Ranking Teams*

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Abstract

A principal wants to rank and reward teams in an organization. Agents perfectly observe the local ranking of their teams, and strictly prefer being on higher-ranking teams. I show there exists an ex-post incentive compatible and efficient team ranking mechanism if (i) there is an agent who belongs to every team (supervisor condition), or (ii) whenever two teams share an agent in common, they share at least two agents in common (connectivity condition). I identify a class of organizations for which these conditions are both necessary and sufficient. In the special case where the principal wants to rank every group of co-workers in the organization, there exists a team ranking mechanism if and only if the organizational network is a star.

Keywords: peer mechanisms, teams, organization design.

1 Introduction

Peer-based evaluations are an increasingly popular way to reward individuals and teams alike. For instance, in settings where production is organized in teams, peer assessments may be used to determine which groups of co-workers are most deserving of a prize, which projects require the most funding, or which product teams have the highest potential to generate revenue.[1] At the same time, it is more and more common for employees to work on multiple teams within the same organization, resulting in situations where individuals simultaneously belong to different teams that compete against each other for resources or recognition.[2] Succinctly, these situations have three key features: (i) A principal is interested in ranking teams rather than individuals, (ii) Agents can be in many teams at once, and (iii) Agents benefit from being on higher-ranking teams.

The existing literature on peer mechanisms has exclusively considered comparing individuals.[3] In the standard setting, agents may be asked to nominate, grade, or rank their peers to determine the allocation of a prize. A natural question, then, is how the analysis changes when the focus is shifted from individuals to teams. When can the principal obtain a complete and honest ranking of the teams in her organization? And how does the structure of the organization affect the principal's ability to design a ranking mechanism?

In this paper, I consider the problem of a principal who wants to rank every team in her organization. More specifically, she wishes to get a complete ranking of these teams based on a single unobservable characteristic, such as work ethic, financial need, or productivity. To elicit this information, she asks each agent to report a ranking of his teams. Agents in the organization perfectly observe the local ranking of the teams they are in, and strictly prefer being on higher-ranking teams in order to receive more resources or a better prize.[4]

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[1]For example, at Valve—one of the largest video game companies in the world—employees work on multiple project teams, resources are allocated to project teams exclusively based on peer assessments, and compensation is determined entirely through peer rankings (Puranam and Håkonsson, 2015). Outside of corporate settings, peer evaluations are also frequently used to determine the allocation of prestigious cultural awards. For instance, both the Academy Awards (Oscars) and Grammy Awards rely on peer nominations to recognize individuals (actors, musicians) and teams (production houses, music groups). Notably, neither organization prohibits its members from nominating their own films or songs, and it is not uncommon for artists to have multiple nominations in the same year. Similarly, at MIT's human resources department (as with many other universities), community members can nominate both individuals and teams to win one of its yearly excellence awards (link: https://hr.mit.edu/recognition/excellence).

[2]This phenomenon—often referred to as *multiple team membership*—is remarkably prominent in modern workforces, with some studies estimating the fraction of employees who work on multiple teams at upwards of 90% (O'leary et al., 2011).

[3]See Olckers and Walsh (2024) for a comprehensive survey on peer mechanisms spanning economics and computer science.

[4]Even in the absence of monetary rewards, the disclosure of team rankings can have a significant effect on the performance of individuals and teams (Bandiera et al., 2013).

If aggregating agents' reports fails to yield a complete ordering of teams, the mechanism completes the partial order by arbitrarily ranking the remaining teams.

The concern for manipulation stems from the fact that, if agents are indifferent to permutations of their teams' ranks, they may be willing to decrease one of their teams' ranks if it leads to a more-than-proportional increase in another of their teams' ranks. Concretely, agents can manipulate the ranking either by completing an incomplete order, or by creating an incompletion and forcing an arbitrary ranking of teams in their favor. Notably, this type of misreporting differs from manipulation in individual peer evaluation problems, where agents typically have a direct incentive to exaggerate their ranking relative to their neighbors', as well as an indirect incentive to under-evaluate agents who are likely to win the prize.

My main result (Theorem 1) identifies two simple sufficient conditions for the existence of a team ranking mechanism that are likely to be met by many real-world organizations: either there exists an agent who is a member of every team (a supervisor, or manager condition), or, whenever two teams share an agent in common they share at least two agents in common (a connectivity condition). In the first case, the principal can exclusively consider the central agent's report simply because he belongs to every team in the organization and is therefore indifferent to how they are ranked. Importantly, the latter of these conditions allows the principal to detect that *some* agent in the organization is lying, but does not provide enough structure to identify *which* agent is lying. Furthermore, since the mechanism outputs a relative ranking of teams, the principal cannot punish all agents when she receives inconsistent reports. To address this, I design a punishment scheme that first detects a pair of colleagues as potential liars, and then penalizes both individuals by down-ranking all of their mutual teams.

As an extension, I consider what would happen if the principal wanted to implement a team *selection* mechanism that awards a prize only to the highest-ranking teams in the organization. Here, agents aim to maximize the number of winning teams they are on. Despite this change in objectives, I verify that the punishment scheme proposed above is still enough to deter agents from lying. Next, I identify a class of organizations for which the sufficient conditions in Theorem 1 are also necessary for the existence of a team ranking mechanism. Interestingly, this class includes organizations that are commonly observed in practice, such as hierarchical structures and core-periphery models.

To conclude, I consider a special case of the problem in which the principal wants to rank every group of *co-workers* in the organization, represented by cliques (complete subgraphs) in the organizational network. Although more limited in scope, this application lends itself to the use of clean network-based arguments and yields a sharp characterization of admissible

organizations. Specifically, I prove that unless the organizational network is shaped like a star, there is no ex-post incentive compatible and efficient mechanism that ranks every group of co-workers (Proposition 3). I also show that this negative result is essentially unchanged if the principal were to implement a team selection mechanism instead.

Related Literature. This paper directly contributes to an emerging literature at the intersection of peer evaluations and social networks, in which agents can only evaluate those they share a connection with (Baumann, 2023; Baumann and Dutta, forthcoming; Babichenko et al., 2020; Bloch and Olckers, 2021, 2022). Within this literature, I largely follow the approach in Bloch and Olckers (2022), where a principal wishes to extract a complete and ordinal ranking of agents in a social network. Their main finding is that a mechanism exists if and only if every pair of friends has a friend in common. In contrast to prior work in this area, I focus exclusively on the problem of ranking *teams* of agents, which leads to fundamentally different conclusions. For instance, in the application considered in Section 4, I show that the star graph is the unique network where the principal can rank all co-workers, a restrictive result when compared with friend-based rankings.

More broadly, this paper is related to the literature on impartial peer mechanisms initiated by Amorós et al. (2002), De Clippel et al. (2008) and Holzman and Moulin (2013) in economics, and Alon et al. (2011) in computer science. Thematically, this literature encompasses a wide range of design issues, including the analysis of peer nomination rules (Fischer and Klimm, 2014; Tamura and Ohseto, 2014; Mackenzie, 2015; Edelman and Por, 2021), peer evaluation systems (De Alfaro and Shavlovsky, 2014; Kurokawa et al., 2015; Aziz et al., 2016, 2019; Dhull et al., 2022), and most pertinent to us, peer ranking mechanisms (Kahng et al., 2018; Xu et al., 2019; Alcalde-Unzu et al., 2022; Lev et al., 2023; Amorós, 2023). While the majority of these works consider strategy-proof mechanisms, I find that even ex-post incentive compatibility is difficult to sustain in many organizations, suggesting large differences in the incentive environment. To the best of my knowledge, this is the first paper to consider situations where agents evaluate their teams rather than their peers.

The paper is arranged as follows. Section 2 describes the team ranking problem. Section 3 presents the main results on team ranking mechanisms, and Section 4 discusses an application to networks. Section 5 offers concluding remarks. All proofs are in the Appendix.

2   Model

An organization $(N, \mathcal{G})$ consists of a finite set of agents $N = \{1, ..., n\}$ and a finite set of teams $\mathcal{G} = \{G_1, ..., G_m\}$, each element of which is a set of two or more agents. To ensure

that all teams are potentially comparable, we assume that for every pair (G_l, G_m), there is an agent i such that $i \in G_l, G_m$, or a sequence of teams $G_l = G_1, ..., G_M = G_m$ and agents $i^1, ..., i^{M-1}$ such that $i^k \in G_k, G_{k+1}$ for $k = 1, ..., M - 1$. Let $\mathcal{G}^i = \{G_k \in \mathcal{G} | i \in G_k\}$ denote the set of teams that agent i belongs to, and we assume $|\mathcal{G}^i| \geq 1$ for every i.

Each team G_l possesses a single characteristic of interest, $\delta_l \in \mathbb{R}$, and we assume that there are no ties: $\delta_l \neq \delta_m$ for any distinct teams (G_l, G_m). Practically, δ_l could represent a team's synergy, work-ethic, or financial need. Conceptually, a team's characteristic can be entirely distinct from the characteristics of the agents in the team. For instance, a team may surpass another in its share of skilled agents while being less productive due to a lack of chemistry. Likewise, a team's financial need may be orthogonal to the financial situations of its members.

The analysis is purely ordinal. Based on the vector of characteristics δ, there exists a true and complete ranking of teams, $\succ_\delta$, that sorts all the teams in $\mathcal{G}$ in descending order of their characteristic values. For example, $\succ_\delta$ could correspond to the objective ranking of teams' financial needs in an organization. Importantly, the principal does not observe $\succ_\delta$, and her goal is to reconstruct as much of this ranking as possible by eliciting information directly from each agent in the organization.

Agents do not directly observe the characteristics of their teams, but perfectly observe the local ranking of their teams. For example, if an agent belongs to the 3rd and 7th highest-performing teams in the organization, he only observes that the former team performs better than the latter. For any agent i and any pair of teams (G_l, G_m), let $t^i_{lm} = 1$ if agent i observes $\delta_l > \delta_m$, $t^i_{lm} = -1$ if he observes $\delta_l < \delta_m$, and $t^i_{lm} = 0$ if he cannot compare teams G_l and G_m. The last scenario can arise if agent i is part of team G_m but not G_l, G_l but not G_m, or neither G_m nor G_l. Agent i's type is summarized by the matrix $T^i = [t^i_{lm}]$. Aggregating these matrices across agents, the vector $\mathbf{T} = (T^1, ..., T^n)$ contains all the information available on team rankings in the organization.

Based on $\mathbf{T}$, one can define a partial order $\succ_{\mathbf{T}}$ corresponding to the portion of the true ranking $\succ_\delta$ that can be inferred from agents' local observations. Formally, $\succ_{\mathbf{T}}$ is the transitive closure of $\mathbf{T}$ after removing all inconsistent reports, which is obtained as follows: for any pair of teams (G_l, G_m), let $G_l \succ_{\mathbf{T}} G_m$ if $t^i_{lm} \neq -1$ for all agents i, there is no sequence of comparisons indicating $\delta_m > \delta_l$ by transitivity, and there exists either an agent i reporting $t^i_{lm} = 1$ or a sequence of comparisons indicating $\delta_l > \delta_m$ by transitivity.

To consider a simple example, suppose we were only given three teams G_l, G_m, G_n and two reports $t^i_{lm} = t^j_{mn} = 1$. In this example, agent i observes that G_l ranks above G_m, and agent j observes that G_m ranks above G_n. Using transitivity, the resulting order $\succ_{\mathbf{T}}$ would be $G_l \succ_{\mathbf{T}} G_m \succ_{\mathbf{T}} G_n$. Now imagine that for the same set of teams, we were faced with

three reports, $t^i_{lm} = 1$, $t^j_{mn} = 1$ and $t^k_{mn} = -1$. In this situation, agent i still ranks G_l above G_m, but agents j and k are providing contradictory comparisons of G_m, G_n. In this case, the resulting order $\succ_{\mathbf{T}}$ will be a partial order $G_l \succ_{\mathbf{T}} G_m$ that does not specify a ranking for G_m, G_n. In fact, even in the absence of conflicting reports, $\succ_{\mathbf{T}}$ may still be a partial order. That is, even if the principal had access to every agent's true information, she may still be unable to recover $\succ_\delta$ in its entirety depending on the structure of the organization (see Example 1).

To determine the final ranking of teams, the principal commits to a *team ranking mechanism* σ that associates to every report vector $\mathbf{T}$ a complete ranking of teams, $\sigma(\mathbf{T})$.

Definition 1. *A team ranking mechanism is a function $\sigma : \times_i \mathcal{T}^i \to \mathcal{S}$, where $\mathcal{T}^i$ is the set of matrices consistent with what agent i can observe given $\mathcal{G}^i$, and $\mathcal{S}$ is the set of all complete orderings on $\mathcal{G}$.*

Mechanically, this procedure assigns a rank σ_j to each team G_j, where the worst rank is $\sigma_j = 1$ and the best rank is $\sigma_j = |\mathcal{G}|$. In a similar fashion, I define the rank of an agent i who is part of k teams as the ordered vector $\sigma^i = (\sigma_1, \sigma_2, ..., \sigma_k)$, where $\sigma_1, \sigma_2, ..., \sigma_k$ are sorted from highest-ranked to lowest-ranked. Agent preferences, $\succ_i$, are defined over the ordered rank vectors σ^i, and are strongly monotonic:

$$\text{if } \sigma^i \geq \tilde{\sigma}^i, \text{ and } \sigma^i \neq \tilde{\sigma}^i, \text{ then } \sigma^i \succ_i \tilde{\sigma}^i$$

Thus, an agent i prefers σ^i over $\tilde{\sigma}^i$ if the highest ranked team in σ^i is at least as highly ranked as the highest ranked team in $\tilde{\sigma}^i$, the second-highest ranked team in σ^i is at least as highly ranked as the second-highest ranked team in $\tilde{\sigma}^i$, etc. with at least one of these comparisons holding strictly.

Notice that although agents only care about the teams they belong to, their preferences ultimately depend on the entire ranking of teams, as determined by the mechanism σ. At the same time, agents are indifferent to permutations of ranks among their own teams.[5] To illustrate this, suppose that there are three teams G_l, G_m, G_n in the organization, and an agent i who belongs to both G_l and G_n. Agent i's preferences clearly depend on the entire ranking of teams since, for example, he prefers the ranking $G_l \succ G_m \succ G_n$ over the ranking $G_m \succ G_l \succ G_n$. However, holding G_m's position fixed, agent i is indifferent between G_l being ranked above G_n, and G_n being ranked above G_l. For example, agent i is indifferent

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[5]This is a reasonable assumption when prizes are not divided among team members, and do not depend on group size. For instance, a principal might distribute a bonus payment to every member of a winning team, assign winning teams to more desirable projects, or supply a public good that can be enjoyed by all team members.

between the ranking $G_l \succ G_m \succ G_n$ and the ranking $G_n \succ G_m \succ G_l$, since in both cases, he is on the first and last team.

It is also worth noting that strong monotonicity is not required for any of the results. Rather, it is the "weakest" condition on preferences with which I am able derive the main results. The proofs remain valid if agents have lexicographic preferences, value the minimum team rank, the sum of team ranks (in case of monetary prizes), or the average team rank (in case of qualitative rewards).[6]

Throughout the paper, I consider the design of team ranking mechanisms that satisfy the following properties.

Definition 2. *A team ranking mechanism σ is ex-post efficient if for any pairs of teams (G_l, G_m) and any truthful report vector $\mathbf{T}$:*

$$\text{if } G_l \succ_{\mathbf{T}} G_m, \text{ then } \sigma_l(\mathbf{T}) > \sigma_m(\mathbf{T})$$

Definition 3. *A team ranking mechanism σ is ex-post incentive compatible if for any agent i, any vector $\mathbf{T} = (T^i, T^{-i})$, and any alternative report $\tilde{T}^i$:*

$$\sigma^i(T^i, T^{-i}) \succsim_i \sigma^i(\tilde{T}^i, T^{-i})$$

In this context, ex-post efficiency can be understood as an accuracy condition, which states that the mechanism should respect all non-contradictory reports in $\mathbf{T}$. Put differently, the ranking assigned by σ should always be a completion of $\succ_{\mathbf{T}}$ when agents report truthfully. Ex-post incentive compatibility states that for every agent, truthful reporting must be a weakly dominant strategy against every other agent's truthful report. The stronger notion of strategy-proofness would require that truthful reporting be a weakly dominant strategy against *every* possible strategy profile. As the results suggest, strategy-proofness is likely too demanding in this setting, since even ex-post incentive compatibility requires the use of nontrivial punishment schemes.

3 Results

As a starting point, it is useful to ask: when would the principal be sure to extract a complete ranking of teams if agents did report truthfully? As the next example illustrates, even if the principal had access to every agent's local observations, she may still be unable to compare

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[6]One exception is if agents have max preferences, in which case Proposition 3 would change slightly: both the triangle and the star admit a team ranking mechanism.

certain teams in the organization.

Example 1 (Uninformative Organization). *Consider an organization consisting of four agents working in three teams, $\{i, j\}, \{j, k\}, \{k, l\}$, whose characteristics are denoted by $\delta_1, \delta_2, \delta_3$, respectively. Now consider the following realization of team characteristics: $\delta_2 > \delta_3 > \delta_1$. Only agents j and k possess ordinal information, and in this case, agent j observes $G_2 \succ_{T^j} G_1$ while agent k observes $G_2 \succ_{T^k} G_3$. Overall, the information in $\mathbf{T}$ does not allow us to rank (G_1, G_3) using transitivity.*

Accordingly, let us call an organization $(N, \mathcal{G})$ *informative* if for any realization of δ, the information in $\mathbf{T}$ results in a complete order $\succ_{\mathbf{T}}$. Our first observation is that this condition is met if and only if every pair of teams has an agent in common, since otherwise, one can find a realization of characteristics for which some teams cannot be compared.[7]

Lemma 1. *An organization is informative if and only if every pair of teams shares an agent in common.*

With this in mind, when can the principal design an ex-post incentive compatible and efficient team ranking mechanism? In this setting, agents can manipulate the ranking in one of two ways: either by completing a partial ranking, or by making two teams that were originally comparable, uncomparable. The former of these situations is depicted in the following example.

Example 2 (Manipulation by Completion). *Consider the uninformative organization described in Example 1, and the same realization of team characteristics, $\delta_2 > \delta_3 > \delta_1$, which prevents us from comparing (G_1, G_3). Since the mechanism must map any vector $\mathbf{T}$ to a complete order, the principal has to assign an arbitrary ranking to G_1 and G_3 while respecting G_2's relative ranking in $\succ_{\mathbf{T}}$. Without loss of generality, suppose that if the principal is unable to compare two teams, she assigns a higher rank to the team with the highest index. Under truthful reporting, agent j is on the first team (team G_2) and the third team (team G_1). Notice, however, that agent j stands to gain from misreporting, assuming that k's report is truthful. By switching his report from $G_2 \succ_{T^j} G_1$ to $G_1 \succ_{\tilde{T}^j} G_2$, the principal now obtains a complete order $G_1 \succ_{\tilde{\mathbf{T}}} G_2 \succ_{\tilde{\mathbf{T}}} G_3$, that puts j on the first and second team.*

Here, the scope for manipulation is jointly determined by the specific realization of δ and the arbitrary ranking rule that the principal commits to. While this type of manipulation is

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[7]The same argument appears in Bloch and Olckers (2022) in the context of constructing a complete ranking of individuals in a social network. To ensure that aggregating local comparisons always results in a complete ordering of individuals—a property they term *completely informative*—they show that every pair of individuals in the network must either be connected or have a mutual connection.

restricted to relatively few agents, the principal lacks the means to detect the deviator when both his truthful report and untruthful report result in a plausible ranking of teams. As the next example shows, the issue of detection is not limited to uninformative organizations that are prone to incomplete rankings.

Example 3 (Manipulation by Cycle). *Consider an organization consisting of three agents that work in pairs, $\{i,j\}, \{j,k\}, \{i,k\}$, with team characteristics $\delta_1, \delta_2, \delta_3$. First, note that this organization is informative, as every pair of teams shares an agent in common. Thus, if agents report truthfully, the principal should obtain a complete ranking of teams. Nevertheless, the principal must commit to a rule that arbitrarily ranks G_2, G_1, G_3 whenever $\succ_{\mathbf{T}}$ features a cycle, and in this example, assume that she imposes $G_1 \succ G_2 \succ G_3$ when this happens. Now consider the following realization of δ: $\delta_1 > \delta_3 > \delta_2$. The only agent capable of creating a cycle is j by announcing $G_2 \succ_{\tilde{T}^j} G_1$. Holding i, k's announcements truthful, the vector $\tilde{\mathbf{T}}$ would produce the following cycle: $G_1 \succ_{\tilde{\mathbf{T}}} G_3 \succ_{\tilde{\mathbf{T}}} G_2 \succ_{\tilde{\mathbf{T}}} G_1 \succ_{\tilde{\mathbf{T}}} G_3 \succ_{\tilde{\mathbf{T}}} \dots$ To see that agent j prefers lying, note that due to the principal's arbitrary ranking, he is now in the first team (team G_1) and second team (team G_2), instead of being on the first and third team.[8] Crucially, the principal cannot infer who lied, since each individual report contradicts the other two reports regarding G_1, G_2, G_3.*

In the examples above, the principal's inability to detect the deviator is due to the fact that every pair of teams is comparable by at most one agent. If teams had multiple overlapping members, the principal could detect contradictory reports and punish agents who send conflicting rankings—a common technique in peer selection. In line with this reasoning, define an organization $(N, \mathcal{G})$ to be *highly-connected* if whenever two teams share an agent in common, they share at least two agents in common.

Clearly, if every pair of teams is observed by three or more agents, then ex-post incentive compatibility can be easily obtained by verifying each agent's report against that of his two colleagues. Whether truthful reporting can also be incentivized in the weaker case of highly-connected organizations, however, is less obvious. To this end, I first introduce the following definitions. We say that an agent i's report *disagrees* with agent j if for some pair (G_l, G_m) we have $t_{lm}^i \neq t_{lm}^j$ and $t_{lm}^i, t_{lm}^j \neq 0$. Now let us say that an agent is *detected* as a potential liar if his report disagrees with at least one agent in the organization, and that he is *identified* as a liar if his report disagrees with two or more agents in the organization. For example, an agent can be identified as a liar if his report disagrees with two other agents on

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[8]The argument does not rely on a specific arbitrary rule. Fixing a rule that ranks $G_l \succ G_m \succ G_n$ in case of a cycle, we can find a realization where G_l is first and G_m is third in the ranking, and the agent who belongs to both G_l, G_m can create a cycle to his benefit.

one single pair of teams, or if his report disagrees with two separate agents on two separate pairs of teams. With these notions in mind, I construct the following mechanism.

Mechanism. If there are no conflicting reports in $\mathbf{T}$, the mechanism assigns ranks according to $\succ_{\mathbf{T}}$ and completes this partial order using the principal's arbitrary rule if necessary. If there are conflicting reports in $\mathbf{T}$, then there must be at least two detected agents, and we proceed by cases:

(i) If only a single agent i is identified as a liar, the principal completely discards his entire report T^i (including those comparisons made by i which were not in conflict with other reports). Formally, the mechanism assigns ranks according to $\succ_{\mathbf{T} \setminus T^i}$ and completes the partial order using the principal's arbitrary rule if necessary.

(ii) If only a single pair of agents (i, j) is detected but neither one of them is identified as a liar, this means that they must disagree on the ranking of some teams $\mathcal{G}' \subset \mathcal{G}$, but neither i nor j disagrees with other agents in the organization. In such cases, the mechanism implements the following punishment scheme: it punishes both i and j by assigning to their mutual teams $\mathcal{G}^{i \cap j} = \{G_k \in \mathcal{G} \mid G_k \in \mathcal{G}^i \cap \mathcal{G}^j\}$ the lowest ranks $1, ..., |\mathcal{G}^{i \cap j}|$, and assigns all other relative ranks according to $\succ_{\mathbf{T} \setminus T^i, T^j}$ and the principal's arbitrary rule if needed.[9]

(iii) In all other cases, the mechanism assigns ranks in any arbitrary manner.

A few features of the mechanism are worth commenting on. First, note that since we are looking to achieve ex-post incentive compatibility (rather than strategy-proofness) we only ever need to worry about a single agent deviating from his truthful report at any given time. In other words, the mechanism must provide enough incentive for each agent to report truthfully assuming that every other agent in the organization is reporting truthfully. Second, note that if a single agent i chooses to deviate in a highly-connected organization, the mechanism will (mechanically) detect both i and some other agent j as potential liars. This is simply because i's non-truthful report must disagree with at least one of his colleagues on at least one pair of teams.

Thus, in highly-connected organizations, any single-person deviation will result in at least one pair of detected agents (i, j). If the deviator i contradicts another agent k in the organization, then he will be immediately identified as a liar and his entire report will

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[9]Notice that the mechanism punishes $\mathcal{G}^{i \cap j}$, because in general, it may not be feasible to assign the lowest ranks to $\mathcal{G}^i \cup \mathcal{G}^j$ since we might have $\mathcal{G} = \mathcal{G}^i \cup \mathcal{G}^j$. Moreover, the exact order of ranks assigned to the teams in $\mathcal{G}^{i \cap j}$ does not matter, since i, j both belong to all of these mutual teams.

be ignored by the principal. If the deviator i is not identified, then there are exactly two detected agents i, j, neither of whom is identified by the mechanism. In this case, the mechanism implements the punishment scheme described above, according to which all of i, j's mutual teams are assigned the lowest ranks possible. Since these are the only two cases that can arise from a single-person deviation, all other cases can be dealt with arbitrarily.

The main result identifies two easy-to-check sufficient conditions for the existence of an incentive compatible and efficient team ranking mechanism.

Theorem 1. *An organization* $(N, \mathcal{G})$ *admits an ex-post incentive compatible and efficient team ranking mechanism if one of the following holds:*
(i) There is an agent who belongs to every team.
(ii) The organization is highly-connected.

The first condition says that, generally, if there is a central agent who belongs to every team in the organization, the principal can solely rely on that agent's report and discard all other reports from her ranking. Intuitively, if an individual is a member of all teams then his payoff is unaffected by their relative ranking, which eliminates any incentive to misreport. Loosely speaking, this is akin to settings where a manager oversees all units in an organization and provides comparative evaluations across them.

The second condition says that, even the absence of a central agent, the principal can deter agents from misreporting if the organization is sufficiently connected. Ideally, the principal would directly punish (or ignore) an agent who tries to manipulate the ranking. Reiterating the earlier discussion, however, even if agents have perfectly correlated signals about their teams, the principal might be unable to distinguish whether an agent, or his colleague, is lying. When this happens, the mechanism penalizes both the agent and his colleague by down-ranking all of their mutual teams. The key step in the proof is to show that the outcome from this punishment is bad enough to dissuade agents from deviating.

On a practical note, should the conditions in Theorem 1 be viewed as permissive? In particular, how "connected" are teams in a typical organization? While the exact fraction of teams with overlapping members may be difficult to observe in survey data, one possible way to proxy for it is to consider the number of teams that employees belong to, on average. As evidence, several studies have noted that it is extremely common for employees to work simultaneously on multiple teams in their organization. In fact, this empirical finding has been documented across a wide range of industries, including primary care units in the United States (Crawford et al., 2019), research and development projects in Italy (Bertolotti et al., 2015), private-sector firms in Germany (Berger et al., 2022), applied research teams in the Netherlands (van de Brake et al., 2018), and retail chains, where a substantial fraction

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of managers concurrently work at different stores (Metcalfe et al., 2023). In a similar vein, it now increasingly common for academic economists to publish co-authored papers, suggesting a high degree of connectedness between research teams in the profession (Jones, 2021). Overall, these patterns point to the fact that cross-team connectedness is likely a common feature of many modern organizations.

Another practical consideration is whether this result is robust to coarser ranking environments. For instance, if a manager is undergoing a restructuring effort, she may only be able to retain the top-performing teams in her department. In another extreme scenario, a principal may only award a prize to the single most deserving team in her organization. To capture such situations, suppose that instead of assigning gradual prizes based on a fine ranking, the principal implements a *team selection mechanism* that simply assigns a prize to the k highest-ranking teams in $\mathcal{G}$—similar in spirit to Lev et al. (2023) and Bloch and Olckers (2021). The next result asserts that Theorem 1 also applies to team selection mechanisms.

Proposition 1. *The conditions in Theorem 1 are sufficient to implement a team selection mechanism that awards a prize to the k highest-ranking teams.*

In a team selection problem, an agent i prefers σ^i over $\tilde{\sigma}^i$ if and only if the number of teams with rank $\sigma_j \geq m - k + 1$ is greater in σ^i than in $\tilde{\sigma}^i$ (where $m = |\mathcal{G}|$). Critically, however, the proof of Theorem 1 establishes that a deviating agent cannot improve the relative rank of *any* of his teams, which directly implies that this result extends to team selection mechanisms. The next example confirms that the conditions stated in Theorem 1 are indeed sufficient but not necessary for a mechanism to exist.

Example 4 (Counterexample). *Consider an organization consisting of five agents arranged in three teams $\{i, j, k\}, \{i, l, m\}, \{j, k, l, m\}$. Clearly, this organization satisfies neither condition in Theorem 1. This is also an informative organization, since every pair of teams shares an agent in common. Thus, if agents report truthfully, the principal always extracts a ranking that is free of incompletions and cycles. Now observe that agents j, k, l, m can never profitably misreport: the only realizations of δ for which they can misreport are those where they can create a cycle. But if one of them creates a cycle, the principal could infer that he is lying (since his colleague's report would not induce a cycle, and is therefore the true report). The only agent capable of creating a cycle without being detected is agent i, who can locally compare teams $\{i, j, k\}$ and $\{i, l, m\}$. To mitigate this kind of manipulation, the principal can implement a mechanism that flips agent i's report whenever she obtains a cycle with no contradictory reports (inferring that i has lied), and that ignores other agents' reports if they are identified as liars.*

Even when the conditions of Theorem 1 fail, it is possible to deter agents from creating a cycle if the deviator can be detected or inferred. In many organizations, however, this logic will not apply since misreporting does not produce a cycle (see for instance, Example 2). Formally, call an organization *acyclic* if there is no sequence of three or more teams $G_l = G_1, ..., G_M = G_l$ and distinct agents $i^1, ..., i^{M-1}$ such that $i^k \in G_k, G_{k+1}$ for $k = 1, ..., M - 1$. This is the case, for instance, in hierarchical organizations, where teams only share mutual agents with subordinate teams or teams above them in the hierarchy. The condition also applies to core-periphery structures, where a core team is connected to peripheral, specialized teams. For this wide class of organizations, it is natural to ask whether the conditions in Theorem 1 are in fact necessary to design a team ranking mechanism. The next result answers this question in the affirmative.

Proposition 2. *In organizations that are acyclic, the conditions in Theorem 1 are both necessary and sufficient for the existence of an ex-post incentive compatible and efficient team ranking mechanism.*

While acyclic organizations rule out manipulations that produce cycles, they are equally prone to other types of manipulations. Specifically, if neither condition in Theorem 1 holds, then some pair of teams must only share a single agent in common, and no alternative path exists to verify that agent's report. In such cases, this individual can strategically misreport to manipulate the relative ranking of these teams without risk of detection. Therefore, in this class of organizations, incentive compatibility breaks down unless the information is centralized through a common agent, or there is sufficient overlap between teams to allow cross-verification.

4   Application to Networks

To connect these results with the existing literature on peer evaluations in networks, imagine that instead of ranking a designated set of teams, the principal decides to rank every group of co-workers in her organization based on a single group-level characteristic. This situation can arise, for example, if a manager wants to identify the most suitable group of employees for a high-stakes project, or if a grant committee wants to target the most deserving pair of co-authors in a field.

In such environments, it is natural to model an organization as an undirected network g, where an edge is drawn between every pair of co-workers. A group of co-workers is then represented as a clique (complete subgraph) C_l with characteristic δ_l, where we consider each clique to be a team. Given an organizational network g, one can define the set of teams as

the set of all cliques in g with two more nodes, which I denote by $\mathcal{C}$. Abusing notation, we write $i \in C_l$ if agent i is in team C_l, and let $\mathcal{C}^i$ denote all teams that agent i belongs to. The central question becomes: for which networks can the principal design a mechanism that ranks every team?

I refer to an organizational network as informative if every realization of δ results in a complete ranking of the teams in $\mathcal{C}$ according to $\succ_{\mathbf{T}}$. By Lemma 1, we know that if two teams do not share an agent in common, we can find instances of δ for which they cannot be compared. In the context of organizational networks, this observation takes a clean graphical form. First, observe that any connected graph with three nodes is either a triangle or a star, both of which satisfy Lemma 1 since every pair of cliques shares a node in common. If a connected graph has four or more nodes, then unless it is a star, it must have an open path of length three. But in this case, the first and last edge on this path make up two teams that do not share a node in common, which violates informativeness by Lemma 1. Hence, any connected and informative graph of size four or greater must be a star.[10]

Corollary 1. *A network is informative if and only if it is a triangle or a star.*

This lets us tackle team ranking mechanisms on a case-by-case basis. If a network is uninformative, then it must have an open path of length three. In particular, such a path matches the structure featured in Example 2, which makes the organization prone to manipulations by completions. If a network is informative, then it is either a triangle or a star. For the triangle, a slight modification of Example 3 shows that certain agents can create a cycle and improve their rank by doing so. Lastly, if the network is a star, it features a central node who belongs to every team, therefore satisfying the first condition of Theorem 1. These observations are captured by the following result, which characterizes the star graph as the uniquely admissible organizational network.

Proposition 3. *A network admits an ex-post incentive compatible and efficient team ranking mechanism if and only if it is a star.*

As we discussed in the previous section, this negative result is driven by the lack of overlapping team comparisons in co-worker networks. This is especially true when ranking consecutive edges in the network, where only a single agent is able to make the comparison. In fact, as the proof makes clear, Proposition 3 applies to any organization in which connected pairs are viewed as teams. Since agents have perfect local observations, the proof is also valid if we allow for any correlation structure between teams. To end this section, I confirm that adopting a team selection mechanism leaves the previous proposition virtually unchanged.

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[10]Comparing this with the first result of Bloch and Olckers (2022), it is clear that every informative network is also completely informative.

Proposition 4. *If σ selects $k > 1$ winning teams, there exists an ex-post incentive compatible and efficient team selection mechanism if and only if the network is a star. If σ selects a single winner, there exists an ex-post incentive compatible and efficient team selection mechanism if and only if the network is a triangle or a star.*

For team selection mechanisms that select two winning teams or more, some agents will be able to increase the number of winning teams they are on by misreporting. When the mechanism only awards a prize to the highest-ranking team, the triangle no longer fails to admit a mechanism. This is because the counterexample previously used to rule out mechanisms in the triangle relies on misreporting that takes the form of a cycle among pairs. However, the only agent capable of producing a cycle must already belong to the highest-ranking pair and therefore has no reason to misreport.

5 Conclusion

This paper discusses the design of team ranking mechanisms when a principal wants to evaluate groups based on a trait she cannot observe. The main message is that agents can manipulate their teams' rankings in ways that differ from individual peer ranking settings. For example, even if agents care about all of their teams' ranks, they may be willing to falsely rank one team below another if it increases the sum of their teams' ranks. If the principal wants to rank an arbitrary set of teams, I propose a punishment scheme that sufficiently deters agents from lying when there is enough overlap between teams. If the principal seeks to rank every group of co-workers in her organization, an impossibility result is obtained: there exists an ex-post incentive compatible and efficient team ranking mechanism if and only if the organizational network is a star. I also show that both results persist if the principal chooses to implement a team selection mechanism instead.

Conceptually, the paper calls attention to a new class of peer mechanism problems—*team evaluation problems*—in which agents are asked to evaluate their teams, rather than their peers. As the analysis illustrates, it is unclear how established results from the peer mechanism literature extend to this new framework. For example, how would reporting behavior change if agents were asked to nominate one of their teams, or to flexibly grade their teams to determine the allocation of resources or prizes? Another especially relevant direction concerns the role of noisy or subjective peer information. While the current model assumes that individuals perfectly observe the relative quality of their teams, many realistic environments will involve imprecise or subjective assessments. In such settings, is it possible to design an impartial but approximately efficient team ranking mechanism? I leave these questions for future research.

A Appendix

A.1 Proof of Lemma 1

Proof. ($\Leftarrow$) Consider an organization $(N, \mathcal{G})$ in which every pair of teams share an agent in common. Then for any two teams (G_l, G_m), we have $t^i_{l,m} = 1, -1$ for some agent i, and the information in $\mathbf{T}$ allows us to order G_l and G_m according to $\succ_{\mathbf{T}}$.

($\Rightarrow$) Let (G_l, G_m) be two teams that do not share a node in common. Since $t^i_{l,m} = 0$ for all i, it is not possible to directly compare (G_l, G_m). The only other way to compare them is indirectly, through transitivity. Following the proof of Lemma 1 in Bloch and Olckers (2022), consider any realization of δ in which δ_l, δ_m are consecutive in the ranking. Such a realization clearly prevents us from comparing G_l, G_m indirectly, thus rendering the pair uncomparable. ∎

A.2 Proof of Theorem 1

Proof. (i) If there is an agent i who belongs to every team, then $\succ_{T^i}$ is a complete order. Moreover, agent i has no incentive to misreport since his rank is constant across any report, i.e. $\sigma^i(T^i) = \sigma^i(\tilde{T}^i)$ for any possible $\tilde{T}^i$. Thus, the mechanism $\sigma(\mathbf{T}) = \succ_{T^i}$ is ex-post incentive compatible and efficient.

(ii) The mechanism described in Section 3 is ex-post efficient by construction. For sake of contradiction, suppose it is not ex-post incentive compatible. Then there exists a highly-connected organization $(N, \mathcal{G})$ and a realization δ for which some agent i can get a higher rank by misreporting $\tilde{T}^i$ instead of truthfully reporting T^i. We obtain a contradiction by establishing a series of claims about the deviator i.

Claim 1. *An agent i who profitably misreports is detected but not identified.*

Proof. This follows from the structure of highly-connected organizations. If agent i lies about the ranking of any pair (G_l, G_m), there is another agent j who belongs to (G_l, G_m) and whose truthful report disagrees with i. The mechanism σ detects both i and j as potential liars. Moreover, agent i cannot be identified by σ, since otherwise, only his report $\tilde{T}^i$ would be discarded, which would violate $\sigma^i(\tilde{T}^i, T^{-i}) \succ_i \sigma^i(T^i, T^{-i})$. Therefore, it must be that agent i's report only disagrees with agent j about some set of teams $\mathcal{G}' \subseteq \mathcal{G}^{i \cap j}$. ∎

Claim 2. *An agent i who profitably misreports about some teams $\mathcal{G}' \subseteq \mathcal{G}^{i \cap j}$ must improve the rank of at least one team $G_k \in \mathcal{G}^i \setminus \mathcal{G}^{i \cap j}$ relative to another team $G_n \in \mathcal{G} \setminus \mathcal{G}^i$.*

Proof. By Claim 1, the mechanism detects i and j but cannot identify which one of them is the liar. As punishment, each team in $\mathcal{G}^{i \cap j}$ receives one of the lowest ranks, $1, ..., |\mathcal{G}^{i \cap j}|$. In other words, agent i is weakly worse off by lying regarding his mutual teams with agent j. But according to our premise, agent i must be made better off by reporting $\tilde{T}^i$:

$$\sigma^i(\tilde{T}^i, T^{-i}) \succ_i \sigma^i(T^i, T^{-i})$$

For this to hold, there must be at least one team $G_k \in \mathcal{G}^i \setminus \mathcal{G}^{i \cap j}$ and another team $G_n \in \mathcal{G} \setminus \mathcal{G}^i$ such that $\sigma_n > \sigma_k$ but $\tilde{\sigma}_k > \tilde{\sigma}_n$. ∎

Claim 3. *An agent i who misreports about some teams $\mathcal{G}' \subseteq \mathcal{G}^{i \cap j}$ cannot affect the relative ranking of a team in $\mathcal{G}^i \setminus \mathcal{G}^{i \cap j}$ with respect to a team outside $\mathcal{G}^i$.*

Proof. Consider any team $G_k \in \mathcal{G}^i \setminus \mathcal{G}^{i \cap j}$ and any other team $G_n \in \mathcal{G} \setminus \mathcal{G}^i$ such that $\sigma_n > \sigma_k$. We show that, holding other agents' reports truthful, any alternative report $\tilde{T}^i$ still yields $\tilde{\sigma}_n > \tilde{\sigma}_k$. If (G_k, G_n) were uncomparable under truthful reporting, they must also be uncomparable when i lies because the principal disregards $\tilde{T}^i$ and T^j, and learns no additional information to compare (G_k, G_n). Therefore she uses the same arbitrary ranking rule and we get $\tilde{\sigma}_n > \tilde{\sigma}_k$. Now suppose that (G_k, G_n) were previously comparable. If G_k and G_n share an agent in common then that same agent correctly ranks them in $\mathbf{T} \setminus \tilde{T}^i, T^{-i}$ and the resulting ranking includes $\tilde{\sigma}_n > \tilde{\sigma}_k$. If G_k and G_n do not share an agent in common, then they must have been previously comparable through a transitive path of comparisons. In other words, there exists a sequence of teams $G_n = G_1, ..., G_M = G_k$ and a sequence of agents $i^1, ..., i^{M-1}$ such that $i^m \in G_m, G_{m+1}$ and $t^{i^m}_{m, m+1} = 1$ for $m = 1, ..., M - 1$. Since the organization is highly-connected, there also exists two agents $i^{1'}$ and $i^{M-1'}$ different from i, j who belong to (G_n, G_2) and (G_{M-1}, G_k), respectively:

$$G_n \succ G_2 \succ ... \succ G_{M-1} \succ G_k$$

The only case to worry about is if the path going from G_n to G_k goes through two of i, j's mutual teams and no other agent is capable of comparing these teams. This case is depicted below, where G_a, G_b are only comparable by i, j:

$$G_n \succ G_a \succ_{T^i, T^j} G_b \succ G_k$$

To resolve this worry, observe that there always exists a shorter path to compare G_n and G_k that goes through at most one of i, j's mutual teams. In the example above, G_a and G_k share agent i in common, and since $G_k \in \mathcal{G}^i \setminus \mathcal{G}^{i \cap j}$ we know that j does not belong to G_k.

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Since the organization is highly-connected, there exists some agent $i' \neq i, j$ who can compare G_a and G_k directly, avoiding the path going through G_a, G_b. This new path is shorter, and does not rely on the information in T^i, T^j. This argument can be used to shorten any path that goes through multiple of agent i, j's mutual teams, to one that goes through only one of their mutual teams and does not rely on T^i, T^j.

Therefore, there is always enough information in $\mathbf{T} \setminus T^i, T^j$ to infer $\delta_n > \delta_k$. As we have exhausted all cases, we confirm that $\tilde{T}^i$ does not affect the relative ranking of any team $G_k \in \mathcal{G}^i \setminus \mathcal{G}^{i \cap j}$ relative to another team $G_n \in \mathcal{G} \setminus \mathcal{G}^i$. ∎

Now to put everything together. By Claim 1, for an agent i to profitably misreport without being identified it must be that he is only lying about a subset of his mutual teams $\mathcal{G}^{i \cap j}$ with some agent j. To achieve a higher payoff despite the principal's punishment, his misreporting must cause at least one of his teams G_k outside of $\mathcal{G}^{i \cap j}$ to now rank above some team $G_n \in \mathcal{G} \setminus \mathcal{G}^{i \cap j}$ where it was previously not the case under T^i, T^{-i}. But as the last claim makes clear, no alternative report $\tilde{T}^i$ can alter the relative ranking of G_k and G_n, thus establishing ex-post incentive compatibility. ∎

A.3   Proof of Proposition 2

Proof. Let $(N, \mathcal{G})$ be an arbitrary organization that is acyclic. We proceed by contrapositive. Suppose that neither condition (i) nor (ii) from Theorem 1 is satisfied. Since $|\mathcal{G}| \geq 3$, there must be at least three teams G_l, G_m, G_n such that (G_l, G_m) only share one agent, i, in common (by violation of condition (ii)), and (G_m, G_n) share at least one agent, j, in common (potentially multiple agents). Similarly to Example 2, consider a realization of δ such that $\delta_m > \delta_n > \delta_l$ are consecutive and are the three lowest entries in δ, and all other entries in δ are arbitrarily chosen. Based on this realization, (G_l, G_n) cannot be compared by transitivity through G_m, and since the organization is acyclic, there is no agent who belongs to (G_l, G_n), nor another sequence of teams that would allow us to compare (G_l, G_n) indirectly (although this is already ruled out by $\delta_m > \delta_l > \delta_n$ being consecutive). In particular, this implies that agent i is the only one capable of comparing (G_l, G_m), and his report will never contradict the information in T^{-i}. Without loss of generality, suppose that the principal's arbitrary rule ranks G_n over G_l whenever they cannot be compared in $\mathbf{T}$. Clearly, agent i can benefit from lying and reporting $G_l \succ_{\tilde{T}^i} G_m$ instead of truthfully reporting $G_m \succ_{T^i} G_l$, since misreporting improves the sum of G_l, G_m's ranks without affecting the rank of any other team he may be a part of. Since the sequence of comparisons $G_l \succ_{\tilde{T}^i} G_m \succ_{T^j} G_n$ is the only way to compare (G_l, G_n), the mechanism assigns $\tilde{\sigma}_l = 3$ and $\tilde{\sigma}_n = 1$, instead of the true ranks $\sigma_l = 1$ and $\sigma_n = 2$. Thus, this realization of δ prevents the principal from achieving ex-post efficiency

and incentive compatibility. If we assume that the principal's arbitrary rule favors G_l over G_n, the argument can be modified to show that other realizations of δ lead agent i to lie. Specifically, if we have $\delta_n > \delta_m > \delta_l$, then agent i will prefer announcing $G_l \succ_{\tilde{T}^i} G_m$ to create an incompletion and force the principal to rank G_l over G_n. ∎

A.4   Proof of Proposition 3

Proof. ($\Leftarrow$) Let g be a star. By condition (i) in Theorem 1, the principal can use the central agent's report and the mechanism $\sigma(\mathbf{T}) = \succ_{T^i}$ is ex-post incentive compatible and efficient.

($\Rightarrow$) If g is not a star then it is either a triangle or it is not informative.

Case 1. Let g be a triangle with nodes i, j, k, and let C_1, C_2, C_3, C_4 denote the teams made up of $(i, j), (j, k), (i, k)$ and (i, j, k), respectively. A simple modification of Example 3 is enough to show that some agent can increase his payoff by creating a cycle among teams C_1, C_2, C_3. Recall that in case of a cycle, the principal must have a rule that assigns an arbitrary ranking. Without loss of generality, suppose the arbitrary rule assigns $C_1 \succ C_2 \succ C_3$, when these teams cannot be compared according to $\succ_{\mathbf{T}}$. Now consider the following realization of team characteristics: $\delta_1 > \delta_3 > \delta_2 > \delta_4$. As illustrated in Example 3, the only agent capable of creating a cycle is j, by announcing $C_2 \succ_{\tilde{T}^j} C_1$. Holding i, k's reports truthful, the principal obtains a cycle and the mechanism assigns the following ranking: $C_1 \succ C_2 \succ C_3 \succ C_4$. Thus, agent j is able to improve his teams' ranks without being detected, which violates ex-post incentive-compatibility.

Case 2. Suppose that g is not informative. By Corollary 1, g must have $n \geq 4$ nodes, $m \geq 3$ cliques, and an open path of length three as featured in Example 1. For one of these open paths, let i, j, k, l denote the nodes and $\delta_1, \delta_2, \delta_3$ denote the characteristics of $(i, j), (j, k), (k, l)$ respectively. Fixing an arbitrary ranking rule in case of incompletions, we can use the same argument as the proof of Proposition 2 to show that either j or k can profitably misreport without being detected (see the realization of δ in Example 2). Since g is an arbitrary graph violating informativeness, we conclude that every uninformative graph does not admit an ex-post incentive compatible and efficient mechanism. ∎

A.5   Proof of Proposition 4

Proof. If g is a star, the central agent i is always part of the k highest-ranking teams, and the mechanism $\sigma(\mathbf{T}) = \succ_{T^i}$ is ex-post incentive compatible and efficient.

Next, let g be a triangle graph with nodes i, j, k, let $\delta_1, \delta_2, \delta_3, \delta_4$ denote the characteristics of teams $(i, j), (j, k), (i, k)$ and (i, j, k), and assume that the principal's arbitrary rule assigns $C_1 \succ C_2 \succ C_3$ in case of a cycle. The mechanism σ must select $k < 4$ teams. If $k = 2$,

then the realization $\delta_1 > \delta_3 > \delta_2 > \delta_4$ allows agent j to improve his teams' ranks by falsely reporting $C_2 \succ_{\tilde{T}^j} C_1$ and creating a cycle. If $k = 3$, the realization $\delta_4 > \delta_1 > \delta_3 > \delta_2$ enables agent j to profitably misreport $C_2 \succ_{\tilde{T}^j} C_1$. By creating a cycle, three of his teams are selected by σ, instead of two. If $k = 1$, we claim that no agent can profitably misreport and that the mechanism $\sigma(\mathbf{T}) = \succ_{\mathbf{T}}$ is ex-post incentive compatible. First, any δ where δ_4 is the largest entry implies that all agents are part of the winning team, so we can restrict our attention to other realizations of δ. Second, assuming that all agents report truthfully, no single agent can misreport regarding the ranking of team (i, j, k), as that would contradict the other two agents' reports. The only type of manipulation left to consider is for an agent to misreport the local ranking of the pairs he belongs to create cycle between C_1, C_2, C_3 (like Example 3). But in order to create a cycle between C_1, C_2, C_3, the agent must be part of the first and last team in C_1, C_2, C_3 according to δ. Since we've ruled out δ's where δ_4 is the largest entry, this means that every realization of δ in which some agent can create a cycle must be such that this agent is already part of the winning team. As this exhausts all possible realizations of δ, we conclude that if $k = 1$, no agent in the triangle can successfully manipulate the ranking.

Finally, suppose that g has an open path of length three with nodes i, j, k, l, let $\delta_1, \delta_2, \delta_3$ denote the characteristics of $(i, j), (j, k), (k, l)$ respectively, and let $k < m$ denote the cutoff rank that determines the set of winning teams. Without loss of generality, assume that the principal's arbitrary rule favors C_1 over C_3 when they cannot be compared. Now consider a realization such that $\delta_3 > \delta_2 > \delta_1$ are consecutive and δ_3 is the k-th largest characteristic in δ. If agent j reports truthfully, the principal assigns the following ranks: $\sigma_3 = m - k + 1$, $\sigma_2 = m - k$, and $\sigma_1 = m - k - 1$, which puts agent j on no winning teams. If he reports $C_1 \succ_{\tilde{T}^j} C_2$ instead, the principal cannot compare (C_1, C_3), and assigns the ranks $\sigma_1 = m - k + 1$, $\sigma_2 = m - k - 1$ and $\sigma_3 = m - k$ which puts j on one winning team, C_1. ∎

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