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Task divisions in teams with complementary tasks☆

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ABSTRACT

A team leader and a team follower non-cooperatively produce a team-specific public good out of two complementary tasks. Both team members are identically productive and can contribute to both tasks. By moving first, the team leader effectively determines the division of the tasks in the team. We show that the existence of multiple but finitely many types of task divisions is associated with a non-convex leader's budget constraint. Non-convexity generates discontinuities and non-monotonicities in the equilibrium provision of the good and also in the follower's utility if incomes are redistributed within the team. Non-monotonicity of the follower's utility motivates the follower to give a cash transfer to the leader. Having received the cash transfer, the leader adopts a task division that compensates the contributions of the follower. Hence, we observe a non-cooperative gift exchange with a monetary gift to the leader and a subsequent non-monetary reward to the follower through a lighter task allocation. These gift exchanges disappear in the presence of infinitely many types of task divisions generated by a continuum of complementary tasks.

1. Introduction

Team production in sports, military, research, business development and management consulting often consists of multiple specialized tasks that exhibit perfect or nearly perfect complementarity (Camerer, 2003, pp. 381–382; Kolmar and Rommeswinkel, 2013). For example, a research proposal succeeds only if it meets both the qualitative and formal standards. Or, in some types of projects, only the slowest contributor determines the speed of production (Brandts and Cooper, 2006). Another kind of perfect complementarity arises in groups which jointly defend multiple targets against adversaries who attack the target with the weakest level of protection, e.g., when securing reliability in information systems (Varian, 2004; Hausken, 2008; Moore and Anderson, 2011).

Complementarity of tasks is conveniently modeled as non-cooperative production of a single weakest-link public good out of multiple tasks. The non-cooperative level of production crucially depends on the domain of contributions. In standard models of the weakest-link public goods (Hirshleifer, 1983; Cornes, 1993; Cornes and Sandler, 1996; Baland and Platteau, 1997; Baland et al., 2007; Cornes and Hartley, 2007; Barbieri and Malueg, 2012; Brookins et al., 2015), each player is responsible only for a single task (*single-task domains*). In this paper, we instead study a common *multiple-task domain*. In the situations with a multiple-task domain, the team members are allowed to select any combination of tasks they wish,

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including pure specialization. In the literature on public goods, the contributions to multiple tasks are known as 'in-kind transfers' between initially specialized players (Vicary, 1990; Sandler and Vicary, 2001; Vicary and Sandler, 2002; Lei et al., 2007; Gregor, 2011; Gregor and Stastna, 2012).

Which assumption on the structure of the domain is more relevant definitely depends on the context. In some sport team contests, the rules of the sport prohibit players from undertaking certain activities. For instance, football defenders cannot use their hands to serve as extra goalkeepers. In contrast, the division of supervision, administration and research tasks in R&D group contests reasonably allows the multiple-task domain.

The assumption of single-task domains is often motivated by heterogeneous abilities of team members. The idea is that under a multiple-task domain, heterogeneous team members self-select into pure specialists. Each pure specialist carries out tasks in which he or she has a relative cost advantage, and therefore the results for single-task and multiple-task domains coincide (Kolmar and Rommeswinkel, 2013). This reasoning overlooks the fact that the incentive for pure specialization depends not only on heterogeneity of abilities (comparative advantages), but also on homogeneity of valuations of the group-specific public good. With sufficiently heterogeneous valuations and a multiple-task domain, differently able team members may abandon pure specialization in favor of an asymmetric task division.

Our key observation in the paper is that for complementary production under a multiple-task domain, any player's strategic variable is not only the amount but also the *structure* of his or her contributions. To highlight the strategic importance of the structure, we study a sequential setting, where Stackelberg leaderships endows a team leader with control over the structure of the tasks in the team. Another motivation for sequential timing under complementarities is that it may arise endogenously in a timing game because it effectively addresses coordination problems (Kempf and Graziosi, 2010). Experimental research indeed confirms that leadership resolves coordination failures in the presence of complementarities, especially if groups are small (Devetag and Ortmann, 2007; Cartwright et al., 2013).

We observe that the leader's ability to determine the task division makes the leader's budget set *non-convex* in the plane defined by the collective (i.e., group-specific public) good and private good. The leader's optimization in the non-convex set implies that the equilibrium variables become *discontinuous* and *non-monotonic* in the exogenous parameters. Specifically for the Cobb–Douglas utility function, we demonstrate that the discontinuity in an income distribution parameter exists for any valuation parameter.

Discontinuity generates interesting incentives. Namely, discontinuity in the income distribution parameter is associated with parametrical configurations where redistribution of income from the follower to the leader motivates the leader to modify the task division such that the follower contributes to fewer tasks. The structural change makes the follower better off even if her initial income decreases. This counterintuitive effect exists because a structural change affects not only the marginal amounts, but also the inframarginal amounts of the tasks of the follower.

Given the existence of the structural changes, the follower may be willing to provide a Pareto-improving cash-transfer to the team leader. Using the traditional terminology of public good games, we observe that under the multiple-task domain, in-kind transfers of the leader co-exist with cash-transfers of the follower (Sandler and Vicary, 2001). Since the cash transfer may be equivalently provided as a resaleable private good, we may alternatively observe that the follower first gives the leader private goods, and consequently the leader selects a Pareto-improving task division where the leader bears responsibility for more tasks than in the absence of the transfer.

The sequence of a pecuniary gift and a reciprocal non-pecuniary reward represents a *non-cooperative gift exchange*. Interestingly, this kind of the gift exchange arises in a non-cooperative setting with selfish preferences and complete and perfect information. Indeed, the only motivation of the cash donor is to increase the recipient's demand for the collective good in order to motivate him or her to select a task division that is more favorable for the donor.

To shed more light on the principles that drive the gift exchange, we begin the analysis with two simple benchmarks. First, for a full class of aggregations exhibiting constant elasticity of substitution, we analyze a hypothetical case when the follower's contributions are not bounded by non-negativity constraints. The absence of the non-negativity constraints linearizes both the follower's and the leader's budget constraints. Since the follower's best response becomes always interior, there is no room for manipulation through task divisions and consequently no room for a gift exchange. As a consequence, the existence of a constrained set of contribution strategies is a necessary condition for the gift exchange.

Second, we examine perfect substitution in the presence of non-negativity constraints. For perfect substitution, even if the follower's strategies are classified into only two strategically different types (i.e., non-contribution and contribution), the leader's budget set becomes non-convex, and therefore a gift exchange may occur. This benchmark demonstrates that team leadership under perfect complementarity is conceptually close to team leadership under perfect substitution. The only difference is that the contribution strategies must be re-classified into multiple subtypes, and the scope for manipulation by the leader through various task divisions is larger for complementarity.

The predictions of the model are derived for identical preferences, identical abilities and perfect complementarity, but situations in which the team leader strategically selects a structure of contributions to manipulate the marginal cost function of the follower, and when the follower uses a cash transfer to motivate the leader to select a different task division, are embedded in other aggregations. As a robustness check, the online appendix demonstrates the existence of a non-convex leader's budget constraint in a class of imperfect complementarities with constant elasticity of substitution.

Additionally, we demonstrate that the non-convexities of the leader's budget set and the resulting gift-exchanges exist because the set of tasks is finite. For infinitely many tasks and therefore infinitely many types of task divisions, the leader can divide any mass of tasks such that all tasks provided on the margin are perfectly complementary. More precisely, by