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A Model of Challenge Funds: How Funding Availability and Selection Rigor Affect Project Quality

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ABSTRACT

Challenge funds (CF) induce competition between grant applicants as they develop proposals to address important social problems. We develop a game theoretic model to study how funding availability and proof of concept requirements (e.g., pilots or other forms of early stage screening) influence investments by applicants and the ultimate success of the CF. Larger budgets and more rigorous proof of concept requirements can reduce applicant investments and lead to less effective funding initiatives. The results show how the design of a CF affect the incentives of those competing for funding, and how the most effective CF design needs to carefully consider how the NGOs or researchers applying for funding will respond to a change in incentives. Otherwise, steps taken to improve the quantity or quality of funded projects can backfire and decrease overall funding effectiveness.

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1 Introduction

Challenge funds (CFs) have become commonplace when donor agencies, foundations, and other funders are interested in more-effectively allocating grants to have greater impact. CFs differ widely in their size and scope, but they all use competition among potential fund recipients to identify the most-promising solutions to social, environmental, or health challenges. For example, Grand Challenges Canada (GCC) is a CF with a funding commitment in excess of $225 million, which focuses on identifying the most promising innovations to increase neonate survival, facilitate early childhood brain development, and improve mental health among marginalized populations. GCC allocates its grants through a series of multiple round funding competitions, with early rounds allocating funding to the most-promising proposals, and later rounds of funding being used to scale up the most-successful ideas from earlier rounds. Similarly, the Africa Enterprise Challenge Fund (AECF) provides competitive grants and conditional loans to businesses in sub-Sahara Africa to pursue innovative projects like transforming agribusiness in Tanzania, extending the reach of renewable energy, and increasing enterprise in post-conflict environments. The U.K. Department for International Development (DFID/UKaid) has established several challenge funds on a range of specific challenge topics, including the Girls' Education Challenge fund in 2012. The U.S. Agency for International Development (USAID) has established the Development Innovation Ventures fund in 2010 and the Grand Challenge for Development Initiative in 2011. The Bill and Melinda Gates Foundation established the Grand Challenges Explorations initiative in 2008.

This paper develops a model of CFs to consider how the availability of funding and proof of concept requirements impact the incentives of applicants as they compete for funding. In practice, more innovative ideas are not enough to assure funding. Rather, they are subject to proof of concept requirements during the application process, which may include external reviews, pilot studies, or preliminary evidence of success. In some cases, CF's actively participate in these reviews, while in others the applicants choose the design of evaluation. As we show, such differences in the governance and rigor of evaluations, as well as the scarcity of funds, interact with the incentives of applicants to develop good ideas, and endogenously affects anticipated project quality and the optimal structure of the funding challenge in the first place.

To fix ideas, consider a baseline (and unrealistic) case in which applicants cannot improve the design of their projects, so that the quality of their proposals is fixed. Then, the analysis is simple: more funding and more rigorous evaluation increases the probability that projects successfully achieve the challenge goal. This is for two reasons. First, as more projects receive funding, the number of successes increase, even if the marginal rate of success decreases in the level of funding. Second, more rigorous evaluations allow the CF to precisely learn about all of the proposals, which makes its allocation more efficient. In this base case, more information is strictly better.

However, similar conclusions do not hold in general when the investments made by applicants to improve the quality of proposals are chosen strategically to maximize the probability of award. We contrast several variations of the model that provide insights regarding how funding availability and evaluation rigor changes the incentives to invest in higher quality proposals, the availability of high-value opportunities, and the ultimate success of the CF.

First, increasing a CF's capacity to fund more projects can *reduce* the number of high-value projects that are implemented. When grants are limited, this provides incentives for applicants to compete for funding, and increases the likelihood that any proposal accepted by the CF results in a success. However, when more funding is available, there is a perverse incentive that reduces the investment that applicants make, simply because applicants do not need to try as hard to get funding. In this case, fewer high-value projects may be implemented in equilibrium.

Second, there is an interaction between evaluation rigor and the incentives of implementers to invest in designing better projects. When project developers anticipate more-rigorous evaluations, they actually may invest *less* in their projects and put forward lower-quality opportunities. So, there turns out to be a tradeoff for the CF when choosing proof of concept requirements in an RFP. Requiring more rigor improves decision-making and allocative efficiency. However, it may also lead to less investment by applicants when developing opportunities in the first place, which can lead to lower quality projects overall. We find that the disincentive effects often dominate the improvements in allocative efficiency, especially when available funds are plentiful. Consequently, requiring fully-revealing evaluations may in fact be subotpimal compared to letting applicants choose their own proof of concept burdens, or not specifying any particular requirements whatsoever. Our results, then, suggest that the effect of more precise evaluations of concepts ahead of allocation decisions is not as straightforward as widely assumed.

Our analysis applies recent developments in information theory to develop a game theoretic model of CF competitions. The model provide novel insights into organizational behavior and the design of CFs and other funding allocation opportunities. Throughout the paper, we highlight the practical importance of our analysis, considering NGO competition for program funding and scientific competition for research funding (e.g., National Institute for Health, NIH). We show how more funding is not strictly better, and can lead to the funding initiative having a lower overall impact than it would have had with a more restrictive budget. The competition between grant applicants to put forth better ideas when faced with limited budgets can more than offset the reduction in the number of grants that can be funded. We also show how subjecting proposals to more rigorous evaluations prior to awarding funding can also reduce innovation and investments in proposal quality, making any given amount of funding less effective. Together, these results show how the design of a CF affect the incentives of those competing for funding, and how the most effective CF design needs to carefully consider how the NGOs or researchers applying for the funding will respond to a change in incentives. Otherwise, steps taken to improve the number or quality of funded projects can backfire and decrease funding effectiveness.

2 Literature

A substantial literature discusses the benefits of evaluations, and the merits of evidence-based policy. These papers generally argue that better evaluation leads to the design and selection of more-effective projects, programs and policies, but also that evaluations face barriers in terms of feasibility, costs, and institutional resistance. Gertler, et al. (2016) provides a detailed review of the benefits and best practices of impact evaluation. Duflo and Banajee (2011) and Karlan and Appel (2011) review the evaluation of several past international development projects, arguing that such evaluations help implementers design better policies and more efficiently allocate funding. Our work is distinct in that we study competition among investigators in a game-theoretic model and find that the opposite is often true: more rigorous proof of concept requirements can be suboptimal.

In other fields, Crosswaite and Curtice (1994) argue that pilot studies increase accountability to better justify the use of funds and van Teijlingen and Hundley (2001) argue that pilots offer many benefits including identifying failures ahead of project implementation. Head (2010) argues that the use of information and evidence in policymaking is often limited by misaligned preferences and entrenched commitments make organizations resistant to change. Mebrahtu (2002) and Merchant-Vega (2011) argue that organizations may be resistant to evaluations that show their work as being ineffective. This stream of past work on the costs and benefits of evaluation focuses on case studies, qualitative assessments and intuition. We complement this literature by developing a game theoretic model of project design, evaluation, and selection in order to better understand the relationships between funding availability, evaluation, and project design, which we use to rigorously evaluate some of this literature's arguments.

The framework we develop builds on recent work that considers how later-stage evaluations affect incentives in earlier stages in strategic environments. For example, it is well-established in the career concerns literature that more monitoring can discourage effort (e.g. Dewatripont, et al 1999 and Holmstrom 1999). Similarly, Coate and Loury (1993) and Taylor and Yildirim (2011) consider how a decision-maker's access to information about an agents type affects the agents decision to invest in quality. In the contracting literature, it is also well established that a principal may want to commit to imperfect monitoring technologies, as doing so leads to more favorable actions taken by agents (e.g. Cremer 1995, Sappington 1986, 1991). Along this same line, our work contributes to a large body of work that implies that people may be better off ignoring information or by committing not to collect it (e.g. Hirshleifer 1971; Morris and Shin 2002).[1]

More closely related to our work are several papers that build on this literature to consider settings in which agents are not only concerned about assessments on an absolute scale, but are also concerned about their assessments relative to other agents. Bodoh-Creed and Hickman (2018) explore the incentives of students to develop human capital when both absolute and relative skills matter. Boleslavsky and Cotton (2015b) show that schools competing to place students invest

[1]See Bikhchandani, Hirschleifer, and Welch (1992), Teoh (1997), Angeletos and Pavan (2007), and Amador and Weill (2012), among others.

less to provide high-quality education when employers are better able to evaluate the quality of their individual graduates. Boleslavsky and Cotton (2015a) show that politicians competing in an election run on less-moderate platforms when they anticipate that more information about their quality will emerge during a campaign.[2] The underlying model in our current paper is most similar to the model in Boleslavsky and Cotton (2015b) in that it explicitly models both investment in quality and the design of an evaluation technology (e.g. grading policy vs. impact evaluation). However, the earlier work does so in a two-agent environment which is not suited to study the allocation of a large amount of funding across a large number of projects.[3] Furthermore, by extending the earlier work to consider a continuum of heterogeneous agents, we are able to consider how the availability of funding affects project design and evaluation strategies, issues that could not be addressed in a model with two agents. Ottaviani (2020) considers a theoretical model in which funding availability affects application rates[4], and where too precise of evaluations can prevent anyone from applying. Our analysis complements these efforts by focusing on how such considerations affect investments in the quality of applications rather than participation rates on the extensive margin.

More broadly, our analysis is related to the literature on optimal grant funding system design. Azoulay and Li (2020) discuss different types of funding mechanisms from contracts, patents, prizes and procurement contracts, arguing that grants are likely better for supporting the development of new ideas and solutions. Horrobin (1990, 1996) argues that peer review in grant funding limits funding for novel and transformative ideas. Berezin (1998) discusses some of the downsides to being highly selective in the distribution of research funds, from favoring established research areas to perpetuating an 'old boys' club'; in contrast, we show how selectivity change the incentives of applicants to submit better projects. Huffman and Evenson (2006) present evidence that competitive grants can have a smaller impact on agricultural productivity than formulaic grant allocation

[2]Moscarini and Ottaviani (2001) and Boleslavsky, Cotton and Gurnani (2017) consider the impact of product information disclosure on price competition.

[3]A number of other papers endogenize the design of evaluation technology in competitive environments without considering investment decisions. See, for example, Gentzkow and Kamenica (2017), Au (2018), Au and Kawaii (2020), Bar and Gordon (2014), Boleslavsky and Cotton (2018), Li and Norman (2018), Hulko and Whitmeyer (2018).

[4]Similar to how capacity constraints affect research submissions to scientific journals (e.g., Cotton 2013).

mechanisms.

3 Model

There is a continuum of project implementers, or ‘agents’, with mass 1. Each agent is responsible for developing and proposing a project (e.g. research project, social program, policy) to a CF decision maker, who selects a subset of opportunities to receive funding. We do not model the inner working of the organizations, treating each as an individual agent.

Each agent i is endowed with an idea for a project, which has probability ρ_i of being an ex post "high-value" idea with the potential to achieve the challenge goal, and probability $1-\rho_i$ of being a "low-value" idea with no chance of achieving the goal. Agents observe their own realizations of ρ_i. For tractability, we assume that the distribution of ρ_i^2 is uniform on $[0,1]$, which is common knowledge.

Knowing ρ_i, each agent i chooses how much to invest in the refinement of the idea and the planning for its implementation. The level of investment in a proposal can be defined as the costs incurred, $C(q_i) = q_i^2$, or by the choice of q_i, which is the resulting probability that a "good" preliminary idea achieves the challenge goals. We say that each agent develops a proposal, where the overall probability that that proposal will achieve the challenge goals if funded is a function of idea quality and investment in planning and design.

As such, the probability of success if funded for proposal i is calculated as $P_i = \rho_i q_i$. Let $\tau_i \in \{0,1\}$ denote the underlying type of proposal i following investment in the project. With probability P_i, $\tau_i = 1$ and the project is effective if funded. With probability $1-P_i$, $\tau_i = 0$ and the project is ineffective. Agent i knows ρ_i and its choice of q_i, but other agents and the CF decision maker only observe P_i.

The CF decision maker can fund up to share $\sigma \in (0,1)$ of all projects. The CF receives a payoff of 1 for each funded project that succeeds, and a payoff of 0 for each funded project that doesn't receive funding or that receives funding and fails. Agents get benefit 1 when they receive funding, which results in total payoff $1-q_i^2$ given their investment in the proposal. They receive benefit 0 when they do not receive funding, resulting in total payoff $-q_i^2$.[5]

After proposals are developed and before the CF chooses which projects receive funding, the proposals are evaluated. This is based on the proof of concept requirements defined in the RFP. Here, we interpret the evaluation process as a pilot study of small scale implementation of the project designed to identify ineffective projects that will fail to achieve the challenge goals. However, it could alternatively be any other form of assessment, such as peer or expert review, that provides additional information about the potential effectiveness of the proposal.

The informativeness of the evaluation process is captured by variable $\gamma_i \in [0, 1]$, which denotes the probability that an ineffective project is correctly identified as such by the evaluation. Hence, $1-\gamma_i$ is the rate at which an evaluation returns a false positive "good project" report for a ineffective project.

	Prob. of a Positive Evaluation	Prob. of a Negative Evaluation
$\tau_i = 1$	1	0
$\tau_i = 0$	$1 - \gamma_i$	γ_i

Given this, the evaluation results in either a negative or positive report. A negative report confirms that the project will be ineffective, while a positive report allows for remaining uncertainty about the true effectiveness of a proposal if funded. As the informativeness of the evaluation process increases, γ_i increases, which decreases the probability of a false positive and increases the probability with which the evaluation identifies an ineffective project. Consequently, as γ_i increases, the CF will be more confident that a project with a positive report will turn out to be an effective project. The posterior belief that a project with a positive evaluation is truly an effective project is

$$B_i(P_i, \gamma_i) = \frac{P_i}{1 - (1 - P_i)\gamma_i}. \tag{1}$$

When $\gamma_i = 0$, the assessment reveals no additional evidence about proposal i and beliefs about project value are determined only by the quality of the proposal: $B_i = P_i$. When $\gamma_i = 1$, the

[5] Many firms, organizations or institutions competing for CF financing likely care about social impact as well as their receipt of funding. For the analysis, however, we focus on the case where there is maximum incentive dis-alignment between the CF decision makers and the agents in order to build intuition about underlying mechanisms related to the competition for funding.

evaluation reveals the value of opportunity i and there is full confidence that a project with a positive evaluation is truly effective: $B_i = 1$.[6] Only projects with a positive probability of being effective at the time of funding allocation are eligible to receive funding.

We solve for Perfect Bayesian Equilibria.

3.1 Exogenous investments

This section briefly considers a benchmark case where investments (and therefore proposal quality) are fixed.

Consider a setting with fixed proposal quality (P_i) for each agent and a common evaluation technology with informativeness γ_i. The evaluation of proposal i will generate a negative report with probability $(1 - P_i)\gamma_i$, in which case the project is ineligible for funding. The evaluation will produce a positive report with probability $1-(1-P_i)\gamma_i$, in which case the common posterior beliefs about the quality of the proposal are given by $B_i(P_i, \gamma)$, denoting the updated probability that the project will be effective if funded.

If the share of projects that receive a positive evaluation report is no greater than σ, then the CF provides funding to all of the projects with a positive report. If more than σ projects receive a positive report, then the CF funds the σ projects with the highest B_i.[7]

The comparative statics in this case are intuitive.

As available funding increases and more projects can be funded (an increase in σ), the share of total projects to effectively achieve the challenge goals increases. However, the average quality of funded projects falls as the selection process becomes less selective and the new funding is allocated to less-promising projects compared to those that were already being allocated funding.

As evaluations become more informative (i.e., γ increases), there is a positive shift in the distribution of B_i for those that receive funding, which means that funded projects become more promising and a larger share of total projects achieving the challenge goals. In this case, better

[6]See Boleslavsky and Cotton (2015b) for the analysis of a general evidence generation structure in a game with two agents and binary types. They show that a false-positive signal binary signal structure like the one used in this paper allows for both the agent preferred and decision-maker preferred signal structure when they can choose any feasible signal structure from a general class of signals.

[7]Funding allocation is randomized at the threshold if a mass-point exists at that point.

evaluations lead to better outcomes.

3.2 Endogenous investments

For the remainder of the paper, we assume that agents simultaneously choose how much to invest in their proposals at the beginning of the game. Endogenizing P_i leads to very different conclusions about the impact of increasing funding or improving evaluations compared to the case in which P_i is fixed.

The game takes place as follows.

$t = 0$: Agents simultaneously choose their investments, q_i, which together with their endowed idea quality, ρ_i, determine their observable proposal quality, $P_i = q_i \rho_i$.

$t = 1$: Each proposal is subjected to an evaluation of informativeness $\gamma_i \in [0, 1]$.

$t = 2$: The CF allocates funding to up to σ proposals.

Within this framework, we consider three cases involving the design of evaluations:

(i) **No evaluations:** the CF does not require proof of concept, which is equivalent to the case of completely uninformative evaluations ($\gamma_i = 0$).

(ii) **Fully-revealing evaluations:** the CF can perfectly identify which proposals will lead to success before allocating funding ($\gamma_i = 1$).

(iii) **Agent-designed evaluations:** The CF delegates proof of concept to the agents, so that they each choose γ_i strategically at $t = 1$.

We assume that the choice of evaluation rigor, $\gamma_i \in [0, 1]$ has no cost. By abstracting from the costs of evidence production, we can focus on the setting where the decision to produce less-informative evidence is driven by strategic considerations rather than the financial costs of being more rigorous. This assumption clarifies our contribution to the literature on evaluations, by isolating a novel strategic force that limits informativeness.

In what follows, we characterize the equilibria in these three cases and address optimal proof of concept requirements for the CF in Section 4.4.

4 Equilibrium Analysis with Endogenous Investments

4.1 Equilibrium with No Evaluations

First, we consider the case where $\gamma_i = 0$ for each proposal i. When there are no evaluations, the decision-maker allocates funding to the σ share of agents with the highest P_i. At the point of fund allocation, P_i defines the likelihood that proposal i meets the challenge goals if it receives funding.

Proposition 1. *(Equilibrium with No Evaluations) When $\gamma_i = 0$ for each i, equilibrium investment results in proposal quality*

$$P_i = \begin{cases} \sqrt{1-\sigma} & for \quad \rho_i \geq \sqrt{1-\sigma} \\ 0 & for \quad \rho_i < \sqrt{1-\sigma}. \end{cases} \tag{2}$$

A mass σ of agents invest in developing a proposal with $P_i = \sqrt{1-\sigma}$, and a mass $\sigma\sqrt{1-\sigma}$ of high-value proposals are funded.

When funding is relatively scarce (low σ), competition for the funding is more fierce. In this case, fewer agents invest in developing proposals, but when they do, they invest in higher quality proposals than when σ is higher. In equilibrium, the σ agents that are endowed with the most promising proposal ideas invest in proposals; but they invest just enough in quality that agents with less promising ideas find it too costly to develop high-enough quality proposal to compete. The σ agents all develop proposals of equal promise P_i and each receives funding.

The CF's payoff is the measure of high-value projects implemented. Thus, the CF is concerned with maximizing the social benefits generated by the given funding level, σ.[8] The decision-maker payoffs are $u_d = \sigma\sqrt{1-\sigma}$.

As previously discussed, if proposal quality were exogenous, then the CF would weakly prefer more funding.[9] However, in our environment, proposal quality is chosen by the agents who tend to produce lower-quality proposals as the available funding increases. In this case, the CF does not strictly prefer higher funding, even if funding were costless. This is because high levels of funding do not provide enough of an incentive for agents to invest in improving their proposals. More

[8] In the analysis, only high-value projects provide a net benefit to society. The assumption that low-value projects return a benefit of 0 to the CF effectively assumes that the benefits of such projects for society equal their costs of implementation.

[9] This is because the net benefits of implementing a high-value projects is positive and the net benefit of implementing low-value projects is assumed to be zero.

scarce funding induces competition between agents, who compete by developing more promising proposals.

Corollary 1. *(More funding is not strictly better) When there are no evaluations, the number of high-value projects that receive funding (which equals u_d) is maximized at $\sigma = 2/3$.*

4.2 Equilibrium with Fully-Revealing Evaluations

Next, we consider the case of fully-revealing evaluations, where $\gamma_i = 1$ for each i. Such evaluations are always preferred by the CF at $t = 2$, taking as given the quality of each proposal, q_i. Such evaluations perfectly reveal the value of each project and assure that the decision-maker has the information he or she needs to allocate funding optimally. In our environment, however, the presence of such evaluations can decrease the incentives to invest in strengthening the design of proposed projects, and may therefore not be preferred by the CF. Here, we consider what such evaluations mean for investment decisions by the agents.

Proposition 2 describes the equilibrium of the game when proposals are subject to fully-revealing evaluations. The incentives that agents have to invest in their proposals depend on the capacity for funding, σ.

Proposition 2. *(Fully-Revealing Evaluations)*

i. When $\sigma \leq 1/4$, agents each invest in proposal quality such that $P_i = 2\rho_i^2\sqrt{\sigma}$, the share σ of proposals are high-value, and the CF funds σ high value proposals.

ii. When $\sigma > 1/4$, agents each invests $P_i = \rho_i^2(1 - \sqrt{\sigma})$, the share $(1 - \sqrt{\sigma})/2 < \sigma$ of proposals are high-value and receive funding.

In contrast to the preceding no-evaluation case, where funding was allocated based on each agent's investment level, with fully-revealing evaluations the CF no longer awards funding based on P_i directly. Rather, the CF awards funding based on the information about actual value that is revealed by the evaluation. In this case, even lower ability agents have some incentive to invest in developing proposals, as even low-quality proposals sometimes result in high-value projects.

In this case, agent investments are maximized when $\sigma = 1/4$. This level of funding maximizes competition between agents. When funding is more scarce, a discouragement effect arises: agents exert less effort because there are fewer prizes relative to the expected proposal quality of their competitors. Lower σ implies a larger discouragement effect and a lower investment by each agent. When funding is more plentiful, agents anticipate that even some low-value proposals will receive funding, which reduces incentives to invest in their projects.

When funding is relatively scarce ($\sigma \leq 1/4$), all funded projects are high-value and the CF's payoff is $u_d = \sigma$. When funding is relatively abundant ($\sigma > 1/4$), the CF's payoff depends on the number of developed projects that are high-value, with $u_d = \frac{1-\sqrt{\sigma}}{2}$. In this, CF payoffs are maximized at the same level of funding that agent investment in quality is maximized, at $\sigma = 1/4$.

Again, we find that being able to fund more projects is only better for the CF up to a point (in this case $\sigma = 1/4$). Beyond this point, increasing the availability of funding actually decreases the CF payoffs, as it decreases the number of high-value projects that are successfully implemented.

Note that the analysis in this section assumes that the organization funds σ projects even if some of these are knowingly low value at the time of funding. This affects the fully-revealing evaluation analysis for the case where $\sigma > 1/4$; however, the main qualitative results will not change if the CF does not provide such proposals funding.

4.3 Equilibrium when agents design evaluations

In equilibrium, the decision-maker implements the σ proposals that are most likely to be high-value following the evaluations. Agents can influence these beliefs by both investing to improve initial proposal quality P_i and by choosing evaluation design γ_i.

When agents choose the evaluation of their own proposals, those agents endowed with the most-promising ideas invest enough in their proposals to guarantee that they will receive funding without the need to subject their proposal to the scrutiny of a rigorous evaluation (e.g., without the need for a pilot or detailed review). Those agents with ex ante less-promising ideas face higher costs of developing an implementation plan and design such that their proposal will be high enough quality to guarantee funding. Such agents therefore invest less in developing their proposals, but subject their proposals to more thorough evaluation in the hopes of finding evidence that their proposal has as much promise as the projects that sound more promising ex ante.

Proposition 3. *(Equilibrium when Agents Design Evaluations) In equilibrium when agents choose their own proposal investment and evaluation rigor:*

- *Agents endowed with the most promising ideas ex ante (i.e., $\rho_i \geq \sqrt{2(1-\sigma)}$) invest such that $P_i = \sqrt{1-\sigma}$ and choose uninformative evaluations $\gamma_i = 0$. Each receives funding in equilibrium.*

- *Agents endowed with ex ante less-promising ideas (i.e., $\rho_i < \sqrt{2(1-\sigma)}$) invest such that $P_i = \rho_i^2/(2\sqrt{1-\sigma})$ and then choose evaluations such that $B_i = \sqrt{1-\sigma}$. They receive funding only when their evaluation produces positive results.*

- *The total mass of high-value proposals that receive funding equals $\sigma\sqrt{1-\sigma}$.*

Agents recognize that even projects with weaker evidence in their favor can receive funding. When designing their evaluations, agents face a trade-off between the probability with which their evaluation generates favorable evidence, and the beliefs associated with favorable evidence. By reducing the informativeness of their evaluations (decreasing γ_i), agents make it less likely that their evaluation reveals a low-value project and more likely that their evaluation produces a favorable report. At the same time, reducing γ_i means that a favorable report is less convincing, and more-likely associated with a low-value project. In equilibrium, agents prefer the least-informative evaluation that they can design while ensuring that their evaluation is not so uninformative that even a favorable report does not receive funding. They will therefore choose an evaluation technology that, when it produces a favorable result, relieves just enough uncertainty about the project to ensure that it receives funding.

As funding capacity increases, the agents with lower ρ_i invest more in their projects than agents with higher ρ_i. Furthermore, given any level of investment, an agent chooses a less-informative evaluation design, on average, as σ increases.

The CF's payoffs depend on both the availability of high-value projects and her ability to identify them. Her payoff simplifies to $u_d = \sigma\sqrt{1-\sigma}$, which is identical the payoff in the no evaluation case. This is because in both the no evaluation and the agent-determined evaluation cases, agents choose strategies that lead to a mass of σ proposals with a similar ex post probability of being high quality (equal to $\sqrt{1-\sigma}$). As was the case without evaluations, u_d is again maximized when $\sigma = 2/3$. There are again benefits to funding scarcity in that they provide incentives to agents to invest in developing stronger proposals whether in terms of intervention design or implementation plans.

4.4 How funded project value depends on evaluation design

This section compares the effectiveness of funding (determined by the number of high-value projects funded) under the three alternative evaluation scenarios. As we discussed before, the analysis abstracts from the costs of evaluation. Therefore, the only adverse effects of (more-informative) evaluations on funding effectiveness comes from how the informativeness of evaluations impacts agent incentives to develop higher-quality proposals.

The analysis has established that the presence of fully informative evaluations decreases the incentives that agents have to invest in proposal quality compared to the less-informative evaluation scenarios. Whether or not this decrease investment in proposal quality leads funding to be less effective under fully informative evaluations depends on the amount of funding that is available.

When funding is relatively scarce ($\sigma \leq 1/4$), fully informative evaluations lead to lower investments in quality, but there are still sufficient investments for there to be σ high value projects. The fully informative evaluations allow the CF to identify and fund these projects, leading to the funding of *only* high value proposals, maximizing CF payoffs and funding effectiveness. The other scenarios do not guarantee that only high value proposals receive funding, leading to lower funding effectiveness.

However, when funding is more abundant ($\sigma > 1/4$), fully informative evaluations decrease investments in proposal quality to the point that it results in the development of fewer high-value proposals than there is available funding. With either no evaluations or agent-determined evaluations, investments in proposals tend to be higher but the CF's ability to distinguish high-value and low-value proposals is lower compared to the case of fully-informative evaluations.

We show, that for most values of σ (specifically, when $(1 - \sqrt{\sigma})/2 < \sigma\sqrt{1 - \sigma}$), the costs of lower investments dominate the benefits of more precise evaluations associated with moving to fully informative evaluations from less-rigorous scenarios. Therefore, in the case of more-abundant funding, subjecting proposals to more thorough evaluations before allocating the CF's funding can decrease the number of high-value proposals implemented and the ultimate effectiveness of the CF.

It is worth highlighting that both the case of no-evaluations and the case of agent-determined evaluations lead to the same level of funding effectiveness. In the case of no evaluations, agents invest more in improving the quality of their proposals compared the case of agent-determined evaluations. However, the gains in effectiveness that come from these increased investments are offset by the losses to funding allocation effectiveness that come from the CF not gaining additional information through an evaluation about the likelihood of a proposal being high value.

Proposition 4. *(Evaluation Design and Funding Effectiveness) There exists a threshold value $\bar{\sigma}$ such that*

i. When funding is scarce ($\sigma \leq \bar{\sigma}$), fully informative evaluations result in higher value projects being funded compared to the cases of no evaluations or agent-designed evaluations.

ii. When funding is more abundant ($\sigma > \bar{\sigma}$), fully informative evaluations result in lower value projects being funded on average compared to the cases of no evaluations or agent-designed evaluations.

The threshold value $\bar{\sigma}$ solves $(1 - \sqrt{\bar{\sigma}})/2 = \bar{\sigma}\sqrt{1 - \bar{\sigma}}$ and is approximately equal to 0.278.

We can further elaborate on these insights by considering an environment where the CF, or rather the agency or foundation providing the financing to the CF, controls the design of the funding environment. This may involve the selection of both the amount of funding to make available, and the the rigor of the proposal evaluation process (from the three possibilities considered) before the full extent of this funding is allocated.

The combination of funding and evaluation rigor that maximizes the number of high-value proposals implemented involves either no evaluations or agent-designed evaluations and funding equal to $\sigma = 2/3$. It does not involve fully informative evaluations, nor full funding such that the CF can afford to provide funding for all projects.

5 Conclusion

Our results highlight two main findings.

First, for a funding organization like a challenge fund, deeper pockets do not imply greater impact. This is because scarcity in resources can induce greater competition between those looking for funding, drive higher investments in developing ideas into interventions that are more-likely to succeed. This means that even when funding is freely available (an incredibly optimistic scenario), restricting the budget can lead to the implementation of more high-value interventions and higher overall social impact.

This result has important implications for funding agencies as they consider setting up competitive funding platforms. For an organization that wants to drive social change on a given issue, directing the maximum funding towards projects in that space may be counterproductive. Counter-intuitively, less funding can mean greater impact as it drives greater competition between the organizations competing for the funding.

Second, more rigorous evaluation of proposals, such as the use of pilot studies and extensive peer review, does not necessarily lead to the funding of better opportunity. This is because extensive evaluations can undermine the incentives that implementers have to invest in the design and planning behind their proposed projects, increasing the likelihood that projects ultimately fail.

Many social sector funding organizations are moving towards performance-based financing models, such as challenge funds or pay-for-results agreements, which tie funding to more-rigorous evaluation. Our analysis highlights that the effect of more-rigorous evaluations on funding effectiveness is more nuanced than generally thought. Introducing a pilot stage to a major grant opportunity that provides an opportunity for implementers to prove the effectiveness of their proposed projects may lead to the submission of lower quality, more-poorly designed or planned, proposals than in an environment where only the most-promising initial proposals receive funding.

We show how the design of a funding mechanism affects the incentives of those competing for funding, sometimes in surprising ways. The most effective CF design needs to carefully consider how the NGOs or researchers competing for funding will respond to a change in incentives that come when more funding is available or proposals are subjected to greater scrutiny. Otherwise, steps taken to improve the number or quality of funded projects can backfire and actually decrease funding effectiveness.

Although our model is constructed with the specifics of the challenge fund environment in mind, the trade-offs that arise in our model are likely to influence incentives in the allocation of funding more generally. The lessons likely extend into other environments where funding is connected to performance, and where performance evaluations may determine payments. This includes, for example, scientific research grants and internal funding allocation processes within organizations.

6 Proofs

Proof of Proposition 1. The decision-maker implements the measure σ of proposals with the highest P_i. Define $\bar{P}$ as the threshold value where those with $P_i > \bar{P}$ receive funding, and those with $P_i < \bar{P}$ do not. We make the following observations about agent strategies. First, agents prefer the lowest P_i such that they receive funding. Thus, there must be a mass with $P = \bar{P}$ and no investment in increasing P_i above this mass point. Second, if $\bar{P} < 1$, then the share of agents with $P_i = \bar{P}$ must equal σ. The probability of funding when $P_i = \bar{P}$ must equal 1, otherwise agents have an incentive to deviate from $P_i = \bar{P}$ to marginally increase their P_i and guarantee funding. Thus, the mass at $P_i = \bar{P} < 1$ cannot exceed σ. Furthermore, agents must not have an incentive to marginally decrease P_i, which means that those with $P_i < \bar{P}$ must not get funding; the mass at $\bar{P}$ must not be less than σ. Third, if $\bar{P} = 1$, then the share of agents with $P_i = \bar{P}$ must be at least σ. Otherwise, agents would have an incentive to reduce their investments. Fourth, agents strictly prefer $P_i = 0$ to any other $P_i < \bar{P}$. Since no $P_i < \bar{P}$ receives funding, it is better to choose the least costly P_i.

The above results imply that each agent chooses either $P_i = 0$ or $P_i = \bar{P}$ for some common $\bar{P} \in (0, 1]$. The costs of investment are strictly decreasing in the quality of an agent's endowed proposal idea (ρ_i). Therefore, there exists a threshold $\bar{\rho}$ such that agents with $\rho_i < \bar{\rho}$ strictly prefer 0, those with $\rho_i > \bar{\rho}$ strictly prefer $\bar{P}$ and those with $\rho_i = \bar{\rho}$ are indifferent. An agent receives 0 from $P_i = 0$. Next, we consider the agent's payoff from $P_i = \bar{P}$.

Consider first the case where the mass of agents with $P_i = \bar{P}$ equals σ. This case captures any equilibrium in which $\bar{P} < 1$, and a special case of equilibria in which $\bar{P} = 1$. In this case, an agent who chooses $P_i = \bar{P}$ receives

$$1 - C(P_i) \to 1 - q_i^2.$$

Given $P_i = \rho_i q_i$ and thus $q_i = P_i/\rho_i$, this expected payoff can be rewritten

$$1 - P_i^2/\rho_i^2 \to 1 - \bar{P}^2/\rho_i^2.$$

Let $\bar{\rho}$ be the value of ρ_i such that the agent is indifferent between $P_i = \bar{P}$ and $P_i = 0$. Therefore, $1 - \bar{P}^2/\bar{\rho}^2 = 0$. Furthermore, we know from above that share σ of the population must have $\rho_i \geq \bar{\rho}$

and from the model, we know that $\rho_i^2 \sim U[0,1]$ and thus $\bar{\rho}^2 = 1 - \sigma$. Therefore, in equilibrium it must be that

$$1 - \frac{\bar{P}^2}{1-\sigma} = 0 \rightarrow \bar{P} = \sqrt{1-\sigma}.$$

For any $\sigma \in (0,1)$, it follows that $\bar{P} \in (0,1)$. Therefore, such an equilibrium exists for all parameter values. Furthermore, we can rule out $\bar{P} = 1$ as such an equilibrium would require a value of $\tilde{\rho} \in (0,1)$ such that agents with $\rho_i \geq \tilde{\rho}$ prefer $P_i = 1$ to $P_i = 0$. Let $\phi \in (0,1]$ denote the probabi ts choosing $P_i = 1$. Thus, it must be that for $\rho_i = \tilde{\rho}$,

$$\phi - \bar{P}^2/\tilde{\rho}^2 \geq 0$$

when $\bar{P} = 1$. This fails to hold as it requires

$$\phi - \bar{P}^2/\tilde{\rho}^2 \geq 0 \rightarrow \phi \geq 1/\tilde{\rho}^2 \rightarrow \tilde{\rho} \geq \sqrt{1/\phi} \geq 1,$$

violating the requirement that $\tilde{\rho} \in (0,1)$.

Proof of Corollary 1. The CF awards funding to the σ projects that have expected quality $\sqrt{1-s}$; the expected measure of high-value projects equals $\sigma\sqrt{1-\sigma}$, which is maximized at $\sigma = 2/3$.

Proof of Proposition 2. Case 1: Suppose there is rationing among high-type projects. Conditional on being high value ($\tau_i = 1$), define $\phi < 1$ to be the probability of receiving funding. Each agent's optimal proposal quality choice P_i maximizes expected payoff $\phi P_i - C(P_i) \rightarrow \phi P_i - P_i^2/\rho_i^2$, and therefore $P_i = \phi\rho_i^2/2$. Given $\rho_i^2 \sim U[0,1]$, the overall measure of high-value projects is

$$\int_0^1 \phi\rho_i^2 \frac{1}{2} f\left(\rho_i^2\right) d\rho_i^2 = \phi/4.$$

For consistency, ϕ must be the share of accepted projects among those that are high-value. Thus, $\phi = \sigma/(\phi/4)$, which implies $\phi = 2\sqrt{\sigma}$. To be consistent with rationing, which requires $\sigma < \phi$, it must be that $\sigma < 1/4$. When $\sigma = 1/4$, the equations still hold with $\phi = 1$. Each agent's investment in quality is calculated as $P_i = \phi\rho_i^2 = 2\rho_i^2\sqrt{\sigma}$, which is increasing in σ and ρ_i. Thus, when, $\sigma \leq 1/4$, $\phi \leq 1$ and therefore there are at least as many high-value proposals that can be identified as there is funding, implying a CF payoff equal to $u_d = \sigma$.

Case 2: Suppose that the decision-maker accepts all projects with $\tau_i = 1$ and fraction ψ of the projects with $\tau_i = 0$. Each agent's optimal quality choice maximizes expected payoff $P_i + (1 - P_i)\,\psi - P_i^2/\rho_i^2$, and is thus $P_i = (1-\psi)\,\rho_i^2/2$. Given this, the overall measure of high-value projects funded is

$$\int_0^1 (1-\psi)\,\frac{\rho_i^2}{2} f\left(\rho_i^2\right) d\rho_i^2 = (1-\psi)\,/4.$$

and overall measure of low-value projects developed is $\sigma - (1-\psi)\,/4$. For consistency ψ must be the share of projects accepted among those that are bad

$$\psi = \frac{\sigma - (1-\psi)\,/4}{1-(1-\psi)\,/4} \to \psi = 2\sqrt{\sigma} - 1$$

In this case, $\psi \in (0,1)$ if $\sigma \in (1/4, 1)$. Each agent's investment in quality is thus

$$P_i = \left(1 - \sqrt{\sigma}\right) \rho_i^2,$$

which is decreasing in funding availability σ and increasing in ρ_i. The CF's payoffs are equal to the overall measure of high-value proposals funded, $u_d = (1-\psi)/4 = (1-\sqrt{\sigma})/2$.

Proof of Proposition 3. Let g_i denote the probability that proposal i is high-value following the evaluation process at the time when funding is allocated. There exists a threshold belief G such that each agent only receives funding if $g_i \geq G$. Similar logic applies to G as applied to $\bar{P}$ in the proof to proposition 1. If $G < 1$, then the measure of projects with posterior beliefs $g_i = G$ must equal σ and any project with posterior beliefs $g_i = G$ must be accepted. Otherwise agents would have an incentive to marginally increase either P_i or γ_i and thus B_i, leading to a discontinuous step up in the probability of receiving funding when they experience a positive evaluation and only a marginal (ϵ small) decrease in the probability of experiencing a positive evaluation. If $G = 1$, then projects must be proven to be high-value in order to receive funding, and the case collapses to the case of fully-revealing evaluations studied above.

Suppose $G < 1$.

If agent i chooses $P_i < G$, then it will receive funding only if it generates ex post beliefs $g_i \geq G$. We know from above it will choose γ_i such that $B_i = G$, which implies that a positive experiment (and the corresponding receipt of funding) will be realized with probability P_i/G. Thus, an agent with ρ_i receives expected payoff $P_i/G - P_i^2/\rho_i^2$ from choosing $q_i < G$. This case is equivalent to investing less, but making up for it with more-informative evaluations.

If agent i chooses $P_i = G$, then it will receive funding without the need to subject its proposal to additional evaluation, allowing it to guarantee funding and set $\gamma_i = 0$. In this case, i expects payoff $1 - P_i^2/\rho_i^2 = 1 - G^2/\rho_i^2$. An agent will always prefer $P_i = G$ to achieving an even higher value of P_i.

Among the agents who choose $P_i < G$, the optimal P_i is

$$P_i = \frac{\rho_i^2}{2G} \quad \text{and} \quad u_i = \frac{\rho_i^2}{4G^2}.$$

Since $P_i < G$, it follows that $\rho_i^2 < 2G^2$ or equivalently $\rho_i < G\sqrt{2}$. One can check that investing such that $P_i = \rho_i^2/(2G)$ is preferred to deviating to $P_i = G$:

$$\frac{\rho_i^2}{4G^2} > 1 - \frac{G^2}{\rho_i^2} \rightarrow (2G^2 - \rho_i^2)^2 > 0$$

which holds with strict inequality. If $\rho_i > G\sqrt{2}$, then the optimal proposal quality is $P_i = G$. Hence, all types with $\rho_i < G\sqrt{2}$ prefer to invest such that $P_i < G$ and then choose an evaluation such that $B_i = G$, whereas types with $\rho_i > G\sqrt{2}$ invest such that $P_i = G$ and do not subject their proposals to evaluation. Hence, the mass of agents with an ex post probability that their proposal is high-value equal to G is

$$\int_0^{2G^2} \frac{\left(\frac{\rho_i^2}{2G}\right)}{G} d\rho_i^2 + \left(1 - 2G^2\right) \rightarrow 1 - G^2.$$

Because no rationing is possible at G, unless $G = 1$, it must be that if there is no rationing in equilibrium, and therefore this expression equals σ. Solving $1 - G^2 = \sigma$ for G gives $G = \sqrt{1-\sigma}$, which implies that $G \in (0, 1)$ for this case for any feasible $\sigma \in (0, 1)$. As with $\bar{P}$ in the proof to the first proposition, we can rule out the possibility that $G = 1$.

Thus, the mass of funded proposals that turn out to be high-value equals $\sigma G = \sigma\sqrt{1-\sigma}$, which denotes u_d. Substituting in for G in the threshold value for ρ_i gives $G\sqrt{2} = \sqrt{2(1-\sigma)}$.

Proof of Proposition 4. Follows from a straightforward comparison of the payoffs previously derived.

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