# Incentives in Contests with Heterogenous Solvers

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The last decade has seen a substantial change in the landscape of the classical research and development (R&D). With the advancement in information technology and global access to skilled individuals, established companies such as HP and P&G started to turn away from classical in-house R&D towards outsourcing R&D activities. One popular and cost-effective approach to R&D outsourcing is using a contest (also called a tournament). A contest is a mechanism wherein a seeker poses a problem to a population of independent solvers, and awards the solver(s) that creates the best solution(s). A contest has been employed to solve problems in various areas, including design (e.g., a logo design contest for FIFA World Cup), health science (e.g., Grand Challenges Explorations of Bill & Melinda Gates Foundation), and software development (e.g., TopCoder Challenges).

A primary benefit of these contests is that a seeker can tap into a large number of experts outside of its firm boundary, and can select the most promising solution from many submitted solutions. However, merely collecting a large number of solutions does not necessarily guarantee the highest quality solution to a seeker. With many contest participants, solvers expect their individual chance of winning a contest to be low, and hence may not have sufficient incentives to exert their best efforts. Therefore, a long-standing question within the contest literature has been "How does increased competition in a contest (i.e., more participants in a contest) affect solvers' incentives to exert effort?".

For contests in which solvers with different ability levels compete, there are two competing theories for this question. When solvers are heterogeneous in their initial expertise, Terwiesch and Xu (2008) have proven analytically that having more solvers in a contest will lead to a lower effort for *every* solver in equilibrium. The intuition behind this negative externality is explained by Terwiesch and Xu (2008) as follows: "the more solvers participate in the contest, the lower the probability of winning for a particular solver. With lower winning probabilities, the solvers' expected profits decrease, leading to weaker incentives for them to exert higher efforts. This underinvestment in effort leads to an inefficiency in an open innovation system"

(page 1536). In contrast, when solvers are heterogeneous in their costs of exerting efforts, Moldovanu and Sela (2006) have shown a contradictory result in which solvers of *different* ability levels tend to react to increased competition differently: high-ability solvers raise their efforts with more participants, while low-ability solvers reduce their efforts. Yet, Moldovanu and Sela (2006) do not explain why solvers behave in this manner. Therefore, the reason behind these conflicting results has been an unsolved puzzle.

Our objective in this paper is to solve the puzzle arising from the above conflicting results in the theory of contests and to offer clear managerial insights into the effect of increased competition on the solvers' incentives. To this end, we consider three models of a contest with heterogeneous solvers. The first model, which we refer to as "cost-based projects," is used by Modovanu and Sela (2006). In this model, solvers are heterogenous with respect to their cost of exerting effort. Modovanu and Sela (2006) use this model to show the result mentioned above. The second model, referred to as "expertise-based projects," is originally proposed by Terwiesch and Xu (2008). In this model, solvers are heterogeneous in their initial expertise levels. Terwiesch and Xu (2008) characterize the equilibrium effort of a solver, and show that it always decreases with the number of solvers in the contest. Then, they use this result to show when it is optimal for a seeker to choose a free-entry open contest that allows the entry of any solver who wishes to participate in the contest. In order to address the discrepancy in the results between these two papers, we propose a third model, which we call "productivity-based projects." In this model, solvers are heterogeneous in their productivity levels so that one unit of effort from a high-productivity solver creates higher value than that from a low-productivity solver. We show that cost-based projects of Modovanu and Sela (2006) and expertise-based projects of Terwiesch and Xu (2008) can be represented as *special cases* of productivity-based projects.

The analysis of productivity-based projects yields the following novel results. First, we prove that the result of Modovanu and Sela (2006) mentioned above can be generalized to productivity-based projects. In other words, this result is robust to a type of solvers'

heterogeneity in a contest. Second, we offer a precise explanation about why solvers with different ability levels react to increased competition in a contest differently. Terwiesch and Xu (2008) have argued that every solver, irrespective of her ability, will underinvest in her effort when facing increased competition in a contest because increased competition will reduce her chance of winning. We find that this negative externality is not the only driver that influences solvers' effort decisions. We have identified (analytically) the second driver which incentivizes solvers to exert higher efforts: More participants in a contest raise the expected performance of a runner-up, and therefore solvers need to make higher efforts in order to win the contest. This seemingly intuitive (but overlooked in prior literature) driver provides opposing force to the negative externality created by increased competition. As a result, depending on which driver dominates the other, solvers react to increased competition differently. In particular, we prove that when facing increased competition, high-ability solvers, whose chances of winning are relatively higher than low-ability solvers, always increase their effort levels, while low-ability solvers reduce their effort levels. Our results are corroborated empirically by Boudreau et al. (2012). Finally, from a seeker's perspective, higher efforts from high-ability solvers caused by increased competition are helpful to obtain better solutions from a contest. When taking into account such positive externality from increased competition, we find that a free-entry open contest is more likely to be optimal than what the prior literature asserted. This finding justifies the increased popularity of an open innovation system, including the contest examples mentioned above.

**References**


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