

Daske, Thomas

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Friends and Foes at Work: Assigning Teams in a Social Network*

Thomas Daske [†]

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In many firms, production requires the division of staff into teams. If only team performance is observable, moral hazard in teams is inevitable. This variant of moral hazard can be overcome or exacerbated by the interpersonal relationships among team members. I investigate how the division of staff into teams should account for the agents' social network of interpersonal relationships. Considering piece rate compensation for teams, I identify rules for efficient team assignment. Depending on the shape of individual effort costs, team assignment follows either a maximin or maximax rule with regard to team members' willingness to cooperate. Generally, the preferences of staff for team composition can collide with efficient production. A universal mechanism guaranteeing efficiency while delegating responsibility for team assignment to the agents does not exist. Successful staffing thus requires knowledge of the interpersonal relationships at work and, at times, control instead of delegation.

JEL classification: D74, D82, D85, M54

Keywords: Staffing, social network, social preferences, delegation, control

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[†]Technical University of Munich, TUM School of Management, Arcisstr. 21, 80333 Munich, Germany. Email to: thomas.daske@tum.de.

1 Introduction

Management consultants, fishery operators, and teachers, too, frequently face a similar task: the division of a group of people into teams. Management consultancies typically serve several clients at once, advising each with a different team of experts. Fishery operators commonly send out several boats at once, in hope of finding the most fruitful fishing grounds. When open house day is near, teachers utilize teamwork in arts classes in order to obtain multiple exhibits that impress parents and, hopefully, donors. Parallel production of this manner is widely used. Often, however, a principal can only observe the performance of a team as a whole. Under such conditions, agents cannot be held accountable for their individual contributions to a team's success or failure; they are presented with the temptation to free-ride on the contributions of their fellow team members.

As is typical for the ubiquitous *project teams*, teamwork is often short-lived, while the group of agents as a whole persists. In persistent groups, however, people develop interpersonal relationships. Their relationships can affect their willingness to cooperate within a team and thereby help to either diminish or increase their incentives to free-ride. Taking an outside perspective, these interpersonal relationships constitute a social network. When dividing the group into teams, this social network will affect both the productivity of teams as well as the agents' subjective well-being.

How then should a principal assign agents to teams when she seeks maximum overall productivity, or maximum profit? And, considering she has no information on the agents' social network, can she leave the decision of who teams up with whom to the agents? Or should she acquire the relevant information and take action? The aim of this study is to answer both questions: Given the agents' social network of interpersonal relationships, what is the efficient assignment of teams? And is there a universal mechanism guaranteeing efficiency while delegating responsibility for team assignment to the agents?

A simple narrative helps to illustrate the economic problem involved. The operator of a fishery is equipped with two boats and four fishermen: John, Joe, Jim, and Jimmy. The boats each have to be run by a crew of two. At the end of a working day, the operator, who herself stays in the harbor, observes every crew's catch and pays each crew a share of the respective market return. Crew members each receive half of their crew's pay, since neither of them can plausibly convey having had a larger impact on their crew's

catch than the other crew member. As always, Jim teams up with his best friend Jimmy, and John teams up with his best friend Joe. But for some reason unrelated to work, conflict breaks out between John and Joe. The formerly altruistic attitudes that John and Joe had toward one another turn into spite. The operator now faces a tradeoff, in case she knows of this conflict: Having John and Joe quarrel all day instead of hauling in nets would decrease productivity. Reassigning crews to consist of John and Jim, and Joe and Jimmy, might prevent the loss of productivity from John and Joe working together. However, such an intervention would come at a loss: separation of the perfectly cooperating Jim and Jimmy. Whether or not reassignment increases overall productivity depends on the fishermen’s willingness to cooperate within the alternative crews. Given these alternatives, the question is whether the highly motivated crew would compensate for the poorly motivated crew, or whether the conflicting parties should be separated. The answer to this question must hinge on the determinants of production; it depends on how exactly an improvement of the interpersonal relationship within a crew translates into higher productivity of said crew. When staffing the crews, a fully informed operator accounts for both the determinants of production and the social network of her staff.

Constantly being informed on the interpersonal relationships in her staff is costly for the operator. She might want to avoid those costs by simply leaving the assignment of crews to the fishermen themselves. In addition, such delegation of responsibility might avoid the hidden costs of control (Falk and Kosfeld, 2006) and increase the fishermen’s motivation (Charness et al., 2012).¹ Would the fishermen self-select into the most profitable composition of crews? To be more precise, is there a mechanism that incentivizes them to do so? - Suppose the perfectly cooperating Jim and Jimmy could indeed compensate for the crew of conflicting John and Joe, as compared to the feasible alternatives. The operator would thus prefer not to change crew composition. However, it is intuitive to think of the fishermen’s social network as such that every individual prefers the separation of the conflicting parties: John and Joe may prefer to be separated for their own sakes; Jim and Jimmy may be willing to sacrifice their own success in order to support

¹Flores-Fillol, Iranzo, and Mane (2017) find similar results in the range of teamwork. Other studies emphasize the drawbacks resulting from delegation: While abstracting from any form of social concerns, or intrinsic motivation, Bester and Krähmer (2008) argue with the help of a principal-single agent model that delegation, generally, cannot lead to efficient outcomes. Ingvaldsen and Rolfsen (2012) show empirically that delegation in large organizations can lead to inefficiencies associated with between-team coordination.

their fellow fishermen. Could delegation succeed if the fishermen’s unanimous preferences are in opposition to those of the operator?

Early theoretical literature on teamwork focused on moral hazard in the context of purely self-interested agents.² As observed in experiments on private contributions to public goods (the laboratory analog to real world teamwork), a substantial share of individuals exhibit social preferences that can be related to concepts of altruism and spite (Saijo and Nakamura, 1995, Levine, 1998, and Andreoni and Miller, 2002).³ In a field experiment with fishermen, Carpenter and Seki (2011) demonstrate that the social preferences observed in the laboratory are positively correlated to individual efforts in real world teamwork environments.⁴ Babcock et al. (2015) observe that team incentives, when combined with the opportunity for regular social interaction, induce participants to be more committed than under individual-based incentives. Since production complementarities are absent, the authors attribute this finding to social preferences in the broader sense. Bandiera, Barankay, and Rasul (2010) find that the network of workplace friendships affects the performance of workers: even when pay is based on individual performance, and production complementarities are absent, workers are on average more productive when those they are socially tied to are close to them during work. Mas and Moretti (2009), in a field experiment with supermarket cashiers, identify positive spillover effects from highly productive workers to those who are less so; they attribute this finding to social pressure through mutual monitoring among those colleagues who frequently work during the same shift.⁵

These field studies provide strong evidence that the interpersonal relationships in the workplace should be accounted for when staffing crews, project teams, and shifts.⁶ How-

²These studies investigate which incentive schemes help to overcome moral hazard in teams, and under which conditions team incentives implement first-best or second-best production levels (e.g., Holmstrom, 1982, Itoh, 1991, and McAfee and McMillan, 1991).

³These preferences tend to be conditional on other participants’ willingness to cooperate (Fischbacher, Gächter, and Fehr, 2001, and Van Dijk, Sonnemans, and van Winden, 2002) and involve the propensity to punish free-riders in order to obtain socially optimal outcomes (e.g., Fehr and Gächter, 2002).

⁴In particular, they find that altruistic attitudes evolve among people who are frequently exposed to team incentives in their everyday work, providing evidence for the theory of Rotemberg (1994).

⁵Their study thus provides evidence for the respective theoretical prediction by Kandel and Lazear (1992).

⁶Other studies on the role and adequate ‘use’ of social networks in organizations focus on communication ties and the efficiency of information flow (Oh, Chung, and Labianca, 2004, and Balkundi and Harrison, 2006), on the distribution of skills within and across teams (Hamilton, Nickerson, and Owan, 2003), or on the composition of teams regarding the demographic or psychological characteristics of team members (Neuman and Wright, 1999, Rulke and Galaskiewicz, 2000, Reagans, Zuckerman, and McEvily, 2004, and Elfenbein and O’Reilly, 2007).

ever, the staffing of teams and the mode in which it affects an organization’s performance at large cannot exclusively be evaluated within the context of social networks. Teamwork and the division of staff into teams are constrained by the organizational context in which they take place. This involves the organization of production on the team level, the difficulty of production on the individual level, and the incentives provided by the principal.

I assume the agents’ social network is determined by their altruistic or spiteful interpersonal preferences. These preferences can range from strong spite to strong altruism; they are assumed to be mutual between every two agents, are exogenously given in the moment of team assignment, and remain unaffected by it. Considering piece rate compensation for teams and within-team efforts that are perfectly substitutable, I identify rules for efficient team assignment.⁷ These rules vary with the structure of individual effort costs. For convex (concave) marginal costs of effort, efficient team assignment follows a maximin (maximax) rule with regard to the agents’ willingness to cooperate. One practical implication of this finding is that team assignment should focus on the separation of conflicting parties if the production of any additional unit of output is very costly.

Utilizing these rules, I discuss the efficiency of delegation. The self-selection of agents into teams, according to a certain mechanism, imposes an externality on the principal. While the principal wants to extract a rent from team assignment, the agents are not following their material self-interest alone, they also take into account the effects of team assignment on their colleagues’ wealth.⁸ I consider mechanisms of *delegation* by which I

⁷An alternative form of incentives for teams has been proposed by [Gershkov, Li, and Schweinzer \(2009\)](#). They show that moral hazard in teams can be overcome through a Tullock contest between team members; if the signals on the agents’ individual efforts are not perfectly correlated, first-best efficient efforts can be implemented. Notice that relative performance incentives impose a negative externality of every agent’s effort on the other agent’s pay, reversing the effects of within-team altruism and spite as compared to piece rate compensation for teams. On the other hand, if the principal observes spite between certain agents, she might even want to exploit this spite by imposing a contest between appropriate teams; see [Bandiera, Barankay, and Rasul \(2013\)](#) for a field experiment on how tournaments between teams affect team performance and overall productivity. However, other empirical studies suggest that contests might increase or even create spite between workers, potentially leading to sabotage (e.g., [Goette et al., 2012](#), and [Charness, Masclet, and Villeval, 2013](#)). When imposing contests within or between teams, the questions addressed in this paper arise similarly.

⁸Due to this externality, the analysis of endogenous team formation in the workplace goes beyond theories on the endogenous formation of networks and network stability ([Dutta, Ghosal, and Ray, 2005](#), and [Page, Wooders, and Kamat, 2005](#)), on networks of endogenous externalities among agents ([Bramoullé and Kranton, 2007](#)), and on equilibrium behavior in network games in general ([Jackson and Wolinsky, 1996](#), and [Galeotti et al., 2010](#)). This paper adds a principal-agent perspective to social network theory.

refer to mechanisms that involve the agents in a strategic game the rules of which exclusively depend on the agents' preference orderings over team composition (for instance, majority voting). Delegation mechanisms, by this requisite, are income neutral: their application does not affect the agents' wealth beyond the implementation of a specific team assignment.

I show that a universal mechanism guaranteeing efficiency while delegating responsibility for team assignment to the agents does not exist. In fact, there exist social networks in which the agents unanimously prefer the implementation of a team assignment that does not maximize overall productivity or the principal's profit. Such a Pareto dominant team assignment from the agents' point of view would inevitably be the outcome of a Nash equilibrium under any kind of delegation mechanism. Hence, there exists no delegation mechanism for which the outcome of *every* Nash equilibrium is the efficient assignment of teams. The respective examples share the trait that the social network is either conflict-laden or, in the absence of spite, asymmetric (that is, at least one team assignment results in one highly cooperative and one poorly cooperative team). Interestingly, even if all the agents are altruistic toward one another, they might unanimously opt for a mode of production that is inefficient overall.

Another way of overcoming the acquisition of information is the *pooling of incentives* by paying every agent an equal share of the market return on the overall output. Team assignment could be arbitrary in this case. Intuitively, pooling would increase the agents' incentives to free-ride. One would expect that there is at least one composition of teams, with teams of two agents being paid according to their own team output, that is more efficient than pooling. Counterintuitively, there do exist social networks for which the pooling of incentives can be efficient. These social networks are all characterized by the presence of a 'spiteful outcast', an agent who is the recipient of all the other agents' spite and who reciprocates this spite. Nevertheless, knowing whether or not pooling is the best response to the agents' social network requires the principal to be informed.

From a purely contract theoretical point of view, team assignment can be arbitrary with respect to the agents' social network. If the principal knows what team output to expect in the case of efficiently working agents, then efficient effort levels can be enforced through [Holmstrom's \(1982\)](#) budget breaking rule: If team output is as large as if every team member had produced efficiently, then team members are paid according to their

reservation utilities; otherwise, they receive no pay. Under such a regime, exerting the efficient efforts constitutes a Nash equilibrium regardless of the team members' interpersonal preferences (except for unrealistically strong spite between agents). Yet often, a principal does not know what the outcome of a team's work could have been at best: Having returned to the harbor with a poor catch, foes John and Joe can simply claim that they were unlucky, the big shoal must have been somewhere else. The operator has no means of falsifying their lie. Consequently, real world fishermen are often paid a share of the market return on their catch. Similarly, the teacher hoping for high quality pieces of art to be exhibited on open house day just might not know beforehand which pieces can be rated 'high quality'. In this respect, understanding team assignment in social networks is first and foremost a matter of practical relevance.

2 The Model

A principal faces a group of four agents, $\{a, b, c, d\}$. Production in the principal's firm requires collaboration in teams of two. The group of agents has to be subdivided into these teams. For a combination of agents, $\{i, j, k, l\} = \{a, b, c, d\}$, denote by $[(ij)(kl)]$ the formation of two teams, one containing i and j , the other one k and l . Exactly three of such *team assignments* are feasible, and one of them must be implemented:

$$(1) \quad [(ij)(kl)] \in \{[(ab)(cd)], [(ac)(bd)], [(ad)(bc)]\}.$$

Once a team (ij) is formed, i and j make simultaneous effort choices $x_i, x_j \in [0, \infty)$. The function of individual effort costs, $C : [0, \infty) \rightarrow [0, \infty)$, is the same for all the agents. It is sufficiently often differentiable and satisfies $C(0) = C_x(0) = 0$; $C_x, C_{xx} > 0$; and $\lim_{x \rightarrow \infty} C_x(x) = \infty$.

The principal can only observe team output. Within teams, individual efforts are perfectly substitutable. Team effort $x_i + x_j$ transforms directly into team output, which the principal sells at a market price of one per unit. Teams receive piece rate compensation for their own team output, of which each team member receives an equal share. The piece rate is exogenously given and the same for both teams. With piece rate $w \in (0, 1]$, team

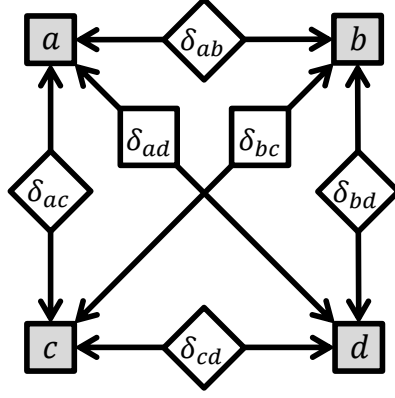


Figure 1: *The social network of interpersonal preferences, $\delta_{ij} \in [-1, 1]$, in the group of agents $\{a, b, c, d\}$.*

(ij) receives compensation $w \cdot (x_i + x_j)$ for its team output. Consequently, agent i ends up with material wealth

$$(2) \quad \pi_i = \frac{1}{2} w (x_i + x_j) - C(x_i).$$

The principal ends up with a profit of $\Pi_{(ij)} = (1 - w)(x_i + x_j)$ from team (ij) and a profit of $\Pi_{(kl)} = (1 - w)(x_k + x_l)$ from team (kl) .

Each agent i maximizes utility

$$(3) \quad u_i = \sum_{j \in \{a, b, c, d\}} \delta_{ij} \pi_j,$$

with $\delta_{ii} = 1$ and $\delta_{ij} \in [-1, 1]$ for all $j \neq i$. That is, every agent has a normalized valuation of their own wealth and has altruistic or spiteful valuations of their coworkers' wealth.⁹

I refer to δ_{ij} as the *degree of altruism* between i and j . The degrees of altruism between every two agents are assumed to be mutual, $\delta_{ij} = \delta_{ji}$ for all i, j .¹⁰ They are exogenously given, will be unaffected by team assignment, and are common knowledge among agents. They determine an interpersonal structure that I refer to as the *social network* $\{a, b, c, d\}$.

Figure 1 illustrates the so defined social network.

⁹A similar approach is taken by Brunner and Sandner (2012) who investigate under which constellations of the degrees of altruism a principal's profit is maximal; in their model, moral hazard in teams is absent, and the principal is fully informed.

¹⁰This mutuality can be interpreted as the result of reciprocity between people who interact frequently. For a survey on reciprocal behavior see Fehr and Schmidt (2006).

Suppose team assignment $[(ij)(kl)]$ has been implemented. Then agent i maximizes utility $u_i = \pi_i + \delta_{ij}\pi_j + \delta_{ik}\pi_k + \delta_{il}\pi_l$ with respect to individual effort. By (2), i 's marginal utility of individual effort x_i is

$$(4) \quad \frac{du_i}{dx_i} = \left(\frac{1}{2} + \frac{1}{2}\delta_{ij} \right) w - C_x(x_i),$$

with marginal return on effort $\left(\frac{1}{2} + \frac{1}{2}\delta_{ij} \right) w_{ij}$ and marginal costs of effort $C_x(x_i)$. In team assignment $[(ij)(kl)]$, i 's effort choice leaves k 's and l 's material wealth unaffected, and vice versa. Agent i 's effort choice is thus independent of his social preferences toward the members of the other team. The marginal return on effort reflects the fact that only half of i 's effort transforms into effective return for i , the other half benefits co-worker j . The weight $\frac{1}{2} + \frac{1}{2}\delta_{ij}$ measures i 's valuation of this externality. I refer to

$$(5) \quad m_{ij} = \frac{1}{2} + \frac{1}{2}\delta_{ij}$$

as i 's *motivation to cooperate with j* ; in brief, i 's *motivation*. The stronger i 's altruism towards j is the greater is i 's motivation to cooperate with j .¹¹ Marginal return on effort, $m_{ij}w$, depends on both the social incentive to engage in production, m_{ij} , and the material incentive to do so, w . By mutuality, $m_{ij} = m_{ji}$. Agent i maximizes utility by exerting an effort of

$$(6) \quad x_i^* = C_x^{-1}(m_{ij}w) \in [0, \infty).$$

Inverse marginal costs of effort, C_x^{-1} , are strictly increasing in marginal return and, therefore, strictly increasing in the motivation to cooperate. The stronger i 's altruism towards j is the more will i produce: $dx_i^*/d\delta_{ij} > 0$. Notice that perfect spite between team members, $\delta_{ij} = -1$, implies zero team output.

Team assignment $[(ij)(kl)]$ leaves the principal a profit of

$$(7) \quad \Pi_{[(ij)(kl)]} = 2(1-w) \left[C_x^{-1}(m_{ij}w) + C_x^{-1}(m_{kl}w) \right].$$

¹¹An alternative reading of the parameters m_{ij} is that they do not represent the agents' willingness to cooperate but rather their capability of doing so. This capability might depend on team familiarity (Huckman, Staats, and Upton, 2009), mutual trust (Moldoveanu and Baum, 2011), or personality traits (Neuman and Wright, 1999). Analytically, the task of efficient team assignment remains the same. However, interpersonal preferences are particularly important when it comes to 'pooling the incentives' (Section 4) and the efficiency of delegation (Section 5).

The principal's objective is to maximize this profit with respect to the feasible team assignments $[(ab)(cd)]$, $[(ac)(bd)]$, and $[(ad)(bc)]$. I assume that every agent has no other option but to agree upon the principal's team assignment decision. I make this assumption to especially account for the pervasive short-lived *project teams* that come together and come apart on a monthly or weekly basis. In the case of fishermen John, Joe, Jim, and Jimmy, crews can be staffed even on a daily basis; the 'outside option' when disagreeing with the operator's staffing decision would then be to get fired and to search for a new job. This might be too large a setback to not to follow the operator's command.

The shape of the principal's profit function (7) is the crucial factor for efficient team assignment. It is determined by the shape of C . Denote by $\varepsilon_{x_i^*, m_{ij}}$ the elasticity of individual effort with respect to the motivation to cooperate: $\varepsilon_{x_i^*, m_{ij}} = (dx_i^*/x_i^*) / (dm_{ij}/m_{ij})$. Since team members are equally motivated by mutuality, the motivation elasticity of individual effort equals the motivation elasticity of team output, $\varepsilon_{x_i^*, m_{ij}} = \varepsilon_{x_i^* + x_j^*, m_{ij}}$. The principal's profit, the effort cost function, and the motivation elasticity of team output do relate as follows.

Lemma 1 *The principal's profit $\Pi_{[(ij)(kl)]}$ is strictly increasing in each team's motivation to cooperate, m_{ij} and m_{kl} . With concave (convex) marginal costs of effort, $C_{xxx} < 0$ ($C_{xxx} > 0$), the principal's profit is convex (concave) in the vector (m_{ij}, m_{kl}) of motivation per team. With concave (convex) marginal costs of effort, team output is elastic (inelastic) in a team's motivation to cooperate, $\varepsilon_{x_i^*, m_{ij}} > 1$ ($\varepsilon_{x_i^*, m_{ij}} < 1$).*

Proof. The proof is straight forward and omitted therefore. ■

The extent to which a highly motivated team can compensate for an unmotivated team thus depends on the steepness of the effort cost function. The steeper the effort cost function is, the smaller would be a team's additional output in response to a marginal increase in that team's motivation. I impose some regularity on the effort cost function: Either $C_{xxx} < 0$, or $C_{xxx} > 0$. Consequently, team output reacts either elastically or inelastically to changes in a team's motivation.

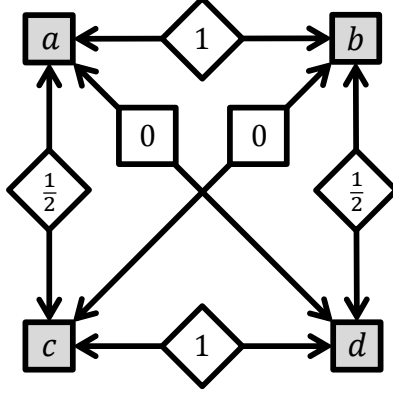


Figure 2: A social network that allows for two highly motivated teams, (ab) and (cd) .

3 Principles of Efficient Team Assignment

How will a principal who is fully informed about the agents' social network assign teams so as to maximize profits? With an exogenously given piece rate for both teams, profit maximization is equivalent to the maximization of overall output and, thus, to efficient production. I refer to a team assignment as *efficient* if it is most profitable among the feasible assignments.

As is obvious from (7) and Lemma 1, the principal prefers a team assignment that allows for a high motivation in both teams.

Proposition 1 *If the least motivated team in assignment $[(ab)(cd)]$ is more motivated than the least motivated team in $[(ij)(kl)]$ and, in addition, the most motivated team in $[(ab)(cd)]$ is more motivated than the most motivated team in $[(ij)(kl)]$, then $[(ab)(cd)]$ is more efficient than $[(ij)(kl)]$.*

Figure 2 gives an example of a social network that allows for the application of Proposition 1. In this social network, agents a and b are perfectly altruistic to one another, $\delta_{ab} = 1$. They both are less altruistic toward c and d : $\delta_{ac} = \delta_{bd} = \frac{1}{2}$ and $\delta_{ad} = \delta_{bc} = 0$. By (5), a 's and b 's motivation to cooperate is strongest in team (ab) , $m_{ab} = 1$. Since c and d are also perfectly altruistic to one another, the efficient team assignment is $[(ab)(cd)]$.

Given the variety of feasible social networks, Proposition 1 is rarely applicable. In many social networks, the formation of the most motivated team may leave the principal no other option but to also form an unmotivated team. When can a highly motivated team compensate for an unmotivated team?

Figure 3 shows a social network in which no two team assignments are comparable in terms of Proposition 1. Here, forming team (ab) , with perfect altruism $\delta_{ab} = 1$ and maximum motivation $m_{ab} = 1$, requires to also form the completely unmotivated team (cd) , with $\delta_{cd} = -1$ and $m_{cd} = 0$. Instead of $[(ab)(cd)]$, the principal may want to implement $[(ad)(bc)]$ so that coworkers have neutral preferences toward one another, $\delta_{ad} = 0 = \delta_{bc}$, and ‘medium’ motivation to cooperate, $m_{ad} = \frac{1}{2} = m_{bc}$. Or, the principal allows for a bit of spite, $\delta_{bd} = -\frac{1}{2}$, in order to allow for a bit of altruism, $\delta_{ac} = \frac{1}{2}$, such that $m_{bd} = \frac{1}{4}$ and $m_{ac} = \frac{3}{4}$. The question is: Can the highly motivated team (ab) compensate for the non-cooperation within the unmotivated team (cd) ? Or is separation of spiteful coworkers superior even though this implies the separation of altruistic coworkers? How does $[(ac)(bd)]$ compare to the alternatives?

Assume for the moment that the feasible assignments $[(ij)(kl)]$ do not differ in the average motivation $\frac{1}{2}(m_{ij} + m_{kl})$ of teams, - as in the case of Figure 3 where this average is always $1/2$. Suppose first, team output is elastic in the team members’ motivation to cooperate, $\varepsilon_{x_i^*, m_{ij}} > 1$. By Lemma 1, the principal’s profit (7) is convex in team (ij) ’s motivation m_{ij} (and similarly for team (kl)). Suppose further, (ij) has a higher motivation than (kl) , $m_{ij} \geq m_{kl}$. Increasing now (ij) ’s motivation by Δm overcompensates for decreasing (kl) ’s motivation by the same quantity Δm , while keeping average motivation constant. Accordingly, the motivation asymmetry between teams should be greatest, and the principal would implement the assignment that allows for the maximum feasible motivation for one team. Due to (5), the principal implements the assignment which solves

$$(8) \quad \max_{[(ij)(kl)]} \max \{ \delta_{ij}, \delta_{kl} \}.$$

In the example of Figure 3, the efficient assignment is $[(ab)(cd)]$, since $\max \{ \delta_{ab}, \delta_{cd} \} = 1 > \max \{ \delta_{ac}, \delta_{bd} \} = \frac{1}{2} > \max \{ \delta_{ad}, \delta_{bc} \} = 0$.

Now suppose team output is inelastic in the team members’ motivation, $\varepsilon_{x_i^*, m_{ij}} < 1$. By Lemma 1, the principal’s profit (7) is concave in teams’ motivations. Suppose again $m_{ij} \geq m_{kl}$. Increasing now (ij) ’s motivation by Δm will not compensate for decreasing (kl) ’s motivation by Δm . In this case, the motivation asymmetry between teams should be as small as possible, and the principal would implement the assignment that allows

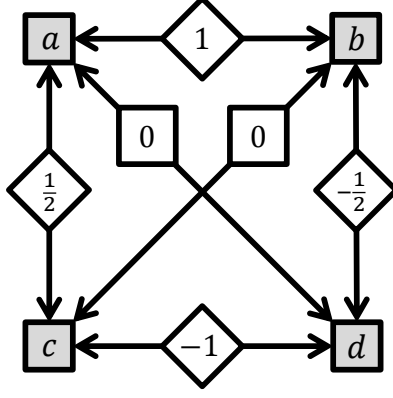


Figure 3: *Forming the highly motivated team (ab) leaves the principal no other option but to also form the unmotivated team (cd).*

for the maximum motivation of the least motivated team. Due to (5), the principal will implement the assignment which solves

$$(9) \quad \max_{[(ij)(kl)]} \min \{\delta_{ij}, \delta_{kl}\}.$$

In the example of Figure 3, now assignment $[(ad)(bc)]$ is efficient, since $\min \{\delta_{ab}, \delta_{cd}\} = -1 < \min \{\delta_{ac}, \delta_{bd}\} = -\frac{1}{2} < \min \{\delta_{ad}, \delta_{bc}\} = 0$. Notice that for both elastic and inelastic team output, implementing the assignment with ‘intermediate’ motivations, $[(ac)(bd)]$, is always inefficient. According to (8) and (9), the principal must go for the extremes.

So far, we have assumed that the feasible team assignments do not differ in the average motivation of the respective teams: $m_{ab} + m_{cd} = m_{ij} + m_{kl}$ for any combination of agents $\{i, j, k, l\} = \{a, b, c, d\}$. If, in this situation, $[(ab)(cd)]$ yields a higher profit than $[(ij)(kl)]$, then, by Proposition 1, this is even more so if the motivation of one of the teams (ab) and (cd) is increased. Together: If $m_{ab} + m_{cd} \geq m_{ij} + m_{kl}$, and, depending on the elasticity of team output, if $[(ab)(cd)]$ solves (8) or (9), then this assignment is efficient.

In two m_{ij} - m_{kl} -diagrams, Figure 4 captures the graphical analog of this reasoning. For the cases of convex (on the left) and concave (on the right) marginal cost of effort, it depicts the principal’s isoprofit curve associated with the profit from a specific assignment $[(ab)(cd)]$. By Lemma 1, isoprofit curves are convex (concave) if the marginal costs of effort are convex (concave). Since profit is symmetric in the teams’ motivations, (m_{ij}, m_{kl}) , isoprofit curves are symmetric to the 45°-line. Besides concavity or convexity, no further assumptions have been made about the specific shape of the function of

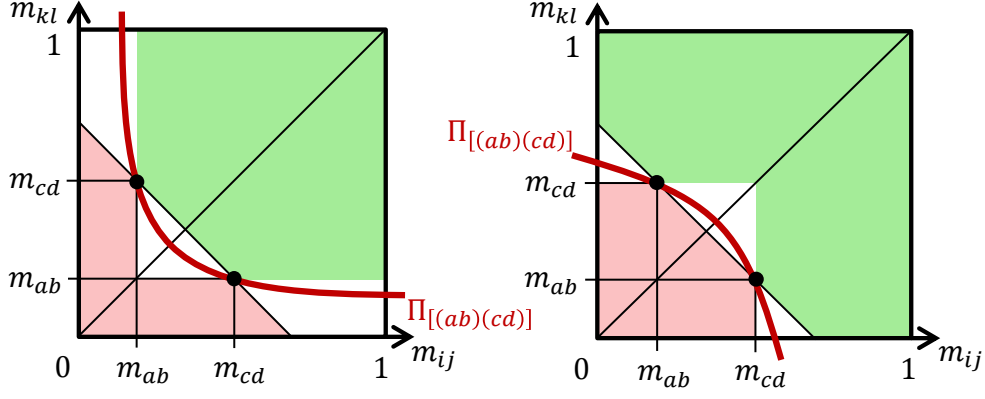


Figure 4: The combinations of within-team motivation that yield more (gray) or less (dotted) profit than team assignment $[(ab)(cd)]$. With convex (concave) marginal costs of effort, the principal's isoprofit curve is convex (concave). How the white areas translate into more or less profit depends more specifically on the shape of effort cost function.

marginal effort costs. Accordingly, the white areas in the diagrams of Figure 4 capture exactly all those pairs (m_{ij}, m_{kl}) of within-team motivation that can locate above as well as below the isoprofit curve through (m_{ab}, m_{cd}) , depending on the specific shape of marginal effort costs. Inevitably superior (inferior) to (m_{ab}, m_{cd}) are all those pairs of within-team motivations belonging to the gray (dotted) area. The gray and dotted areas are exactly those that cannot be crossed by any convex or concave isoprofit curve through (m_{ab}, m_{cd}) . For convex marginal costs of effort, each combination (m_{ij}, m_{kl}) in the gray shaded area satisfies $m_{ij} + m_{kl} \geq m_{ab} + m_{cd}$ and $\min\{\delta_{ij}, \delta_{kl}\} \geq \min\{\delta_{ab}, \delta_{cd}\}$; and compared to every combination in the dotted area, (m_{ab}, m_{cd}) satisfies $m_{ab} + m_{cd} \geq m_{ij} + m_{kl}$ and $\min\{\delta_{ab}, \delta_{cd}\} \geq \min\{\delta_{ij}, \delta_{kl}\}$. On the other hand, for concave marginal costs of effort, each combination (m_{ij}, m_{kl}) in the gray shaded area satisfies $m_{ij} + m_{kl} \geq m_{ab} + m_{cd}$ and $\max\{\delta_{ij}, \delta_{kl}\} \geq \max\{\delta_{ab}, \delta_{cd}\}$; and compared to every combination in the dotted area, (m_{ab}, m_{cd}) satisfies $m_{ab} + m_{cd} \geq m_{ij} + m_{kl}$ and $\max\{\delta_{ab}, \delta_{cd}\} \geq \max\{\delta_{ij}, \delta_{kl}\}$. This proves the following Proposition.

Proposition 2 *Suppose average motivation in $[(ab)(cd)]$ is at least as high as in $[(ij)(kl)]$. Then $[(ab)(cd)]$ is more efficient than $[(ij)(kl)]$ if one of the following conditions is satisfied.*

- (i) *Marginal costs of effort are concave, and the most motivated team in $[(ab)(cd)]$ is more motivated than the most motivated team in $[(ij)(kl)]$.*
- (ii) *Marginal costs of effort are convex, and the least motivated team in $[(ab)(cd)]$ is more motivated than the least motivated team in $[(ij)(kl)]$.*

Proposition 2 suggests a rule of thumb that relates efficient team assignment to the steepness of the effort cost function ($C_{xxx} \gtrless 0$): ‘The more difficult the production of any additional unit of team output is the more important is the separation of agents who are less altruistic to one another.’

4 Pooling and the Integration of a Spiteful Outcast

To assign teams efficiently, the principal needs the information on the agents’ social network. Obtaining this information might be costly. Can the principal ‘get around’ the team assignment decision by simply paying each agent an equal share of the market return on overall output? Even though each agent would still have to collaborate with some other agent in a team of two, he would internalize the externalities of his efforts on all the other agents, regardless of whom he is sitting in the same boat with. In terms of incentives, payoffs, and profits, actual team assignment could then be arbitrary. Intuitively, one might expect that this cannot be more efficient than each of the feasible team assignments $[(ij)(kl)]$, where teams are paid for their own team output: Receiving an equal share of the overall return would increase every agent’s incentive to free-ride; the group of beneficiaries of individual effort should thus be as small as practically feasible. The objective of the following analysis is to confirm this intuition for most social networks, but to reject it for some.

For some fixed piece rate w , let $[(abcd)]$ denote the principal’s strategy to pay each agent an equal share, $\frac{1}{4}w$, of overall return. I refer to $[(abcd)]$ as *the pooling of incentives* or, likewise, as *4-assignment*. By contrast, I refer to the assignments $[(ab)(cd)]$, $[(ac)(bd)]$, and $[(ad)(bc)]$ as *2 + 2 -assignments*.

Consider some combination of agents $\{i, j, k, l\} = \{a, b, c, d\}$, and suppose the principal utilizes the pooling of incentives. Then, with all else equal, agent i ends up with material wealth

$$(10) \quad \pi_i = \frac{1}{4}w(x_a + x_b + x_c + x_d) - C(x_i).$$

Since within-team efforts are perfectly substitutable, this holds regardless of who teams up with whom exactly. Again, i maximizes utility $u_i = \pi_i + \delta_{ij}\pi_j + \delta_{ik}\pi_k + \delta_{il}\pi_l$ with respect to individual effort x_i . His marginal utility from exerting effort is given by

$$(11) \quad \frac{du_i}{dx_i} = \left(\frac{1}{4} + \frac{1}{4}\delta_{ij} + \frac{1}{4}\delta_{ik} + \frac{1}{4}\delta_{il} \right) w - C_x(x_i).$$

Marginal return on effort, $\left(\frac{1}{4} + \frac{1}{4}\delta_{ij} + \frac{1}{4}\delta_{ik} + \frac{1}{4}\delta_{il} \right) w$, reflects the fact that now only a quarter of i 's individual effort transforms into effective return for i . The remaining three quarters are in favor of the other agents. The weight $\frac{1}{4} + \frac{1}{4}\delta_{ij} + \frac{1}{4}\delta_{ik} + \frac{1}{4}\delta_{il}$ measures i 's valuation of this income effect. I refer to

$$(12) \quad M_i = \frac{1}{4} + \frac{1}{4}\delta_{ij} + \frac{1}{4}\delta_{ik} + \frac{1}{4}\delta_{il}$$

as i 's *motivation in 4-assignment* $[(abcd)]$. This motivation increases in i 's altruism toward each of the other agents. Obviously, $M_i \in [-\frac{1}{2}, 1]$. If i 's motivation in $[(abcd)]$ is negative, he will exert zero effort, since every unit of effort then yields negative marginal return. Therefore, i has a dominant strategy in exerting effort

$$(13) \quad x_i^* = C_x^{-1}(w \max\{0, M_i\}).$$

The principal's profit associated with the pooling of incentives is given by

$$(14) \quad \Pi_{[(abcd)]} = \sum_{i \in \{a,b,c,d\}} (1-w) C_x^{-1}(w \max\{0, M_i\}).$$

Not surprisingly, 4-assignment $[(abcd)]$ does not in general yield a higher profit than every 2 + 2-assignment. An obvious example is the social network of Figure 2. There, the efficient 2 + 2-assignment is $[(ab)(cd)]$ in which every agent exerts an effort $C_x^{-1}(w)$. Due to the symmetry of this social network, the agents are identically motivated under the pooling of incentives; namely, $M_i = \frac{1}{4} \left(1 + 1 + \frac{1}{2} + 0 \right) = \frac{3}{8}$ for all i . By (13), agents each exert an effort $C_x^{-1}\left(\frac{3}{8}w\right) < C_x^{-1}(w)$. Thus, $\Pi_{[(abcd)]} < \Pi_{[(ab)(cd)]}$. In this example, the inferiority of $[(abcd)]$ is driven by the decrease of every agent's motivation when enlarging the group of beneficiaries of their individual efforts.

Suppose i 's motivation in $[(abcd)]$ is positive, $M_i > 0$. As before, i 's optimum individual effort is elastic in i 's motivation to cooperate, $\varepsilon_{x_i^*, M_i} > 1$, if the marginal costs of effort are concave. Optimum effort is inelastic, $\varepsilon_{x_i^*, M_i} < 1$, if the marginal costs of effort are convex. The intuition behind Proposition 2 raises the question: When implementing $[(abcd)]$ instead of the efficient 2 + 2-assignment, would the potential increase in some agents' motivation compensate for another agent's demotivation? The answer is: Yes, sometimes. For this, the marginal costs of effort must be convex, and the respective social networks must contain an agent who can be named a 'spiteful outcast'.

I refer to agent d as a *spiteful outcast* in the social network $\{a, b, c, d\}$ if d is completely unmotivated in $[(abcd)]$, $M_d < 0$, while all the other agents' motivation in $[(abcd)]$ is positive: $M_a, M_b, M_c > 0$. The term 'spiteful outcast' is suggested by the following observation: The definition implies that $\delta_{ad} + \delta_{bd} + \delta_{cd} < -1$ and $\delta_{ad} + \delta_{bd} + \delta_{cd} < \delta_{ab} + \delta_{ac} + \delta_{bc}$.¹² Hence, agents $\{a, b, c\}$ are on average spiteful toward d , a spite that is reciprocated by d , and their average spite toward d is stronger than their average spite toward one another (if they are spiteful toward one another at all). Relative to their relationships to d , agents $\{a, b, c\}$ form a *clique* that dislikes and is disliked by the spiteful outcast d . The following example shows that integrating a spiteful outcast through the pooling of incentives can indeed be more efficient than any 2 + 2-assignment.

Figure 5 depicts a clique of agents $\{a, b, c\}$ who are perfectly altruistic toward one another. Each member is perfectly spiteful toward agent d , and vice versa. The vector (M_a, M_b, M_c, M_d) of the agents' motivations in 4-assignment $[(abcd)]$ equals $(\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, -\frac{1}{2})$. By definition, d is a spiteful outcast. All the 2 + 2-assignments are symmetric: in each, there is one highly motivated team and one completely unmotivated team. Cooperation between d and a clique member $i \in \{a, b, c\}$ is zero in any 2 + 2 -assignment: $m_{id} = 0$. Now focus on $[(ab)(cd)]$. By (6), clique members a and b each exert an effort $C_x^{-1}(w)$, while agents c and d each exert zero effort. The pooling of incentives increases c 's motivation (from $m_{cd} = 0$ to $M_c = \frac{1}{2}$) at the expense of demotivating agents a and b (from $m_{ab} = 1$ to $M_a = M_b = \frac{1}{2}$). Can it be that the increase in c 's motivation overcompensates for the decrease in a 's and b 's motivation? - The answer depends on the shape of the effort cost function.

¹²Let $M_d < 0$, and $-M_a, -M_b, -M_c < 0$. Adding all four inequalities yields $-\frac{1}{2}(1 + \delta_{ab} + \delta_{ac} + \delta_{bc}) < 0$. Thus, $\delta_{ad} + \delta_{bd} + \delta_{cd} < -1 < \delta_{ab} + \delta_{ac} + \delta_{bc}$.

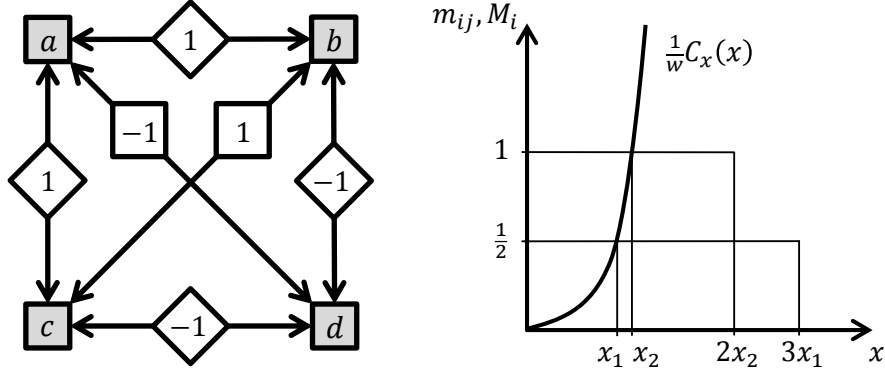


Figure 5: A social network with a spiteful outcast, d , and a production process for which pooling the incentives is efficient. In $[(abcd)]$, agents a , b , and c each exert an effort x_1 , while d exerts zero effort. In $[(ab)(cd)]$, a and b each exert an effort x_2 , while c and d exert zero effort.

Figure 5 also depicts a production process, represented by the marginal costs of effort, that indeed makes the pooling of incentives the best response to the underlying social network. Here, team output is inelastic in the motivation to cooperate, $C_{xxx} > 0$. In $[(abcd)]$, each clique member exerts an effort $x_1 = C_x^{-1}(\frac{1}{2}w)$. Overall output is $3x_1$, since d exerts zero effort. In $[(ab)(cd)]$, clique members a and b each exert an effort $x_2 = C_x^{-1}(w)$ while c and d exert zero effort. The marginal costs of effort are chosen such that, when implementing $[(abcd)]$ instead of $[(ab)(cd)]$, the motivation increase of c overcompensates for the demotivation of a and b : $3x_1 > 2x_2$. This positive effect of integrating a spiteful outcast is not driven by the outcast himself, who is demotivated anyway; motivating clique member c renders integration of d efficient.¹³

Notice that the condition $C_{xxx} > 0$ does not suffice to make the integration of a spiteful outcast efficient: If C_x in Figure 5 was chosen nearly linear, the positive effect of integration would collapse.

Of course, the social network of Figure 5 would allow for an even more efficient payment scheme: pay each member of the clique $\{a, b, c\}$ an equal share of overall return, and pay d zero. But doing so requires the principal to be informed about the agents'

¹³The definition of a spiteful outcast characterizes the efficiency of pooling in the following sense:

- (1) Without a spiteful outcast, pooling is always inferior (see Proposition 3).
- (2) Pooling can be efficient even if $M_a, M_b, M_c > 0$ are arbitrarily small: Let $\delta_{ab}, \delta_{ac}, \delta_{bc} = 5\varepsilon$, and $\delta_{ad}, \delta_{cd}, \delta_{bd} = 2\varepsilon - 1$. Then, $M_d = 3\varepsilon - \frac{1}{2}$; $M_a, M_b, M_c = 3\varepsilon$; $m_{ab} = \frac{1}{2} + 5\varepsilon$; $m_{cd} = \varepsilon$. For any $\varepsilon > 0$ sufficiently small, marginal effort costs can be chosen appropriately (similarly as in Figure 5), such that pooling is efficient.
- (3) Pooling can be efficient even if $M_d < 0$ is arbitrarily close to zero: Let $\delta_{ab}, \delta_{ac}, \delta_{bc} = 1$, and $\delta_{ad}, \delta_{cd}, \delta_{bd} = -\frac{1}{3} - \varepsilon$. Then, $M_d = -\frac{3}{4}\varepsilon$; $M_a, M_b, M_c = \frac{2}{3} - \frac{3}{4}\varepsilon$; $m_{ab} = 1$; $m_{cd} = \frac{1}{3} - \frac{1}{2}\varepsilon$. For any $\varepsilon > 0$ sufficiently small, marginal effort costs can be chosen appropriately, such that pooling is efficient.

network. The consideration of pooling rather serves the purpose of understanding whether the principal can avoid obtaining such information. Even though this is only occasionally the case, I discuss the pooling of incentives in detail because the findings reject the naive intuition that pooling would never be more efficient than incentivizing the agents on a smaller group level.

Proposition 3 *The pooling of incentives can be more efficient than any 2+2-assignment if output is inelastic in the agents' motivation to cooperate and, at the same time, the social network contains a spiteful outcast. Otherwise, there exists at least one 2 + 2-assignment that is more efficient than pooling.*

Proof. See the Appendix. ■

In the absence of a spiteful outcast, or if the marginal costs of effort are concave, teams (in terms of compensation) should be as small as practically feasible. The imperative of small teams imposes an information problem on the principal. Even for assessing whether or not pooling can be efficient, she needs to have the information on the interpersonal relationships at work.

5 Delegation or Control?

Suppose the principal is uninformed about the social network of her staff while, as before, preferences are common knowledge among agents. Can the principal leave the decision on who teams up with whom to her staff?

One can think of several ways of how this decision could be ‘delegated’. One is to ‘let the agents vote’, according to some well-designed voting rules. Another one is to make the agents reveal their interpersonal degrees of altruism by applying some more sophisticated mechanism. I focus here on the first of these alternatives. I do not address the question of how the principal would incentivize the agents to internalize the externalities that their actions impose on her, which I interpret as ‘control’.¹⁴

I consider *delegation mechanisms*, by which I refer to strategic games between the agents that translate the announced preferences for (or preference orderings over) team

¹⁴The adequate tool for the latter approach is *Nash implementation* in the manner of [Maskin \(1999\)](#) and [Moore and Repullo \(1990\)](#).

compositions into final team assignments but that do not affect the agents' ex post utilities beyond team assignments. Without loss of generality, side payments to or between agents can be neglected.

Denote by $\mathbb{A} = \{[(ab)(cd)], [(ac)(bd)], [(ad)(bc)], [(abcd)]\}$ the set of feasible team assignments. For $i \in \{a, b, c, d\}$, denote by T the set of (every) agent i 's feasible preference orderings over \mathbb{A} . Suppose the social network determinants $(\delta_{ab}, \delta_{ac}, \delta_{ad}, \delta_{bc}, \delta_{bd}, \delta_{cd}) \in [-1, 1]^6$ are common knowledge among the agents, but unknown to the principal.¹⁵ The agents thus know which team assignment $A^* \in \mathbb{A}$ maximizes the principal's profit, the principal herself does not.¹⁶

The principal seeks to *ensure* implementation of A^* by application of a mechanism as follows. She asks agents simultaneously to tell her their true preference orderings over \mathbb{A} and builds her decision to implement a team assignment $A \in \mathbb{A}$ upon the collection $[t_a, t_b, t_c, t_d] = t \in T^4$ of messages received.

A *delegation mechanism* M is a collection of density functions $m[t] : \mathbb{A} \rightarrow [0, 1]$ which, conditional on the messages received, determine the probabilities with which every $A \in \mathbb{A}$ will be implemented. Thus, $\sum_{A \in \mathbb{A}} m[t](A) = 1$ for each $t \in T^4$. The principal seeks to design M in such a way that equilibrium behavior under M yields a profit maximizing team assignment with likelihood 1.

Denote by $\tau_i : T \rightarrow [0, 1]$ an agent i 's (possibly degenerate) mixed strategy which, for every $t_i \in T$, determines the probability $\tau_i(t_i)$ with which i announces that his preference ordering over \mathbb{A} was t_i . Let $u_i(A)$ denote i 's utility from implementation of $A \in \mathbb{A}$. Agent i 's expected utility associated with the mixed strategy profile (τ_i, τ_{-i}) of all agents is thus given by

$$(15) \quad EU_i(\tau_i, \tau_{-i}) = \sum_{[t_i, t_{-i}] \in T^4} \prod_{j \in \{a, b, c, d\}} \tau_j(t_j) \left(\sum_{A \in \mathbb{A}} m[t_i, t_{-i}](A) \cdot u_i(A) \right),$$

where τ_{-i} and t_{-i} , respectively, collect the mixed strategies of and the messages from the agents other than i . A mixed strategy Nash equilibrium of M is a collection $[\tau_a^*, \tau_b^*, \tau_c^*, \tau_d^*]$

¹⁵To be sure, the principal has a belief about the social network structure realized in her staff, represented by a probability density $f : [-1, 1]^6 \rightarrow \mathbb{R}$ on the set of feasible combinations of degrees of altruism. In what follows, the essential assumption is that $f(x) > 0$ for all $x \in (-1, 1)^6$.

¹⁶For the purpose of this Section, it suffices to concentrate on social networks for which the profit maximizer A^* is unique.

of mixed strategies such that $EU_i(\tau_i^*, \tau_{-i}^*) \geq EU_i(\tau_i, \tau_{-i}^*)$ for all τ_i available to each $i \in \{a, b, c, d\}$.

As an example, consider the way teachers tend to form soccer teams during sports classes: The teacher announces two students who then, by turns, select their preferred class mates out of those still unselected. Within the model framework, the following mechanism \overline{M} provides agents $\{a, b, c, d\}$ with equivalent incentives. The principal randomly assigns one agent i who then selects his preferred team mate and, thereby, dictates the composition of the remaining team; agent i then decides whether every team is to be paid for their own team output or whether the incentives are to be pooled. That is, $\overline{m}[t'_i, t_{-i}](A') = 1$ for all t_{-i} if and only if assignment A' is most preferred by i according to the announced preference ordering t'_i . In this case, agent i has a weakly dominant strategy in announcing one of those preference orderings in T that rank his truly preferred assignment first. The mixed strategies τ_{-i}^* of the agents other than i can be chosen arbitrarily, since they do not affect the outcome.

In the following, I show that team assignment that is unanimously preferred by all the agents *might not* maximize the principal's profit. As soon as the social network is asymmetric, subjective well-being on the one hand, and material efficiency on the other, can collide. This potential divergence negates the existence of a delegation mechanism that *ensures* maximum overall productivity and maximum profit for the principal.

The results of Sections 3 and 4 indicate that the uninformed principal cannot rule out any of the four team assignments in \mathbb{A} when she seeks to maximize her profit. Since she wants to *ensure* maximum profit, M must not preclude any feasible team assignment from being implemented with certainty. Formally:

Condition 1 *For any $A' \in \mathbb{A}$, there exists at least one collection of messages $t' \in T^4$ for which the respective density function $m[t']$ satisfies $m[t'](A') = 1$.*

Condition 1 implies that, if there is a social network for which a specific team assignment $A' \in \mathbb{A}$ is Pareto dominant for the group of agents, then M implements A' in (some) Nash equilibrium. But with A' being Pareto dominant, and given (15), the following strategy profile does constitute a Nash equilibrium: If t' satisfies $m[t'](A') = 1$, then $\tau_i(t'_i) = 1$ for each agent i .

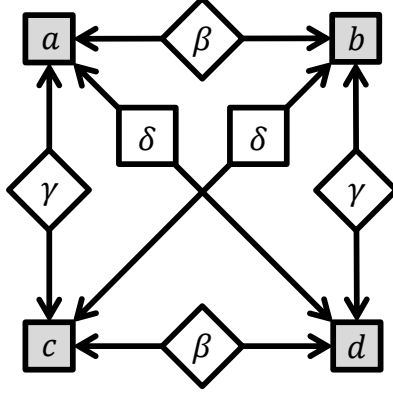


Figure 6: If $\beta > \gamma > \delta$, the efficient team assignment is $[(ab)(cd)]$. If $\beta + \gamma + \delta < -1$, however, the agents unanimously prefer $[(ad)(bc)]$. Each delegation mechanism would implement $[(ad)(bc)]$.

Proposition 4 *There is no delegation mechanism that, for any social network, ensures the profit maximizing composition of teams.*

Proof. In light of Condition 1, it suffices to identify a social network that provides all the agents with a unanimous preference for an assignment $A' \neq A^*$.

Consider the social network in Figure 6. For $\beta, \gamma, \delta \in (-1, 1)$, assume $\beta > \gamma > \delta$. According to Proposition 1, $A^* = [(ab)(cd)]$. Behold the symmetry of this network. Let π_β , π_γ , and π_δ denote every agent's material wealth in $[(ab)(cd)]$, $[(ac)(bd)]$, and $[(ad)(bc)]$, respectively. Let π_4 denote every agent's material wealth in 4 -assignment $[(abcd)]$. Every agent i then realizes utility $u_i = (1 + \beta + \gamma + \delta) \pi_\beta$ in $[(ab)(cd)]$, utility $u_i = (1 + \beta + \gamma + \delta) \pi_\gamma$ in $[(ac)(bd)]$, utility $u_i = (1 + \beta + \gamma + \delta) \pi_\delta$ in $[(ad)(bc)]$, and utility $u_i = (1 + \beta + \gamma + \delta) \pi_4$ in $[(abcd)]$. Notice that $\pi_\beta > \pi_\gamma > \pi_\delta > 0$. Now assume $\beta + \gamma + \delta < -1$. Thus, $M_i < 0$ for each i and, by (13), $\pi_4 = 0$. In this case, each agent i 's preference ordering is given by

$$(16) \quad [(abcd)] \succ_i [(ad)(bc)] \succ_i [(ac)(bd)] \succ_i [(ab)(cd)].$$

Hence, A^* is least preferred: The desired mechanism does not exist. ■

The counter examples presented in this proof are not just artifacts; they do not involve the effort cost function and its effects on equilibrium effort choices. Furthermore, since all inequalities in the proof of Proposition 4 are strict, it is easy to see that the counter examples hold when adding a little, independently distributed noise to each degree of

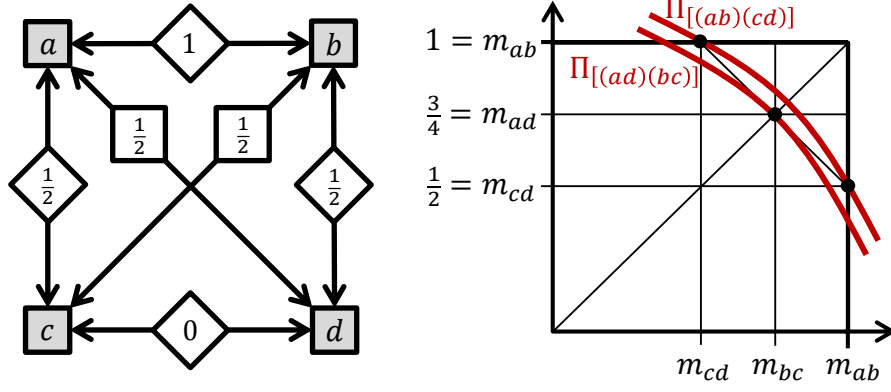


Figure 7: A social network in which no two agents are spiteful toward one another and a production process for which marginal effort costs and thus the principal's isoprofit curves are concave but nearly linear. The agents unanimously prefer $[(ac)(bd)]$, or $[(ad)(bc)]$, while the principal prefers $[(ab)(cd)]$.

altruism in the network of Figure 6. Nevertheless, these social networks might appear unrealistic, or ‘unlikely’: Since $\beta + \gamma + \delta < -1$, they all contain at least two dyads engaged in conflict (spite).

However, it is not necessarily spite that rejects the existence of a delegation mechanism yielding efficient team assignment: Loosely speaking, it is rather the social network's (potential) asymmetry that rejects the existence of such a mechanism. In the absence of spite, this asymmetry concerns configurations of the form $\delta_{ab} > \delta_{ac}, \delta_{ad}, \delta_{bc}, \delta_{bd} > \delta_{cd}$.

Proposition 5 *Even in the absence of spite, the social network and the costs of effort can be such that agents unanimously prefer a team assignment that yields inefficient production overall.*

Proof. Consider the social network of Figure 7. By Proposition 3, $[(abcd)]$ need not be considered to justify the argument. Notice that $[(ac)(bd)]$ and $[(ad)(bc)]$ are equivalent by symmetry. Suppose $C_{xxx} < 0$. By Proposition 2, the principal prefers $[(ab)(cd)]$.

Choose $C_x(x) = x^{1/\kappa}$, with $\kappa > 1$. Thus, $C_x^{-1}(m_{ij}w) = m_{ij}^\kappa w^\kappa$. Then each member of a team (ij) realizes material wealth

$$(17) \quad \pi_i(m_{ij}) = \frac{w^{1+\kappa}}{1+\kappa} m_{ij}^\kappa (1 + \kappa - \kappa m_{ij}),$$

which increases in $m_{ij} \in [0, 1]$. Motivations would be $m_{ab} = 1$ and $m_{cd} = \frac{1}{2}$ in $[(ab)(cd)]$, and $m_{ij} = \frac{3}{4}$ in all the other 2 + 2-assignments. Comparison of the respective utilities

from team assignment reveals that each agent prefers $[(ac)(bd)]$ as $\kappa \rightarrow 1$: In $[(ab)(cd)]$, agents a and b each realize utility

$$(18) \quad u_{[(ab)(cd)]}^{a,b} = \frac{w^{1+\kappa}}{1+\kappa} \left[2 + \left(\frac{1}{2} \right)^\kappa \left(1 + \frac{\kappa}{2} \right) \right] \xrightarrow{\kappa \rightarrow 1} \frac{w^{1+\kappa}}{1+\kappa} \cdot \frac{11}{4},$$

and in $[(ac)(bd)]$, they each realize utility

$$(19) \quad u_{[(ac)(bd)]}^{a,b} = \frac{w^{1+\kappa}}{1+\kappa} 3 \left(\frac{3}{4} \right)^\kappa \left(1 + \frac{\kappa}{4} \right) \xrightarrow{\kappa \rightarrow 1} \frac{w^{1+\kappa}}{1+\kappa} \cdot \frac{45}{16} > \frac{w^{1+\kappa}}{1+\kappa} \cdot \frac{11}{4}.$$

In $[(ab)(cd)]$, agents c and d each realize utility

$$(20) \quad u_{[(ab)(cd)]}^{c,d} = \frac{w^{1+\kappa}}{1+\kappa} \left[1 + \left(\frac{1}{2} \right)^\kappa \left(1 + \frac{\kappa}{2} \right) \right] \xrightarrow{\kappa \rightarrow 1} \frac{w^{1+\kappa}}{1+\kappa} \cdot \frac{7}{4},$$

and in $[(ac)(bd)]$, they each realize utility

$$(21) \quad u_{[(ac)(bd)]}^{c,d} = \frac{w^{1+\kappa}}{1+\kappa} 2 \left(\frac{3}{4} \right)^\kappa \left(1 + \frac{\kappa}{4} \right) \xrightarrow{\kappa \rightarrow 1} \frac{w^{1+\kappa}}{1+\kappa} \cdot \frac{30}{16} > \frac{w^{1+\kappa}}{1+\kappa} \cdot \frac{7}{4}.$$

Finally, since motivations (5) in $[(ac)(bd)]$ are greater than motivations (12) in $[(abcd)]$, and since all agents attach positive weight to the wealth of (almost) all other agents, $[(ac)(bd)]$ Pareto dominates $[(abcd)]$.

Notice that even though marginal effort costs are concave, individual material wealth from teamwork (17) is not convex but concave in m_{ij} if $\kappa > 1$ is sufficiently small: Since $m_{ij} \in [\frac{1}{2}, 1]$, we have $\frac{d^2}{dm_{ij}^2} \pi_i = w^{1+\kappa} k m_{ij}^{k-2} [k(1 - m_{ij}) - 1] < 0$ for all $\kappa \in (0, 2)$. Material wealth from team output is therefore inelastic in a team's motivation. With nearly linear marginal costs of effort ($\kappa \rightarrow 1$), the gains of c and d when implementing $[(ac)(bd)]$ instead of $[(ab)(cd)]$ outweigh the respective losses of a and b . Social preferences are such that a and b are willing to sacrifice some of the returns from their joint teamwork in order to support c and d , and c and d prefer a and b to make that sacrifice. ■

Again, the example is robust with respect to the addition of noise to the agents' degrees of altruism, and by the same principle, many more such examples can be constructed.

It would thus be naive to think that, just because all group members value each other's material well-being, team assignment that is unanimously preferred by all group members would coincide with efficient overall production.

6 Conclusion

Efficient team assignment is sensitive to both the determinants of the agents' social network of interpersonal relationships and the shape of individual effort costs. If the marginal costs of effort are convex, team output responds inelastically to an increase in team members' willingness to cooperate; in this case, the principal must focus on separating the least cooperative groups of agents. Conversely, if the marginal costs of effort are concave, team output responds elastically; and the principal must focus on grouping those agents which cooperate most. In any case, team assignment in the agents' social network poses a problem of information to the principal. Neither the pooling of incentives, nor the delegation of team assignment ensure overall efficient production. Even in the absence of spite, agents might unanimously opt for a composition of teams that makes production inefficient. The principal has no option but to acquire information on the interpersonal relationships in the workplace, and intervene in the team assignment process when necessary. The gains or savings acquired from staffing under the awareness of the agents' social network may outweigh the hidden costs of control ([Falk and Kosfeld, 2006](#)) and, in the case of intervention, the forgone motivational effects of delegation ([Charness et al., 2012](#)).

The old-fashioned way of observing the interpersonal relationships at work is to spend time with personnel: watching them, talking to them, observing who joins whom for lunch. But having entered the era of 'big data', another option has evolved. A market has emerged in which firms offer the investigation of individuals' behavior patterns within organizations. These analyses involve linguistics and utilize data traces that employees leave whenever communicating digitally.¹⁷ These strategies of information acquisition are costly. No matter the approach, they require time or cause expenses. This study indicates that staffing managers might have a willingness to pay for information on their employees' interpersonal relationships.

¹⁷For a brief overview see [Hoffmann \(2010\)](#); for a detailed, popular description see [Charnock \(2010\)](#).

APPENDIX

For a proof of Proposition 3, it is convenient to reformulate Proposition 2. For this purpose, let $x_{i,(ij)}$ denote i 's effort in assignment $[(ij)(kl)]$, as given by (6), and let $x_{i,(abcd)}$ denote i 's effort in assignment $[(abcd)]$, as given by (13).

Lemma 2 *Let w be a fixed piece rate for both teams. Suppose there is a combination of agents, $\{i, j, k, l\} = \{a, b, c, d\}$, such that $m_{ij} + m_{kl} \geq M_i + M_k, M_j + M_l$. And suppose that one of the following conditions is satisfied.*

(i) *Marginal costs of effort are concave, and*

$$(22) \quad \begin{aligned} \max \{m_{ij}, m_{kl}\} &> \max \{ \max \{M_i, 0\}, \max \{M_k, 0\} \}, \\ &\max \{ \max \{M_j, 0\}, \max \{M_l, 0\} \}. \end{aligned}$$

(ii) *Marginal costs of effort are convex, and*

$$(23) \quad \begin{aligned} \min \{m_{ij}, m_{kl}\} &> \min \{ \max \{M_i, 0\}, \max \{M_k, 0\} \}, \\ &\min \{ \max \{M_j, 0\}, \max \{M_l, 0\} \}. \end{aligned}$$

Then $\Pi_{[(ij)(kl)]} > \Pi_{[(abcd)]}$.

Proof. The assumptions imply that $x_{i,(ij)} + x_{k,(kl)} > x_{i,(abcd)} + x_{k,(abcd)}$ and $x_{j,(ij)} + x_{l,(kl)} > x_{j,(abcd)} + x_{l,(abcd)}$. Hence, $\Pi_{[(ij)(kl)]} > \Pi_{[(abcd)]}$. ■

Proof of Proposition 3

Suppose throughout $M_a \geq M_b \geq M_c \geq M_d$. I distinguish between the following cases.

- (A) $0 \geq M_a \geq M_b \geq M_c \geq M_d$.
- (B) $M_a > 0 \geq M_b \geq M_c \geq M_d$, or $M_a \geq M_b > 0 \geq M_c \geq M_d$.
- (C) $M_a \geq M_b \geq M_c > 0 \geq M_d$, and $C_{xxx} < 0$.
- (D) $M_a \geq M_b \geq M_c \geq M_d > 0$, and $C_{xxx} < 0$.
- (E) $M_a \geq M_b \geq M_c \geq M_d > 0$, and $C_{xxx} > 0$.

The case $M_a \geq M_b \geq M_c > 0 \geq M_d$, with $C_{xxx} > 0$, has been discussed in Section 4.

Ad (A): By (7) and (14), $\Pi_{[(ij)(kl)]} \geq 0 = \Pi_{[(abcd)]}$.

Ad (B): By (13), c and d exert zero effort in $[(abcd)]$. Let $j \in \{b, c, d\}$ such that $m_{aj} = \max\{m_{ab}, m_{ac}, m_{ad}\}$, and let $\{k, l\} = \{b, c, d\} \setminus \{j\}$. Then, either $m_{aj} > M_a$ or $m_{ab} = m_{ac} = m_{ad} = 1$. If $m_{aj} > M_a \geq M_b$, Lemma 2 yields

$$\begin{aligned}
 \Pi_{[(aj)(kl)]} &\geq (1-w) [C_x^{-1}(m_{aj}w) + C_x^{-1}(m_{aj}w)] \\
 &> (1-w) [C_x^{-1}(w \max\{M_a, 0\}) + C_x^{-1}(w \max\{M_b, 0\})] \\
 (24) \quad &= \Pi_{[(abcd)]}.
 \end{aligned}$$

If $m_{ab} = m_{ac} = m_{ad} = 1$, then $\delta_{ad} = 1$. In this case, $4M_d \geq 2 + \delta_{bd} + \delta_{cd} \geq 0$. By assumption, $0 \geq M_c \geq M_d$, thus, $M_c = M_d = 0$. Together, $\delta_{ab} = \delta_{ac} = \delta_{ad} = 1$ and $\delta_{bc} = \delta_{bd} = \delta_{cd} = -1$. But then, also $M_b = 0$. Thus, for all $\{j, k, l\} = \{b, c, d\}$, $\Pi_{[(aj)(kl)]} = 2(1-w)C_x^{-1}(1 \cdot w) > (1-w)C_x^{-1}(1 \cdot w) = \Pi_{[(abcd)]}$.

Ad (C): The conditions of this case imply that $1 > M_a$: If $M_a = 1$, then $\delta_{ad} = 1$, and $M_d \geq 0$, a contradiction. Again, d exerts zero effort. Obviously, $m_{aj} < M_a$ for at most one $j \neq a$. I distinguish between (I) $m_{ab}, m_{ac} \geq M_a$, (II) $m_{ab}, m_{ad} \geq M_a$, and (III) $m_{ac}, m_{ad} \geq M_a$.

Consider (I). Assume that $m_{ab} + m_{cd} \leq M_b + M_c$ and $m_{ac} + m_{bd} \leq M_b + M_c$. Summing up both inequalities yields $\delta_{bc} \geq 1$. If $\delta_{bc} < 1$, then this implies that $m_{ab} + m_{cd} > M_b + M_c$ or $m_{ac} + m_{bd} > M_b + M_c$. By assumption, $m_{ab}, m_{ac} \geq \max\{M_a, M_b, M_c, M_d\}$. Obviously, $m_{ab} + m_{cd}, m_{ac} + m_{bd} \geq M_a + 0$. Lemma 2(i) implies that $\Pi_{[(ab)(cd)]} > \Pi_{[(abcd)]}$ or $\Pi_{[(ac)(bd)]} > \Pi_{[(abcd)]}$. If $\delta_{bc} = 1$ instead, then $m_{bc} = 1 > M_a = \max\{M_a, M_b, M_c, M_d\}$. Obviously, $m_{bc} + m_{ad} = 1 + m_{ad} > M_c + 0$. From $M_a \geq M_b$ and $\delta_{bc} = 1$ follows $\delta_{ad} \geq \delta_{bd}$. With this, $m_{bc} + m_{ad} \geq M_a + M_b$. By Lemma 2(i), $\Pi_{[(ad)(bc)]} > \Pi_{[(abcd)]}$.

Consider (II). Assume that $m_{ab} + m_{cd} \leq M_a + M_c$ and $m_{ad} + m_{bc} \leq M_a + M_c$. Summing up both inequalities yields $\delta_{ac} \geq 1$. If $\delta_{ac} = 1$, case (I) applies. If $\delta_{ac} < 1$, then $m_{ab} + m_{cd} > M_a + M_c$ or $m_{ad} + m_{bc} > M_a + M_c$. By assumption, $m_{ab}, m_{ad} \geq \max\{M_a, M_b, M_c, M_d\}$

. Obviously, $m_{ab} + m_{cd}, m_{ad} + m_{bc} \geq M_b + 0$. By Lemma 2(i), $\Pi_{[(ab)(cd)]} > \Pi_{[(abcd)]}$ or $\Pi_{[(ad)(bc)]} > \Pi_{[(abcd)]}$.

Consider (III). Assume that $m_{ac} + m_{bd} \leq M_a + M_b$ and $m_{ad} + m_{bc} \leq M_a + M_b$. Summing up both inequalities yields $\delta_{ab} \geq 1$. If $\delta_{ab} = 1$, case (I) applies. If $\delta_{ab} < 1$, then $m_{ac} + m_{bd} > M_a + M_b$ or $m_{ad} + m_{bc} > M_a + M_b$. By assumption, $m_{ac}, m_{ad} \geq \max\{M_a, M_b, M_c, M_d\}$. Obviously, $m_{ac} + m_{bd}, m_{ad} + m_{bc} \geq M_c + 0$. By Lemma 2(i), $\Pi_{[(ac)(bd)]} > \Pi_{[(abcd)]}$ or $\Pi_{[(ad)(bc)]} > \Pi_{[(abcd)]}$.

Ad (D): Assume, without loss of generality, that $\delta_{ij} + \delta_{kl} \geq \delta_{ik} + \delta_{jl} \geq \delta_{il} + \delta_{jk}$ and $\delta_{ij} \geq \delta_{kl}$ for some combination of agents, $\{i, j, k, l\} = \{a, b, c, d\}$.

We have $m_{ij} + m_{kl} \geq M_i + M_k$, since $2 + \delta_{ij} + \delta_{kl} \geq 2\delta_{ik} + \delta_{il} + \delta_{jk}$ by $\delta_{ij} + \delta_{kl} \geq \delta_{il} + \delta_{jk}$ and $1 \geq \delta_{ik}$. Similarly, $m_{ij} + m_{kl} \geq M_j + M_l$. If, in addition, $\max\{m_{ij}, m_{kl}\} = m_{ij} \geq \max\{M_i, M_j, M_k, M_l\}$, then Lemma 2(i) yields $\Pi_{[(ij)(kl)]} \geq \Pi_{[(abcd)]}$, where $\Pi_{[(ij)(kl)]} = \Pi_{[(abcd)]}$ holds if and only if $\delta_{ij} = 1$ for all $i, j \in \{a, b, c, d\}$. I show in the following that $\Pi_{[(ik)(jl)]} > \Pi_{[(abcd)]}$ if $m_{ij} < \max\{M_i, M_j, M_k, M_l\}$.

If $m_{ij} < \max\{M_i, M_j, M_k, M_l\}$, then at least one of the following inequalities does not hold: (I) $m_{ij} \geq M_i$, (II) $m_{ij} \geq M_j$, (III) $m_{ij} \geq M_k$, (IV) $m_{ij} \geq M_l$. On the other hand, at most one of these inequalities does not hold. To see this, assume that, for instance, (III) and (IV) are not satisfied. Then, adding up yields $m_{ij} + m_{ij} < M_k + M_l$, such that $2 + 4\delta_{ij} < \delta_{ik} + \delta_{il} + \delta_{jk} + \delta_{jl} + 2\delta_{kl}$. Therefore, $4\delta_{ij} < \delta_{ik} + \delta_{il} + \delta_{jk} + \delta_{jl}$, which contradicts $\delta_{ij} + \delta_{kl} \geq \delta_{ik} + \delta_{jl} \geq \delta_{il} + \delta_{jk}$, and $\delta_{ij} \geq \delta_{kl}$. The argument is similar for any other two inequalities among (I)-(IV). Furthermore, $m_{ik} + m_{jl} \geq M_i + M_j$ since $2 + \delta_{ik} + \delta_{jl} \geq 2\delta_{ij} + \delta_{il} + \delta_{jk}$ by $\delta_{ik} + \delta_{jl} \geq \delta_{il} + \delta_{jk}$ and $1 \geq \delta_{ij}$. Similarly, $m_{ik} + m_{jl} \geq M_k + M_l$. I show that $\max\{m_{ik}, m_{jl}\} > \max\{M_i, M_j, M_k, M_l\}$ in all four cases in which exactly one inequality among (I)-(IV) does not hold. Lemma 2(i) then implies that $\Pi_{[(ik)(jl)]} > \Pi_{[(abcd)]}$.

Assume (I) does not hold, $m_{ij} < M_i$. Then, $1 + \delta_{ij} < \delta_{ik} + \delta_{il}$. Therefore, $\delta_{ij} < \delta_{ik}, \delta_{il}$, since $\delta_{ik}, \delta_{il} \leq 1$. By $\delta_{ij} + \delta_{kl} \geq \delta_{ik} + \delta_{jl}$ and $\delta_{ij} < \delta_{ik}$ we have $\delta_{kl} > \delta_{jl}$. By $\delta_{ij} + \delta_{kl} \geq \delta_{il} + \delta_{jk}$ and $\delta_{ij} < \delta_{il}$, we have $\delta_{kl} > \delta_{jk}$. Together, $\delta_{ik}, \delta_{il} > \delta_{ij} \geq \delta_{kl} > \delta_{jk}, \delta_{jl}$. With this, it is easy to see that $\max\{m_{ik}, m_{jl}\} = m_{ik} > \max\{M_i, M_j, M_k, M_l\}$.

Assume (II) does not hold, $m_{ij} < M_j$. Then $\delta_{jk}, \delta_{jl} > \delta_{ij} \geq \delta_{kl} > \delta_{ik}, \delta_{il}$ and $\max\{m_{ik}, m_{jl}\} = m_{jl} > \max\{M_i, M_j, M_k, M_l\}$.

Assume (III) does not hold, $m_{ij} < M_k$. Then, $1 + 2\delta_{ij} < \delta_{ik} + \delta_{jk} + \delta_{kl}$. Thus $1 + \delta_{ij} < \delta_{ik} + \delta_{jk} + \delta_{kl} - \delta_{ij} \leq \delta_{ik} + \delta_{jk}$. Therefore, $\delta_{ij} < \delta_{ik}, \delta_{jk}$ since $\delta_{ik}, \delta_{jk} \leq 1$. Similarly as above, $\delta_{ik}, \delta_{jk} > \delta_{ij} \geq \delta_{kl} > \delta_{il}, \delta_{jl}$. With this, $\max\{m_{ik}, m_{jl}\} = m_{ik} > \max\{M_i, M_j, M_k, M_l\}$.

Assume (IV) does not hold, $m_{ij} < M_l$. Then $\delta_{il}, \delta_{jl} > \delta_{ij} \geq \delta_{kl} > \delta_{ik}, \delta_{jk}$. With this, $\max\{m_{ik}, m_{jl}\} = m_{jl} > \max\{M_i, M_j, M_k, M_l\}$.

In all four cases, Lemma 2(i) yields $\Pi_{[(ik)(jl)]} > \Pi_{[(abcd)]}$.

Ad (E): Assume, without loss of generality, that $\delta_{ij} + \delta_{kl} \geq \delta_{ik} + \delta_{jl} \geq \delta_{il} + \delta_{jk}$ and $\delta_{ij} \geq \delta_{kl}$ for some combination of agents, $\{i, j, k, l\} = \{a, b, c, d\}$. This yields $2(1 + \delta_{ij}) \geq 2(\delta_{ij} + \delta_{kl}) \geq (\delta_{ik} + \delta_{jl}) + (\delta_{il} + \delta_{jk})$. Thus, $m_{ij} + m_{ij} \geq M_i + M_j$ and $m_{kl} + m_{kl} \geq M_k + M_l$. Therefore, $m_{ij} \geq \min\{M_i, M_j\}$ and $m_{kl} \geq \min\{M_k, M_l\}$. By Lemma 2(ii), $\Pi_{[(ij)(kl)]} \geq \Pi_{[(abcd)]}$, where $\Pi_{[(ij)(kl)]} = \Pi_{[(abcd)]}$ if and only if $\delta_{ij} = 1$ for all $i, j \in \{a, b, c, d\}$. ■

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