interval of  $\mu_{0i}$  where type  $\alpha_l$  would choose a monitor whereas type  $\alpha_h$  would choose no monitor. Therefore the  $\sigma$  separating equilibrium exists only for  $0 < \mu_{0i} < \bar{\mu}_{0i}^{*\alpha_l}$ . If  $\mu_{0i} > \bar{\mu}_{0i}^{*\alpha_l}$  there is no separating equilibrium and both types vote for no monitor.

□

### 2.6.6.2 Proof of Proposition 2.2

Given the level of contribution under the exogenous monitor we computed in Proposition 1 it easy to compare contributions with or without the monitor. Irrespective of agents' types, the positive impact on optimal contributions of the monitor  $\Delta c$  writes

$$\Delta c = \frac{\delta}{2\theta}$$

Then, it follows immediately that the impact  $\Delta c$  is higher for  $\delta_H$ , i.e. high central monitors, and for low  $\theta$ , which we assume regulate interactions in sparse groups.

□

### 2.6.6.3 Proof of Proposition 2.3

We compare the total contribution prompted by endogenous monitors, i.e. after the priors are updated, with the average contribution when no such signalling occurs, i.e. for exogenously assigned monitors. In particular, we pool together the contributions of both  $\alpha_l$  and  $\alpha_h$  types to have get a more general result. However, the same results can be derived comparing contributions taking into consideration self-selection into monitoring technologies imposed by the separating equilibrium  $\sigma$ . In that case, the contrast would be even more neat.

The total contribution before the elected monitor is revealed writes

$$\frac{2\alpha_l \mu_{0i} - 1}{4} + \frac{\delta}{2\theta} + \frac{2\alpha_l \mu_{0i} - 1}{4} + \frac{2\alpha_h \mu_{0i} - 1}{4} + \frac{\delta}{2\theta} + \frac{2\alpha_h \mu_{0i} - 1}{4}$$

while the total contribution after the elected monitor is revealed is

$$\frac{4\alpha_l - 3}{12} + \frac{\delta}{2\theta} + \frac{2\alpha_l - 1}{4} + -\frac{1}{4} + \frac{\delta}{2\theta} + \frac{4\alpha_h - 3}{12}$$

Comparing the two total contributions we find that the latter is greater than the former only when

$$\mu_{0i} < \frac{5\alpha_l + 2\alpha_h}{6(\alpha_l + \alpha_h)}$$

which concludes the proof. □



# Chapter 3

## Delegating Conflict

### Abstract <sup>1</sup>

Governments often delegate the fight for control over natural or political resources to local armed groups. This paper presents a model of proxy war in which governments delegate conflict by sending non-negotiable offers to militias. Contracts are composed of monetary transfers and of a sharing rule of political influence. Armed groups are positioned along a continuum representing the ideological misalignment between each militia and its government sponsor. Using a principal-agent model with two principals and two agents, I characterize the optimal contracts under complete and incomplete information about the militias' ideological positions. The analysis shows that the equilibrium can be mainly characterized in function of ideological misalignments. While incomplete information of the opponent's ideological position can have an ambiguous effect on optimal transfers, when governments hold incomplete information on their own proxies, at equilibrium they set lower transfers but leave higher political independence to the militia.

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## 3.1 Introduction

Governments seeking to further their international strategic goals often delegate costly fighting to third parties. Sponsoring governments act as patrons and accord financial and military assistance to armed groups, which are in charge of fighting on their sponsors' behalf. Militias aligned with an external party receive resources to strengthen their political and military power, while giving up a portion of their political autonomy. Conflicts by proxy take a heavy toll on civilians and inflict heavy damages on human capital, hampering economic development and shaping the balance of internal and intrastate power for years to come ([Ray and Esteban \(2017\)](#)). Existing economic theories of conflict fail to study the contractual aspect of conflict by proxy, and are unable to explain observed varying patterns of militias' autonomy, the degrees of foreign assistance and fighting intensities. This paper fills precisely this gap and studies the contracting of militias by states.

History abounds with examples of delegated conflicts across time and geography. Since classical antiquity and the Middle Ages, through the Renaissance to modern history, proxies were exploited in internal and external conflicts. In early modern history, the Thirty Years' War represents a classic example of power struggle between two main powers – the royal houses of the Habsburg and Bourbon – for the hegemony over Europe. It is an emblematic representation of a proxy conflict and exemplifies its characteristics. Based on affiliations rooted in ideological and religious differences between Catholics and Protestants, this war involved proxies ranging from Sweden to the Italian city-states, and caused Germany to lose 40% of its population which dropped from roughly 20 million to 12 million between 1618 and 1648 ([Wedgwood \(2016\)](#)). The Treaty of Westphalia, which signed the end of the conflict, placed the following centuries of European politics in a new frame.

The end of World War II saw the US and the URSS confronting each other for more than four decades in a series of proxy wars. The delegated conflicts of the Cold War, which channeled the tensions between the two superpowers, have been the main causes of battle deaths in the 1946-1989 period. The end of the Cold War came with a sharp decrease in battle deaths, which decreased by two thirds when considering the years between 1990 and

2002 (Lacina and Gleditsch (2005))<sup>2</sup>. Consider, for example, how the Carter and then Reagan administrations responded to the 1979 Soviet invasion of Afghanistan by arming, funding and training the fledgling Afghan mujahedeen. More than 1 million civilians died and millions of Afghans fled the country as refugees to neighboring Pakistan and Iran. The instability caused by that war still resonates in contemporary Afghanistan. Similarly, the Soviet use of Cuban proxies during the civil war in Angola, where conflict first broke out in 1974, left 800,000 killed and 4 million displaced. Nearly 70,000 Angolans became amputees as a result of land mines. The wars of Korea between 1950 and 1953, the Vietnam war and the Nicaraguan civil war caused incalculable losses and can all be placed in this context.

In recent times, the Middle East and North Africa have become the main theaters of proxy wars. Since the civil war in Lebanon in the 70s and 80s, external powers acted as sponsors to a constellation of local militias by giving financial and military support in exchange for geopolitical influence. During the Lebanese civil war, the system of patron-client relations was firmly anchored in the religious dimension, whereby Hezbollah received strong support from Iran and many of the Christians militias were flanked by Israel and by Western countries. Approximately 120,000 died and more than one third of the entire population left the country. This conflict left its mark on the Lebanese political system where proxy relationships between armed parties and external sponsors are still at the heart of the balance of power. Nowadays, the struggle for regional supremacy between Iran, on one side, and Saudi Arabia on the other<sup>3</sup>, permeates daily life and politics in Iraq, Yemen and Syria. Recent estimates show that more than 1 million human lives have been lost and several millions are displaced in these three conflicts combined<sup>4</sup>. In Iraq, after the invasion led by the United States, Iran sought a more friendly Shia-dominated government and supported sympathetic rebel factions as part of an effort to undermine the U.S. led coalition, which Iran feared would install a government hostile to its interests. Symmetrically, the United States and Saudi Arabia support the government of Kurdistan and its Sunni armed groups as a barrier to the expansion of Iranian influence in the

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<sup>2</sup>. This represent an underestimation of the number of deaths because of measurement difficulties. Moreover, it only considers battle deaths and not those inflicted on civilians, genocides and violence on the population.

<sup>3</sup>. In turn supported by the United States.

<sup>4</sup>. ACLED for Yemen, <https://www.iraqbodycount.org/database>, <http://iraqdtm.iom.int/IDPsML.aspx>., Global Conflict Tracker for Syria <https://www.cfr.org>

region. In Yemen, a country historically in the sphere of influence of Saudi Arabia, the Shia dominated Houthi militias are used by Iran as a means to assert its influence in the southern Arabian Peninsula while the central Sunni government is armed and supported by Saudi Arabia. Another example of a proxy conflict in the region is represented by the war in Libya, where Russia and Turkey confront each other for geopolitical influence in the Southeastern Mediterranean.

I present here a simple model of conflict delegation. Two governments compete to exert influence in a third country, in the form of extracting resources at a low price, having preferential access to its markets for domestic firms or more generally want to expand their political and military influence in a wider geopolitical context. The territory which represents the battlefield is often a fragile or failed state, where institutions are weak and captured by interest groups and militias. In this political context, control over physical and political resources is held by these armed groups. I assume that the universe of groups is divided into two parties. Each governmental actor uses one of these two parties to fight on her behalf against the other<sup>5</sup>. In the model, sponsor governments act as principals that offer non-negotiable contracts to their militias which in turn act as their agents. Each militia receives offers of contracts from one single government. The offered contracts are made up of two elements, a transfer of resources and a share of influence over militias' policymaking. The two governments send monetary transfers to their militias, which can be used to recruit fighters and buy weapons or can be invested in productive activities. In return, armed groups give away a share of their political independence to the government that supports them. Militias can either accept the contract and become the governments' delegated fighters or turn down the offer and remain neutral, keeping their whole political independence and receiving a fixed positive payoff. When they accept the contract, militias fight each other to appropriate the contested geopolitical and natural resources as well as the investments in productive activities. The total prize of the contest is then divided within the winning party<sup>6</sup>, according to a fixed sharing rule which is the result of ex-post negotiations.

I formalize this situation with a two-stage game where in the first stage governments simultaneously set their proposed transfers and degrees of control over militias' policy-

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5. Throughout the paper I use the terms "armed groups" and "militias" interchangeably.

6. In what follows, a party is composed by the union of a militia and her sponsoring government



making. Contracts are offered to their respective militias, which can choose to either turn down the contract and remain neutral or accept the contract. If they accept, in the second stage militias strategically choose their optimal effort of combat and fight against each another for the control of resources. The key parameters are the ideological misalignments between each government and its militia, which influence the strategic considerations of all players in the game. The higher the misalignment, the higher is the sponsors' political cost of transferring resources to militias, due to deeper scrutiny in parliamentary committees and stronger critiques from the general public for the involvement in foreign conflicts through local groups. Secondly, it enters the utility of militias through the cost of recruiting fighters. The higher the misalignment, the more local groups have to reward local combatants to have them fight on behalf of a foreign power. This, in turn, influences the strategic decisions of fighting intensity and ultimately the equilibria of the game.

The aim of this paper is to bring the literature forward by offering a formalization of delegated conflicts through a principal-agent model with two principals and two agents. I ask three main research questions. First, what is the equilibrium of a simple two-stage game where in the first stage sponsors send transfers and then militias fight each other? Second, what are the optimal contracts offered by governments to local armed groups and what are the equilibrium fighting efforts of militias? Third, in the presence of informational asymmetries whereby governments hold incomplete information on their militias' ideological position or on that of their opponent, how can governments design optimal contracts? The universe of local armed groups is often complex and it is difficult for sponsors to know the exact misalignment between the opposing government and its local militia. That can also happen when contracting one's own delegate. [Salehyan \(2010\)](#) argues that governments often face adverse selection when contracting local armed groups, as these groups lack a fixed ideological structure and frequently change leadership and inspiration. Research in political science (e.g. [Krieg \(2016\)](#); [Pfaff \(2017\)](#)) has shown that when states transfer the burden of warfare from their own military to local groups, they never really know – or at least sometimes misinterpret – the militia's ideology and interests. Governments may face domestic and international criticism as informational asymmetries may increase the reputation costs of delegating fighting to third parties. Militias can damage the sponsor's public image by taking unexpected violent actions motivated by their ideology (e.g. human rights abuses, [De Lauri and Suhrke \(2020\)](#)) or by adopting a rhetoric incompatible with that of the sponsor. While many scholars in

international relations and conflict studies tackle this issue with the tools of qualitative principal-agent theory ([Krieg \(2016\)](#); [Berman and Lake \(2019\)](#)), little has been done to formalize it.

The first main contribution is to study contests that are fought indirectly, by delegating the task of fighting to third parties. The equilibrium of the baseline case can be characterized in a simple way, and it hinges fundamentally on the relative ideological misalignments between the two parties. The government that is ideologically closer to its militia transfers more resources. Its local armed group fights more than the opponent because it can more easily recruit fighters, and has a higher probability of winning the contest. The second main contribution of this paper is to formally highlight and quantify the role of asymmetric information in the contracting of proxies by their sponsors. I find that when sponsors have incomplete information on their militia's ideology, they can design a menu of second-best contracts that are incentive-compatible. Governments are able to elicit the militia's true ideology and each militia picks the contract that has been designed for her. In second-best contracts, offers are characterized by transfers that are lower compared to the case of complete information, while militias are left with more political independence. Since governments transfer more resources to groups ideologically closer, militias seek to exploit their informational advantage to receive higher transfers. By lowering the schedule of transfers for every ideological type, governments can offset the militias' incentive to falsely declare to be more ideologically aligned than they actually are. Lower transfers have to be balanced by leaving a higher degree of political independence to militias.

### 3.1.1 Related Literature

This study naturally relates to the literature on the theory of incentives, to that on contests and third-party intervention, as well as to the literature on conflicts in international relations. Following the seminal papers by [Baron and Myerson \(1982\)](#) and [Maskin and Riley \(1984\)](#), the theory of incentives has found great success in modeling economic and political problems. While the traditional setting has been largely applied to the theory of the firm, most applications in political science have abstracted away from the game-theoretical formalization. Notable exceptions can be found, for instance, in [Alesina and Tabellini \(2005\)](#) and [Alesina and Tabellini \(2007\)](#), which look at the strategic decision of

politicians to delegate some tasks to bureaucrats. They find that politicians would not delegate tasks that would be socially optimal to delegate, but instead prefer to delegate risky policies to shift risk and blame on bureaucracies<sup>7</sup>.

Despite a surge of recent studies in international relations and conflict studies that exploit the qualitative results of the theory of incentives ([Carter and Pant \(2017\)](#); [Gates \(2002\)](#); [Salehyan et al. \(2011\)](#)), none of these articles engages in the formal discussion of strategic decisions of actors involved in delegated conflicts. This paper departs from these studies by offering a full-fledged model of conflict delegation that takes inspiration from seminal papers in the theory of contracts and looks at the literature on conflicts from a different perspective by exploring the role of asymmetric information in the government-militia relationship<sup>8</sup>.

This is also, for the best of my knowledge, the first paper to explicitly study the role of adverse selection in states' contracting of local armed groups. [Baik and Kim \(2014\)](#) studies a two-player contests in which, in order to win a prize, each player hires a delegate to expend effort on her behalf; neither party's delegation contract is revealed to the rival party when the delegates choose their effort levels. This study differs in many aspects. First, I introduce the differentiation of delegates along the ideological spectrum. Second, offers are composed by two contracting variables. The literature on contests in economics<sup>9</sup> has investigated principal-agent problems only marginally, while research in political and development economics has looked at the policy implications of third-party interventions in the context of attempts to avoid civil conflicts spilling into neighboring countries ([Silve and Verdier \(2018\)](#)), as a means to quell a rebellion ([Kathman \(2010\)](#), [Kathman \(2011\)](#)), to lower the overall level of conflict ([Siqueira \(2003\)](#)) or to maximize society's welfare ([Amegashie and Kutsoati \(2007\)](#)). [Sambanis et al. \(2020\)](#) shows how external intervention interacts with polarization of group identities to induce rebellion and civil war. While providing statistical evidence for the importance of this interaction, and proposing a model supporting their findings, their study differs significantly from this work in that it does not tackle the question of incentives.

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7. An excellent overview of delegation problems in political economy can be found in [Persson and Tabellini \(2002\)](#)

8. [Laffont and Martimort \(2009\)](#) gives an excellent overview of methods and insights on general models in contract theory.

9. [Garfinkel and Skaperdas \(2007\)](#) gives a comprehensive overview of the main models.

The paper proceeds as follows: Section 2 first presents the theoretical framework, characterizes the equilibrium of the baseline model and presents the comparative statics. Section 3 studies a situation of complete information where governments send contracts to their militias. Section 4 introduces asymmetric information and studies optimal contracting in incomplete information on groups' ideology. The Conclusion summarizes the findings and outlines directions for future research.

## 3.2 The Baseline Model

### 3.2.1 Players, actions and payoffs

The model formalizes the interaction between two governments and two militias that operate in a weakly institutionalized polity where the rule of law is weak or absent. Actions are taken sequentially. First, the two competing governments delegate fighting to militias which are positioned along a continuum of types  $\theta_{k=i,j} \in (0, 1]$  representing the ideological misalignment between themselves and their governmental sponsors. Governments offer contracts made of two contracting variables: a transfer of resources and a demanded share of control over the militia's policymaking. Each armed group is affiliated to only one government. Once offers are extended, in the second stage militias compete for control over resources by strategically choosing their fighting efforts  $a_{k=i,j} \in \mathbb{R}_+$ . Fighting between militias takes place and the winning party gets the whole prize. Formally, we have a set of players  $(G_k, m_k)_{k=i,j}$  consisting in two governments  $G_{k=i,j}$  and two militias  $m_{k=i,j}$ . Contracts are represented by a set of allocations  $\mathcal{A} = \{(t_k, \gamma_k) : t_k \in \mathbb{R}_+, \gamma_k \in [0, 1]\}_{k=i,j}$ , consisting in a set of transfers and in the demanded shares of political power. Players play simultaneously within each stage of the game. We assume throughout the paper that governments have negligible budget constraints with regards to this type of intervention and that militias perfectly know each others' ideological types. This is a reasonable assumption, as armed groups are deeply rooted in the territory, often share a common language and have interacted before the contest takes place.

Once militias receive the transfers from their sponsors, they can choose how to allocate resources between two ways of generating income: peaceful production  $l_k$  or appropriative

efforts to seize resources previously controlled by others – which costs  $\mu\theta_k a_k$ <sup>10</sup>. The marginal cost of fighting  $\mu\theta_k$  represents the unit cost that militia leaders undergo to engage in combat-related activities. It represents the cost of recruiting fighters, mobilization and logistics. It is composed of two parameters,  $\mu$  and  $\theta_k$ . The former is constant across militias and it relates to the conditions of local labor markets and to the characteristics of the contested region's geography. The latter varies across armed groups and represents the ideological misalignment between the militia and the sponsor government. I assume the marginal cost of fighting  $\mu\theta_k$  to be less than 1. It is a reasonable assumption since armed groups can engage in fighting activities at a discount with respect to regular armies, which I assume in this paper to have a marginal cost of fighting equal to one<sup>11</sup>. The higher is the ideological misalignment  $\theta_k$ , the higher is the compensation militia leaders have to pay recruits to fight for an external entity that is not perfectly aligned to their ideology. The received transfer is strategically split between fighting and productive activities

$$t_k = l_k + \mu\theta_k a_k$$

Rearranging we can see that what is invested in productive activities can be expressed in terms of the transfer received by the sponsor government net of what is spent in fighting effort

$$l_k = t_k - \mu\theta_k a_k$$

The stakes of the contest are represented by  $V > 0$ , which captures the value of disputed natural resources and geopolitical importance combined. The stakes  $V$  and the output of the two militias' joint production  $\bar{L} = \sum_{k=i,j} l_k = \sum_k t_k - \mu\theta_k a_k$ , are subject to dispute, which I assume to be resolved in a winner-take-all contest. The overall prize  $T$  of the contest writes

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10. This trade-off is widely documented by a wealth of studies in the economics of conflicts ([Garfinkel and Skaperdas \(2007\)](#)) and its appropriative nature is well captured by Vilfredo Pareto's (1927)

11. Local armed groups engage in lighter forms of combat, and often use techniques of guerrilla due to their superior knowledge of the territory. Militias' fighters receive lower salaries compared to members of regular armies of major powers and their wage structure is quite flat. See, for an interesting study on Iraq, [Bahney et al. \(2013\)](#)

$$\begin{aligned}
T &= V + \bar{L} \\
&= V + \sum_{k=i,j} l_k \\
&= V + \sum_{k=i,j} t_k - \mu \theta_k a_k
\end{aligned}$$

Each militia's probability of winning is modeled by a standard Tullock contest function and depends on the militias' relative investment in fighting. The probability that militia  $k$  wins the contest is <sup>12</sup>

$$p(\text{winner} = k) = \frac{a_k}{a_k + a_{-k}}$$

In case of defeat, militias get a normalized payoff of 0 from the contest. Once the outcome of the contest is realized, the winning party splits the spoils of war between the sponsoring government and the delegated militia according to a sharing rule. A portion  $s^g$  of the total prize  $T$  goes to the government while  $s^m$  is received by the militia, such that  $s^g + s^m = 1$ . For the sake of simplicity, I assume the sharing rule of the spoils of war to be ex-ante homogenous across parties <sup>13</sup>, as this can be considered the equilibrium outcome of negotiations occurring after the outcome of the contest is realized. Militias also enjoy from a degree of political independence  $P$  in the realm of policymaking, independently from the outcome of the conflict. This represents the autonomy in establishing internal laws and enforcing social norms, regulating the exploitation of resources under militias' control as well as the political influence over their electoral base. When a militia  $m_k$  becomes a proxy for an external entity, it gives up a share  $\gamma_k$  of its independence in policy-making  $P$  to its sponsor (Salehyan (2010)). Sponsoring governments thus capture a share of the internal decision-making process of militias over social and political matters by influencing its leaders, who in turn lose a portion of their political independence. Militias who fight on behalf of a foreign power maximize their utility

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<sup>12</sup>. By construction, militia  $k$ 's victory implies the victory of her sponsoring government and the probability of winning  $p(\text{winner} = k)$  applies as well to governments. Another possible way to interpret  $p_k$  could be to consider it as the share of the total prize that is appropriated by  $k$ .

<sup>13</sup>. As outlined above, a party is composed by a militia  $k$  and her sponsoring government  $k$ .

$$\begin{aligned}
u_k^m &= (1 - \gamma_k)P + \frac{a_k}{a_k + a_{-k}} s^m T \\
&= (1 - \gamma_i)P + \frac{a_i}{a_i + a_j} s^m \left( V + \sum_{k=i,j} (t_k - \mu\theta_k a_k) \right)
\end{aligned}$$

for  $k = i, j$  and where I substituted the expression for the total prize  $T = V + l_i + l_j$ . Governments delegating fighting to local armed groups maximize the following utility function, where they extract some control of policy-making  $\gamma_k P$  from their militias and expect to receive a share  $s^g$  of the total prize  $T$

$$u_k^G = \gamma_k P + \frac{a_k}{a_k + a_{-k}} s^g \left( V + \sum_k (t_k - \mu\theta_k a_k) \right) - \omega\theta_k t_k^2$$

where  $\omega\theta_k t_k^2$  represents the political and logistics cost of transferring resources to a local militia. It is reasonable to assume that the higher is the ideological misalignment between a government and its proxy, the higher is the marginal cost of financing it, either for domestic political resistance (parliamentary committees etc.), retaliation vis á vis allies or criticism from the public opinion. The assumption of increasing marginal costs of transferring funds is also realistic. The political damage of increasing the transferred funds by one unit is small when the level of assistance is also small – it can be dissimulated as humanitarian aid and can be more easily hidden from the public opinion. In other words, the possibility of plausible deniability of supporting foreign groups decreases as governments' involvement increases. When the level of support for the delegated militia is high, increasing the transfer by one unit entails a higher political damage potentially due to domestic and international criticism. From this functional specification, we see how a portion of sponsors' transfers that is not used in fighting can be recovered as part of the contest's prize. This is consistent with the fact that investments in productive activities by militias (e.g. financial institutions, social cooperatives, irrigation or health services) increase the political returns of such strategies of sponsor states by maximizing

sentiments of loyalty of the local population towards the sponsor <sup>14</sup>.

### 3.2.2 Equilibrium

Let us assume for now that the vector of ideological misalignments between both governments and their militias  $\theta = (\theta_i, \theta_j)$  is perfectly known by all players of this game. For now, I also assume  $\gamma_k$  to be an exogenous parameter, representing the equilibrium result of previous negotiations. I relax this assumption in the rest of the paper. Let us solve the model backward. Given the transfers, militias have to strategically decide how much to invest in fighting. They simultaneously maximize their utilities with respect to the fighting efforts  $(a_i, a_j)$  and the first order conditions for militias  $i$  and  $j$  respectively write

$$\begin{cases} \frac{a_j}{(a_i + a_j)^2} (V + t_i + t_j - \mu\theta_i a_i - \mu\theta_j a_j) s^m - \frac{a_i}{a_i + a_j} \mu\theta_i s^m = 0 \\ \frac{a_i}{(a_i + a_j)^2} (V + t_i + t_j - \mu\theta_i a_i - \mu\theta_j a_j) s^m - \frac{a_j}{a_i + a_j} \mu\theta_j s^m = 0 \end{cases}$$

where the first term represents the effect of a marginal increase in fighting effort on the increased probability of winning while the second term represents the negative impact on the final prize. Subject to the conflict technology and vector of ideological misalignments, each militia  $k$  chooses her effort in fighting  $a_k$  taking  $a_{-k}$  as given. Analyzing the best responses of the two militias, we see that there can be only one interior equilibrium where both militias actively fight <sup>15</sup>. Solving for the interior solution of the fighting stage, the optimal fighting efforts write

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<sup>14</sup>. Other, maybe simpler, functional forms of utilities fail to properly account for the non-military returns that sponsors receive from funding local groups. Sectarian identities are an important tool for geopolitical influence, and represent a widely exploited strategy. See, for instance, the report by the Brookings Doha Center [Gause III \(2014\)](#).

<sup>15</sup>. It is possible to define the contest function  $p(a_i = 0, a_j = 0) = 1/2$  where the outcome of the contest is random if none of the two militias fight actively. However, the conflict technology rules out the possibility that peace, i.e.  $a_i + a_j = 0$ , is a Nash equilibrium. As pointed out by [Skaperdas and Syropoulos \(1997\)](#), the existence of the equilibrium derives from the fact that  $p_k \partial^2 p_k / \partial a_k^2 < (\partial p_k / \partial a_k)^2$  for  $k = i, j$ , and uniqueness of that equilibrium follows from the general characteristics of the contest function as specified above. Theorem 2 of [Skaperdas and Syropoulos \(1997\)](#) shows that if at least one pure-strategy equilibrium is in the interior of the strategy space, that equilibrium will be unique.



$$a_i^*(t_i, t_j) = \frac{t_i + t_j + V}{2\mu(\theta_i + \sqrt{\theta_i\theta_j})}$$

$$a_j^*(t_i, t_j) = \frac{t_i + t_j + V}{2\mu(\theta_j + \sqrt{\theta_i\theta_j})}$$

This equilibrium is characterized by fighting efforts that are always positive and that depend positively on the *sum* of resources transferred to militias  $i$  and  $j$  because a part of the resources transferred, i.e. the resources not invested in fighting but in productive activities, become subject to dispute and can be seized through fighting. Interestingly, the optimal fighting effort of militias is not directly dependent on the sharing rule of the spoils of war  $s^m$  and armed groups optimally respond to each other only taking into consideration their ideological positions and the total resources at stake in the contest. Solving backward the model, we maximize the governments' utilities given the militias' best responses. Substituting and simplifying we have,

$$\begin{cases} u_i^G(\mathbf{a}^*) = \gamma_i P + \frac{\theta_j}{2(\theta_j + \sqrt{\theta_i\theta_j})} s^g(t_i + t_j + V) - \omega\theta_i t_i^2 \\ u_j^G(\mathbf{a}^*) = \gamma_j P + \frac{\theta_i}{2(\theta_i + \sqrt{\theta_i\theta_j})} s^g(t_i + t_j + V) - \omega\theta_j t_j^2 \end{cases}$$

The problem of finding the optimal transfers is now completely decoupled between the two governments, since the strategic interaction between the two parties is fully taken into account at the fighting stage. The utilities of governments, when evaluated at the equilibrium of fighting efforts  $(a_i^*, a_j^*)$ , depend additively on the transfers, and each government optimizes independently. Solving independently the two first order conditions of the the system in  $(t_i, t_j)$  we find the equilibrium values of the optimal transfers and of the optimal fighting efforts.

$$\begin{aligned}
t_i^* &= s^g \frac{\theta_j}{4\theta_i(\theta_j + \sqrt{\theta_i\theta_j})\omega} & \text{and} & & a_i^* &= \frac{s^g(\theta_i + \theta_j - \sqrt{\theta_i\theta_j}) + 4\theta_i\theta_j V\omega}{8\theta_i\theta_j(\theta_i + \sqrt{\theta_i\theta_j})\mu\omega} \\
t_j^* &= s^g \frac{\theta_i}{4\theta_j(\theta_i + \sqrt{\theta_i\theta_j})\omega} & & & a_j^* &= \frac{s^g(\theta_i + \theta_j - \sqrt{\theta_i\theta_j}) + 4\theta_i\theta_j V\omega}{8\theta_i\theta_j(\theta_j + \sqrt{\theta_i\theta_j})\mu\omega}
\end{aligned}$$

First, let us note that the equilibrium fighting efforts are always positive since  $\theta_i + \theta_j > \sqrt{\theta_i\theta_j}$ . Interestingly, the optimal transferred resources crucially depend on a combination of the ideological parameters and on the sharing rule of the spoils of war. The higher is the amount of the spoils that will be assigned to the governments, the more resources they transfer at equilibrium. This mechanism feeds into the optimal fighting between militias, which at optimum counter-intuitively increases with the share of the spoils going to governments because this in turn increases the contested amount of resources they try to appropriate. In other words, the higher is the share of the spoils of war that goes to governments, the higher are the optimal transfers and ultimately the fighting intensities of both groups.

**Proposition 3.1.**

*In a sequential game of proxy conflict, the government most ideologically aligned to its militia transfers the highest amount of resources, its delegated militia exerts a higher fighting effort and it has a strictly higher probability of winning the contest, i.e. if  $\theta_j > \theta_i$  then*

$$p_i(a_i^*(\theta_i, \theta_j), a_j^*(\theta_i, \theta_j)) = \frac{\theta_j}{\theta_j + \sqrt{\theta_i\theta_j}} > p_j(a_i^*(\theta_i, \theta_j), a_j^*(\theta_i, \theta_j)) = \frac{\theta_i}{\theta_i + \sqrt{\theta_i\theta_j}}$$

Proposition 1 highlights that the main determinant of strategic decisions is the reciprocal position of militias and governments on the ideological spectrum. It crucially affects the equilibrium choices of transfers and fighting intensities and it ultimately represents the

parameter influencing the probability of victory. The proof of Proposition 1 is in the Appendix <sup>16</sup>.

### 3.2.3 Comparative statics

Let us conduct some comparative statics on the equilibrium transfers, on fighting intensities and on the probabilities of winning at equilibrium. The optimal transfers to the militias  $(t_i^*, t_j^*)$  are such that an increase in the misalignment between government  $k$  and its armed group decreases the amount of resources transferred at equilibrium, while an increase in the opposing party's misalignment impacts positively on government  $k$ 's transfer through a net increase in its probability of winning. The following proposition studies the impact of changes in ideological misalignments on equilibrium transfers, fighting efforts and winning probabilities.

**Proposition 3.2.**

*When the ideological misalignment  $\theta_k$  between militia  $k$  and its sponsor increases, government  $k$  transfers less resources, the militia decreases its fighting and the probability of victory for party  $k$  decreases. When the ideological misalignment of the opposing party  $\theta_{-k}$  increases, government  $k$  transfers more resources, the militia decreases its fighting effort less than its opponent and the probability of victory for party  $k$  increases.*

We see that in a contest by proxy with complete information, the more severe is the misalignment of the militia to her government, the higher is the marginal cost of transferring resources due to the increased political cost of supporting a local armed group.

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<sup>16</sup>. The general results of the baseline model are robust to some changes in the functional form of utilities, provided that the cost of fighting of militias depends linearly on the ideological misalignment, i.e. the cost is  $-\theta_k a_k$ , and provided that the total prize for militia  $k$  depends on the transfer she receives  $t_k$ . Otherwise, it would not be possible to link the strategic decision of fighting by militias to the strategic transfer by sponsor states. One could think of another class of functional forms where the transfer increases the technology of fighting of militias. Even though such class of functions would yield the same qualitative dependencies between fighting efforts, ideological misalignments and transfers, it would fail to account properly for the non-military returns that sponsors receive by delegating conflict. Moreover, given the contest function, that would soon become too complex to be studied analytically.

A higher ideological misalignment in party  $k$  thus lowers the transfer militia  $k$  receives and disproportionately reduces the fighting effort of militia  $k$  compared to its opponent's,  $\partial a_k^* / \partial \theta_k < \partial a_{-k}^* / \partial \theta_k < 0$ . As a consequence, as  $\theta_k$  increases party  $k$  faces a lower probability of winning the contest. In the same logic, the more misaligned is the opponent's militia to her sponsoring government, the higher is the incentive to transfer resources to his own militia and the higher is the probability of winning the war. A marginal increase in the misalignment between the opposing players  $\theta_{-k}$ , brings a decrease in fighting effort  $a_{-k}$  that is in magnitude bigger than the decrease  $a_k$ , thus resulting in a higher probability of winning for government  $k$ . In this scenario, the total cost of transferring a higher amount of resources is thus more than counterbalanced by the larger expected prize from the contest, since the total transfers make up a part of the prize. When  $\theta_{-k}$  increases, holding  $\theta_k$  fixed, the unit cost of transferring resources is constant while the marginal expected benefit increases through the increased probability of winning.

**Proposition 3.3.**

*When the marginal cost of recruiting for militias' fighters  $\mu$  increases, the equilibrium amount of transferred resources does not change, while the optimal fighting efforts of both militias decrease equally. Moreover, an increase in the cost technology of transferring funds results in a decrease in total transfers and consequently in a decrease in equilibrium fighting for both militias.*

An increase in the marginal cost of recruiting and mobilization due to changes in the labor market of fighters  $\mu$ , e.g. a decrease of the unemployment rate<sup>17</sup>, does not affect the optimal transfers while it impacts negatively the fighting effort of both militias. Also, an increase in the cost technology of transferring funds  $\omega$  has obviously a negative impact on optimal transfers  $\frac{\partial t_k}{\partial \omega} < 0$ , and it also negatively impacts the fighting effort of militias through the combined effect on the transfers. For the sake of simplicity, in the rest of the paper I assume  $\omega = 1$ . This will not change any of the insights coming from the results, while it simplifies the exposition.

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17. See for instance Darden [Darden et al. \(2019\)](#), who highlights how worsening economic vulnerability can create an increase in terrorist groups' recruitment of youth.

### 3.3 Contracts: Complete Information

Let us now consider a situation where the control over militias' policy-making  $\gamma_k$  is no more an exogenous parameter, but it is determined strategically by governments. Militias know their own type and that of their opponent, and governments learn both their types perfectly. Governments now have the possibility to offer a menu of contracts conditional on the ideology position of both militias. They simultaneously offer contracts of the form

$$\left(t_i(\theta_i, \theta_j), \gamma_i(\theta_i, \theta_j)\right) \quad \text{and} \quad \left(t_j(\theta_i, \theta_j), \gamma_j(\theta_i, \theta_j)\right)$$

A contract consists of a transfer  $t_k(\cdot)$  and of a proposed control over policy-making  $\gamma_k(\cdot)$  that are functions of the vector of ideological misalignments  $\boldsymbol{\theta} = (\theta_i, \theta_j)$ . Now, militias have the choice not to accept the contract. In this case, they do not receive any transfer from the government sponsor, do not enter the dispute for resources and adopt a strategy of neutrality which gives a fixed payoff of  $N > P > 0$ . This captures the fact that by choosing to remain neutral, militias retain full control over their political autonomy in policy-making and benefit from an additional fixed payoff deriving from not getting into fighting. I expand about the role of the outside option in the following sections of this paper. Since militias always have complete information about the ideological types, the second stage of the game is as before and the best responses of militias are

$$a_i^*(t_i, t_j) = \frac{t_i(\theta_i, \theta_j) + t_j(\theta_i, \theta_j) + V}{2\mu(\theta_i + \sqrt{\theta_i \theta_j})} \quad a_j^*(t_i, t_j) = \frac{t_i(\theta_i, \theta_j) + t_j(\theta_i, \theta_j) + V}{2\mu(\theta_j + \sqrt{\theta_i \theta_j})}$$

Substituting the best responses of militias in their utilities, the participation constraints of militias write<sup>18</sup>

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<sup>18</sup>. In the next section of the paper, I relax the assumption on the identical values of the outside option for both militias.

$$\begin{cases} u_m^i(a_i^*, a_j^*) = (1 - \gamma_i(\theta_i, \theta_j))P + \frac{\theta_j}{2(\theta_j + \sqrt{\theta_i\theta_j})} s^m (t_i(\theta_i, \theta_j) + t_j(\theta_i, \theta_j) + V) \geq N \\ u_m^j(a_i^*, a_j^*) = (1 - \gamma_j(\theta_i, \theta_j))P + \frac{\theta_i}{2(\theta_i + \sqrt{\theta_i\theta_j})} s^m (t_i(\theta_i, \theta_j) + t_j(\theta_i, \theta_j) + V) \geq N \end{cases}$$

which implies that the participation constraints for the two militias can be written in terms of the proposed shared control over policy-making by the governments as

$$\begin{cases} \gamma_i(\theta_i, \theta_j) \leq 1 - \frac{1}{P} \left( N - \frac{\theta_j(t_i(\theta_i, \theta_j) + t_j(\theta_i, \theta_j) + V)}{2(\theta_j + \sqrt{\theta_i\theta_j})} s^m \right) & (PC_i) \\ \gamma_j(\theta_i, \theta_j) \leq 1 - \frac{1}{P} \left( N - \frac{\theta_i(t_i(\theta_i, \theta_j) + t_j(\theta_i, \theta_j) + V)}{2(\theta_i + \sqrt{\theta_i\theta_j})} s^m \right) & (PC_j) \end{cases}$$

The principals' programs in compact form are

$$\max_{(\gamma_k, t_k)} u_G^k = \max_{(\gamma_k, t_k)} \gamma_k(\theta_i, \theta_j)P + \frac{\theta_{-k}(t_k(\theta_i, \theta_j) + t_{-k}(\theta_i, \theta_j) + V)}{2(\theta_{-k} + \sqrt{\theta_k\theta_{-k}})} s^g - \omega\theta_k t_k(\theta_i, \theta_j)^2$$

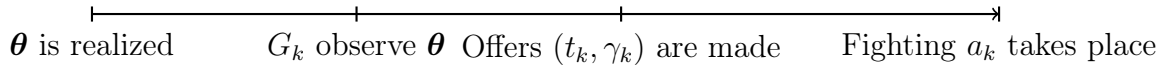
subject to

$$(1 - \gamma_k)P + \frac{\theta_{-k}(t_k(\theta_i, \theta_j) + t_{-k}(\theta_i, \theta_j) + V)}{2(\theta_{-k} + \sqrt{\theta_k\theta_{-k}})} s^m \geq N$$

for  $k = i, j$ .

We can rewrite the programs of the principals only in terms of the transfers when the participation constraints are binding. In fact, with complete information the participation constraint must bind at equilibrium because the governments are able to extract all rents of militias by offering a combination  $(t_k(\theta_i, \theta_j), \gamma_k(\theta_i, \theta_j))$  to keep them slightly above the

indifference point between accepting the contract and staying neutral. In this setting there is no uncertainty, so both governments maximize their utilities given  $\theta = (\theta_i, \theta_j)$  and the participation constraints. The game unfolds as below for both parties



When the constraint binds, and taking into account the fact that  $s^g + s^m = 1$  the utility of the governments is

$$u_G^k = P - N + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_i, \theta_j) + t_{-k}(\theta_i, \theta_j) + V \right) - \omega \theta_k t_k(\theta_i, \theta_j)^2$$

and the first order condition in complete information writes

$$\frac{\partial u_G^k}{\partial t_k} = \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} - 2\omega \theta_k t_k(\theta_i, \theta_j) = 0$$

We see that the strategic interaction between the two parties enters the game only in the second stage through the best responses of militias to one another. When governments optimize over their transfers, they internalize the reaction of militias to one another which depend on the vector of types  $\theta = (\theta_i, \theta_j)$  and on the transfers  $\mathbf{t} = (t_i(\theta_i, \theta_j), t_j(\theta_i, \theta_j))$ .

**Proposition 3.4 (CI).**

*The first best contracts when the both types of militias are perfectly observed are*

$$\begin{cases} t_i^* &= \frac{\theta_j}{4\theta_i(\theta_j + \sqrt{\theta_i \theta_j})\omega} \\ \gamma_i^* &= 1 - \frac{1}{P} \left[ N - \frac{s^m}{8\theta_i\omega} \left( \frac{\theta_i + \theta_j + 4\theta_i\theta_j V - \sqrt{\theta_i \theta_j}}{\theta_j + \sqrt{\theta_i \theta_j}} \right) \right] \end{cases}$$

and for party  $j$

$$\begin{cases} t_j^* &= \frac{\theta_i}{4\theta_j(\theta_i + \sqrt{\theta_i\theta_j})\omega} \\ \gamma_j^* &= 1 - \frac{1}{P} \left[ N - \frac{s^m}{8\theta_j\omega} \left( \frac{\theta_i + \theta_j + 4\theta_i\theta_jV - \sqrt{\theta_i\theta_j}}{\theta_i + \sqrt{\theta_i\theta_j}} \right) \right] \end{cases}$$

Two observations are in order. First, the amount transferred when militias have the outside option of remaining neutral and  $\gamma_k$  are contracting variables, is higher than the amount transferred when there is no participation constraint and  $\gamma_k$  are exogenous parameters. Second, the demanded share of political control by governments  $\gamma_k$  is highest for the most ideologically aligned militia. Overall, the government ideologically closest to its militia offers at equilibrium a higher monetary transfer than the opponent but also demands a higher share of political power. The value of the outside option  $N$ , enters the optimal contract only in the consideration of how much control of policymaking sponsor governments are willing to extract from militias. In the limit of  $N \rightarrow 0$ , it is easy to verify that below a certain threshold on  $N$ , militias always accept the contract even if governments take fully control over militias' policymaking.

## 3.4 Incomplete Information

### 3.4.1 Incomplete information on the opposing militia's ideology

Let us suppose now that the misalignment  $\theta_k$  between each government  $k$  and its proxy is private information to government  $k$ . Consequently, governments ignore the ideological misalignment between the enemy government and its militia. The following analysis always assumes that militias perfectly know the ideological positions of all actors of the game, implying that the fighting stage of the game is unaffected and asymmetric information plays a role only in the strategic decisions of governments. This is a reasonable assumption, as armed groups are deeply rooted in the territory, often share a common



history and have interacted before the delegated contest takes place. Also, I assume the ideological distances to be distributed uniformly  $(0, 1]$ . The programs of governments are then

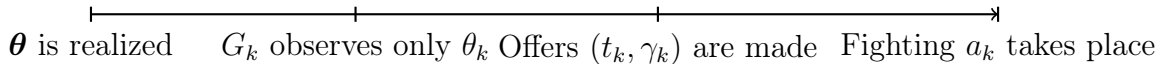
$$\begin{aligned} \max_{t_k, \gamma_k} \mathbb{E} u_G^k(\mathbf{t}, \gamma_k | \theta_k) &= \max_{t_k, \gamma_k} \int_{\theta_{-k}} u_G^k(\mathbf{t}, \gamma_k | \theta_k) d\theta_{-k} \\ &= \max_{t_k, \gamma_k} \int_{\theta_{-k}} \gamma_k(\theta_k) P + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) s^g - \omega \theta_k t_k^2 d\theta_{-k} \end{aligned}$$

subject to

$$(1 - \gamma_k(\theta_k))P + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) s^m \geq N$$

for  $k = i, j$ .

The amount of information in possession of the two principals now is quite different. It is useful to draw a time line to visualize how the game unfolds. We have that



Let us solve government  $i$ 's program since  $j$ 's will be perfectly symmetric. The optimal transfer for government  $k$  now can only depend explicitly on  $\theta_k$ , since it does not receive any signal on the misalignment of the opponents. At the level of the militias' best responses

$$a_i^*(t_i, t_j) = \frac{t_i(\theta_i) + t_j(\theta_j) + V}{2\mu(\theta_i + \sqrt{\theta_i \theta_j})} \quad a_j^*(t_i, t_j) = \frac{t_i(\theta_i) + t_j(\theta_j) + V}{2\mu(\theta_j + \sqrt{\theta_i \theta_j})}$$

We take into consideration the participation constraints of the two militias and we set them both to be binding. Governments are able to fully exploit the perfect knowledge of the type of their own militia to offer a combination of  $(t_k(\theta_k), \gamma_k(\theta_k))$  barely sufficient to convince her to accept the contract. Substituting into government's  $k$  utility function, the optimization program of governments is reduced to a problem in one variable, thus considerably reducing its complexity. The utility of government  $k$  writes,

$$u_G^k(\mathbf{t}, |\theta_k) = P - N + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k(\theta_k)^2$$

Taking the expectation over the opponent's type  $\theta_{-k}$  and factoring out constant terms

$$\begin{aligned} \mathbb{E} u_G^k(\mathbf{t}, |\theta_k) &= \int_0^1 P - N + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k(\theta_k)^2 d\theta_{-k} \\ &= P - N + \int_0^1 \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k(\theta_k)^2 d\theta_{-k} \end{aligned}$$

The first order condition writes

$$\int_0^1 \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} - 2\omega \theta_k t_k(\theta_k) d\theta_{-k} = 0$$

where we have simply taken the derivative of the integrand with respect to the transfer  $t_k$  and set it equal to zero. Solving the integral we obtain the first best transfers offered by government  $k$ , when the opponent's ideology is unknown. This scenario is quite realistic and it implicitly assumes that the transparent communication between government  $k$  and its militia  $k$  contributes to the perfect knowledge of the misalignment parameter, while keeping some uncertainty on that of their opponents. While it is possible that militia  $k$  could communicate to its sponsor the ideological position of the opposing militia, that information could be discarded by government  $k$  as not credible. The proof of Proposition 3 is in the appendix.

**Proposition 3.5** ( $IN_{-k}$ ).

*The first best transfers when each government  $k$  observes perfectly the type of his its own militia  $\theta_k$  but does not observe the opponent's,  $\theta_{-k}$ , is characterized by*

$$\begin{cases} t_i^{*,IN} = \frac{1}{2\omega} \left[ \log \left( \frac{1 + \sqrt{\theta_i}}{\sqrt{\theta_i}} \right) - \frac{2\sqrt{\theta_i} - 1}{2\theta_i} \right] \\ t_j^{*,IN} = \frac{1}{2\omega} \left[ \log \left( \frac{1 + \sqrt{\theta_j}}{\sqrt{\theta_j}} \right) - \frac{2\sqrt{\theta_j} - 1}{2\theta_j} \right] \end{cases}$$

Let us compare the optimal transfers in the incomplete information setting with the complete information. For the sake of exposition, I denote by  $CI$  the setting where the ideological positions of militias are publicly observed and all actors play a game of complete information. Moreover, I denote by  $IN_{-k}$  a situation where government  $k$  only observes the ideological type of its own delegate  $\theta_k$  and holds incomplete information about that of the opponent  $\theta_{-k}$ .

**Proposition 3.6.**

*There exists a threshold  $\widehat{\theta}_j$  such that if  $\theta_j > \widehat{\theta}_j$ , militia  $i$  receives a higher transfer in complete information than in incomplete information about the opposing militia's misalignment. Conversely if  $\theta_j < \widehat{\theta}_j$ , militia  $i$  receives a higher transfer in incomplete information than in complete information. More formally,*

$$\begin{cases} t_i^{IN} > t_i^{CI} & \text{if } \theta_j < \widehat{\theta}_j \\ t_i^{CI} > t_i^{IN} & \text{if } \theta_j > \widehat{\theta}_j \end{cases}$$

where  $\hat{\theta}_j = \frac{\left(1 + 2\theta_i \log\left(\frac{\sqrt{\theta_i} + 1}{\sqrt{\theta_i}}\right) - 2\sqrt{\theta_i}\right)^2}{4\left(\sqrt{\theta_i} \log\left(\frac{\sqrt{\theta_i} + 1}{\sqrt{\theta_i}}\right) - 1\right)^2}$ . The symmetric result applies for the opponent.

Proposition 4 formalizes the fact that in incomplete information government  $i$  takes an average of the possible values of  $\theta_j$  when computing the optimal transfer to its own militia. So, since  $t_i^{CI}$  is increasing and concave in  $\theta_j$  and  $t_i^{IN-k}$  constant in  $\theta_j$ , there must be a value of  $\theta_j$  for which the two are equal. This is particularly interesting, because it means that if militia  $i$  is responsible of communicating to her sponsor the true type of militia  $j$ , it would indeed do so only if militia  $j$ 's type is high, thus putting the government in a setting of complete information. In this way, militia  $i$  would be able to receive a higher transfer. On the contrary, if the true type of militia  $j$  were lower than the  $\hat{\theta}_j$ , militia  $i$  would have no interest of communicating it to her sponsor and would prefer to leave her government in a setting of incomplete information <sup>19</sup>.

### 3.4.2 Incomplete information on the ideology of both militias: second best contracts

I now study a situation where governments do not perfectly observe the ideological type of their proxies and militias have the possibility to misreport their ideology to their governmental sponsors. In this setting it is not clear a priori whether militias have an incentive to report a lower misalignment in order to get a higher transfer and possibly get a lower share of political power or report a higher misalignment and retain a higher political independence. Thus, militias are not only strategic in their mutual fighting effort  $a_k$  but also in the revelation of the ideological type vis à vis their respective governments. I always assume that militias perfectly know each others' ideology position. This is a reasonable assumption considering these armed groups share the same territory, language, history

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<sup>19</sup>. This reasoning would apply only if we assume that militias cannot misreport the opposing militia's ideology and only if government  $i$  cannot strategically draw information on the opposing militia's ideology from the decision of militia  $i$  whether to reveal or not  $j$ 's type.

and share a good deal of informal contacts and networks. The revelation principle is valid in this context, hence we can focus our attention to direct revelation mechanisms of the form  $\{ t(\tilde{\theta}_k), \gamma(\tilde{\theta}_k) \}$ , whereby governments are able to incentivize their militias to reveal their true ideology. These mechanisms are then truthful, i.e., such that

$$u_m^k(\theta_k, \theta_{-k}) \geq u_m^k(\tilde{\theta}_k, \theta_{-k})$$

which implies that

$$\left(1 - \gamma_k(\theta_k)\right) P + C(\theta_k, \theta_{-k}) \left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right) \geq \left(1 - \gamma_k(\tilde{\theta}_k)\right) P + C(\theta_k, \theta_{-k}) \left(t_k(\tilde{\theta}_k) + t_{-k}(\theta_{-k}) + V\right)$$

for any  $(\theta_k, \tilde{\theta}_k) \in (0, 1]^2$ . In particular, for militia  $k$  this implies that

$$\left(1 - \gamma_k(\theta_k)\right) P + C(\theta_k, \theta_{-k}) \left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right) \geq \left(1 - \gamma_k(\theta'_k)\right) P + C(\theta_k, \theta_{-k}) \left(t_k(\theta'_k) + t_{-k}(\theta_{-k}) + V\right)$$

and similarly

$$\left(1 - \gamma_k(\theta'_k)\right) P + C(\theta'_k, \theta_{-k}) \left(t_k(\theta'_k) + t_{-k}(\theta_{-k}) + V\right) \geq \left(1 - \gamma_k(\theta_k)\right) P + C(\theta'_k, \theta_{-k}) \left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right)$$

for all pairs  $(\theta_k, \theta'_k) \in (0, 1]^2$  where  $C(\theta_k, \theta_{-k}) = \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} s^m$  and  $C(\theta'_k, \theta_{-k}) =$

$\frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta'_k \theta_{-k}})} s^m$ . Adding the last two inequalities we obtain the monotonicity constraint

$$\left(C(\theta_k, \theta_{-k}) - C(\theta'_k, \theta_{-k})\right) (t_k(\theta_k) - t_k(\theta'_k)) \geq 0$$

Incentive compatibility alone requires that the schedule of transfers should be non-increasing

in  $\theta_k$ . The fact that we can restrict our attention to direct revelation mechanisms that are truthful implies that the following first-order condition must hold for every  $\theta_k \in (0, 1]$

$$\left(1 - \dot{\gamma}_k(\theta_k)\right)P + C(\theta_k, \theta_{-k})\left(\dot{t}_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right) = 0$$

since announcing its true ideology  $\theta_k$  is an optimal response for militia  $k = i, j$  (revelation principle). Now, thanks to the envelope theorem and the condition above, the local incentive constraint can be written

$$\dot{u}_m^k(\theta_k, \theta_{-k}) = \dot{C}(\theta_k, \theta_{-k})\left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right)$$

Integrating both sides of the last equation yields

$$u_m^k(\bar{\theta}_k, \theta_{-k}) - u_m^k(\theta_k, \theta_{-k}) = \int_{\theta_k}^{\bar{\theta}_k} \dot{C}(\theta_k, \theta_{-k})\left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right) d\theta_k$$

or

$$\begin{aligned} u_m^k(\theta_k, \theta_{-k}) &= u_m^k(\bar{\theta}_k, \theta_{-k}) - \int_{\theta_k}^{\bar{\theta}_k} \dot{C}(\theta_k, \theta_{-k})\left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right) d\theta_k \\ &= N - \int_{\theta_k}^{\bar{\theta}_k} \dot{C}(\theta_k, \theta_{-k})\left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right) d\theta_k \\ &= N + \int_{\theta_k}^{\bar{\theta}_k} \frac{\theta_{-k}^2}{2\sqrt{\theta_k\theta_{-k}}(\theta_{-k} + \sqrt{\theta_k\theta_{-k}})^2} \left(t_k(\theta_k) + t_{-k}(\theta_{-k}) + V\right) s^m d\theta_k \end{aligned}$$

since incentive compatibility implies that only the participation constraint of the most inefficient type can be binding. Because the principals want to minimize the militias' rents, at least one participation constraint must be binding (otherwise, the principal could decrease all rents uniformly without affecting neither the incentive constraints nor the monotonicity requirement). The participation constraint must be binding for  $\theta_k = 1$  and every type of militia is willing to participate whenever the worst type is willing to do so. We also know that the shared control over policymaking can be written as

$$\gamma_k(\theta_k) = 1 - \frac{1}{P} \left( u_m^k(\theta_k) - \int_{\theta_{-k}} C(\theta_k, \theta_{-k}) (t_k(\theta_k) + t_{-k}(\theta_{-k}) + V) d\theta_{-k} \right)$$

and I use this expression to write the optimal  $\gamma_k(\theta_j)^{SB}$  that takes into consideration the local incentive constraint and the optimal transfers at the second best optimum  $t_k^{SB}$  and  $t_{-k}^{SB}$ . Writing the program of governments in terms of the rents of militias  $u_m^k$  and taking the expectation over  $\theta_{-k}$ , the program of governments writes

$$\max_{\{(t_k, u_m^k)\}} \int_{\theta_{-k}} \int_{\theta_k} P + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} (t_k(\theta_k) + t_{-k}(\theta_{-k}) + V) - \omega \theta_k t_k^2(\theta_k) - u_m^k(\theta_k) f(\theta_{-k}) f(\theta_k) d\theta_{-k} d\theta_k$$

subject to

$$\begin{cases} \dot{u}(\theta_k, \theta_{-k}) = \dot{C}(\theta_k, \theta_{-k}) (t_k(\theta_k) + t_{-k}(\theta_{-k}) + V) \\ \dot{t}(\theta_k) \leq 0 \\ u_m^k(\theta_k) \geq N \end{cases}$$

The first constraint is the local incentive constraint, the second is the monotonicity constraint and the third is the participation constraint of militias. Since it is easy to see that the Spence-Mirrlees property holds with a negative sign, local incentive constraints imply the global incentive constraints and the optimization program of governments is well defined as above. The monotone hazard rate is also respected since

$$\frac{\partial}{\partial \theta_k} \frac{1 - F(\theta_k)}{f(\theta_k)} = \frac{\partial}{\partial \theta_k} (1 - \theta_k) \leq 0$$

The Proposition below characterizes the second best contracts.

**Proposition 3.7.**

*When government  $k$  holds incomplete information on its own militia's ideology it offers a menu of contracts  $\{(t_k(\theta_k), \gamma_k(\theta_k))\}$  such that*

- *There is no distortion for the most misaligned militia.*
- *The second best transfers are  $t_k^{SB} = t_k^{IN-k} - \frac{s^m}{4\theta_k \omega} \left( 1 + \frac{(1 - 2\theta_k)}{\sqrt{\theta_k}} - (1 - \theta_k) \log \left( \frac{(1 + \sqrt{\theta_k})^2}{\sqrt{\theta_k}} \right) \right)$*

Each militia  $\theta_k$  picks the contract that is designed for her by revealing her true type, and there is no bunching of types, since the monotonicity constraint is always satisfied. The governments transfer a sub efficient quantity of resources to militias of all ideologies, except of the most extreme ones, thus reducing the fighting efforts of both proxy militias. Governments have an incentive to offer this menu of contracts because they want to decrease the incentive that militias have to mimic less misaligned armed groups in order to receive a higher transfer. Moreover,  $t_k^{SB}$  is clearly decreasing, all types choose therefore different allocations and there is no bunching in the optimal contract.

It is also interesting to note that, while the share of the spoils of war did not enter the optimal contract  $IN_{-k}$ , the second best solution depends negatively on it. The higher is the share of the spoils of war supposed to go the armed groups, the lower would the transfer be at the second best optimum. Because of the incentive constraint,  $s^m$  enters into the optimal contract for all ideological types except for the most misaligned militia. The following Proposition compares the second best contract with that offered by governments when they perfectly observe their own militia's type but ignore that of their opponent.



**Proposition 3.8.**

*When government  $k$  holds incomplete information on its own militia's ideology, it transfers less resources compared to a situation where it perfectly knows its militia's ideology, but it leaves her a higher share of political power, i.e. the second best contract is such that*

$$\begin{cases} t_k^{SB}(\theta_k) & \leq t_k^{IN-k}(\theta_k) \\ 1 - \gamma_k^{SB}(\theta_k) & \geq 1 - \gamma_k^{IN-k}(\theta_k) \end{cases}$$

Compared to the setting of full information on their own delegated armed groups, asymmetric information alters the governments' optimization problem by the subtraction of the expected rent that has to be given to militias. We note that there is no distortion for the most misaligned militia – since the hazard rate  $\frac{1-F(\theta_k)}{f(\theta_k)} = (1 - \theta_k)$  equals 0 when  $\theta_k = 1$  – and a downward distortion for all the other types. At the optimal contract, governments have no incentive to increase the transferred resources to  $t_k^{SB}(\theta_k) + \epsilon$  because, even though it would bring an increase in total surplus through type  $\theta_k$ , they would have to give higher information rents to all types  $\theta'_k < \theta_k$ . Thus, all types have a positive information rent except the most aligned type of militia. Governments *could* implement the first best and offer instead  $\{(t_k(\theta_k)^{IN-k}, \gamma_k(\theta_k)(\theta_k)^{IN-k})\}$ , since it also respects the monotonicity requirement. However, it is not optimal for principals to do so, because the expected rent she would have to pay is greater: while the rent to a type  $\theta_k = 0$  is zero, the rent to any higher type buyer is determined by the quantity assigned to its strictly lower type, and increases with that quantity. Hence, it is optimal for governments to depart from the first best  $IN_{-k}$  and reduce the quantity assigned to a every type  $\theta_k < 1$ , so as to save on the rent left to all higher types.

## 3.5 Conclusion

This paper builds a model of conflict delegation, where two states competing for dominance over a given territory contract local armed groups to wage war on their behalf.

Sponsoring governments transfer resources but demand a share of control over militias' policymaking. Armed groups are positioned on a continuum of ideological types. The analysis shows that sponsors' incomplete information on their militias' true ideology has the effect of lowering the transfers offered in second-best contracts, resulting in a net improvement in the welfare of local populations due to a lower fighting intensity. This comes at cost of a higher political independence left to delegates, and in governments' weaker control over militias' policymaking. This sheds some light on a possible mechanism underlying the governments' lack of control of armed groups that is observed in real conflicts.

This model can easily applied to a more general setting where two principals struggle for influence through their delegated agents who receive a transfer of resources and give up a portion of their organizational independence, resulting in agency loss. This model could serve as a starting point for further investigation in a number of directions. First, it could be integrated in the study of the role of international institutions acting as brokers of peace as inspired by [Myerson and Satterthwaite \(1983\)](#) and [Meirowitz et al. \(2021\)](#). Waging war through proxies gives states the benefit of plausible deniability and it presents the international community with new challenges in the mediation efforts for peace. Secondly, it would be interesting to allow the model to integrate a new set of actors who have emerged to be the proxy war-wagers of the future, including private military companies and internet hackers. These new warriors are able to be co-opted by states with low appetite for direct military action and are predicted to have an increasingly important role in international political confrontations ([Mumford \(2013\)](#); [Maurer \(2016\)](#)). Furthermore, it could guide future research on the micro determinants of militias' existence, and link it to the role of labor market conditions and of local institutions.

## 3.6 Appendix: Proofs

### 3.6.1 Proof of Proposition 3.1

We want to show that

$$t_i^* = s^g \frac{\theta_j}{4\theta_i(\theta_j + \sqrt{\theta_i\theta_j})\omega} > t_j^* = s^g \frac{\theta_i}{4\theta_j(\theta_i + \sqrt{\theta_i\theta_j})\omega}$$

Rearranging the terms we can write

$$\frac{\theta_i + \sqrt{\theta_i\theta_j}}{\theta_j + \sqrt{\theta_i\theta_j}} = \sqrt{\frac{\theta_i}{\theta_j}} > \left(\frac{\theta_i}{\theta_j}\right)^2$$

which is always true for  $\theta_j > \theta_i$ . For the optimal fighting effort are

$$a_i^* = \frac{s^g(\theta_i + \theta_j - \sqrt{\theta_i\theta_j}) + 4\theta_i\theta_j V\omega}{8\theta_i\theta_j(\theta_i + \sqrt{\theta_i\theta_j})\mu\omega} \quad \text{and} \quad a_j^* = \frac{s^g(\theta_i + \theta_j - \sqrt{\theta_i\theta_j}) + 4\theta_i\theta_j V\omega}{8\theta_i\theta_j(\theta_j + \sqrt{\theta_i\theta_j})\mu\omega}$$

we can see that they are identical except for one term at the denominator. Simple algebra gives us the result when  $\theta_j > \theta_i$   $\square$

### 3.6.2 Proof of Proposition 3.2

Computing the derivatives of equilibrium transfers we have that

$$\begin{aligned} \frac{\partial t_k^*}{\partial \theta_k} &= -\frac{\theta_{-k}(2\theta_{-k} + 3\sqrt{\theta_k\theta_{-k}})}{8\omega\theta_k^2(\sqrt{\theta_k\theta_{-k}} + \theta_{-k})^2} s^g < 0 \\ \frac{\partial t_k^*}{\partial \theta_{-k}} &= \frac{\theta_{-k}}{8\omega\sqrt{\theta_k\theta_{-k}}(\sqrt{\theta_k\theta_{-k}} + \theta_{-k})^2} s^g > 0 \end{aligned}$$

while for the winning probabilities we have

$$\begin{aligned}\frac{\partial p_k^*}{\partial \theta_k} &= -\frac{\theta_{-k}^2}{2\sqrt{\theta_k\theta_{-k}}(\theta_{-k} + \sqrt{\theta_k\theta_{-k}})} < 0 \\ \frac{\partial p_k^*}{\partial \theta_{-k}} &= \frac{\sqrt{\theta_{-k}\theta_j}}{2(\theta_{-k} + \sqrt{\theta_k\theta_{-k}})} > 0\end{aligned}$$

Computing the derivatives of the fighting efforts at equilibrium

$$\begin{aligned}\frac{\partial a_k}{\partial \theta_k} &= \frac{-2\theta_k \left( 4\omega V \theta_{-k} \sqrt{\theta_k\theta_{-k}} + s^g \sqrt{\theta_k\theta_{-k}} + 2\omega V \theta_{-k}^2 - s^g \theta_{-k} \right) - s^g \theta_{-k} \left( 2\sqrt{\theta_k\theta_{-k}} + 3\theta_{-k} \right)}{16\mu\omega(\theta_k\theta_{-k})^{3/2} \left( \sqrt{\theta_k\theta_{-k}} + \theta_k \right)^2} < 0 \\ \frac{\partial a_k}{\partial \theta_{-k}} &= \frac{\theta_{-k} s^g \left( 2\sqrt{\theta_k\theta_{-k}} - \theta_{-k} \right) - 2\theta_k \left( s^g \sqrt{\theta_k\theta_{-k}} + 2\theta_{-k}^2 \omega V + \theta_{-k} s^g \right)}{16\theta_{-k}^2 \mu \omega \sqrt{\theta_k\theta_{-k}} \left( \sqrt{\theta_k\theta_{-k}} + \theta_k \right)^2} < 0\end{aligned}$$

□

### 3.6.3 Proof of Proposition 3.3

Computing the derivatives of the optimal transfers and fighting efforts with respect with  $\mu$  and  $\omega$  it is easy to see that

$$\begin{aligned}\frac{\partial t_k}{\partial \mu} &= 0 \\ \frac{\partial a_k}{\partial \mu} &= -\frac{\frac{\theta_k}{4\theta_{-k}\omega(\sqrt{\theta_k\theta_{-k}}+\theta_k)} s^g + \frac{\theta_{-k}}{4\theta_k\omega(\sqrt{\theta_k\theta_{-k}}+\theta_{-k})} s^g + V}{2\mu^2 \left( \sqrt{\theta_k\theta_{-k}} + \theta_k \right)} < 0 \\ \frac{\partial a_k}{\partial \omega} &= -\frac{\frac{\theta_k}{4\theta_{-k}\omega^2(\sqrt{\theta_k\theta_{-k}}+\theta_k)} s^g + \frac{\theta_{-k}}{4\theta_k\omega^2(\sqrt{\theta_k\theta_{-k}}+\theta_{-k})} s^g}{2\mu \left( \sqrt{\theta_k\theta_{-k}} + \theta_k \right)} < 0\end{aligned}$$

□

### 3.6.4 Proof of Proposition 3.5

First, from the optimization problem in one variable, the first order condition is

$$\begin{aligned}
 \frac{\partial u_G^k(\mathbf{t}, |\theta_k)}{\partial t_k} &= \frac{\partial}{\partial t_k} \int_0^1 \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k(\theta_k)^2 d\theta_{-k} \\
 &= \int_0^1 \frac{\partial}{\partial t_k} \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k(\theta_k)^2 d\theta_{-k} \\
 &= \int_0^1 \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} - 2\omega \theta_k t_k(\theta_k) d\theta_{-k} = 0
 \end{aligned}$$

Let us take this integral for the utility maximization of government  $i$  and solve it in isolation. The case for government  $j$  is perfectly symmetric. Let us start by substituting  $u = \sqrt{\theta_i \theta_j}$  and  $du = \frac{\theta_i}{2\sqrt{\theta_i \theta_j}}$  and we can rewrite the integral as

$$\begin{aligned}
 \frac{2}{\theta_i^2} \int_u \frac{u^3}{u^2/\theta_i + u} du &= \frac{2}{\theta_i} \int_u \frac{u^2}{\theta_i + u} du \\
 &= \frac{2}{\theta_i} \left( \int_u \frac{\theta_i^2}{u + \theta_i} + u - \theta_i du \right)
 \end{aligned}$$

I can now solve the three integrals separately. By substituting  $s = u + \theta_i$  and  $ds = du$  I can write the three integral above as

$$2\theta_i \int_s \frac{1}{s} ds + \frac{2}{\theta_i} \int_u u du - 2 \int_u du = 2\theta_i \log(s) + \frac{u^2}{\theta_i} - 2u$$

and by substituting back  $s = u + \theta_i$  and  $u = \sqrt{\theta_i \theta_j}$  we get to

$$\begin{aligned}
\int_0^1 \frac{\theta_j}{(\theta_j + \sqrt{\theta_i \theta_j})} d\theta_j &= 2\theta_i \log(\sqrt{\theta_i \theta_j} + \theta_i) + \theta_j - 2\sqrt{\theta_i \theta_j} \Big|_0^1 \\
&= 1 + 2\theta_i \log\left(\frac{\sqrt{\theta_i} + 1}{\sqrt{\theta_i}}\right) - 2\sqrt{\theta_i}
\end{aligned}$$

Inserting the integral in the first order condition and simplifying we find that

$$t_i^{*,IN} = \frac{1}{2\omega} \left[ \log\left(\frac{1 + \sqrt{\theta_i}}{\sqrt{\theta_i}}\right) - \frac{2\sqrt{\theta_i} - 1}{2\theta_i} \right]$$

□

### 3.6.5 Proof of Proposition 3.6

I prove Proposition 6 for party  $i$ , but the proof is perfectly symmetrical for  $j$ . First, we know that

$$\frac{\partial t_i^{CI}}{\partial \theta_j} = \frac{\theta_j}{4\theta_i(\theta_j + \sqrt{\theta_i \theta_j})\omega} > 0$$

and that

$$\lim_{\theta_j \rightarrow 0} t_i^{CI} = 0$$

Second, we also know that with incomplete information about  $\theta_j$

$$t_i^{IN} = \frac{1}{2\omega} \left[ \log\left(\frac{1 + \sqrt{\theta_i}}{\sqrt{\theta_i}}\right) - \frac{2\sqrt{\theta_i} - 1}{2\theta_i} \right] > 0$$

for every  $\theta_i \in (0, 1]$  and we know that  $t_i^{IN}$  is constant in  $\theta_j$ . This implies that there always

exists a value  $\widehat{\theta}_j$  of  $\theta_j$ , such that  $t_i^{CI}(\widehat{\theta}_j) = t_i^{IN}$ . Moreover, for the monotonicity of  $t_i^{CI}$ , we know that for  $\theta_j > \widehat{\theta}_j$  we have that  $t_i^{CI} > t_i^{IN}$  and for  $\theta_j < \widehat{\theta}_j$  we obtain that  $t_i^{CI} < t_i^{IN}$ . In order to find the value  $\widehat{\theta}_j$  we set the condition  $t_i^{CI}(\widehat{\theta}_j) = t_i^{IN}$  and we solve in  $\widehat{\theta}_j$ . Apart from the constant factor  $\frac{1}{2\omega}$

$$\begin{aligned} \log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right) - \frac{2\sqrt{\theta_i}-1}{2\theta_i} &= \frac{\theta_j}{2\theta_i(\theta_j + \sqrt{\theta_i\theta_j})} \\ \Rightarrow \theta_j - 2\theta_i(\theta_j + \sqrt{\theta_i\theta_j}) \left( \log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right) - \frac{2\sqrt{\theta_i}-1}{2\theta_i} \right) &= 0 \end{aligned}$$

which can be rearranged as

$$\begin{aligned} &2\theta_j\sqrt{\theta_i} - 2\theta_i\theta_j\log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right) + \sqrt{\theta_i\theta_j}\left(2\sqrt{\theta_i} - 2\theta_i\log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right) - 1\right) \\ &= \theta_i\theta_j\left(\frac{2}{\sqrt{\theta_i}} - 2\log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right)\right) + \sqrt{\theta_i\theta_j}\left(2\sqrt{\theta_i} - 2\theta_i\log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right) - 1\right) \\ &= \sqrt{\theta_j}\left(\sqrt{\theta_i} - 2\theta_i - 2\sqrt{\theta_i\theta_j} + 2\theta_i^{3/2}\log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right) + 2\theta_i\sqrt{\theta_j}\log\left(\frac{1+\sqrt{\theta_i}}{\sqrt{\theta_i}}\right)\right) \\ &= 0 \end{aligned}$$

which is true if  $\theta_j = 0$ , which is not acceptable, or if the term inside the parenthesis equals zero, which happens when

$$\theta_j = \widehat{\theta}_j = \frac{\left(1 + 2\theta_i\log\left(\frac{\sqrt{\theta_i}+1}{\sqrt{\theta_i}}\right) - 2\sqrt{\theta_i}\right)^2}{4\left(\sqrt{\theta_i}\log\left(\frac{\sqrt{\theta_i}+1}{\sqrt{\theta_i}}\right) - 1\right)^2}$$

This expression is always positive and

$$\frac{\widehat{\partial \theta_j}}{\partial \theta_i} > 0$$

but it is easy to show that is bounded below one  $\widehat{\theta_j} \leq 1$ , as  $\widehat{\theta_j}(0) = 0$  and

$$\widehat{\theta_j}(1) = \frac{(\log(4) - 1)^2}{4(\log(2) - 1)^2} < 1$$

□

### 3.6.6 Proof of Proposition 3.7

By taking into account the incentive constraint in the governments' programs, I can write

$$\begin{aligned} \max_{t_k} \int_{\theta_{-k}} \int_{\theta_k} P - N + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k^2(\theta_k) + \\ \int_{\theta_k}^1 \left( \dot{C}(\tau, \theta_{-k}) \left( t_k(\tau) + t_{-k}(\theta_{-k}) + V \right) d\tau \right) d\theta_{-k} d\theta_k = \end{aligned}$$

$$\begin{aligned} \max_{t_k} \int_{\theta_{-k}} \int_{\theta_k} P - N + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k^2(\theta_k) + \\ \frac{1 - F(\theta_k)}{f(\theta_k)} \dot{C}(\theta_k, \theta_{-k}) \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) d\theta_{-k} d\theta_k \end{aligned}$$

where we have applied the Fubini Theorem and integrated by parts. Substituting  $\frac{1-F(\theta_k)}{f(\theta_k)} = (1 - \theta_k)$  since the ideological types are distributed uniformly in  $(0, 1]$ , the governments' program writes



$$\max_{t_k} \int_{\theta_{-k}} \int_{\theta_k} P - N + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k^2(\theta_k) +$$

$$(1 - \theta_k) \dot{C}(\theta_k, \theta_{-k}) \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) d\theta_{-k} d\theta_k =$$

$$\max_{t_k} \int_{\theta_{-k}} \int_{\theta_k} P - N + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k^2(\theta_k) +$$

$$- (1 - \theta_k) \frac{\theta_{-k}^2}{2\sqrt{\theta_k \theta_{-k}}(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})^2} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) s^m d\theta_{-k} d\theta_k$$

where we substituted

$$\dot{C}(\theta_k, \theta_{-k}) = - \frac{\theta_{-k}^2}{4\sqrt{\theta_k \theta_{-k}}(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})^2} s^m$$

We can maximize pointwise the integrand since the principal's payoff function is globally concave in  $t_k$  and we can thus focus on the relaxed problem. The monotone hazard rate is also respected since

$$\frac{\partial}{\partial \theta_k} \frac{1 - F(\theta_k)}{f(\theta_k)} = \frac{\partial}{\partial \theta_k} (1 - \theta_k) \leq 0$$

We can see that there is no distortion in the optimal amount transferred to the most misaligned militia, i.e. when  $\theta_k = 1$ . For all other types of ideologies there is a downward

distortion of the optimal proposed transfer. The first order condition is then

$$\begin{aligned} & \int_{\theta_{-k}} \int_{\theta_k} \frac{\partial}{\partial t_k} P - N_k + \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) - \omega \theta_k t_k^2(\theta_k) + \\ & \quad (1 - \theta_k) \dot{C}(\theta_k) \left( t_k(\theta_k) + t_{-k}(\theta_{-k}) + V \right) d\theta_{-k} d\theta_k \\ &= \int_{\theta_{-k}} \int_{\theta_k} \frac{\theta_{-k}}{2(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})} t_k(\theta_k) - 2\omega \theta_k t_k(\theta_k) - (1 - \theta_k) \frac{\theta_{-k}^2}{4\sqrt{\theta_k \theta_{-k}}(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})^2} s^m t_k(\theta_k) d\theta_{-k} d\theta_k \end{aligned}$$

I now solve the integral of the first order condition with respect to  $\theta_{-k}$ . The integration of the first term with respect to  $\theta_{-k}$  is identical to the previous case of Proposition 3. On the other hand, the second term is new and comes from the incentive constraint. That is, up to a factor  $s^m$ ,

$$\begin{aligned} & \int_{\theta_{-k}} -(1 - \theta_k) \frac{\theta_{-k}^2}{2\sqrt{\theta_k \theta_{-k}}(\theta_{-k} + \sqrt{\theta_k \theta_{-k}})^2} t_k(\theta_k) d\theta_{-k} = \\ &= -\frac{t_k(\theta_k)}{2} (1 - \theta_k) \int_{\theta_{-k}} \frac{\sqrt{\theta_{-k}}}{\sqrt{\theta_k}(\sqrt{\theta_k} + \sqrt{\theta_{-k}})^2} d\theta_{-k} = \\ &= -\frac{t_k(\theta_k)}{2} \left( \frac{1}{\sqrt{\theta_k}} - \sqrt{\theta_k} \right) \int_{\theta_{-k}} \frac{\sqrt{\theta_{-k}}}{(\sqrt{\theta_k} + \sqrt{\theta_{-k}})^2} d\theta_{-k} \end{aligned}$$

Substituting  $u = \sqrt{\theta_{-k}}$  and  $du = \frac{1}{2\sqrt{\theta_{-k}}}$  we can rewrite the integral as

$$\begin{aligned} & -\frac{t_k(\theta_k)}{2} \left( \frac{1}{\sqrt{\theta_k}} - \sqrt{\theta_k} \right) \int_{\theta_{-k}} \frac{u^2}{(u + \sqrt{\theta_k})^2} du \\ &= -t_k(\theta_k) \left( \frac{1}{\sqrt{\theta_k}} - \sqrt{\theta_k} \right) \int_{\theta_{-k}} \frac{\theta_k}{(u + \sqrt{\theta_k})^2} - \frac{2\sqrt{\theta_k}}{u + \sqrt{\theta_k}} + 1 du \\ &= -t_k(\theta_k) \left( (2\theta_k - 2) \int_{\theta_{-k}} \frac{1}{u + \sqrt{\theta_k}} du + (\sqrt{\theta_k} - \theta_k^{3/2}) \int_{\theta_{-k}} \frac{1}{(u + \sqrt{\theta_k})^2} du + \left( \frac{1}{\sqrt{\theta_k}} - \sqrt{\theta_k} \right) \int_{\theta_{-k}} 1 du \right) \end{aligned}$$

Substituting again  $s = u + \sqrt{\theta_k}$ ,  $p = u + \sqrt{\theta_k}$  we can rewrite

$$\begin{aligned} & -t_k(\theta_k) \left( (2\theta_k - 2) \int_{\theta_{-k}} \frac{1}{s} ds + (\sqrt{\theta_k} - \theta_k^{3/2}) \int_{\theta_{-k}} \frac{1}{p^2} dp + \left( \frac{1}{\sqrt{\theta_k}} - \sqrt{\theta_k} \right) \int_{\theta_{-k}} 1 du \right) = \\ & -t_k(\theta_k) \left( (2\theta_k - 2) \log(s) - \frac{(\sqrt{\theta_k} - \theta_k^{3/2})}{p} + \left( \frac{1}{\sqrt{\theta_k}} - \sqrt{\theta_k} \right) u \right) + \text{const.} \end{aligned}$$

Now, substituting back and computing the definite integral for  $\theta_k \in (0, 1]$

$$\begin{aligned} & -t_k(\theta_k) \frac{(1 - \theta_k) \left( -\sqrt{\theta_k \theta_{-k}} + 2(\theta_k + \sqrt{\theta_k \theta_{-k}}) \log(\sqrt{\theta_k} + \sqrt{\theta_{-k}}) + \theta_k - \theta_{-k} \right)}{\theta_k + \sqrt{\theta_k \theta_{-k}}} \Bigg|_0^1 \\ & = (1 - \theta_k) \log \left( \frac{(1 + \theta_k)^2}{\theta_k} \right) - \frac{1 - 2\theta_k}{\sqrt{\theta_k}} - 1 \end{aligned}$$

Substituting back in the first order condition

$$\begin{aligned} & \int_{\theta_k} \frac{1}{2} \left[ 1 + 2\theta_i \log \left( \frac{\sqrt{\theta_i} + 1}{\sqrt{\theta_i}} \right) - 2\sqrt{\theta_i} \right] t_k^{SB}(\theta_k) - 2\omega \theta_k t_k^{SB}(\theta_k) + \\ & \frac{s^m}{2} \left[ (1 - \theta_k) \log \left( \frac{(1 + \sqrt{\theta_k})^2}{\sqrt{\theta_k}} \right) - \frac{(1 - 2\theta_k)}{\sqrt{\theta_k}} - 1 \right] t_k^{SB}(\theta_k) d\theta_k \end{aligned}$$

where  $t_k^{SB}(\theta_k)$  is the second best optimal transfer. Maximizing pointwise I obtain

$$\begin{aligned}
t_k^{SB} &= t_k^{IN-k} + A(\theta_k) \\
&= t_k^{IN-k} + \frac{s^m}{4\omega\theta_k} \left( (1 - \theta_k) \log \left( \frac{(1 + \sqrt{\theta_k})^2}{\sqrt{\theta_k}} \right) - \frac{(1 - 2\theta_k)}{\sqrt{\theta_k}} - 1 \right)
\end{aligned}$$

In particular, we can easily check that the additional term  $A(\theta_k)$  is always negative for  $\theta_k \in (0, 1)$  and equals 0 when  $\theta_k = 1$ , i.e. there is no distortion for the most misaligned militia. Moreover,  $t_k^{SB}$  is clearly decreasing, all types choose therefore different allocations and there is no bunching in the optimal contract.  $\square$

### 3.6.7 Proof of Proposition 3.8

We can now see that the contracting variable  $\gamma_k^{SB}$  of the share of power can be written as

$$\begin{aligned}
\gamma_k^{SB}(\theta_k) &= 1 - \frac{1}{P} \left( u_m^{k,SB}(\theta_k) - \int_{\theta_{-k}} C(\theta_k, \theta_{-k}) \left( t_k^{SB}(\theta_k) + t_{-k}^{SB}(\theta_{-k}) + V \right) d\theta_{-k} \right) \\
&= 1 - \frac{1}{P} \left( N - \int_{\theta_{-k}} \int_{\theta_k}^1 \dot{C}(\tau, \theta_{-k}) \left( t_k(\tau) + t_{-k}(\theta_{-k}) + V \right) d\tau \right. \\
&\quad \left. - C(\theta_k, \theta_{-k}) \left( t_k^{SB}(\theta_k) + t_{-k}^{SB}(\theta_{-k}) + V \right) d\theta_{-k} \right] \Big)
\end{aligned}$$

where I substituted

$$u_m^{k,SB}(\theta_k) = \int_{\theta_{-k}} N - \int_{\theta_k}^1 \dot{C}(\tau, \theta_{-k}) \left( t_k(\tau) + t_{-k}(\theta_{-k}) + V \right) d\tau$$

I want to show that at equilibrium  $\gamma_k^{SB} < \gamma_k^{IN-k}$  and, by neglecting the integration over  $\theta_{-k}$  we have

$$\begin{aligned}
\gamma_k^{SB} &= 1 - \frac{1}{P} \left( N - \int_{\theta_k}^1 \dot{C}(\tau)(t_k(\tau) + t_{-k} + V) d\tau - C(\theta_k)(t_k^{SB}(\theta_k) + t_{-k}^{SB}(\theta_{-k}) + V) \right) < \\
&1 - \frac{1}{P} \left( N - C(\theta_k)(t_k^{IN-k}(\theta_k) + t_{-k}^{IN-k}(\theta_{-k}) + V) \right) \\
&= \gamma_k^{IN-k}
\end{aligned}$$

Rearranging and simplifying we obtain

$$\int_{\theta_k}^1 \dot{C}(\tau)(t_k(\tau) + t_{-k} + V) d\tau + \frac{C(\theta_k)(t_k^{SB}(\theta_k) + t_{-k}^{SB}(\theta_{-k}) + V)}{P} < \frac{C(\theta_k)(t_k^{IN-k}(\theta_k) + t_{-k}^{IN-k}(\theta_{-k}) + V)}{P}$$

which is always true because

$$\int_{\theta_k}^1 \dot{C}(\tau)(t_k(\tau) + t_{-k} + V) d\tau < 0$$

where  $\dot{C}(\tau) < 0$ . The fact that  $t_k^{IN-k} > t_k^{SB}$  and  $t_{-k}^{IN-k} > t_{-k}^{SB}$  completes the proof.

□



# Chapter 4

## Hiring Guns: Strategic Delegation and Common Agency

### Abstract <sup>1</sup>

When do governments hire local armed groups to fight on their behalf? How do governments compete to optimally contract a common militia? This paper sheds light on some puzzling aspects of conflicts by proxy. Using a principal-agent model with two principals and two agents, the analysis shows that when governments strategically choose whether to fight by delegation or engage directly in conflict, equilibria can be characterized in function of the local support to militias. The delegation of conflict emerges as an equilibrium when local armed groups receive weak local support from the local population. If governments compete to recruit the same armed group, the militia generally carves out higher rents, it keeps all its political autonomy and pledges allegiance to the government ideologically closer.

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## 4.1 Introduction

States increasingly turn to informal armed groups to delegate the task of fighting on their behalf. While modern states tend to monopolize violence within their borders ([Powell \(2013\)](#)), they often act as patrons to foreign militias by according financial assistance in return for access to material and political resources. Conflicts by proxy are based on a mechanism of indirect engagement in a struggle for power whereby powers may use a local war to advance their global and regional strategic interests without the need to intervene with their own forces ([Deutsch \(1964\)](#); [Bar-Siman-Tov \(1984\)](#)). The formal strategic incentives underpinning governments' decisions to delegate fighting have been overlooked in past research, as were also the effects of competition between various sponsors seeking to recruit the same militia. This paper aims at shedding light precisely on these issues.

States employ delegated fighters for two main reasons ([Mumford \(2013\)](#); [Ahram \(2011\)](#)). First, hiring a proxy offers the possibility of achieving strategic goals more economically, with fewer political costs and less risk. Direct involvement in a war is a costly strategy, as the state burns resources and lives are lost. While it must spend resources to finance local armed groups, the sponsor bears neither direct ties nor the associated domestic war weariness and discontent. Second, when there is no international legitimacy for direct intervention, proxy wars might be the best way to advance one's own interests ([Byman and Kreps \(2010\)](#); [Gleditsch et al. \(2008\)](#); [Regan \(2002a\)](#) and [Regan \(2002b\)](#)). The international community often looks the other way when states delegate conflict to local groups, and such sovereignty violations are not condemned as strongly as border violations by government troops. Symmetrically, armed groups are willing to accept an informal allegiance in return for two main rewards ([Salehyan \(2010\)](#), [Salehyan et al. \(2011\)](#)). First, they demand resources that can significantly augment the groups' military and political capabilities. Local armed groups face the challenge of mobilizing supporters, training recruits, finding sources of finances, and acquiring arms. Foreign patrons can help overcome large power asymmetries between local groups and, importantly, can help mobilizing resources quickly. Second, in case of victory, armed groups can take control of geopolitical and natural resources which will be shared with the sponsor government.

This mechanism has its own tradeoffs. Religious and ideological misalignment between a government and its sponsor is always costly – whether politically, financially or materi-



ally – and the long term strategic objectives of local armed groups and their state sponsors often diverge. Sponsor governments want to influence policymaking of their proxies, which in turn lose a portion of organizational and political independence (Salehyan (2010)). As proxies begin to develop greater perceptions of autonomy, the political and strategic costs of delegating conflict to third parties are likely to become more important. Moreover, local militias are considered by external governments as mercenary forces, tools to be bought in order to exert influence in a given territory. This might spur competition between sponsors trying to recruit the same militia, which can sell its allegiance in return for greater benefits. Two main puzzling facts emerge from qualitative evidence. Governments often support groups that are initially weak and have low fighting capacity (Byman (2018)) and contracted militias are left with considerable political autonomy by the sponsor<sup>2</sup>. This paper sheds light precisely on these issues by extending the framework of Chapter 3 with a model exploring two relevant dimensions: the strategic delegation of conflict and the common agency problem of contracting militias.

This paper asks two main research questions. First, under which conditions is delegating conflict an equilibrium? States struggling for dominance are often faced with the dilemma of whether to wage war directly or to delegate it to third parties. Direct confrontation entails higher human and material costs, but avoids the negative consequences of being associated to a group that is ideologically misaligned. I describe this situation with a strategic delegation model where principals fully commit to the contracts they offer. As highlighted by Fershtman et al. (1991), the principals of a delegation game can strategically use agents to play on their behalf by offering contracts that are common knowledge. While their seminal paper shows that cooperative outcomes emerge as equilibria in the game with delegation<sup>3</sup>, what conditions underpin equilibria where principals delegate the task of fighting?

Second, what are the optimal contracts when two governments compete to hire the same militia? Weak polities are characterized by the fractiousness of its armed groups. When local groups first form (or after their partial disintegration), the choice of which external

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2. See, for instance, the case of the National Defense Forces in Syria which were hired by the Assad regime (<https://www.mei.edu/publications/all-presidents-militias-assads-militiafication-syria>) or the Lashkar-i-Taiba group in Kashmir hired by Pakistan (Ahram (2011))

3. Providing that each principal is fully committed to the contract he signed with his agent and the contracts are fully observed.

support to accept is a crucial decision. External sponsors, often allies, compete to hire local combatants and armed groups receive different offers. I model this situation with a common-agency model inspired by [Bernheim and Whinston \(1986\)](#), where two principals – the external governments – compete to hire a common agent – the militia.

The first main contribution of this paper lies in the characterization of equilibria of the delegation game. The analysis shows that the equilibria hinge on the relative ideological misalignments and on the level of support that armed groups receive from local populations. The delegation of conflict is the unique equilibrium when militias receive weak support from local populations. In this case, groups are at the fringe of society and lack the networks to recruit fighters and buy weapons. This finding is in accord with evidence, as highlighted by the qualitative literature on conflicts (e.g. [Byman \(2018\)](#)). Militias that lack local support are in desperate need of external resources and are easily hired by foreign principals, which can spend little resources recruiting them. The equilibria are always unique, except when the ideological misalignments of the two parties are identical. When this happens, multiple equilibria could arise for intermediate levels of local support.

The second main contribution is the characterization of equilibria of the common agency game. Equilibria hinge on the relative ideological misalignments of each government vis-à-vis the militia, the value of resources at stake and the outside option of neutrality. In general, both governments try to get the allegiance of the militia by sending offers. The competition triggers a sequence of undercuttings à la Bertrand over the control of the militia's political autonomy. If one of the two governments has a distinct ideological advantage over the other and the outside option is not much attractive, then the former is able to keep the latter out of the competition by leaving high political independence to the militia. When the option of remaining neutral becomes very attractive for the militia, the ideologically advantaged government must further increase the offered share of political independence left to the militia until a point where it gives it all away to the delegated group. Moreover, when the two principals are in tight ideological competition – their ideological misalignments to the armed group are almost the same – or when the value of resources at stake is very high, neither government can keep a positive share of political influence. The recruited militia has complete independence in policymaking and the two governments compete on the offered transfers. For the most aligned principal it is sufficient to offer slightly more than its competitor to win the militia's allegiance.

### 4.1.1 Related Literature

This paper takes inspiration from two large strands of literature. First, it relates to studies focused on third party interventions and strategic militarization in conflicts. While the early studies on these topics ([Snyder and Diesing \(1977\)](#); [Snyder \(1984\)](#)) already identified the possible excessive adventurism of the client as one of the main problems of external intervention, they lacked the appropriate game theoretical tools to analyze strategic incentives of involved actors. More recently, [Zagare and Kilgour \(2006\)](#) studies specifically how third-party intervention influences the dilemma between deterrence versus restraint in international conflicts. [Kydd and Straus \(2013\)](#) focuses on the potential negative effects that third-party intervention can have on war atrocities. Integrating a simple bargaining model into an intervention game, they show that the negative effects of intervention can be mitigated if the third party is relatively neutral and if alternative costs are imposed on decision makers.

Recently, a number of papers have studied the problem of strategic militarization in connection to deterrence and to the causes of war. While [Jackson and Morelli \(2008\)](#) studies countries choosing armament levels and whether they go or not to war, [Meirowitz et al. \(2008\)](#) looks at why states may create informational asymmetries that lead to war and shows that self interest and strategy are to blame for the emergence of uncertainty about military strength and war. [Baliga and Sjöström \(2015\)](#) considers a simple bargaining model where conflict occurs if players cannot agree to share a resource peacefully, while [Meirowitz et al. \(2021\)](#) uses a game-theoretic model of intervention with strategic militarization and bargaining. While considering a wide variety of possible interventions that range from commitment to military assistance in case of war, to subsidizing a challenger's militarization, they do not consider the role of delegation of conflict per se and do not explore the ideological dimension in the issue of third party intervention. I depart from all these studies by proposing a model that studies a government's strategic tradeoffs when it seeks to exert influence in an external territory by delegating (or not) the task of fighting to a local client. None of the papers mentioned above offers a model of strategic delegation nor introduces the possibility of competition between sponsors trying to recruit a common militia.

Secondly, this study is related to seminal papers in the theory of contracts, particularly to problems of strategic delegation ([Fershtman et al. \(1991\)](#); [Fershtman and Kalai \(1997\)](#)) and common agency ([Bernheim and Whinston \(1986\)](#)). Models of strategic delegation have been widely used in the theory of the firm and in the economics of organizations. Some studies look at the problem of selection of managers as a commitment device that can strategically alter the competitive interaction among competing firms ([Goering \(2007\)](#); [Lambertini and Trombetta \(2002\)](#); [Englmaier \(2010\)](#)). Others study the provision of incentives comparing profit-only versus mixed incentives ([Vickers \(1985\)](#); [Fershtman and Judd \(1987\)](#); [Skivas \(1987\)](#)) or absolute versus relative evaluations of performance ([Fumas \(1992\)](#); [Aggarwal and Samwick \(1999\)](#)). This paper differs significantly from all these studies in two aspects. First, it is the first one looking into the problem of strategic delegation in contests. Second, I introduce a two-stage game in the framework of strategic delegation, where in the second stage militias strategically fight each other.

The common agency framework introduced by the seminal work of [Bernheim and Whinston \(1986\)](#) has found numerous applications, in particular in modeling public goods provision (e.g. [Siqueira and Sandler \(2007\)](#); [Martimort and Stole \(2009\)](#)), in industrial organization (e.g. [Martimort \(1996\)](#); [Raff and Schmitt \(2006\)](#)) and in modeling lobbying for tariffs ([Grossman and Helpman \(1994\)](#)) or for producer taxes and subsidies ([Dixit et al. \(1997\)](#)). This paper departs from all those mentioned above as it is, to the best of my knowledge, the first one to introduce such framework in the study of contests to understand the effect of government competition on optimal contracting.

The paper proceeds as follows: Section 2 first presents the theoretical framework and characterizes the equilibria of the strategic delegation game. Section 3 introduces competition between governments and studies a problem of common agency. The Conclusion summarizes the findings and outlines avenues for future research.

## 4.2 Strategic Delegation of War

### 4.2.1 Players, actions and types

Two governments  $G_{k=i,j}$  compete to exert influence in a third country, in the form of extracting resources at a low price, gaining preferential access to markets for their domestic firms or more generally exerting geopolitical influence. As in Chapter 3, militias  $m_{k=i,j}$  can be of a continuum of types  $\theta_{k=i,j} \in (0, 1]$  representing the ideological misalignment between each government and the militia linked to it<sup>4</sup>. All players have complete information on the ideological type of their opponent. Government  $k$  can offer a contract which specifies a transfer of resources  $t_k$  and a demanded share of control over the militia's political autonomy  $\gamma_k$ . The contract is in the form

$$\left( t_k(\theta_i, \theta_j), \gamma_k(\theta_i, \theta_j) \right)$$

Militias can turn either accept or turn down the offer. If they turn down the contract, they remain neutral and get a normalized payoff of  $N > 0$ . On the contrary, if militias accept the contract they fight on behalf of the external sponsor. They receive a transfer of resources  $t_k$  that can be strategically split between two ways of generating income: peaceful production  $l_k$  or appropriative efforts  $a_k \in \mathbb{R}_+$  to seize resources previously controlled by others, i.e.  $t_k = l_k + \theta_k a_k$ . The higher is the ideological misalignment  $\theta_k$ , the higher is the marginal cost of fighting and the compensation militia leaders have to pay recruits to fight for an external entity that is not perfectly aligned to their ideology. Thus, I assume the militias' marginal cost of fighting to be less than 1<sup>5</sup>. It is a reasonable assumption since armed groups can engage in fighting activities at a discount with respect to regular armies, which I assume in this paper to have a marginal cost of fighting equal

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4. I assume for now that each militia receives offers only from one government, but this assumption is relaxed in the next section of the paper.

5. Local armed groups engage in lighter forms of combat, and often use techniques of guerrilla due to their superior knowledge of the territory. Militias' fighters receive lower salaries compared to members of regular armies of major powers and their wage structure is quite flat. See, for an interesting study on Iraq, [Bahney et al. \(2013\)](#).

to one<sup>6</sup>.

Militias also enjoy from a degree of political autonomy  $P$  representing the independence in establishing internal laws, enforcing social norms and in regulating the exploitation of natural resources. When an armed group accepts an offer, it has to give up a share  $\gamma_k$  of its independence to its sponsor (Salehyan (2010)). Thus, government sponsors can potentially capture a share of the internal decision-making process of militias and influence their political actions. The stakes of the contest are represented by  $V > 0$ , which captures the combined value of disputed natural resources and geopolitical importance. The stakes  $V$  and the total outcome of production by militias participating in the contest  $\bar{L} = \sum_{k=i,j} l_k = \sum_k t_k - \mu\theta_k a_k$  are subject to dispute, which is resolved in a winner-take-all contest. The technology of the contest is modeled by a standard Tullock contest function which depends on the relative investments in fighting. The probability that party  $k$  wins the contest is

$$p(\text{winner} = k) = \frac{a_k}{a_k + a_{-k}}$$

The winning party splits the spoils of war  $T = V + \sum_{k=i,j} t_k - \mu\theta_k a_k$  according to a sharing rule that I assume to be the result of ex-post negotiations. A portion  $s^m$  of the total prize is assigned to the winning militia, while the government sponsor receives a share  $s^g$ , such that  $s^g + s^m = 1$ . Militias that accept the contract optimally choose their fighting effort  $a_k$  and maximize the following utility function, given the offered pair  $(t_k(\theta_i, \theta_j), \gamma_k(\theta_i, \theta_j))$ . The utility of militia  $k$  writes

$$u_k^m = (1 - \gamma_i(\theta_i, \theta_j))P + \frac{a_i}{a_i + a_j} s^m \left( V + \sum_{k=i,j} (t_k(\theta_i, \theta_j) - \theta_k a_k) \right)$$

When governments delegate fighting to a militia they optimize the following program

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6. For expositional simplicity I assume that marginal impact of the ideological misalignment  $\theta_k$  is the same for the governments' transfers and for militias' fighting efforts. This does not affect the results of this paper. A more general discussion can be found in Chapter 3.

$$\max_{(\gamma_k, t_k)} u_G^k = \max_{(\gamma_k, t_k)} \gamma_k(\theta_i, \theta_j)P + \frac{a_k}{a_k + a_{-k}} s^g \left( V + \sum_k (t_k(\theta_i, \theta_j) - \theta_k a_k) \right) - \theta_k t_k^2$$

subject to

$$(1 - \gamma_i(\theta_i, \theta_j))P + \frac{a_i}{a_i + a_j} s^m \left( V + \sum_{k=i,j} (t_k(\theta_i, \theta_j) - \theta_k a_k) \right) \geq N$$

where they extract some control of policy-making  $\gamma_k P$  from their militias and expect to receive a share  $s^g$  of the total prize  $T$ . Governments which delegate fighting to militias pay  $\theta_k t_k^2$  for the political and logistics costs of transferring resources to a local militia. The higher is the ideological misalignment  $\theta_k$  between a government and its proxy, the higher is also the cost of financing it.

### 4.2.2 The game

The involvement of governments in conflicts can be of two general types: either direct intervention or indirect engagement through third parties. We now turn to studying the strategic decision of governments about whether or not to delegate conflict when the ideological types of both available militias are public information. This situation can be represented as a normal form game, where the action space of government  $k$  is  $I_k = (D, ND)$ , i.e. governments choose whether to delegate (D) or not to delegate conflict (ND). We also assume, as before, that governments fully commit to the offered contracts. When governments enter conflict directly, they avoid the political and monetary cost of transferring resources to local proxies  $-\theta_k t_k^2$  while renouncing to capturing a share of political influence over the armed group's policymaking  $\gamma_k P$ . In this case, government  $k$  directly exerts a fighting effort that influences both the probability of winning  $\frac{a_k}{a_k + a_{-k}}$  and the total prize. The outside options of militias to remain neutral can be decomposed, for

the sake of exposition, as  $N = P + R$ , representing the fact that militias that do not fight enjoy support by local populations  $R$ <sup>7</sup> and enjoy full independence in the formulation and implementation of policymaking  $P$ . In this framework, the governments' strategic considerations of whether to delegate conflict to their militias are twofold. First, they have to decide whether delegation is payoff maximizing given the opposing government's type of involvement into the conflict – delegated or direct. Secondly, they have to either optimize over the contracting variables  $(t_k, \gamma_k)$  or to optimally choose the fighting efforts  $a_{G_k}$ , for every given combination of the action space  $I = I_i \times I_j = (D, ND)^2$ . This situation can be represented in a normal form as

		Government $i$	
		$D$	$ND$
Government $j$	$D$	$u_i^G(D, D), u_j^G(D, D)$	$u_i^G(ND, D), u_j^G(ND, D)$
	$ND$	$u_i^G(D, ND), u_j^G(D, ND)$	$u_i^G(ND, ND), u_j^G(ND, ND)$

where  $u_k^G(\cdot, \cdot)$  is the payoff government  $k$  gets given the optimal contracts offered to the militias and their mutual best responses in fighting efforts. Governments engaging directly in conflict do not invest in productive activities locally and face a unit cost of fighting  $-1$  that is higher than that of militias  $-\theta_k$ . This is a reasonable assumption given that the mobilization of a regular army is an extremely expensive operation – including transportation, provisioning and arming – while local militias are already located in the territory, can recruit fighters at a low cost and generally employ a lighter type of warfare. We have now to specify the payoffs of governments for all four possible combinations of actions. Let us focus on government  $i$  since the payoffs of  $j$  are symmetric. When both governments delegate, i.e. the action profile is  $(D, D)$  and we resume the results of Chapter 3. In this case, militias optimally respond to each other choosing

$$\begin{cases} a_i^*(D, D) = \frac{t_i + t_j + V}{2(\theta_i + \sqrt{\theta_i \theta_j})} \\ a_j^*(D, D) = \frac{t_i + t_j + V}{2(\theta_j + \sqrt{\theta_i \theta_j})} \end{cases}$$

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<sup>7</sup>. Support can either be material, e.g. financial resources and food, or non material, e.g. shelter and medical assistance to militia members



which implies that the optimal transfers are

$$\begin{cases} t_i^*(D, D) = \frac{\theta_j}{4\theta_i(\theta_j + \sqrt{\theta_i\theta_j})} \\ t_j^*(D, D) = \frac{\theta_i}{4\theta_j(\theta_i + \sqrt{\theta_i\theta_j})} \end{cases}$$

Substituting in government's  $i$  payoff we obtain at equilibrium

$$u_i^G(D, D) = \frac{\frac{\theta_j^2}{\theta_i} + 8\theta_j V(\sqrt{\theta_i\theta_j} + \theta_j) + 2\sqrt{\theta_i\theta_j}}{16(\sqrt{\theta_i\theta_j} + \theta_j)^2} - R$$

where  $R = N - P$ . When computing  $u_i^G(ND, D)$ , it is necessary to be a little more careful. In this case, government  $i$  enters conflict with its proper means and human resources, does not transfer resources to third party combatants and fights against the militia sponsored by  $G_j$ . Militia  $i$  is not involved anymore and we denote by  $a_{G_i}^*$  the optimal fighting effort by government  $i$ . At the fighting stage, governments  $i$  maximizes

$$u_i^G(ND, D) = \frac{a_i}{a_i + a_j}(V + t_j - \theta_j a_j - a_i)$$

where government  $i$  does not have to share the spoils of war with its delegated armed group, since it enters conflict directly. Militia  $j$  optimizes<sup>8</sup>

$$u_m^j(ND, D) = (1 - \gamma_j)P + \frac{a_j}{a_i + a_j}(V + t_j - \theta_j a_j - a_i)s^m$$

The equilibrium of the fighting stage implies that

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8. It is possible to envisage other ways of representing the cost of fighting incurred by government  $i$ , for instance writing  $u_i^G(ND, D) = \frac{a_i}{a_i + a_j}(V + t_j - \theta_j a_j) - a_i$ . This would slightly change the optimal fighting efforts and the optimal contract, but it would not change the characterization of the equilibria presented in this section of the paper.

$$\begin{cases} a_{g_i}^*(ND, D) = \frac{t_j + V}{2(1 + \sqrt{\theta_j})} \\ a_j^*(ND, D) = \frac{t_j + V}{2(\theta_j + \sqrt{\theta_j})} \end{cases}$$

and the utility of government  $i$  writes

$$u_i^G(ND, D) = \frac{\sqrt{\theta_j}}{2(1 + \sqrt{\theta_j})} (V + t_j)$$

The same reasoning applied in the previous section implies that government  $j$  offers  $\gamma_j$  in a way that the participation constraint always binds and

$$\gamma_j^*(ND, D) = 1 - \frac{1}{P} \left( N - \frac{V + t_j}{2(1 + \sqrt{\theta_j})} s^m \right)$$

When the participation constraint binds, and taking into account the fact that  $s^m + s^g = 1$  the utility of government  $j$  writes

$$u_j^G(ND, D) = P - N + \frac{V + t_j}{2(1 + \sqrt{\theta_j})} - \theta_j t_j^2 = -R + \frac{V + t_j}{2(1 + \sqrt{\theta_j})} - \theta_j t_j^2$$

from which we can compute the optimal transfer of government  $j$ ,

$$t_j^*(ND, D) = \frac{1}{4\theta_j(1 + \sqrt{\theta_j})}$$

Substituting the equilibrium values in the utility of government  $i$  we find

$$u_i^G(ND, D) = \frac{1 + 4(1 + \sqrt{\theta_j})\theta_j V}{8(1 + \sqrt{\theta_j})^2 \sqrt{\theta_j}}$$

Following the same reasoning for the reverse situation, where government  $i$  delegates and government  $j$  enters directly in the conflict we obtain

$$\begin{cases} a_i^*(D, ND) = \frac{t_i + V}{2(\theta_i + \sqrt{\theta_i})} \\ a_{g_j}^*(D, ND) = \frac{t_i + V}{2(1 + \sqrt{\theta_i})} \end{cases}$$

and the participation constraint for militia  $i$  is

$$\gamma_i^* = 1 - \frac{1}{P} \left( N - \frac{V + t_i}{2(1 + \sqrt{\theta_i})} s^m \right)$$

When the participation constraint binds, government  $i$  is able to put its delegated armed group's utility down to its reservation value  $N_i$ , the utility of government  $i$  is then

$$u_i^G(D, ND) = -R + \frac{V + t_i}{2(1 + \sqrt{\theta_i})} - \theta_i t_i^2$$

From this expression, we can write the first order conditions and compute the optimal transfer

$$t_i^*(D, ND) = \frac{1}{4\theta_i(1 + \sqrt{\theta_i})}$$

Substituting the equilibrium values in the utility of government  $i$  we find

$$u_i^G(D, ND) = \frac{1 + 8(1 + \sqrt{\theta_i})\theta_i V}{16(1 + \sqrt{\theta_i})^2 \theta_i} - R$$

Finally, when both countries do not delegate and fight each other directly we go back to the classical model of conflict between two states without delegation. In this simple situation, governments only choose their fighting effort. The functional form of the utilities

of governments is now identical. For government  $k = i, j$  it writes  $u_k^G(ND, ND) = \frac{a_k}{a_k + a_{-k}}(V - a_k - a_{-k})$ <sup>9</sup>. The two competing governments exert identical fighting efforts

$$a_{G_i}^* = a_{G_j}^* = \frac{V}{4}$$

Substituting in the utility of government  $i$  we obtain

$$u_i^G(ND, ND) = u_j^G(ND, ND) = \frac{V}{4}$$

Having computed the payoffs of government  $k = i, j$  for all strategy profiles, we can study what are the conditions under which government  $k = i, j$  has profitable deviations, given the strategy of the opponent. In particular, we are seeking the conditions under which government  $i$  has an incentive to delegate given that government  $j$  delegates as well, and the conditions under which it prefers to enter conflict directly given that the opponent does the same. The symmetric reasoning applies to government  $j$ .

### 4.2.3 Results

In order to illustrate the mechanism, let us first consider the strategic decision of government  $i$  to delegate conflict or not, given that government  $j$  delegates: we focus on the payoffs  $u_i^G(D, D)$  and  $u_i^G(ND, D)$ . We observe that  $u_i^G(D, D)$  is linearly decreasing in  $R$  while  $u_i^G(ND, D)$  does not depend on  $R$ . Moreover, when  $R = 0$  we see that  $u_i^G(D, D) > u_i^G(ND, D)$ , implying that there exists a threshold of  $R$ , such that for values of  $R$  smaller than that threshold, it is profitable for government  $i$  to deviate from  $ND$  and choose  $D$  instead, given that the opponent also delegates. Similarly, we see that  $u_i^G(D, ND)$  is linearly decreasing in  $R$  while  $u_i^G(ND, ND)$  is constant. Also, in  $R = 0$  it is easy to see that  $u_i^G(D, ND) > u_i^G(ND, ND)$ . This implies that there exists another threshold of  $R$  such that for values larger than the threshold, government  $i$  has an incentive to deviate from  $D$  and choose  $ND$ , given that the opponent also does not delegate

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<sup>9</sup>. As before, we could write the utilities of governments using different specifications, e.g.  $u_k^G(N, N) = \frac{a_k}{a_k + a_{-k}}V - a_k$ . The optimal fighting efforts would remain unchanged as well as the results of this section.

and enters conflict directly. We can thus define for government  $i$  two thresholds on  $R$ ,  $\lambda_i^N$  and  $\lambda_i^D$ , where  $\lambda_i^N$  represents the minimum value of  $R$  for which  $i$ 's dominant strategy is to enter conflict directly – choosing  $ND$  – given that  $j$  also does not delegate. Similarly,  $\lambda_i^D$  is the maximum value of  $R$  such that  $i$ 's dominant strategy is to choose  $D$  when also the opponent delegates. A symmetrically analysis applies for government  $j$ . Once defined the thresholds, I can compute them by setting  $u_i^G(D, D) = u_i^G(ND, D)$  to compute  $\lambda_i^D$  and by setting  $u_i^G(D, ND) = u_i^G(ND, ND)$  to compute  $\lambda_i^N$ . The following Lemma establishes the order of the thresholds  $\lambda_k^N$  and  $\lambda_k^D$  for  $k \in \{i, j\}$ . In what follows, we assume that the value of the contest prize  $V$  is large,  $V \gg 0$ . This is a quite natural assumption since we are considering a situation where countries engage in war to capture the resources, be it natural or geopolitical, of an external territory. It just means that for both parties the stakes are high, which is consistent with the subject and the multidisciplinary literature on conflict.

**Lemma 4.1** (Order of Thresholds).

*Let the value of the contested resources  $V$  be large. Then*

$$\left\{ \begin{array}{ll} \lambda_j^D > \lambda_j^N > \lambda_i^N > \lambda_i^D & \text{if } \theta_i > \theta_j \\ \lambda_i^D > \lambda_i^N > \lambda_j^N > \lambda_j^D & \text{if } \theta_j > \theta_i \\ \lambda_i^N = \lambda_j^N > \lambda_i^D = \lambda_j^D & \text{if } \theta_i = \theta_j \end{array} \right.$$

This Lemma just says that, given the respective order of ideological misalignments, the order of the thresholds on the value of  $R$  defines disjoint intervals for each party. It defines the intervals on  $R$  such that government  $k$  has a dominant strategy to delegate if the opponent delegates and not to delegate if the opponent does not delegate as well. The respective order of  $\lambda_k^N$  and  $\lambda_k^D$  is different for parties  $i$  and  $j$  if  $\theta_i \neq \theta_j$  where the most misaligned party enjoys the most intuitive  $\lambda^N > \lambda^D$ . Moreover, if parties are characterized by the same ideological misalignment, the four threshold values collapse to only two. It is interesting to notice that in this case, the most natural order of  $\lambda^N > \lambda^D$  is restored for

both parties. It is interesting to note that in the special case when  $\theta_i = \theta_j = 1$ , the two thresholds further collapse into only one, i.e.  $\lambda^D = \lambda^N = \lambda$  and we obtain only two possible equilibria, depending on the value of  $R$ . For  $R > \lambda$  the unique equilibrium is characterized by both governments entering conflict directly and for  $R < \lambda$  both delegate fighting. The proof is in the Appendix. I use this Lemma to prove Proposition 9, which gives a characterization of pure strategy Nash equilibria in relation to the thresholds  $\lambda_k^D$  and  $\lambda_k^N$  for  $k = i, j$ . In case  $\theta_i = \theta_j$ , the four thresholds defined above collapse to only two, which we denote by  $\lambda^D$  and  $\lambda^N$ .

**Proposition 4.1.**

*There exist multiple equilibria of the delegation game, depending on the relative ideological misalignments  $\theta_k$  and the value of local support to militias  $R$ .*

- When  $\theta_i > \theta_j$ 
  - If  $R < \lambda_i^D$  the unique equilibrium is  $(D, D)$
  - If  $\lambda_i^D < R < \lambda_j^N$  the unique equilibrium is  $(ND, D)$
  - If  $R > \lambda_j^N$  the unique equilibrium is  $(N, N)$
- When  $\theta_j > \theta_i$ 
  - If  $R < \lambda_j^D$  the unique equilibrium is  $(D, D)$
  - If  $\lambda_j^D < R < \lambda_i^N$  the unique equilibrium is  $(D, ND)$
  - If  $R > \lambda_i^N$  the unique equilibrium is  $(N, N)$
- When  $\theta_i = \theta_j$ 
  - If  $R < \lambda^D$  the unique equilibrium is  $(D, D)$
  - If  $\lambda^D < R < \lambda^N$  there exist two equilibria  $(ND, D)$  and  $(D, ND)$
  - If  $R > \lambda^N$  the unique equilibrium is  $(N, N)$

The proposition shows that the ex-ante strength of local support to militias  $R_k$  is an important parameter characterizing the strategic delegation game. In general, a weak support from the local population implies armed groups are at the fringe of society, and

for government sponsors it is cost effective to recruit militias and engage in indirect conflict. On the contrary, militias that are endowed with strong local support demand wider political autonomy and higher transfers of resources from the sponsor, hence making direct confrontation optimal for the external government. More in particular, the respective ideological misalignment is crucial in the characterization of equilibria where one government delegates fighting and the opponent enters conflict directly. For intermediate values of  $R$ , only the most aligned government delegates fighting at equilibrium while the opponent does not. Only the relative position between  $\theta_i$  and  $\theta_j$  matters. The unicity of equilibria is lost when  $\theta_i = \theta_j$  and for intermediate values of  $R$ .

## 4.3 Competing for a Common Militia

### 4.3.1 Setting and governments' programs

Governments often compete with one another to “hire” a local armed group whose task is to fight a third party to seize resources or exert geopolitical influence. Consider for instance a situation where the governments of two countries are willing to destabilize a given (external) territory in order to obtain preferential access to its resources. One strategy would be to delegate costly fighting to a local armed group which in turn would fight against the central power of the contested region. I model this situation by allowing two governments  $G_i$  and  $G_j$  to send simultaneous, non-negotiable offers to one local militia  $m$ . The offers are, as before, made of a transfer  $t_k$  and of a share of political power  $\gamma_k$ , for  $k = i, j$ . Once the militia receives the two offers, she evaluates which one makes her better off, selects one and declares publicly her allegiance. The government whose offer is turned down gets a normalized payoff of 0, which is also the value of the outside option for both competing governments. Afterwards, fighting between the militia and the central power  $C$  takes place and payoffs are realized.

When evaluating the optimal contracts, both governments and the militia take into consideration the costs and benefits of getting into this type of contracts.. Similarly to our previous discussion,  $\theta_i$  and  $\theta_j$  represent the religious and ideological distances respectively of governments  $G_i$  and  $G_j$  to the militia  $m$  and this is perfectly known to all players. Let

us assume for the sake of exposition that  $\theta_i > \theta_j$ , i.e. government  $G_j$  is ideologically closer to the militia than government  $G_i$ . The central authority  $C$  of the contested region is also a strategic player: it can decide how much of some given stock of resources  $S$  to invest in productive activities and how much to invest in costly fighting. Let us assume that the outside option of  $C$  is  $-\infty$ , so that it is always willing to fight against the militia. Thus, at the fighting stage, the militia and the central government  $C$  simultaneously maximize

$$\begin{cases} u_m^k = (1 - \gamma_k)P + \frac{a_k}{a_k + a_C}(V + t_k - \theta_k a_k + S - a_C) s^m \\ u_C = \frac{a_C}{a_k + a_C}(V + t_k - \theta_k a_k + S - a_C) \end{cases}$$

where  $k = i, j$ , i.e. depends on whether the militia pledges allegiance to government  $i$  or  $j$ ,  $a_C$  is the central power's fighting effort which enters both the probability of victory and the total stakes of the contest. The central power also has to split its resources between investing an amount  $S - a_C$  in productive activities or fighting, which implies disbursing financial resources to recruit, mobilize and supply its army. Solving for the best responses of the fighting stage, I obtain that

$$\begin{aligned} a_k^* &= \frac{t_k + V + S}{2(\theta_k + \sqrt{\theta_k})} \\ a_C^* &= \frac{t_k + V + S}{2(1 + \sqrt{\theta_k})} \end{aligned}$$

We focus on the first equilibrium, where both parties actively fight, because the second equilibrium implies that the optimal transfer by any of the two external governments will be  $t_k = 0$ . In this case, for any proposed share of political independence  $\gamma > 0$ , the militia will be better off not getting into any contract and prefers getting the value of the outside option  $N$ , since  $N > P$ . In this equilibrium, fighting does not occur and the central power  $C$  keeps the status quo. The utility of the militia computed at equilibrium writes



$$u_m^k(\mathbf{a}^*) = (1 - \gamma_k)P + \frac{t_k + \tilde{V}}{2(1 + \sqrt{\theta_k})} s^m$$

where  $\tilde{V} = V + S$  and depending on whether she declares allegiance to government  $k = i$  or  $k = j$ . The program of government  $k$  takes into account two constraints. First, that the militia eventually prefers to declare allegiance to government  $k$  and not to government  $-k$ . I denote this constraint coming from the presence of a common agent – the militia – as *CA*. Second, that her utility at the optimal contract is higher than the outside option  $N$ , which represents the participation constraint and I denote this constraint as *PC*. More formally, each government maximizes the following program

$$\max_{\gamma_k, t_k} \quad \gamma_k P + \frac{t_k + \tilde{V}}{2(1 + \sqrt{\theta_k})} s^g - \theta_k t_k^2$$

*s.t.*

$$\left\{ \begin{array}{l} (1 - \gamma_k)P + \frac{t_k + \tilde{V}}{2(1 + \sqrt{\theta_k})} s^m \geq (1 - \gamma_{-k})P + \frac{t_{-k} + \tilde{V}}{2(1 + \sqrt{\theta_{-k}})} s^m \quad (CA) \\ (1 - \gamma_k)P + \frac{t_k + \tilde{V}}{2(1 + \sqrt{\theta_k})} s^m \geq N \quad (PC) \end{array} \right.$$

### 4.3.2 Optimization

The two governments maximize over the transfers when the first constraint is binding and I check ex-post whether the participation constraint is respected. Analyzing for instance the program of  $G_i$ , from the constraint CA I am able to write the second element of the contract  $\gamma_i$  in function of all the other contracting variables

$$\gamma_i = \gamma_j + \frac{s^m}{2P} \left( \frac{t_i + \tilde{V}}{1 + \sqrt{\theta_i}} - \frac{t_j + \tilde{V}}{1 + \sqrt{\theta_j}} \right)$$

and symmetrically for  $G_j$ . The utility of government  $k$  computed at the equilibrium of the fighting stage and when the first constraints (CA) binds, depends directly on  $-k$ 's offer of control over policy making  $\gamma_{-k}$ . The more control over policymaking  $\gamma_{-k}$  government  $-k$  retains for itself, the less would be left to the militia  $(1 - \gamma_{-k})$ , thus lowering the likelihood that the armed group pledges allegiance to government  $-k$  and increasing the likelihood that it will choose  $k$  instead. Writing  $s^m = 1 - s^g$ , the utilities of governments are

$$\begin{cases} u_G^i = P \left[ \gamma_j + \frac{1 - s^g}{2P} \left( \frac{t_i + \tilde{V}}{1 + \sqrt{\theta_i}} - \frac{t_j + \tilde{V}}{1 + \sqrt{\theta_j}} \right) \right] + \frac{t_i + \tilde{V}}{2(1 + \sqrt{\theta_i})} s^g - \theta_i t_i^2 \\ u_G^j = P \left[ \gamma_i + \frac{1 - s^g}{2P} \left( \frac{t_j + \tilde{V}}{1 + \sqrt{\theta_j}} - \frac{t_i + \tilde{V}}{1 + \sqrt{\theta_i}} \right) \right] + \frac{t_j + \tilde{V}}{2(1 + \sqrt{\theta_j})} s^g - \theta_j t_j^2 \end{cases}$$

At this stage, the maximization over the optimal transfers is completely decoupled between the two sponsoring governments. Moreover, we can see that the additional term that derives from the competition between the two governments brings a markup in the optimal transfers, whose cost is borne by governments. The first order conditions write

$$\begin{cases} \frac{1 - s^g}{2(1 + \sqrt{\theta_i})} + \frac{s^g}{2(1 + \sqrt{\theta_i})} - 2\theta_i t_i = 0 \\ \frac{1 - s^g}{2(1 + \sqrt{\theta_j})} + \frac{s^g}{2(1 + \sqrt{\theta_j})} - 2\theta_j t_j = 0 \end{cases}$$

which imply that the optimal transfers are

$$\begin{cases} t_i^{*CA} = \frac{1}{4\theta_i(1 + \sqrt{\theta_i})} \\ t_j^{*CA} = \frac{1}{4\theta_j(1 + \sqrt{\theta_j})} \end{cases}$$

The optimal transfers when there is a common agent – the militia – and the governments compete to “hire” it, turns out to be exactly what governments would have transferred had they had the monopoly over the contracted militia. This is because the new binding constraint  $CA$  has the same impact on transfers than the binding participation constraint in the case of monopoly contracting. At the same time, governments compete on the offered share of control over policymaking  $\gamma_k$  and militias receive higher rents from this contracting variable. Assuming without loss of generality that  $\theta_i > \theta_j$ , implies that  $t_i^{*CA} < t_j^{*CA}$ , i.e. the government that is most aligned with the local militia offers a higher monetary transfer in equilibrium and, given the binding constraint (CA),

$$\gamma_i = \gamma_j + \underbrace{\frac{s^m}{2P} \left( \frac{t_i^* + \tilde{V}}{1 + \sqrt{\theta_i}} - \frac{t_j^* + \tilde{V}}{1 + \sqrt{\theta_j}} \right)}_{<0} \Rightarrow \gamma_j > \gamma_i$$

Thus, the government ideologically closest to the militia,  $G_j$ , offers a strictly higher transfer but demands a higher share of political power compared to government  $G_i$ . This is driven by the fact that government  $j$  faces a lower marginal cost of transferring funds and is able to incentivize a higher fighting effort through the anticipated militia’s best responses in the fighting stage. The binding constraint  $CA$ , which imposes a condition of indifference for the militia’s choice of allegiance, implies that  $j$  is able to demand a higher share of political power  $\gamma_j$  to the detriment of the militia’s interests. Thus, the two governments play a game where they offer a contract where the optimal transfers are computed maximizing independently over the monetary transfers, taking into account the best responses at the fighting stage and the ideological parameters  $\theta_k$ . However, if the two governments offered respectively  $\gamma_i$  and  $\gamma_j$  as above, the militia would be indifferent between choosing either of the two governments, by construction of the constraint  $CA$ . This is clearly not an equilibrium because both governments can profitably deviate by a series

of undercutting of the proposed share of political power  $\gamma_k$ , resulting in a Bertrand-like competition.

The government that is most aligned to the militia,  $G_j$  in this instance, has a clear advantage, because it has a stronger position to exert a lower level of political influence  $\gamma_j$  whose loss would be compensated by a higher expected reward from the prize of the contest itself – resources  $\tilde{V}$  and the output of productive activities – compared to a situation of monopoly contracting. This implies it can cut its proposed  $\gamma_j$  until such a level where the opposing government will be indifferent between entering the contest and offering a contract to the militia or stay out and get a normalized payoff of zero. I define  $\gamma_j^{CA}$  as the minimum value of control over policymaking offered by  $G_j$  such that government  $G_i$  is indifferent between entering the contest or staying out. For every proposed share of power  $\gamma_j$  smaller than  $\gamma_j^{CA}$ , government  $i$  stays out of the competition. Assuming as before  $\theta_i > \theta_j$ , which implies  $\gamma_i < \gamma_j$ , government  $j$  is able to put  $i$ 's utility down to zero by choosing  $\gamma_j^{CA}$  such that

$$u_G^i(\gamma_j^{CA}) = P \left[ \gamma_j^{CA} + \frac{1-s^g}{2P} \left( \frac{t_i^* + \tilde{V}}{1 + \sqrt{\theta_i}} - \frac{t_j^* + \tilde{V}}{1 + \sqrt{\theta_j}} \right) \right] + \frac{t_i^* + \tilde{V}}{2(1 + \sqrt{\theta_i})} s^g - \theta_i t_i^{*2} = 0$$

which, computing it at the optimal values  $t_i^*$  and  $t_j^*$ , implies

$$\begin{aligned} \gamma_j^{CA} &= \frac{1}{P} \left( \theta_i t_i^{*2} - \frac{t_i^* + \tilde{V}}{2(1 + \sqrt{\theta_i})} s^g + \frac{1-s^g}{2} \left( \frac{t_j^* + \tilde{V}}{1 + \sqrt{\theta_j}} - \frac{t_i^* + \tilde{V}}{1 + \sqrt{\theta_i}} \right) \right) \\ &= \frac{1}{16P} \left( 8V \left( \frac{1-s^g}{1 + \sqrt{\theta_j}} - \frac{1}{1 + \sqrt{\theta_i}} \right) + \frac{2(1-s^g)}{\theta_j(1 + \sqrt{\theta_j})^2} - \frac{1}{\theta_i(1 + \sqrt{\theta_i})^2} \right) \end{aligned}$$

Assuming for now that  $0 \leq \gamma_j^{CA} \leq 1$ , the series of undercutting of  $\gamma_k$  by both governments  $k = i, j$  stops when  $\gamma_j = \gamma_j^{CA}$ . For this value of the proposed share of power, government  $G_i$  is indifferent between trying to contract the militia or stay out of the contest. At the

same time, government  $i$  offers  $\gamma_i$  which by definition is smaller than  $\gamma_j^{CA}$ , but not small enough to put government  $j$  out of competition. Now, it sufficient for government  $G_j$  to offer  $\gamma_j^{CA} - \varepsilon$ , get the allegiance of the militia and the prize of the contest with probability  $p(\text{winner} = j) = \frac{1}{1+\sqrt{\theta_j}}$ , while government  $G_i$  is out of competition.

I have put aside the participation constraint and we have now to check whether the participation constraint is satisfied when offering the share of power of the common agency game  $\gamma_j^{CA}$ . The participation constraint alone would imply that the optimal share of power offered in the contract should be found when the constraint binds. In that situation, the contracting government would have to give up as much political power as necessary to incentivize the militia to take up the contract, given the optimal transfers. However, when there is competition between governments, the militia is able to demand more political power and gain more rents. From the participation constraint evaluated at  $t_{j,CA}^*$  when it binds

$$\begin{aligned}\gamma_j^{PC} &= 1 - \frac{1}{P} \left( N - \frac{t_j^* + \tilde{V}}{2(1 + \sqrt{\theta_j})} s^m \right) \\ &= 1 - \frac{1}{P} \left( N - \frac{1 + 4(1 + \sqrt{\theta_j})\theta_j \tilde{V}}{8(1 + \sqrt{\theta_j})^2 \theta_j} s^m \right)\end{aligned}$$

### 4.3.3 Results

The proposed share of power derived from the participation constraint is bigger than that coming from the common agency game only if the total value of the outside option of remaining neutral  $N$  is small enough. For values of  $N$  bigger than a threshold  $N_j^*$ ,  $\gamma_j^{PC}$  is smaller than  $\gamma_j^{CA}$ . In this situation the ability of government  $j$  to concede more power to the militia in order to keep the opposing government out is somehow limited by the attractiveness of the outside option. The attractiveness of remaining neutral and getting a fixed payoff independent of the outcome of the context has to be counterbalanced by offering to keep a share of control over policymaking small enough. The following Lemma

formalized this idea and finds the value of the outside option  $N^*$  such that it equalized  $\gamma_j^{PC}$  and  $\gamma_j^{CA}$ .

**Lemma 4.2.**

*Let us assume that  $\theta_i > \theta_j$ . Then, there exists a value of the outside option  $N_j^* > 0$  such that*

- *if  $N < N_j^*$  then  $\gamma_j^{PC} > \gamma_j^{CA}$*
- *if  $N > N_j^*$  then  $\gamma_j^{PC} < \gamma_j^{CA}$*

*where  $N^* = P + \frac{1 + 8(1 + \sqrt{\theta_i})\theta_i V}{16(1 + \sqrt{\theta_i})^2 \theta_i}$ . This applies symmetrically to party  $i$ .*

Interestingly, from the point of view of government  $j$  the threshold value of the outside option  $N^*$  that equalizes the binding participation constraint  $\gamma_j^{PC}$  and  $\gamma_j^{CA}$  depends only on the opponent's misalignment to the militia  $\theta_i$  and not on its own  $\theta_j$ . The following Lemma establishes that when government  $j$ 's misalignment is much smaller than that of government  $i$ 's, the former has a distinct advantage over the latter and is able, in some cases, to demand a positive share of political power, depending on the value of  $\tilde{V}$ . In this case, it characterizes for which values of the total stakes  $\tilde{V}$ , the offered  $\gamma_j^{CA}$  is indeed in  $[0, 1]$ . On the contrary, when competition is too tight and  $\theta_i \sim \theta_j$ , government  $j$  has to give up demanding any positive share of power and can only offer  $\gamma_j^{CA} = 0$ .

**Lemma 4.3.**

*Assume  $\theta_i > \theta_j$  and let us define  $\Delta = \frac{\theta_j}{\theta_i} \left( \frac{1 + \sqrt{\theta_j}}{1 + \sqrt{\theta_i}} \right)^2$ .*

- *When  $\Delta < 2^{-s^m}$ , government  $j$  is ideologically much closer to the militia than government  $i$ . There generally exist two thresholds  $\tilde{V}'$  and  $\tilde{V}''$  such that  $1 \geq \gamma_j^{CA} \geq 0$  iff  $\tilde{V}'' \geq \tilde{V} \geq \tilde{V}'$ . Moreover, if  $\tilde{V} > \tilde{V}''$  government  $j$  can only offer  $\gamma_j^{CA} = 0$  and leaves all the political power to the militia. Similarly, if  $\tilde{V} < \tilde{V}'$  government  $j$  can offer  $\gamma_j^{CA} = 1$ .*

- When  $1 > \Delta > 2 s^m$ , the competition between the governments is too tight because  $\theta_j \sim \theta_i$ , and government  $j$  can only offer to leave all political power to the militia by offering  $\gamma_j^{CA} = 0$  for any value of  $\tilde{V}$ .

Focusing on the case where  $\Delta < 2 s^m$ , Lemma 3 just says that if the total value of the prize is smaller than a certain amount  $\tilde{V}'$ , government  $i$  gets a small benefit from getting into the conflict. When this happens, government  $j$  is able to extract all the control of policymaking from the militia,  $\gamma_j^{CA} = 1$ , since it is easy to prevent the opposing government from sending offers. In the opposite scenario, when the value of the prize is very large, government  $i$  enjoys a high utility from getting into the conflict trying to get the militia to its side. In this situation, government  $j$  does its best to get the militia's allegiance and thus offers a contract where it leaves all the political power to its proxy,  $\gamma_j^{CA} = 0$ , knowing that if  $\tilde{V}$  is too large it will not be enough to restrain the opponent to send offers. Now we have all the elements to find the equilibrium of the common agency game.

**Proposition 4.2.**

*When two governments compete to hire a common armed group, the militia carves out higher rents by receiving more transfers and by keeping more political power, compared to a situation of monopolistic contracting. Let us assume that  $\theta_i > \theta_j$ . We have two regimes.*

- (i) *When government  $j$  has a decisive ideological advantage and the stakes are not too high, i.e.  $\Delta < 2 s^m$  and  $\tilde{V} < \tilde{V}''$ , government  $j$  is able to put the opposing government out of competition by keeping a positive share of control over policymaking  $\gamma_j \in (0, 1]$ .*
- (ii) *When the stakes are very high or the ideological competition is too tight, i.e.  $\tilde{V} > \tilde{V}''$  or  $1 > \Delta > 2 s^m$ , government  $j$  its opponent just by offering a low  $\gamma_j$ . The whole political power is left to the militia,  $\gamma_j = 0$ , and  $j$  wins the competition by offering a transfer higher than that offered by government  $i$ .*

Proposition 2 shows that when two governments compete to hire a common militia, the

rents offered to the armed group are higher than if governments monopolistically contract the militia. This effect is even stronger when the two governments are in tight competition or the stakes are very high, i.e.  $1 > \Delta > 2 s^m$  or  $\tilde{V} > \tilde{V}''$ : the militia is able to extract the maximum amount of rent from the competition and enjoys the full political power  $P$ . In this case, the government with the smallest ideological misalignment is not able to throw the opponent out of the race for hiring militia just by proposing a small  $\gamma_j$ . Both contenders offer a contract where they leave all political power to the militia  $\gamma_i = \gamma_j = 0$ , but government  $j$  always offers a higher transfer since he has a lower cost of transferring funds. The Proposition below exactly characterizes the optimal contracts in function of the relevant parameters of the problem: the value of the outside option of staying neutral  $N$  and the value of the prize  $\tilde{V}$ .

**Proposition 4.3.**

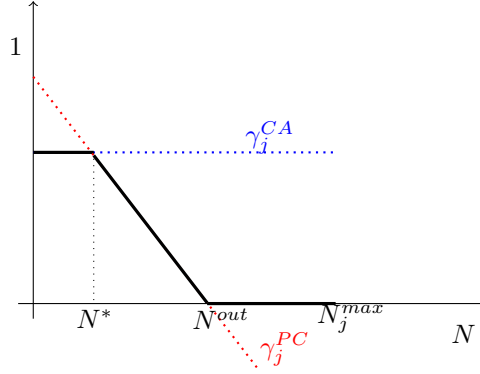
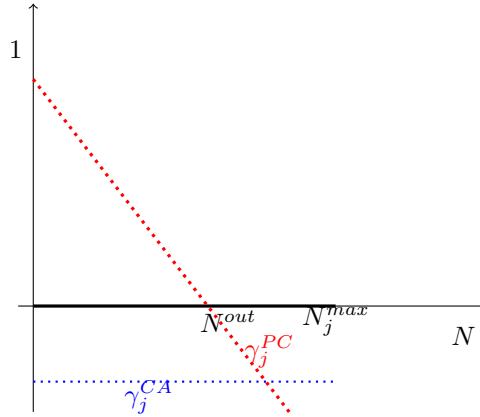
*Assume that  $\theta_i > \theta_j$ . The equilibria can be then characterized in function of the prize  $\tilde{V}$  and of the value of neutrality  $N$ .*

- *When government  $j$  has a decisive ideological advantage over government  $i$ , i.e.  $\Delta < 2 s^m$ , and  $\tilde{V} < \tilde{V}''$ .*
  - *If  $\tilde{V}' < \tilde{V} < \tilde{V}''$  and  $N < N^*$ , government  $j$  optimally offers  $(t_j^{*CA}, \gamma_j^{CA})$ . If  $N^* < N < N_{out}$ , government  $j$  optimally offers  $(t_j^{*CA}, \gamma_j^{PC})$ . If  $N^{max} > N > N_{out}$ , government  $j$  offers  $\gamma_j = 0$  and increases the transfer to match the outside option until  $t_j^{max}$ . The militia pledges allegiance to  $j$ . For  $N > N^{max}(t_j^{max})$  neither government is willing to contract the militia.*
  - *If  $\tilde{V} < \tilde{V}'$ . If  $N < N^{out}$  Government  $j$  offers  $(t_j^{*CA}, \gamma_j = 1)$  if  $\gamma_j^{PC} \geq 1$  and  $(t_j^{*CA}, \gamma_j^{PC})$  otherwise. If  $N^{max} > N > N_{out}$ , government  $j$  offers  $\gamma_j = 0$  and increases the transfer until  $t_j^{max}$ . The militia pledges allegiance to  $j$ . For  $N > N^{max}(t_j^{max})$  neither government is willing to contract the militia.*
- *When the governments are in tight ideological competition  $1 > \Delta > 2 s^m$  or  $\tilde{V} > \tilde{V}''$ . Then, both governments send offers characterized by  $\gamma_j = \gamma_i = 0$  for any value of  $N$ . Despite government  $i$  offering its maximum possible transfer, for  $j$  it is sufficient to offer slightly more to win the militia's allegiance.*



This Proposition analyzes the effects of competition between two governments willing to “hire” a common armed group on the optimal contracting. The presence of competing principals modifies the optimal contracts on two fronts thus bestowing higher rents to the militia. First, it adds a constraint in the maximization program of each principal due to the imposed condition on the militia’s choice of allegiance. This term puts an extra pressure on both governments to transfer more financial resources compared to a situation with monopolistic contracting. The militia gets higher financial rents simply because she has the possibility of aligning itself with the opposing government. Second, it also modifies the optimal contracting regarding the proposed share of political power  $\gamma$ , by triggering a sequence of reciprocal undercutting à la Bertrand ending when the most misaligned government becomes indifferent between entering the competition or staying out and receive a fixed payoff of zero. The government that is most closely aligned has a distinct advantage with respect to the opponent. Its marginal cost of transferring funds is strictly lower than that of the competing government, and this allows larger room for undercutting  $\gamma$  in order to put the opposing government out of competition and ensuring the militia will accept its contract.

In such a situation, the militia is able to extract considerably higher rents along both dimensions of the contract. The offered transfer is at least double what it would have received with no competition. Moreover, with competition, governments are forced to limit the offered political control over the militia. The lower the proposed  $\gamma$ , the lower it is the competing government’s utility and the margin over its own offered share of power. This triggers a set of non-cooperative under-cuttings until the equilibrium is reached.

**Figure 4.1** – Optimal  $\gamma_j$  when  $\Delta < 2 s^m$  and  $\tilde{V} < \tilde{V}''$ **Figure 4.2** – Optimal  $\gamma_j$  when  $1 > \Delta > 2 s^m$  or  $\tilde{V} > \tilde{V}''$ 

## 4.4 Conclusion

This paper studies a model of war by proxy, where two governments seek to gain dominance of natural or political resources. Governments can engage in conflict in one of two ways. Either they fight each other directly, or they act as principals hiring local militias – the agents. Direct confrontation entails higher human and material costs, but avoids the negative consequences of being associated to a group that is ideologically misaligned.

Hired militias receive a transfer of resources but give away a portion of their political autonomy. When they pledge allegiance to an external sponsor, they choose strategically their fighting effort in the second stage of the game. The analysis explores the conditions for which delegating conflict is indeed an equilibrium of a strategic delegation game. When militias have little resources and weak support, sponsoring governments do not have an incentive to deviate from contracting them, and delegation emerges as the unique equilibrium. As the value of ex-ante resources available to militias increases, the potential net benefit of hiring delegate fighters decreases as it becomes politically and financially more costly. This paper also analyzes a setting where two governments compete to recruit the same armed group. The sponsor that is ideologically closer has a distinct advantage due to the lower cost of transferring funds and to the better capacity of the armed group to recruit and motivate fighters. However, competition creates space for more demands from the militia, which generally carves out higher rents. This model can easily be applied to a more general setting where two principals struggle for influence through their delegated agents who receive a transfer of resources and give up a portion of their organizational independence.

This paper is a jumping-off point for the study of delegated conflicts and their impact on local institutions. Future research could consider the case of unobservable contracts. In many situations of conflict the delegation contract to informal actors, or even its existence, is not observable. Throughout this study I have analyzed a situation where governments simultaneously send offers to militias, which can observe perfectly the offered contracts. Also, how would the introduction of contract renegotiation affect the outcomes of the game? This is indeed a realistic aspect of proxy wars worth investigating, given the absence of institutions to enforce such agreements in weak polities. Finally, it would be important to integrate into this framework a study of the role of peace mediators, their impact on the equilibria of the delegation game and on the intensity of fighting.

## 4.5 Appendix: Proofs

### 4.5.1 Proof of Lemma 4.1

Let us assume without loss of generality that  $\theta_i > \theta_j$  and let us focus on party  $i$ . The proof for  $\theta_j > \theta_i$  is symmetric. As a preparatory step, I find the thresholds on  $\lambda_i^D$  and  $\lambda_i^N$  by setting respectively  $u_i^G(D, D) = u_i^G(ND, D)$  and  $u_i^G(D, ND) = u_i^G(ND, ND)$ . First, it is easy to see that  $\lambda_k^N$  and  $\lambda_k^D$  are positive in  $V = 0$ , for  $\theta_j \in (0, 1]$ . Second, I show that both  $\lambda_k^i$  and  $\lambda_i^D$  are strictly increasing in  $V$ . Third, showing that the slope of  $\lambda_i^N$  is greater than the slope of  $\lambda_i^D$  when  $\theta_i > \theta_j$ , implies that for  $V$  large enough  $\lambda_i^N > \lambda_i^D$ . This will imply that for party  $j$  the reverse condition applies, i.e.  $\lambda_j^D > \lambda_i^N$ . Fourth, showing that  $\lambda_j^N > \lambda_i^N$  means that the intervals defined by  $\lambda_k^D$  and  $\lambda_k^N$  are disjoint for the two parties. Finally, I show that when  $\theta_i = \theta_j = \theta$  only two thresholds are obtained and  $\lambda^N > \lambda^D$ .

0. The preliminary step to the proof is to find the thresholds  $\lambda_k^D$  and  $\lambda_k^N$  as defined above. This yields

$$\lambda_i^N = \frac{1 + 4(1 - \theta_i)\theta_i V}{16(1 + \sqrt{\theta_i})^2 \theta_i}$$

$$\lambda_i^D = \frac{1}{16} \left( \frac{\frac{\theta_j^2}{\theta_i} + 8\theta_j V(\theta_j + \sqrt{\theta_i \theta_j}) + 2\sqrt{\theta_i \theta_j}}{(\theta_j + \sqrt{\theta_i \theta_j})^2} - \frac{2(1 + 4\theta_j(1 + \sqrt{\theta_j})\theta_j V)}{(1 + \sqrt{\theta_j})^2 \sqrt{\theta_j}} \right)$$

and symmetrically for government  $j$

$$\lambda_j^N = \frac{1 + 4(1 - \theta_j)\theta_j V}{16(1 + \sqrt{\theta_j})^2 \theta_j}$$

$$\lambda_j^D = \frac{1}{16} \left( \frac{\frac{\theta_i^2}{\theta_j} + 8\theta_i V(\theta_i + \sqrt{\theta_i \theta_j}) + 2\sqrt{\theta_i \theta_j}}{(\theta_i + \sqrt{\theta_i \theta_j})^2} - \frac{2(1 + 4\theta_i(1 + \sqrt{\theta_i})\theta_i V)}{(1 + \sqrt{\theta_i})^2 \sqrt{\theta_i}} \right)$$

1. Let us start by showing that both quantities are increasing in  $V$ . We have that

$$\frac{\partial \lambda_i^N}{\partial V} = \frac{1 - \theta_i}{4(1 + \sqrt{\theta_i})^2} > 0$$

when  $1 > \theta_i > 0$ .

and, up to a constant factor,

$$\begin{aligned} \frac{\partial \lambda_i^D}{\partial V} &= \frac{\theta_j}{\theta_j + \sqrt{\theta_i \theta_j}} - \frac{\sqrt{\theta_j}}{1 + \sqrt{\theta_j}} \\ &= \frac{\theta_j(1 - \sqrt{\theta_i})}{(\theta_j + \sqrt{\theta_i \theta_j})(1 + \sqrt{\theta_j})} > 0 \end{aligned}$$

for  $1 > \theta_i > 0$ .

2. Now, I show that the slope of  $\lambda_i^N$  is greater than the slope of  $\lambda_i^D$  when  $\theta_i > \theta_j$ . Up to a constant factor, I want to show that

$$\frac{\partial \lambda_i^N}{\partial V} = -\frac{1}{2} + \frac{1}{1 + \sqrt{\theta_i}} > -1 + \frac{1}{1 + \sqrt{\theta_j}} + \frac{\theta_j}{\theta_j + \sqrt{\theta_i \theta_j}} = \frac{\partial \lambda_i^D}{\partial V}$$

Rearranging and writing  $\frac{\theta_j}{\theta_j + \sqrt{\theta_i \theta_j}} = \frac{\theta_j^2 - \theta_j \sqrt{\theta_i \theta_j}}{\theta_j(\theta_j - \theta_i)} = \frac{\theta_j - \sqrt{\theta_i \theta_j}}{\theta_j - \theta_i}$  we have

$$\begin{aligned} \frac{\partial \lambda_i^N}{\partial V} - \frac{\partial \lambda_i^D}{\partial V} &= \frac{1}{2} + \frac{\sqrt{\theta_j} - \sqrt{\theta_i}}{(1 + \sqrt{\theta_i})(1 + \sqrt{\theta_j})} - \frac{\sqrt{\theta_j}}{\sqrt{\theta_i} + \sqrt{\theta_j}} \\ &= \frac{(1 - \sqrt{\theta_i})(1 - \sqrt{\theta_j})(\sqrt{\theta_i} - \sqrt{\theta_j})}{2(1 + \sqrt{\theta_i})(1 + \sqrt{\theta_j})(\sqrt{\theta_i} + \sqrt{\theta_j})} > 0 \end{aligned}$$

if  $\theta_i > \theta_j$ .

3. Now, I show that  $\lambda_j^N > \lambda_i^N$ , i.e. the intervals defined by  $\lambda_k^D$  and  $\lambda_k^N$  are disjoint for the two parties. More formally this implies that

$$\frac{1 + 4(1 - \theta_j)\theta_j V}{16(1 + \sqrt{\theta_j})^2 \theta_j} - \frac{1 + 4(1 - \theta_i)\theta_i V}{16(1 + \sqrt{\theta_i})^2 \theta_i} > 0$$

Rearranging and simplifying, we can write that this condition is true if and only if

$$\frac{\sqrt{\theta_i} - \sqrt{\theta_j}}{\theta_i \theta_j (1 + \sqrt{\theta_i})^2 (1 + \sqrt{\theta_j})^2} \left( 8V\theta_i \theta_j (1 + \sqrt{\theta_i})(1 + \theta_j) + \theta_i^{3/2} + \theta_j^{3/2} + \theta_i \sqrt{\theta_j} + \theta_j \sqrt{\theta_i} + 2\sqrt{\theta_i \theta_j} + 2(\theta_i + \theta_j) + \theta_i + \theta_j \right)$$

which is verified if  $\theta_i > \theta_j$ .

4. Finally, it is easy to see that when  $\theta_i = \theta_j$ , we have that  $\lambda_i^N = \lambda_j^N = \lambda^N$  and  $\lambda_i^D = \lambda_j^D = \lambda^D$ . We have still to show that  $\lambda^N > \lambda^D$ . When  $\theta_i = \theta_j = \theta$  I can write that the difference between the two thresholds is

$$\lambda^N - \lambda^D = \frac{\theta(1 + 2\sqrt{\theta} - 3\theta)}{64\theta^2(1 + \sqrt{\theta})^2} > 0$$

for any  $\theta \in (0, 1)$  since  $(1 + 2\sqrt{\theta} - 3\theta)$  is monotonically decreasing in  $\theta$ , and while in  $\theta = 0$  it equals 1, for  $\theta = 1$  it equals 0. Moreover, this also shows that when  $\theta = 1$ , then  $\lambda^N = \lambda^D$  and there exists only one threshold. This concludes the proof.

□

### 4.5.2 Proof of Proposition 4.1

Let us assume without loss of generality that  $\theta_i > \theta_j$ . The proof for  $\theta_j > \theta_i$  is perfectly symmetric. Thanks to Lemma 1 we know that the order of the thresholds is such that  $\lambda_j^D > \lambda_j^N > \lambda_i^N > \lambda_i^D$ .

When  $R < \lambda_i^D$ , we know that  $R$  is also smaller than  $\lambda_j^N$  and consequently also smaller than  $\lambda_j^D$ . By definition of the threshold  $R < \lambda_i^D$ , government  $i$ 's dominant strategy is to delegate, no matter what is the opponent's action. At the same time, government  $j$  delegates as well if  $i$  delegates, since  $R < \lambda_j^D$  and it also delegates if  $i$  does not delegate since  $R < \lambda_j^N$ . Neither government has a profitable deviation from this action profile and the only equilibrium is  $(D, D)$ .

When  $\lambda_i^N > R > \lambda_i^D$  government  $i$  does not have a dominant strategy anymore. When the opponent  $j$  delegates government  $i$  has a profitable deviation to change his strategy from playing  $D$  to playing  $ND$ . On the contrary, if the opponent  $j$  does not delegate,  $i$  does not have a profitable deviation from playing  $D$ , since  $R < \lambda_i^N$ . At the same time, government  $j$  does not deviate from his dominant strategy and it plays  $D$  because  $R < \lambda_j^N < \lambda_j^D$ . Hence, the unique equilibrium is  $(ND, D)$ .

When  $\lambda_j^N > R > \lambda_i^N$  government  $i$  has, by definition of the thresholds, a dominant strategy not to delegate fighting. It has no profitable deviation from this strategy since  $R > \lambda_i^N$ . Similarly, also government  $j$  has a dominant strategy to delegate fighting no matter what its opponent does. This implies that the only possible equilibrium in this case is  $(ND, D)$ .

When  $\lambda_j^D > R > \lambda_j^N$  government  $i$  has, again, a dominant strategy not to delegate fighting since  $R > \lambda_j^N$  implies also that  $R > \lambda_i^N$ . Thus, government  $i$ 's optimal strategy is to directly enter conflict no matter what its opponent does. On the other hand, government  $j$  does not have a dominant strategy. If government  $i$  delegates, government  $j$  would also delegate since  $\lambda_j^D > R$  and it has no profitable deviation by the definition of  $\lambda_j^D$ . If government  $i$  does not delegate,  $j$  has no profitable deviation from choosing  $N$  given the definition of  $\lambda_j^N < R$ . Hence, the unique equilibrium is  $(N, N)$ .

Finally, when  $R > \lambda_j^D$  both governments have always a dominant strategy not to delegate

since  $R > \lambda_j^D$  implies, by Lemma 1, both  $R > \lambda_j^N$  and  $R > \lambda_i^N$ .

When  $\theta_i = \theta_j$  Lemma 1 shows that there exist only two thresholds  $\lambda^N$  and  $\lambda^D$  such that  $\lambda^N > \lambda^D$ .

□

### 4.5.3 Proof of Lemma 4.2

Since  $\gamma_j^{CA}$  is constant with respect to  $N$  and  $\gamma_j^{PC}$  is decreasing linearly with respect with  $N$ , it is sufficient to show that in  $N = 0$ ,  $\gamma_j^{PC} > \gamma_j^{CA}$  to prove the Lemma. If this is the case,  $\gamma_j^{PC}$  and  $\gamma_j^{CA}$  cross for a unique value of  $N = N^*$ .

The participation constraint can be written then

$$\gamma_j^{PC} = 1 - \frac{1}{P} \left( N - s^m \left( \frac{\tilde{V}}{2(1 + \sqrt{\theta_j})} + \frac{1}{8\theta_j(1 + \sqrt{\theta_j})^2} \right) \right)$$

I want to show that the difference  $\gamma_j^{PC} - \gamma_j^{CA} > 0$  in  $N = 0$ . I can write the difference as,

$$\begin{aligned} \gamma_j^{PC} - \gamma_j^{CA} &= \frac{1 - 16(\theta_i + \sqrt{\theta_i})^2(N - P) + 8\theta_i V(1 + \sqrt{\theta_i})}{16\theta_i(1 + \sqrt{\theta_i})^2 P} \\ &> 0 \end{aligned}$$

if and only the numerator is positive. This condition is always satisfied because when  $N = 0$  all terms in the numerator are positive. Moreover, we can find the exact expression for  $N^*$  by setting  $\gamma_j^{CA} = \gamma_j^{PC}$

$$1 - 16(\theta_i + \sqrt{\theta_i})^2(N^* - P) + 8\theta_i V(1 + \sqrt{\theta_i}) = 0$$



which implies

$$N^* = P + \frac{1 + 8(1 + \sqrt{\theta_i})\theta_i V}{16(1 + \sqrt{\theta_i})^2 \theta_i}$$

□

#### 4.5.4 Proof of Lemma 4.3

First, I have to show that

$$\frac{\partial \gamma_j^{CA}(\mathbf{t}^*)}{\partial \tilde{V}} < 0$$

Second, I find the condition for which  $\gamma_j^{CA}(\tilde{V} = 0) > 0$  and the two thresholds  $\tilde{V}'$  and  $\tilde{V}''$  can exist. Finally, I find the conditions on  $\tilde{V}$  such that  $1 \geq \gamma_j^{CA} \geq 0$ .

1. I want to show that the offered  $\gamma_j^{CA}$  is downward sloping in  $\tilde{V}$ . I have that

$$\frac{\partial \gamma_j^{CA}(\mathbf{t}^*)}{\partial \tilde{V}} = \frac{1}{2P} \left( \frac{1 - s^g}{1 + \sqrt{\theta_j}} - \frac{1}{1 + \sqrt{\theta_i}} \right)$$

which is always negative since

$$\frac{1 - s^g}{1 + \sqrt{\theta_j}} - \frac{1}{1 + \sqrt{\theta_i}} < 0 \iff 1 - s^g = s^m < \frac{1 + \sqrt{\theta_j}}{1 + \sqrt{\theta_i}}$$

which is true for any  $\theta_i > \theta_j$  and any  $s^m < 1/2$ . In fact, the right hand side of the last inequality ranges between  $1/2$ , when  $\theta_j = 0$  and  $\theta_i = 1$ , and  $1$  when  $\theta_i \sim \theta_j$ .

2. Now, to find the conditions for which the two thresholds  $\tilde{V}'$  and  $\tilde{V}''$  exist and  $\gamma_j^{CA}$  is positive for some range of  $\tilde{V}$  it is sufficient to compute  $\gamma_j^{CA}(\tilde{V} = 0)$ .

$$\gamma_j^{CA}(\tilde{V} = 0) = -\frac{1}{16P} \left( -\frac{2(1-s^g)}{\theta_j(1+\sqrt{\theta_j})^2} + \frac{1}{\theta_i(1+\sqrt{\theta_i})^2} \right) > 0$$

which is true if and only if

$$\left( -\frac{2(1-s^g)}{\theta_j(1+\sqrt{\theta_j})^2} + \frac{1}{\theta_i(1+\sqrt{\theta_i})^2} \right) < 0$$

which can be written, substituting  $s^m = 1 - s^g$ , as

$$\frac{\theta_j}{\theta_i} \left( \frac{1+\sqrt{\theta_j}}{1+\sqrt{\theta_i}} \right)^2 < 2 s^m$$

This condition tells us that when  $\theta_j$  is considerably smaller than  $\theta_i$ , government  $j$  has a distinct advantage over its opponent and can demand a positive share of power from the militia. If the condition is not satisfied, the competition is too tight and government  $j$  can only offer  $\gamma_j^{CA} = 0$ .

3. Now, I focus on  $\gamma_j^{CA}$  when  $\Delta < 2 s^m$ . In this case, there exist a range of values of the stakes of war  $\tilde{V}$  such that the offered  $\gamma_j^{CA}$  is indeed in the interval  $[0, 1]$ . The conditions that make  $\gamma_j^{CA}$  be in the desired interval can be characterized in function of  $\tilde{V}$  as follows

$$\gamma_j^{CA} = \frac{1}{16P} \left( 8V \left( \frac{1-s^g}{1+\sqrt{\theta_j}} - \frac{1}{1+\sqrt{\theta_i}} \right) + \frac{2(1-s^g)}{\theta_j(1+\sqrt{\theta_j})^2} - \frac{1}{\theta_i(1+\sqrt{\theta_i})^2} \right) > 0$$

when

$$\tilde{V} < \frac{2(1-s^g)(1+\sqrt{\theta_i})\theta_i - (1+\sqrt{\theta_j})^2\theta_j}{8\theta_i\theta_j(1+\sqrt{\theta_i})(1+\sqrt{\theta_j}) \left( s^g(1+\theta_i) - \sqrt{\theta_j} - \sqrt{\theta_i} \right)} = \tilde{V}''$$

Similarly

$$\gamma_j^{CA} = \frac{1}{16P} \left( 8V \left( \frac{1-s^g}{1+\sqrt{\theta_j}} - \frac{1}{1+\sqrt{\theta_i}} \right) + \frac{2(1-s^g)}{\theta_j(1+\sqrt{\theta_j})^2} - \frac{1}{\theta_i(1+\sqrt{\theta_i})^2} \right) < 1$$

when

$$\tilde{V} > \frac{(1+\sqrt{\theta_i})(1+\sqrt{\theta_j})}{(1-s^g)(1+\sqrt{\theta_i}) - (1+\sqrt{\theta_j})} \left[ 2P \left( 1 + \frac{\frac{1-s^g}{(1+\sqrt{\theta_j})^2\theta_j} - \frac{1}{(1+\sqrt{\theta_i})\theta_i}}{16P} \right) \right] = \tilde{V}'$$

□

### 4.5.5 Corollary

The following Corollary shows the relative position of  $N^{out}$  and  $N^*$ , where  $N^{out}$  is the value of the outside option of neutrality that makes the militia indifferent between accepting the contract and leaving the contest, i.e. when  $\gamma_j^{PC}(t_j^{CA}) = 0$ . Now we have all the elements to find the equilibrium of the common agency game.

#### Corollary 4.1.

*Let us assume that government  $j$  has a clear ideological advantage, i.e.  $\Delta > 2$ . The value of the outside option  $N^* \leq N^{out}$  if  $\tilde{V} \leq \tilde{V}'$ . Otherwise, if  $\tilde{V} \geq \tilde{V}'$  then  $N^* \geq N^{out}$*

#### 4.5.5.1 Proof of Corollary

We know from Lemma 2 that if  $N < N^*$  then  $\gamma_j^{PC} > \gamma_j^{CA}$  and  $N^* \leq N^{out}$  when  $\gamma_j^{CA}$  is positive. This occurs when  $\tilde{V} \leq \tilde{V}'$  by Lemma 3. When  $\tilde{V}$  increases  $\gamma_j^{CA}$  decreases, until a point where it becomes equal to zero for any value of  $N$ . At this point  $N^* = N_{out}$ .

In fact

$$\frac{\partial \gamma_j^{CA}}{\partial \tilde{V}} = -\frac{3}{1 + \sqrt{\theta_i}} + \frac{1}{1 + \sqrt{\theta_j}} < 0$$

since  $\sqrt{\theta_i} < 2 + 3\sqrt{\theta_j}$ . When  $\tilde{V}$  further increases then  $N^* \geq N^{out}$  because

$$\begin{aligned} \frac{\partial N^*}{\partial \tilde{V}} &= \frac{3P}{\sqrt{\theta_i} + 1} + \frac{1 - 2P}{2\sqrt{\theta_j} + 2} > \\ \frac{\partial N_{out}}{\partial \tilde{V}} &= \frac{1}{2(1 + \sqrt{\theta_j})} \end{aligned}$$

□

#### 4.5.6 Proof of Proposition 4.2

As Lemma 3 shows, if  $\Delta < 2 s^m$  and  $\tilde{V} < \tilde{V}''$  then  $\gamma_j^{CA}$  is indeed positive. In this case, government  $j$  is able to put  $i$ 's utility down to zero by offering a share of power smaller or equal to  $\gamma_j^{CA}$ , since  $u_G^i$  increases with  $\gamma_j$ . Government  $i$  then abstains from sending offers since he is put out of competition by the contract offered by  $j$ . The militia receives higher rents because she receives  $\gamma_j^{CA} < \gamma_j^{PC}$ . On the other hand, if  $\tilde{V} > \tilde{V}''$  or  $1 > \Delta > 2 s^m$  then  $\gamma_j^{CA} < 0$ , meaning that government  $j$  is not able to put  $i$  out of competition by offering a low  $\gamma_j$ , which is bounded by definition to be at least 0. In this situation, both governments send offers characterized by  $\gamma_i = \gamma_j = 0$  and they compete on the transfers. Government  $i$  can increase the transfer until a point where  $u_G^i(t_i^{max}) = 0$ , which defines a maximum value of  $N$  that can be counterbalanced by  $i$ 's offer. Since government  $j$  has a lower cost of transferring funds (and the militia has a lower cost of paying its fighters when affiliated to government  $j$ ), it can easily offer  $t_j = t_i^{max} + \varepsilon$  to get the militia's allegiance.

□

### 4.5.7 Proof of Proposition 4.3

Let us start with noticing that  $u_G^i$  and  $u_G^j$  are concave with respect to  $t_i$  and  $t_j$ . They maximize with respect to the transfers when the constraint CA is binding. It is easy to prove that the constraint CA must be binding. Suppose it is not. Then, for government  $i$  there exists a contract  $(\gamma_i, t_i)$  such that  $u_m^i > u_m^j$  strictly. Following the same reasoning, government  $j$  also offers an optimal contract  $(\gamma_j, t_j)$  and  $u_m^j > u_m^i$  strictly. Since the offers are simultaneous it implies that both  $u_m^i > u_m^j$  and  $u_m^j > u_m^i$ , a contradiction. Then the constraint CA must bind and the two principals maximize over the optimal transfers when the constraint binds with equality. I find the optimal  $t_{k,CA}^*$  when CA is binding. It is easy that  $u_G^j(t_{j,CA}^*) > 0$  for any value of  $\gamma_j$  and of  $\tilde{V}$ .

Let us assume without loss of generality that  $\theta_i > \theta_j$ . I divide the proof in two parts: first when  $\Delta < 2 s^m$  and  $\tilde{V} < \tilde{V}''$ , second when  $1 > \Delta > 2 s^m$  or  $\tilde{V} > \tilde{V}''$ .

(i)  $\Delta < 2 s^m$  and  $\tilde{V} < \tilde{V}''$

As Lemma 3 shows, when  $\Delta < 2 s^m$  there exist two thresholds  $\tilde{V}'$  and  $\tilde{V}''$  for which  $\gamma_j^{CA}$  is between 0 and 1. Let us first look at the case where  $\tilde{V}'' > \tilde{V} > \tilde{V}'$  which implies  $1 > \gamma_j^{CA} > 0$ .

I first consider the case where  $N < N^*$ . Using Lemma 2 and Lemma 3 we know that in  $N = 0$ ,  $\gamma_j^{PC} > \gamma_j^{CA}$ . Since  $\gamma_{CA}$  is constant in  $N$  and  $\gamma_{PC}$  linearly decreasing, we showed that there is a threshold level of the outside option  $N^* > 0$  such that for values smaller than  $N^*$ ,  $\gamma_{PC} > \gamma_{CA}$  and for values bigger than  $N^*$ ,  $\gamma_{PC} < \gamma_{CA}$ . Let us first analyze the case where  $N < N^*$ . In this case, government  $j$  offers  $\gamma_j^{CA}$  and, by definition of  $\gamma_j^{CA}$ , government  $i$  is indifferent between entering or not. Suppose this is not an equilibrium, and government  $j$  deviates by offering  $\gamma_j^{dev} > \gamma_j^{CA}$ . In this case, government  $i$  still participates to the contest and tries to hire the militia offering  $t_i^{CA}$  and possibly undercutting  $\gamma_i$  to such a low level that makes the militia indifferent between pledging allegiance to  $i$  or to  $j$ . This is clearly not an equilibrium, because  $j$  has now an incentive to undercut  $\gamma_j$  by offering  $\gamma_j < \gamma_j^{dev}$  and by triggering a sequence of mutual under-cuttings until a point where  $j$  offers  $\gamma_j^{CA} - \varepsilon$ , it is able to throw the opponent  $i$  out of competition and gets the militia. Similarly,  $j$  has no incentive to deviate by offering less than  $\gamma_j^{CA}$ . If it does, it just reduces the

benefit from political control over the militia, in a situation where it does not face any competition and the militia accepts the offer for sure. Finally, let us consider a deviation on both contracting variables whereby  $j$  changes by  $\varepsilon$  the transfer. This entails a loss of order  $\varepsilon^2$  that has to be compensated by an increase in the demanded  $\gamma_j$ . By doing so, government  $i$  re-enters the competition. This is not an equilibrium because it would start a new series of undercuttings of  $\gamma_i$  and  $\gamma_j$  until a point where  $j$  offers  $\gamma_j^{CA}$  and  $i$  is put at the indifference level. Now,  $j$  wins the competition for the militia and changes the transfer to its optimal value.

When  $N^* < N < N^{out}$ ,  $\gamma_j^{CA}$  is no more optimal. For those values of  $N$ ,  $\gamma_j^{CA} > \gamma_j^{PC}$  and the participation constraint has to bind. Government  $j$  optimally offers the participation constraint itself and  $i$  always stays out of the competition since  $\gamma_j^{PC} < \gamma_j^{CA}$ . Suppose this is not an equilibrium and  $j$  demands a higher share of  $\gamma_j$ . Then the militia does not accept the offer because the participation constraint is violated and the government  $j$  receives a payoff of 0; this is not an equilibrium because by lowering its demanded share of power until  $\gamma_j^{PC}$  it gets a positive payoff. By offering less than  $\gamma_j^{PC}$ , it uselessly gives away some political power to the militia. This is clearly not an equilibrium because it can increase  $\gamma_j$  until  $\gamma_j^{PC}$  and still get the militia's allegiance.

When  $N > N^{out}$  the share of power derived from the participation constraint touches its floor,  $\gamma_j^{PC} = 0$ , and the militia is indifferent between accepting and refusing the contract. Now, I can define a  $N_j^{max}$  as the value of outside option  $N$  that can be hired by government  $j$  with the maximum transfer  $t_j^{max}$  such that  $u_G^j(t_j^{max}) > 0$ . For every  $N_j^{max} > N > N^{out}$  government  $j$  is able to increase the transfer to  $t_j(N)$  in order to keep the militia at the indifference level. Suppose this is not an equilibrium. For any deviation away from  $(t_j(N), \gamma_j = 0)$ , the militia will prefer to remain neutral and government  $j$  gets a payoff of 0 which is strictly less of its payoff when offering  $(t_j(N), \gamma_j = 0)$ . Moreover, since government  $j$ 's utility is concave in the transfers, it can increase the transfer only until a point defined by a maximum value of the outside option  $N^{max}$ . If  $N = N^{max} + \varepsilon$ , the required transfer  $t_j^{max} + \varepsilon$  to hire the militia is too high,  $u_G^j(t_j^{max} + \varepsilon) < 0$  and it prefers to stay out of the contest.

- (ii)  $1 > \Delta > 2 s^m$  or  $\tilde{V} > \tilde{V}''$ .

These conditions imply that  $\gamma_j^{CA} < 0$  and, by Lemma 3, that government  $j$  is not able to put  $i$ 's utility down to zero by offering the minimum possible value of  $\gamma_j = 0$ .

Government  $i$  also enters the competition and offers  $\gamma_i = 0$ . Now, both governments can compete only by increasing the transfers. Government  $i$  has a higher cost of transferring funds and stops when  $N$  is too large, i.e. when  $N = N_i^{max} < N_j^{max}$ , which is the maximum value of  $N$  that  $j$  can afford. For government  $j$  it is sufficient to offer  $t_j$  such that  $u_m^j > u_m^i$  which implies

$$\frac{t_j + \tilde{V}}{1 + \sqrt{\theta_j}} > \frac{t_i^{max} + \tilde{V}}{1 + \sqrt{\theta_i}}$$

$$\implies t_j > (t_i^{max} + \tilde{V}) \frac{1 + \sqrt{\theta_j}}{1 + \sqrt{\theta_i}} - \tilde{V}$$

and the militia pledges allegiance to  $j$ .

□





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