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Decision Support

Defense against an opportunistic challenger: Theory and experiments ☆

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ABSTRACT

This paper considers a contest setting in which a challenger chooses between one of two contests to enter after observing the level of defense at each. Despite the challenger's chance of success being determined by a proportional contest success function, the defenders effectively find themselves in an all-pay auction that largely dissipates the value of the defended resources because the challenger will target the weaker defender. However, if the defenders form a protective alliance then their expected profits increase despite the fact that a successful challenge is theoretically more likely, given the overall reduction in defense. Controlled laboratory experiments designed to test the model's predictions are also reported. Observed behavior is generally consistent with the comparative static predictions although challengers exhibit the familiar overbidding pattern. Defenders appear to anticipate this reaction and adjust their behavior accordingly.

1. Introduction

In many situations that can be described as a contest, one of the participants (a challenger) can decide which contest to enter after observing the behavior of the other contestants (the defenders). For example, the challenger could be a terrorist who has a single bomb and multiple possible targets such as planes owned by different airlines. The terrorist has the advantage of being able to observe the relative strength of each target's defense and respond accordingly. Intuition suggests that the terrorist would prefer to attack the weaker target thereby increasing the chance of success. Since the more strongly defended target does not get attacked, each defender has an incentive to be slightly better protected than its rival resulting in an all-pay auction among the defenders. Such a situation arises in other settings as well. *Ceteris paribus*, a criminal prefers to burgle the least protected house in a neighborhood, explaining the popularity of home security and "Beware of Dog" signs. An employee hoping to become a regional manager only needs to outshine the weakest current person in that position, just as a new politician can gain office by unseating the weakest incumbent.[1] An entrepreneur looking to start a new retail store would prefer to operate where the competitor is the weakest. A young male animal would prefer to usurp the feeblest established male to claim mating rights. This situation also arises in the old joke about two people going hiking in an area inhabited by bears when one points out that they cannot outrun a bear, and the other says, "I just have to outrun you."[2]

Rather than providing separate defenses, in some settings the defenders could band together and form an alliance. For example, airplane security is done at the airport level rather than the airline level. Residential communities often form neighborhood watches. Incumbent firms may seek a zoning ordinance to keep potential entrants out. In fact, alliances are common throughout society and psychologists have argued that people favor the formation of an alliance when facing conflicts due to the competitive disadvantage of the lone individual confronting a group (Baumeister & Leary, 1995).

In this paper, we construct a formal model to analyze these two strategic situations and test the model using controlled laboratory experiments. The theoretical results confirm that the challenger will prefer to attack the weaker defender when targets are protected

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[1] Ryvkin (2010) discusses various types of tournaments for trying to identify high quality employees when talent is heterogeneous, although the structure of uncertainty is different in his setup.

[2] Of course, any of these situations could involve multiple challengers: two burglars could operate in the same neighborhood; other employees may be seeking a promotion; etc. Allowing for more players may introduce multiple and/or asymmetric equilibria. However, this paper restricts attention to the case of two defenders and one challenger.

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independently leading defenders to invest heavily. A challenger who targets the weak link has the flair of previous research on the attack and defense of a network (e.g., Levitin, 2003a,b; Major, 2002; O'Hanlon et al., 2002; Woo, 2002, 2003). In contrast, when the defenders work together in an alliance, the aggregate level of defense is much lower resulting in both a greater likelihood of a successful challenge and simultaneously higher expected profits for defenders.

The normal intuition for an alliance is that the joint defense is greater than each individual defense and thus the alliance is better able to deter or handle a challenger. Research by Sheremeta and Zhang (2010) suggests alliances make better decisions in contests than individuals. Specifically, in lottery contests when team members are able to communicate, groups are found to make more rational decisions than individuals. While most of the literature on contests has not focused on alliances, there has been some work considering the impact of how the alliance shares the spoils of its success (Esteban & Sakovics, 2003; Katz & Tokatlidu, 1996; Konrad, 2004 Muller & Warneryd, 2001; and Warneryd, 1998).[3] In these models there is typically a single prize to be allocated among members of the alliance.

In general these models find that the internal conflict diminishes the contribution of alliance members. This outcome is also found when there are spillovers between independently defended targets in a network such as in Kunreuther and Heal (2003). However, Ke, Konrad, and Morath (2010) conduct an experimental analysis of alliances and show that the future internal conflict does not prevent alliance members from fighting shoulder-to-shoulder. On average, they find that allies in a contest against an outside opponent devote the same contest effort irrespective of how they will share the spoils of victory. In addition, the collaboration in alliances is reasonably good, leading to higher success against a lone challenger than predicted. Garfinkel (2004) develops a positive analysis of alliance formation, building on a simple economic model that features a "winner-take-all" contest for control of some resource. When an alliance forms, members pool their efforts in that contest and, if successful, apply the resource to a joint production process. Due to the familiar free-rider problem, the formation of alliances tends to reduce the severity of the conflict over the contestable resource. Despite the conflict that arises among the winning alliance's members over the distribution of their joint product, under reasonable conditions, this effect alone is sufficient to support stable alliance formation in a non-cooperative equilibrium.

Our model is distinct from these papers in that each member of the alliance values its own item so that the alliance is about common protection rather than an arrangement for increasing the chance of claiming a shareable prize of a given size.[4] Thus, in our setting there is no distributional conflict within the alliance resulting from a successful defense. Further, in our model the challenger cannot claim more than one prize regardless of whether or not the defenders opt to form an alliance. Returning to the example of a terrorist with a single bomb attempting to attack a plane, if the terrorist is unsuccessful both airlines retain their respective planes but if the terrorist is successful only one airline incurs the entire loss while the other incurs no harm. In the example of an employee vying for a regional manager job, an incumbent who keeps her job is not harmed when someone else is let go.

The paper most closely related to ours in structure is Dighe, Zhuang, and Bier (2009), which considers an attack and defense game with two possible targets and one challenger. In their game, defense is a binary choice and the outcome is deterministic, as an attack is only successful if launched against an undefended target. They compare a decentralized defense where different decision makers defend each target and a centralized defense where a single decision maker makes both defense decisions jointly thereby internalizing the externality associated with defense. In their setup, defense is unobservable and they find that centralized decision making is optimal since deterrence can be achieved in some scenarios by protecting only one target. Our paper is also similar to Hausken and Bier (2011) which considers a single defender with multiple attackers using a similar conflict success function. They show how the move order and relative values of the attackers will encourage some attackers to abandon the contest.

We also report the results of controlled laboratory experiments designed to test the empirical validity of our model. In our laboratory experiments, defenders are observed to bid less when in an alliance as predicted by the model. However, the difference in the bids is not as dramatic as predicted. There are now several experimental papers on contests (cf. Sheremeta, Dechenaux, & Kovenock, 2012 for a thorough survey) and one of the common findings is that people overbid to the point that the equilibrium surplus is often fully depleted (cf. Davis & Reilly, 1998; Gneezy & Smorodinsky, 2006; Lugovskyy & Puzzello, 2008; Potters, de Vries, & van Winden, 1998). Noussair and Silver (2006) address the effect of experience, showing that experience helps decrease over-bidding but does not eliminate it. Contrary to these previous contest experiments, we find that defenders underbid when defending separately, perhaps because the theoretical predictions are relatively greater in our setting. Our results are also driven in part by the fact that the alliance members do not internalize the benefits of their defense investments for the other alliance members. This aspect of alliance behavior was pointed out at least as far back as Olson and Zeckhauser (1966). However, Ke et al. (2010) observe group members overbidding in a setting where the group shares a common bid against another party and equally split the proceeds from a successful bid. Recently, Nitzan and Ueda (2008) examine the effect of group size on performance in a collective contest and find that larger groups tend to be less effective at pursuing the collective interest.

2. Theoretical model

Consider a situation in which a single challenger has two possible targets, T_1 and T_2, each valued at $P \geq 0$. T_i is valued at $V \geq 0$ by defender *i*. Allocation of the targets is determined by the outcome of a contest resolved with a proportional success function (Tullock, 1980) based upon the level of investment by the relevant contestants. Let the investment (bid) by defender *i* be denoted by $b_i \geq 0$ and the investment (bid) of the challenger be denoted by $b_C \geq 0$. Before investing in defense, the defenders have the option to defend the targets independently or form an alliance. After observing the defense structure and the investments of the defenders, the challenger decides how to proceed. A key feature of this set-up is that a challenger can enter at most one contest and can claim at most one target.[5] Our model is meant to capture the situation in which the second mover terrorist

[3] An alliance in our setting reduces the game to a single battle, which is distinct from the setting in which the entire defense of a network is defended by a single decision maker as in Bier and Abhichandani (2002), Bier, Nagaraj, and Abhichandani (2005), Azaiez and Bier (2007) and Hausken (2008) where defense remains target specific. Kovenock and Roberson (2012a,b) provide the necessary conditions for and discuss the misunderstandings in Hausken (2008) results.

[4] Our results are unchanged if alliance members agree to equally share all prizes that any member claims. The alliance structure in our paper is also related to the literature on group contests (cf. Muenster, 2009 who extends the axiomatic characterization of contest success functions of Skaperdas (1996) and Clark and Riis (1998) to contests between groups). Baik (2008) examines the equilibrium effort levels of individual players and groups in contests in which *n* groups compete to win a group-specific public-good prize. In the basic model the chance of success depends on total effort and only the highest-valuation players expend positive effort leading to under-investment in the contest for the group as a whole. Lee (2012) considers the situation in which the probability of winning follows a weakest-link rule so that it is the lowest-valuation players in each group who play the decisive roles. Ryvkin (2010) studies how aggregate effort exerted in contests between groups of heterogeneous players depends on the sorting of players into groups. Abbink, Brandts, and Herrmann (2010) examine the impact of group members being able to punish each other.

[5] If the challenger could enter both contests in the event that the defenders opted to defend separately, the result would be two independent standard Tullock contests.