Semi-public Contests *

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Abstract

Entrepreneurs with ideas of uncertain value have to be matched with investors to create economic value. If the matching procedure does not involve screening of ideas, all investors form the same expectation and compete away any profit. Conversely, if the procedure involves screening, the entrepreneur expects that the investor uses his inside information and extracts rents from him. This threat can deter the development of innovations and reduce welfare. This paper proposes a mechanism, called *semi-public contest*, to mitigate the dilemma. By sponsoring a contest, an investor obtains information on participating entrepreneurs' project values, which benefits him by placing better-informed bids. He reduces his payoff by publicizing contest winners but thereby he creates incentives for entrepreneurs to participate in the contest because winners can expect high payoffs and reputation. The sponsor retains exclusive information about losers' projects, though. One form of semi-public contests are business plan competitions.

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1 Introduction

To foster innovation two main ingredients are necessary, according to Scotchmer (2004): inventions, and institutions supporting the transformation of inventions into innovations. This paper proposes a new institution to the economic literature and shows how it can mitigate a dilemma that arises at a very early stage of innovative activity.

Entrepreneurs, endowed with project ideas of uncertain value, have to be matched with investors, each of whom owns financial resources and the relevant expertise to innovate but lacks ideas. If the procedure of matching both sides does not involve screening of the project quality, all investors have the same expectation and will compete away any profit to be made when bidding for them. If investors have to bear a cost for market research, this zero profit may be insufficient to attract market entry. Conversely, if an investor screens an entrepreneur's project and gains inside information on the project value, the entrepreneur may expect that the investor will use his superior information when bidding and will extract some profit from the entrepreneur, a form of hold-up. As entrepreneurs have to bear a cost for developing a prototype, the expected profit reduction can deter the development of innovations and, thus, reduce welfare. This paper proposes a mechanism (or institution), called *semi-public contest*, to mitigate this dilemma.

According to this mechanism, an investor outsources screening to a jury of experts that produces a ranking of those entrepreneurs' projects who voluntarily participate in screening, which is costly for both sides. The identities of the contest winners are publicized by the jury, which creates symmetric information amongst investors on the winners' project values. Thus, winners expect high bids for their projects and they earn a reputation, whose value grows in the level of competitiveness of the contest. The project values of contest losers, however, remain exclusive inside information of the contest sponsor.

Why would an investor sponsor a contest that exhibits a positive externality, as the sponsor pays all screening costs but competing investors also learn the types of winners? The answer is that the sponsor benefits from exclusive inside information on contest losers by placing better informed bids on their projects. By publicizing the identity of winners he reduces his payoff compared to exclusive private screening. But he creates an incentive for entrepreneurs to participate in the contest because they strive for the reputation and high payoff in case of winning.

Semi-public contests are frequent phenomena in practice. For instance, apart from friends and family, a relatively new form of startup financing has appeared since the 1980s. Venture capital firms and business angels have joined with universities to attract ideas for new businesses through *business plan competitions*. In a business plan competition, entrepreneurs prepare and submit a complete business plan, including the description of their product or process idea, the target market, the management team, strategy, marketing, financial planning, etc.[1] Business plans are screened by a jury of experts, often encompassing venture capitalists, consultants, lawyers, public accountants, and business professors. The most promising business ideas are declared winners of the contest and, hence, earn the winners high reputation and exposure to investors, some of whom sponsor the contest.[2]

I show that, if investors face competition and if the expected value of the reputation of a winner, which is created by publicizing the winners, is sufficiently high as compared to the screening cost of investors and entrepreneurs, both sides are motivated to participate in a semi-public contest. In deciding this, an entrepreneur trades off the expected benefit in case of winning the contest against the cost he incurs during the specific screening procedure and the expected loss in bidding in case of losing the contest.

I also show that in equilibrium only one investor sponsors a given semi-public contest. Sponsoring is exclusive because the sponsor prefers not to share the inside information on losers' types and willingly rejects the potential to share screening costs with other investors. The market for semi-public contest has characteristics of a natural monopoly. I show that, depending on parameter realizations, it is possible in equilibrium that a unique contest is organized but also that competition among contests for participants is feasible.

Summarizing, semi-public contests can mitigate, yet not eliminate, a hold-up problem faced by entrepreneurs in exclusive private screening. Non-exclusive private screening is unprofitable for investors and, hence, does not exist in equilibrium. I show that a semi-public contest can serve as a welfare enhancing "compromise" between investors and entrepreneurs saving each side a positive expected payoff from matching.

As these contests only exist if they are efficient when compared to no screening and private screening, this model does not suggest that government author-

[1]For instance, the "Moot Corp Competition". See Appendix A.

[2]Other applications comprise TV casting shows for would-be pop stars (for instance, the TV show "American Idol", see Appendix A); talent competitions among young artists, classical musicians, or software developers; architecture competitions; and industry sponsored project grants for researchers or graduates.

ities intervene directly. However, there is an indirect role for public policy. First, as semi-public contests depend on active competition among investors, it is crucial that competition policy authorities safeguard competitive markets. Second, as the semi-public contest mechanism has only been used selectively in practice but could be used in many more fields, spreading information on how it works could let "investors" in some markets, who are feeling now that they only have the choice between private screening and no screening, contemplate about a new mechanism to match with "entrepreneurs".

I endogenize the investors' choice of mechanism and the entrepreneurs' product development and contest participation decisions in a four-stage multi-principal multi-agent game with incomplete information. First, entrepreneurs decide whether to develop their ideas into projects and investors decide whether to enter the market, or not. Second, investors choose sequentially among private screening, no screening, and a semi-public contest. In a contest, they also choose the number (not the identity) of winners. Third, entrepreneurs choose simultaneously if to allow screening at all and which investor to allow it in case there is more than one screening offered. Contest winners' identities are publicized and sponsors learn losers' values exclusively. Finally, every investor places a bid for every project in a first-price sealed bid auction.

The final stage draws on Engelbrecht-Wiggans, Milgrom, and Weber (1983) (henceforth: EMW), who analyze a first-price sealed bid auction in a common-value setting when one bidder has more information on the item auctioned and the other bidders have symmetrically less information. The key insight from EMW used in this model is that it pays for an investor to know more about the value of a project than competing investors.

The paper most related to this one is Rajan (1992), which also draws on EMW. Rajan models the trade-off faced by an entrepreneur to choose between different forms of credit financing. He argues that the apparently efficient form, borrowing from an informed (insider) bank, comes at a cost: banks have bargaining power over the entrepreneurial firm's profits. This notion is related to the hold-up problem I identified above. Rajan's focus and model, however, are different. In his model there is only one entrepreneur, not many, market entry of entrepreneurs and investors is not endogenous, and the entrepreneur may exert effort that affects the distribution of project returns.

Felli and Roberts (2002) also use the latter assumption. In their matching model, many sellers of a good meet many buyers. In various specifications of the game, either sellers or buyers or both groups can invest specifically in their qualities, which influences their respective values when being matched. Subsequently, buyers may simultaneously and independently submit bids to the sellers. In contrast both to Rajan (1992) and to Felli and Roberts (2002), in my model the value of an entrepreneur's project is exogenously given, yet unknown to all players, and the complementarity of inputs from every entrepreneur and every investor is perfect. In turn, this model differs by proposing a new mechanism to the literature that can mitigate a dilemma at the very beginning of the process of innovation, where ideas may or may not be developed up to a stage where they can be discussed with complementary experts.

This focus on the early idea development stage is shared with Biais and Perotti (2008), who treat the problem of stealing innovative ideas. They start from the notion that ideas may have several dimensions that can be discussed by an entrepreneur with different experts and propose a mechanism that allows the entrepreneur to avoid idea stealing.

This paper is also related to the literature on research contests.[3] In a research contest, suppliers of an innovation bid for a procurement contract that is offered by a monopsonistic buyer. In a semi-public contest, in contrast, first the suppliers (entrepreneurs) endogenously develop innovations. Next they have to be incentivized to reveal information about their project values despite knowing that the inside buyer will exploit them when bidding against less informed buyers. A semi-public contest can mitigate this problem because it serves as a buyer's commitment device to only exploit losers, not winners.

The paper is organized as follows. Section 2 describes the model. Section 3 characterizes the conditions that make existence of a semi-public contest part of a Perfect Bayesian Equilibrium; this section also shows the main results. Section 4 discusses robustness of several assumptions. Section 5 concludes by proposing the application of the model to other contexts. Appendix A describes two applications of the model, business plan competitions and TV casting shows, in more detail. All proofs are in Appendix B.

2 The Model

Entrepreneurs

On the seller side of a market there are N *entrepreneurs*, each of whom may develop one project. N is common knowledge but, because the N entrepreneurs

[3] See Taylor (1995), Fullerton and McAfee (1999), Fullerton et al. (2002), and Che and Gale (2003).

are drawn from a large population, their identities are unknown. The cost of development for entrepreneur i is D_i, which is drawn from a continuous distribution $\mathbf{D} \in (0, \infty)$. All draws are i.i.d., $\mathbf{D}$ is common knowledge, and i learns D_i privately before he decides whether to develop the project, or not. If i decides to spend D_i, he obtains a project worth Z_i, which also represents i's talent and is drawn from a continuous, atomless distribution $\mathbf{Z} \in [0, \overline{Z}]$ with expectation $E(\mathbf{Z})$. $\mathbf{Z}$ is statistically independent of $\mathbf{D}$ and is common knowledge but nobody, including entrepreneur i, knows the realization Z_i. Consequently, each entrepreneur has the same expectation about his own Z_i. Every entrepreneur needs an investor to realize Z_i.

The independence of $\mathbf{Z}$ and $\mathbf{D}$ captures that the development cost of an idea depends on several exogenous factors, such as the industry or the potential production technology of the project, but that the market value of an idea depends on other factors, such as the degree of competitiveness and consumer demand. Similarly, the assumption that i knows D_i but not Z_i reflects that the development cost is determined on the supply-side, which entrepreneurs are assumed to know something about, while the market value is determined on the demand-side. Moreover, i does not know his potential competitors.

Investors

On the buyer side of the market there are $m + 1$ identical *investors*. They can be considered experts, who have both the knowledge to compare project values and the means to transform a "raw" project into real economic value. However, they lack innovative ideas and, thus, need an entrepreneur's project to realize a positive value. To obtain an overview of the market and to learn which projects are developed by entrepreneurs, every investor j has to spend an entry cost $F \geq 0$ for market research. Without further investigation each investor just can guess the true value of a randomly chosen project and therefore expects $E(\mathbf{Z})$.

Screening

Each investor can hire an independent *jury* (see details below), which can screen an entrepreneur's project for a unit cost k. When offered a screening, entrepreneur i can choose to collaborate, which costs him c. Both k and c are specific to one screening procedure. They reflect the time and the effort spent to interact with each other and to produce documents, etc. that are targeted to one specific screening. If a screening takes place, the jury learns the value of the entrepreneur's project, Z_i, and informs the investor financing the screening, but nobody else, about it. An investor with such superior information is an *insider*. The remaining m investors are *outsiders* with respect to entrepreneur i. The entrepreneur, however, cannot compare his project to others' and, thus, does not learn by getting screened.

Forms of Screening

Screening can take either of two forms: *exclusive private screening* or *semi-public contest*. After a private screening the jury reports the value Z_i of every project screened only to the investor who pays its screening cost.[4] Alternatively, if an investor organizes a semi-public contest, he picks a number $n \leq N$ of winning slots and the independent jury publicly declares the n entrepreneurs with the highest project values "winners" of the contest, detailing who is the first, the second, ..., the nth winner.

Outsourcing the picking of winners to a jury serves as a commitment device of the contest sponsor that indeed the best entrepreneurs are declared winners. If the sponsor picked or published the contest winners himself, similar to private screening, he would have an incentive to misreport and to keep information on the best entrepreneurs private. This incentive would be foreseen by the outsiders and, hence, no reputation would be produced for the contest winners.

One interpretation of the completely truthful jury is that the jurors have a high reputation themselves, which translates into high expected future payoffs. If they falsely declare winners, there is a probability of being detected and losing this reputation.[5]

Publishing the identity of winners of a contest by the jury has two effects. First, all outside investors can update their beliefs about the value of winners' and losers' projects. Second, each winner gains a reputation for being smart or talented, which is worth $R(\alpha_j)$ to him. I make the following key assumption.

Assumption 1 (Reputation production function) $R(\alpha_j) \in [0, \bar{R}]$ *is the reputation production function of a semi-public contest, where* $\alpha_j \equiv \frac{n_j}{N_j} \in [0, 1]$ *is the probability of winning the contest sponsored by investor* j, n_j *is the number*

[4] See section 4 for a discussion of private screening by more than one investor.

[5] It is straightforward to model such a subgame as a repeated game and to show that jurors who value future payoffs sufficiently highly will not declare winners falsely in equilibrium. To simplify the analysis I just assume truthful reporting.

of winning slots, and N_j is the total number of participants in contest j.

$$R(\alpha_j = 1) = 0, \quad \frac{dR}{d\alpha_j} < 0, \quad \frac{d^2R}{d\alpha_j^2} > 0. \tag{1}$$

Assumption 1 implies that winning a contest is only valuable if not every participant "wins" and that the value of winning a contest increases convexly the less likely it is to win. R can be interpreted as the *net present value of future earnings* attributable to winning the contest, apart from getting higher bids when selling a project.[6] Alternatively, R can be interpreted as the non-pecuniary utility from the *esteem* attached to winning a contest, which is enjoyed in other social situations. In both interpretations, the more exclusive it is to be a winner of a truly competitive contest the higher winning is valued. Note that private screening does not create reputation utility because its results are not published.

The publication of winners' identities creates a *public* signal on their value. Analogous to private screening, I assume the jury informs the contest sponsor about the precise realization Z_i of *every* entrepreneur participating in the contest in *private*. Hence, the insider has an information advantage over outsiders with respect to the losers of the contest.

Besides private screening and semi-public contest, the third option of an investor is *no screening*. After screening or not screening, the project of one entrepreneur at a time is auctioned among all investors in a first-price, sealed-bid auction.

Investors and entrepreneurs are assumed to be risk-neutral. Investors face no budget constraints and have infinite demand for investment projects with non-negative expected payoff net of cost. I assume that, before placing their auction bids, all investors learn whether an entrepreneur was screened, or not.

Timing of the Game

First, entrepreneurs decide whether to develop a project, or not. Investors decide whether to enter the market, or not. Second, investors are ordered

[6] This interpretation is intuitive if we assume that, in a repeated game context, it is prohibitively costly for an investor to check the history of past contest participation of each entrepreneur. In contrast, winners can prove that they have actually won a contest. Hence, contest losers and new entrepreneurs will be pooled in the future. Then we can normalize the reputation of each member of this pool to be zero. Investors will believe that the probability that a former winner has a high talent is larger than this probability of another entrepreneur. This belief creates $R \geq 0$.

randomly by nature. The first investor chooses among *exclusive private screening*, *semi-public contest*, and *no screening*. The other investors follow in the order of the random draw. The sponsor of a contest determines n, which is published. Third, if private screening or a contest is chosen by an investor, each entrepreneur simultaneously decides whether and where to participate in screening. Juries screen participating entrepreneurs and inform their sponsors. Fourth, each investor places a bid b for each project being auctioned. The highest positive bid wins and is transferred from the bidder to the entrepreneur. In exchange, the entrepreneur assigns ownership of the project to the highest bidder. Figure 1 displays the timing of the endogenous decisions in the game.

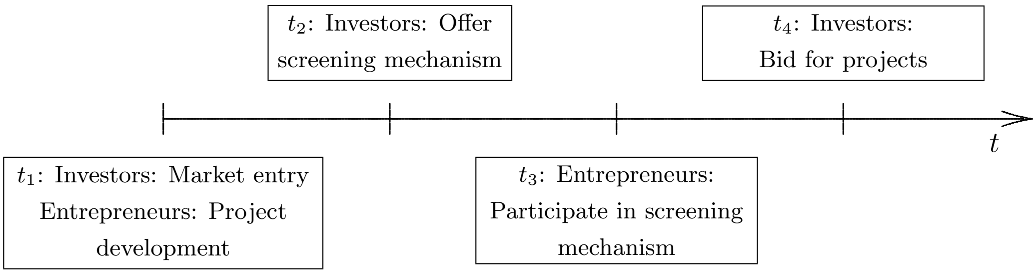

Figure 1: Time structure of the model

The solution concept used is Perfect Bayesian Equilibrium. As usual in such games, there are multiple equilibria, each sustained by its own expectations. Due to the ex ante symmetry of entrepreneurs, on the one side, and investors, on the other, I focus on symmetric equilibria and pick one equilibrium that gives each screening technology its best shot. I proceed by first analyzing the benchmark case of no screening. Then, I introduce the option of exclusive private screening. Finally, I allow every investor to set up a semi-public contest and show the conditions under which the existence of contests and active participation of entrepreneurs therein characterize an equilibrium.

3 Analysis

The Benchmark: No Screening

If no screening of an entrepreneur takes place, in stage 4 all investors have symmetric information, and they know that they have symmetric information. Let b denote the bid and $E(\pi_j)$ denote the expected auction payoff of an investor.

Lemma 1 (No screening) *In equilibrium, each investor bids $b = E(\mathbf{Z})$ and realizes $E(\pi) = 0$.*

If in a common-value auction with symmetric bidders one bidder bids more than the others, he will bid more than the average value of projects auctioned and thereby reduce his expected payoff. This characteristic is known as the *winner's curse*.[7] Note that the bidding strategies in Lemma 1 do not depend on costs incurred by the investors in earlier stages, namely F, as these costs are sunk in stage 4. The situation of bidders is related to Bertrand competition with homogenous goods.

Exclusive Private Screening

If an investor screened entrepreneur i exclusively, he is an insider, by definition. Thus, at stage 4, I am looking for an equilibrium in a first-price sealed-bid auction, where one bidder has precise information about the value of the project auctioned, whereas m bidders symmetrically have less information.

Engelbrecht-Wiggans, Milgrom, and Weber (1983) analyze such an auction. Let $\beta(\mathbf{Z})$ denote a pure strategy of the insider, in which he maps each value Z that he learns via screening onto a bid b.[8] For each outsider j, a mixed strategy is a distribution G_j on $\mathbf{R}_+$ where $G_j(b)$ is the probability that his bid does not exceed the insider's bid b. Let $G(b) = G_1(b) \cdot ... \cdot G_m(b)$. Then, $G(b)$ denotes the distribution of the maximum of the bids made by the outsiders.

Lemma 2 (Auction equilibrium with asymmetric information) *(i): The $(m+1)$-tuple $(\beta, G_1, ..., G_m)$ is an equilibrium point if and only if:*

$$\beta(\mathbf{Z}) = E[\mathbf{Z}|\mathbf{Z} < Z] \quad \textit{and} \tag{2}$$

$$G(b) = Prob(\beta(\mathbf{Z}) \leq b). \tag{3}$$

(ii): In equilibrium, each outsider expects $E(\pi_{OUT}) = 0$, the insider expects $E(\pi_{INS}) = (1 - \theta(\mathbf{Z}))E(\mathbf{Z})$, entrepreneur i expects $E(\pi_i) = \theta(\mathbf{Z})E(\mathbf{Z})$.

Comparing equilibrium strategies in Lemmas 1 and 2.(i), in an auction that was preceded by screening, the outsiders are more cautious than in the symmetric information case if they believe that an insider has additional useful information. They bid according to a mixed strategy over $[0, E(\mathbf{Z})]$ and, thus, avoid the winner's curse in expectation.

[7] See, for instance, Milgrom and Weber (1982).

[8] According to EMW, p.164, if $\mathbf{Z}$ had an atom at some Z, $\beta(\mathbf{Z})$ would have to be a mixed strategy.

The key insight from Lemma 2.(ii) for my model is that it pays for an investor, at least in gross terms, to be an insider. Unavoidably, this comes at a cost for the entrepreneur selling his project because the project value is not influenced by screening but here the insider can appropriate a share of it. If the entrepreneur does not agree to screening, this refusal cannot rationally be used as a signal for low ability from the investors' perspective, though, because entrepreneurs do not know their own relative ability.

Semi-public Contests

Consider the following candidate equilibrium: At stage 1, all entrepreneurs whose project development does not cost more than $\bar{D}$ develop their projects. All investors spend the entry cost F as long as it is not larger than a threshold level, $\bar{F}$. At stage 2, the first of the $m+1$ investors, who was randomly selected, chooses to sponsor a semi-public contest and determines a number of winning slots n^* for the best entrepreneurs. The remaining m investors do not offer a contest. At stage 3, all N entrepreneurs participate in the contest and get screened by the jury. All investors observe the contest winners' types, while the insider retains an information advantage with respect to the losers' types. At stage 4, the auction takes place, in which all investors bid the value Z_i for each winner of the contest. For each loser, however, bids of the insider and the outsiders differ (in an adjusted version of Lemma 2).

The remainder of this section is dedicated to prove that such a Perfect Bayesian Equilibrium exists and to show the conditions under which it exists. As noted before, this equilibrium is not unique but it is efficient when compared to private screening and no screening. I do not regard a market breakdown equilibrium in more detail, in which no entrepreneur develops a project, no investor enters the market and, hence, innovation does not take place.

Recall that $\alpha_j \equiv \frac{n_j}{N_j}$ is the share of winners in all entrepreneurs participating in a contest j.

Definition 1 (Average values of contest winners and losers) *Consider contest j. I define Z_n as the lowest value of a winner's project, Z_w as the average value of a winner's project, and Z_l as the average value of a loser's project.*

By assumption, the identities of the best n_j entrepreneurs are published as winners. Because all investors know the distribution $\mathbf{Z}$, they also know the realization of Z_n and, consequently, Z_w and Z_l. It follows that $Z_l < E(\mathbf{Z}) < Z_w$ and that $0 < Z_l < Z_n < Z_w < \bar{Z}$ for $\alpha_j \in (0, 1)$.

What is the bidding equilibrium for an entrepreneur's project at stage 4 if he is a contest winner? In this case, all investors symmetrically have precise information on the value of his project: Z. By the Bertrand competition logic applied in Lemma 1, each investor bids Z and earns an expected payoff of zero. In stage 3, when the entrepreneur has to decide about contest participation, he does not know the exact value of his project. However, he knows the number of winning slots n_j and can form a belief about the number of contest participants N_j (see details below). Hence, he can form a belief on α_j and use it, together with his knowledge on $\mathbf{Z}$, to guess the average value of a winning project, Z_w.

What is the bidding equilibrium if an entrepreneur is a contest loser? This case is similar to the one analyzed in Lemma 2, with the exception that the support of the project value distribution is $[0, Z_n]$, which changes the support of bidding strategies in Lemma 2.(i). It changes Lemma 2.(ii) to $E(\pi_{INS}) = (1-\theta)Z_l$ and $E(\pi_i) = \theta Z_l$, respectively. All this is common knowledge.

At stage 3, each entrepreneur has to make two decisions: (i) whether he wants to participate in a contest at all, or whether he prefers private screening or no screening; (ii) conditional on contest participation, where he wants to participate if there are multiple contests offered.

Definition 2 (Entrepreneurs' beliefs) *From the perspective of entrepreneur i, $\tilde{N}_j$ is the expected number of participants in contest j* before *i decides about his participation, and $\tilde{\alpha}_j \equiv \frac{n_j}{\tilde{N}_j+1}$ is the expected winning probability in contest j* after *i decided to participate in j.*

At stage 3, the development cost D_i is sunk. If he participates in contest j, entrepreneur i expects a payoff of:

$$\tilde{\alpha}_j[R + Z_w] + (1-\tilde{\alpha}_j)[\theta Z_l] - c. \tag{4}$$

By using $E(\mathbf{Z}) = \tilde{\alpha}_j Z_w + (1-\tilde{\alpha}_j)Z_l$, this can be rewritten as:

$$E(\mathbf{Z}) + \tilde{\alpha}_j R(\tilde{\alpha}_j) - (1-\tilde{\alpha}_j)(1-\theta)Z_l(\tilde{\alpha}_j) - c. \tag{5}$$

An entrepreneur can influence his expected payoff $E(\pi_i)$, as in (5), by choosing to participate in a certain contest j, which increases the expected number of participants in that contest by one and, thus, has an influence on the winning probability in j.

Note that $\tilde{\alpha}_j$ influences $E(\pi_i)$ via three arguments: it has a direct effect (via $\tilde{\alpha}_j$) and two indirect effects (via $R(\tilde{\alpha}_j)$ and $Z_l(\tilde{\alpha}_j)$). Due to the decreasing effect of $\tilde{\alpha}_j$ on R, $E(\pi_i)$ is non-monotonic in $\tilde{\alpha}_j$.

Lemma 3 (Optimal winning probability) *From entrepreneur i's perspective, there is a unique, well-defined winning probability α^* that maximizes his expected payoff.*

Lemma 3 implies that entrepreneurs face a trade-off when deciding in which contest to participate in. If the winning probability in a contest is high, it comes at a cost because the reputation benefit of being a winner in that contest is small. In contrast, competition for the high reputation benefit that can be gained in a very exclusive contest is intense. However, there the winning probability is small, by definition, which reduces the expected utility from participation. Therefore, the expected payoff function of entrepreneurs from contest participation is hump-shaped in the expected winning probability; see Figure 2. This implies that, for $\tilde{\alpha}_j > \alpha^*$, there are positive network externalities, i.e. the expected utility of the participants in contest j increases if another entrepreneur participates in this contest. For $\tilde{\alpha}_j \leq \alpha^*$, there are negative network externalities because every additional participant drives $\tilde{\alpha}_j$ further away from α^*.

To facilitate the comparison of mechanisms I define the winning probability levels, for which entrepreneurs expect the same payoff as from no screening:

Definition 3 (Threshold winning probabilities) *The winning probabilities in contest j, for which $E(\pi_i(\tilde{\alpha}_j)) = E(\mathbf{Z})$ holds, are defined as $\underline{\alpha}$ and $\bar{\alpha}$, where:*

$$\underline{\alpha} \equiv \frac{c + (1-\theta)Z_l(\underline{\alpha})}{R(\underline{\alpha}) + (1-\theta)Z_l(\underline{\alpha})} \leq \frac{c + (1-\theta)Z_l(\bar{\alpha})}{R(\bar{\alpha}) + (1-\theta)Z_l(\bar{\alpha})} \equiv \bar{\alpha}. \tag{6}$$

Lemma 4 (Entrepreneurs' preferred mechanism) *Assume $E(\pi_i(\alpha^*)) \geq E(\mathbf{Z})$. (i): From an entrepreneur's view, $\forall\ \tilde{\alpha}_j > 0$, private screening is dominated by no screening and by a semi-public contest. (ii): If $\tilde{\alpha}_j \in [\underline{\alpha}, \bar{\alpha}]$, an entrepreneur prefers a semi-public contest over no screening, and vice versa otherwise.*

The intuition of Lemma 4.*(i)* is that entrepreneurs have no interest in providing information about their types to a single investor as this is not only costly but, due to lower bids, also decreases their expected auction revenues.

The intuition of Lemma 4.*(ii)* is that a semi-public contest can be entrepreneur's most preferred mechanism if the expected winning probability of a contest lies in an intermediate range and thereby the expected reputation benefit from winning, $\tilde{\alpha}_j R(\tilde{\alpha}_j)$, is high. This result is mainly due to the inverted effect from α on $R(\alpha)$. Furthermore, the value of $R(\alpha)$ must be sufficiently large at its maximum α^* in order to make contest participation attractive for entrepreneurs. Only then it is possible that in expectation the reputation benefit conditional on becoming a contest winner outweighs the screening cost of an entrepreneur plus the share of the project value that the insider can appropriate conditional on the entrepreneur becomes a contest loser. For the remainder of the analysis I assume that this holds:

Assumption 2 (Expected contest payoff) $E(\pi_i(\alpha^*)) \geq E(\mathbf{Z})$.

Figure 2 summarizes Lemmas 3 and 4 by plotting entrepreneurs' expected payoff from contest participation, $E\pi_i(SPC)$, and from no screening, $E\pi_i(NS)$, as a function of the expected winning probability in contest j.

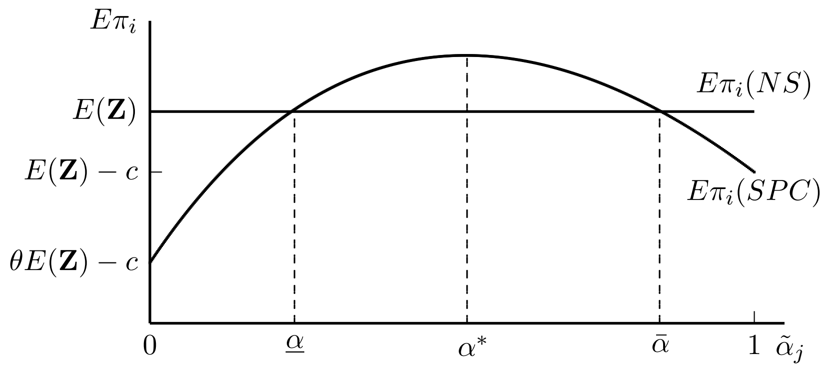

Figure 2: Expected payoffs from contest participation and no screening.

Lemma 4 captures entrepreneurs' participation constraint in semi-public contests as a whole. As a next step, I characterize the equilibrium specifying the one contest in which an entrepreneur participates, given that the participation constraint holds and there are possibly multiple contests offered.

Lemma 5 (Contest participation equilibrium) *Let Q be the number of contests that offer at least one winning slot (for which $n_j \geq 1$). (i): If $\frac{n_j}{N} \in [\underline{\alpha}, \bar{\alpha}]$, there exists a unique symmetric Nash equilibrium in pure strategies that dominates no screening. (ii): Given that $\tilde{\alpha}_j(\phi_j^*) \in [\underline{\alpha}, \bar{\alpha}]$, there exists a symmetric Nash equilibrium in mixed strategies, $\Phi(\phi_j^*), \forall j \in \{1, 2, ..., Q\}, \forall i$, that dominates no screening. Every entrepreneur participates in every contest with probability ϕ_j^*, where:*

$$\phi_j^* = \frac{n_j(N + (Q-1)) - \sum_{q=1}^{Q} n_q}{(N-1)\sum_{q=1}^{Q} n_q}. \tag{7}$$

If $\frac{n_j}{N} \notin [\underline{\alpha}, \bar{\alpha}]$ but $\tilde{\alpha}_j(\phi_j^*) \in [\underline{\alpha}, \bar{\alpha}]$ (or vice versa), $\Phi(\phi_j^*)$ is the unique symmetric equilibrium (and vice versa).

When every entrepreneur has to decide about contest participation, all entrepreneurs have the same information on the number of winning slots in each contest $\{n_1, ..., n_Q\}$ and have identical characteristics in expectation. However, they cannot coordinate their participation choices and have no rational basis for asymmetric beliefs on the other entrepreneurs' choices. This explains the concept of *symmetric* Nash equilibrium.

In a symmetric pure strategy Nash equilibrium, all entrepreneurs, by definition, participate in the same contest j. Thus, the expected winning probability in this contest is $\tilde{\alpha}_j = \frac{n_j}{N}$. Lemma 5.(i) states that this winning probability, depending on the reputation associated with it and the screening cost incurred by the entrepreneurs, can lead to higher expected utility for entrepreneurs than their outside option, no screening, which secures them an expected payoff $E(\mathbf{Z})$ from auctioning off their projects.

Lemma 5.(ii) starts from the fact that the expected winning probability of an entrepreneur in contest j is higher than in the symmetric pure strategy equilibrium if the other entrepreneurs participate in j with less than probability one, because they participate in other contests with some positive probability, too. Then it is possible that entrepreneurs expect a higher utility than under no screening (and than in the pure strategy equilibrium). To make this situation an equilibrium the strategies of the other entrepreneurs make every entrepreneur i indifferent between playing *any* mixed strategy because they make sure that i faces the same ex post winning probability in every contest, i.e. given he participates in it. Given this strategy combination, $\Phi(\phi_j^*), \forall j \in \{1, 2, ..., Q\}, \forall i$, i expects a winning probability of:

$$\tilde{\alpha}_j(\phi_j^*) = \frac{\sum_{q=1}^{Q} n_q}{N + Q - 1} \quad \forall j \in \{1, ..., Q\}. \tag{8}$$

The mixed strategy equilibrium is unique if the winning probability from the pure strategy equilibrium, $\frac{n_j}{N}$, is too low and, thus, is dominated by no screening. Moreover, the pure strategy equilibrium and the mixed strategy equilibrium coincide if only one contest is organized by investors ($Q = 1$).

Now consider the second stage of the game, in which nature determines an order of investors, $\{1, ..., m+1\}$, and investors decide sequentially, starting with investor 1, among no screening, private screening, and semi-public contest.

Abstracting from sunk market entry cost F, investor j expects a payoff of zero from no screening; see Lemma 1. From private screening he expects $[(1-\theta)E(\mathbf{Z}) - k]$ from each entrepreneur screened; see Lemma 2. If $\tilde{\alpha}_j(\phi_j^*) \in [\underline{\alpha}, \bar{\alpha}]$, all entrepreneurs will participate in a contest. Then, he expects $[-k]$

from each winner and $[(1-\theta)Z_l - k]$ from each loser. In total, he expects:

$$(\phi_j^* N - n_j)(1-\theta)Z_l - \phi_j^* N k, \tag{9}$$

where $\phi_j^* N$ is the expected number of entrepreneurs participating in his contest. It is straightforward to observe from (9) that an investor will never organize a semi-public contest if the screening cost k is prohibitive. As the minimum number of winning slots in case a contest is offered is $n_j = 1$, I will only consider cases for the remainder of the analysis, for which the following assumption holds:

Assumption 3 (Investor's screening cost) $k \leq \frac{N-1}{N}(1-\theta)Z_l \equiv \bar{k}$.

Lemma 6 (Competing contests and investor payoff) *Conditional on offering a contest himself, the expected payoff of investor j decreases in the number of contests offered:*

$$\frac{dE(\pi_j)}{dQ} < 0. \tag{10}$$

Lemma 6 implies that, if investor 1 offers a semi-public contest, his expected payoff decreases in the number of competing contests. This is due to two effects. First, because of the mixed strategy of entrepreneurs when deciding about contest participation (see Lemma 5.(ii)), investor 1 expects less participants in his contest for each additional contest that is offered. This also decreases the number of losers in his contest, who are the source of his positive expected payoff in the final auction. It also implies an increased winning probability $\tilde{\alpha}_j$ for entrepreneurs, which reduces the average value of losers' projects. Therefore, an investor is hurt twice for each additional contest that is offered.

Consequently, Lemma 6 implies that, given investor 1 offers a contest, he has an incentive to foreclose entry of other investors into the market of contests and to create a monopoly. More precisely, investor 1 has an incentive to deter investor 2 from entry. If this is successful, every investor deciding about offering a contest after investor 2 faces the same problem as investor 2 and will, thus, not enter the contest market.

How can investor 1 avoid that investor 2 offers a contest? Given the sequential set-up of stage 2 of the game, investor 1 can be regarded as the Stackelberg leader and investor 2 the Stackelberg follower. Investor 1 can exploit a first-mover advantage and set n_1 such that investor 2's payoff from playing his best response is negative if and only if $n_1 \in (\underline{n}_1, \bar{n}_1)$.[9] This captures two *competitive*

[9]See the proof of Proposition 1 in the appendix for details, including a specification of $\underline{n}_1, \bar{n}_1$.

constraints of investor 1 when maximizing his own expected payoff. In addition, he has to make sure that the two *demand constraints* defined in Lemma 5 hold for $Q = 1$:

$$\frac{n_1}{N} \in [\underline{\alpha}, \bar{\alpha}]. \tag{11}$$

Definition 4 (Threshold parameter values) *Define* $\underline{n}, \bar{n}$ *as investor 1's* binding constraints, $\bar{\bar{k}}$ *as a cost level that is relevant if the lower demand constraint is binding,* $\hat{k}$ *as the effective upper screening cost level of investors,* $\hat{c}$ *as the entrepreneurial cost level below which participation in more than one contest is profitable, and* $\bar{c}_j$ *as the prohibitive cost level of entrepreneurs in contest* j*:*

$$\begin{aligned} \underline{n} &\equiv max\{\underline{n}_1, \underline{\alpha}N\}, \quad \bar{n} \equiv min\{\bar{n}_1, \bar{\alpha}N\}, &(12)\\ \bar{\bar{k}} &\equiv \frac{(R(\underline{\alpha}) - c)(1-\theta)Z_l}{R(\underline{\alpha}) + (1-\theta)Z_l}, \quad \hat{k} \equiv min\{\bar{k}, \bar{\bar{k}}\} &(13)\\ \hat{c} &\equiv \tilde{\alpha}_2 R_2 + (1-\tilde{\alpha}_1)(1-\theta)Z_l, &(14)\\ \bar{c}_j &\equiv \tilde{\alpha}_j R_j - (1-\tilde{\alpha}_j)(1-\theta)Z_l. &(15) \end{aligned}$$

Note that, if and only if $\underline{n} \leq \bar{n}$, then the intervals $(\underline{n}_1, \bar{n}_1)$ and $[\underline{\alpha}N, \bar{\alpha}N]$ overlap. Only then it is possible for investor 1 to satisfy both the demand constraints and the competitive constraints.

Proposition 1 (Semi-public contest equilibrium) *(i): If either* $c \leq \hat{c}$ *or if* $\underline{n} \leq \bar{n}$ *and if* $k \leq \hat{k}$*, then there is a unique equilibrium at stage 2 of the game, in which investor 1 organizes a semi-public contest with* $n_1 = \underline{n} \equiv n^*$ *winning slots. All other investors do not organize a contest. (ii): If* $\hat{c} < c \leq \bar{c}_j \forall j \in \{1, ..., Q\}$ *and if* $\underline{n} > \bar{n}$*, the first* $Q \geq 2$ *investors to decide at stage 2 each organize a semi-public contest as long as* k *is sufficiently low.*

The proposition's intuition starts from the notion that some supported parameter realizations allow investor 1 to foreclose the market of semi-public contests to subsequent investors while still attracting participation of all entrepreneurs and making a positive expected payoff. This is a sign of a natural monopoly.

If the screening cost of entrepreneurs is low ($c \leq \hat{c}$), more than one contest could be organized but entrepreneurs would have an incentive to participate in two contests. This would let the two insiders compete with symmetric information in the auction, thereby increasing the expected bid and increasing the probability of the entrepreneur of being a contest winner. In turn, this behavior would make the net payoff from organizing the contest negative for both insiders. Knowing this, the second and all subsequent investors do not organize a contest. Hence, together with Assumption 3, $c \leq \hat{c}$ is a sufficient condition for existence of a unique contest in equilibrium.

Alternatively, if $c > \hat{c}$, investor 1 prefers to set n_1 to the *lowest* level that satisfies the demand constraints and the competitive constraints. If the lower demand constraint ($\underline{\alpha}N$) is binding, he can foreclose the contest market in more cases if the reputation gained by winners $R(\alpha)$ is increasing or if the entrepreneur's cost from getting screened (c) is decreasing. Both of these conditions let $\hat{k}$ increase and $\underline{\alpha}N$ decrease. In this case a low screening cost and a high reputation benefit for winners are substitutes, despite k's direct impact on investors and R's direct impact on entrepreneurs. The transmission channel is the number of winners in the contest, n^*. If R grows, investor 1 reduces n^* but, despite the reduced probability of becoming a winner, entrepreneurs still participate in the contest because they value the increased R in case of winning. In turn, the investor benefits from a reduction in n^* because he only declares winners openly to attract participation of entrepreneurs. His payoff comes from contest losers. Consequently, if R grows, he can afford to set up a contest for higher screening cost levels. However, if investor 1 reduces n^* too much, he risks hurting the competitive constraint. Then it becomes profitable for investor 2 to also set up a contest.

In general, comprising the cases where the lower demand constraint or the lower competitive constraint are binding, a monopolistic semi-public contest is more likely if the screening cost of investors (k) is low or if the share of the expected average value of a contest loser's project that investor 1 can appropriate ($(1-\theta)Z_l$) is high.

If $\underline{n} > \bar{n}$, investor 1 cannot deter profitable entry of a second investor in the semi-public contest market and attract participation of entrepreneurs at the same time. It depends on the parameter realizations whether investors 1 and 2 can profitably prevent entry of a third, investor, etc. The set of parameter values for which the existence of more than one contest becomes an equilibrium, increases in $\tilde{\alpha}_1$, the winning probability in contest 1.

Summarizing, it can occur in equilibrium that zero, one, or more semi-public contests are organized, depending on the realizations of the reputation function R, the screening costs k and c, and the expected average value of a contest loser's project that an inside investor can appropriate, $(1-\theta)Z_l$, which depends on the project value distribution $\mathbf{Z}$. Every investor who offers a contest in equilibrium makes nonnegative payoff, while entrepreneurs make an extra expected payoff, on top of their no screening outside option $E(\mathbf{Z})$, only if the demand constraint is not binding ($\underline{\alpha}N < \underline{n}_1$). Proposition 1 implies the following corollary.

Corollary 1 (Private screening and exclusivity of insider) *Given $\underline{n} \leq \bar{n}$ and the lower demand constraint is binding ($\underline{\alpha}N = \underline{n}$) but $k > \hat{k}$, no contest will be offered. For $\hat{k} < k \leq \bar{k}$, investor 1 may offer* private screening *in stage 2. The other investors do neither offer a contest nor private screening. Whenever a semi-public contest is established in equilibrium, there is only one exclusive sponsor.*

A private screener's net expected payoff is $(1-\theta)E(\mathbf{Z}) - k$ per entrepreneur screened, as long as he is the only insider with respect to a certain entrepreneur. If investor 1 offers private screening, all subsequent investors can only change their status from outsider to non-exclusive insider by also offering private screening. However, a second inside investor faces perfect competition with the first insider in the auction at stage 4 and, hence, expects a gross payoff of zero but still has to pay the screening cost k, see Lemma 1. It follows that screening of a certain entrepreneur can only be profitable if it takes place exclusively. This also explains why sponsoring of a given contest is always exclusive in equilibrium.

Now it is straightforward to find the equilibrium of stage 1 of the game, where every entrepreneur has to decide whether he wants to develop a project for an individually drawn cost D_i and where every investor has to decide about spending the market entry fee F.

Proposition 2 (Market entry equilibrium) *Assume that, according to Proposition 1, Q contests exist in equilibrium and the expected winning probability in contest j is $\tilde{\alpha}_j^*(\phi_j^*) = \frac{\sum_{q=1}^{Q} n_q^*}{N+Q-1}$. Entrepreneur i develops his idea into a project if and only if $D_i \leq \bar{D}$ and investor j enters the market if and only if $F \leq \bar{F}$, where:*

$$\bar{D} \equiv E(\mathbf{Z}) + \tilde{\alpha}_j^*(\phi_j^*)R(\tilde{\alpha}_j^*(\phi_j^*)) - (1-\tilde{\alpha}_j^*(\phi_j^*))(1-\theta)Z_l - c \geq E(\mathbf{Z}), \quad (16)$$

$$\bar{F} \equiv \sum_{q=1}^{Q} \frac{(\phi_q^* N - n_q^*)(1-\theta)Z_l - \phi_q^* N k}{m+2-q} > 0. \quad (17)$$

Proposition 2 states that at stage 1 of the game every entrepreneur will develop his own idea into a project if the development cost is not larger than the expected payoff from owning the project. Similarly, it states that investors will only enter a market as long as the market entry cost is not larger than the expected payoff from entering.

Corollary 2 (Competition and hold-up) *Competition among investors ($m > 0$) is necessary to establish a semi-public contest in equilibrium. The contest alleviates a hold-up problem faced by entrepreneurs in private screening.*

If there is no competition among investors ($m = 0$), the monopsonistic investor has no incentive to finance any form of screening. He bids $b = \epsilon$ in the auction for every project and expects a high monopoly payoff, given that entrepreneurs develop projects. In turn, this reduces entrepreneurs' expected gross payoff from developing an idea to ϵ and, hence, deters all entrepreneurs from doing so. Note that any announcement of the monopsonist to organize a contest or to bid more than ϵ is not subgame-perfect but cheap talk.

Abstracting from semi-public contests and just comparing private screening and no screening reveals that, in private screening, entrepreneurs suffer from a *hold-up problem*: first, they are required to spend a relationship-specific investment (c) and, then, are left with less payoff than without screening because $E(\mathbf{Z})$ has to be shared with the monopsonist. Lemma 4.(i) shows that this hold-up problem lets the private screening market break down. Proposition 1 shows that, given investors organize contests, entrepreneurs can benefit from it and participate. In this situation, they voluntarily spend relationship-specific cost as they uniquely provide the sponsor with inside information conditional on becoming a contest loser. The entrepreneurs are motivated to do so because of the very characteristic of a semi-public contest, that with a certain probability ($\tilde{\alpha}_j$) they are among the winners of a contest and receive a high payoff from information revelation. Hence, the existence of semi-public contests alleviates the entrepreneurs' hold-up problem faced in private screening.

Corollary 3 (Positive expected payoffs) *If, according to Proposition 1, one or more semi-public contests exist in equilibrium and the lower demand constraint is binding ($\underline{n} = \underline{\alpha}N$), investors expect higher payoff than under no screening. If the lower demand constraint is not binding ($\underline{n} > \underline{\alpha}N$), entrepreneurs also expect higher payoff than under no screening.*

This corollary follows from the inequalities in (16) and (17), which compare expected payoffs in the contest case and the no screening case, abstracting from entry cost F and development cost D_i. This result is important because no screening dominates private screening for entrepreneurs, according to Lemma 4.(i). Thus, without considering semi-public contests as a mechanism, any perfect equilibrium would entail *no screening*, given that investors' market entry cost $F = 0$. Every investor would expect a zero payoff while every entrepreneur would expect $E(\mathbf{Z}) - D_i$ and develop his idea up to a cost of $E(\mathbf{Z})$.

For $F > 0$, the unique perfect equilibrium would be a complete market breakdown: entrepreneurs do not develop their ideas, investors do not enter the market. Every player gets zero payoff. To prepare the final proposition I make the following definition.

Definition 5 (Welfare and relative efficiency) Welfare *comprises the aggregate expected net payoffs of all entrepreneurs and all investors, given a certain mechanism. The one mechanism creating higher welfare than the other two mechanisms is* relatively efficient*.*

Proposition 3 (Relative efficiency) *If, according to Proposition 1, one or more semi-public contests exist in equilibrium, the contest mechanism is relatively efficient.*

The intuition of Proposition 3 is that, in stage 2 of the game, investor 1 (and potentially subsequent investors) organizes a contest only if he is sure that entrepreneurs participate in it and that he makes a positive payoff. Going back to stage 1 of the game, every investor calculates the expected payoff from market entry, thereby considering the probability that he will be one investor who organizes a contest profitably. Corollary 3 implies that this occurs in more cases than without considering the contest mechanism an option.

Entrepreneurs profit from investors' consideration of semi-public contests as a mechanism because it increases their expected payoff from owning a developed project over the alternative case, no screening. Hence, they are willing to develop projects whose development cost exceeds their expected gross payoff from no screening, $E(\mathbf{Z})$, up to $\bar{D} \geq E(\mathbf{Z})$. This means that in a world with contests more projects are developed than in a world without contests. Many of them (for which $D_i < \bar{D}$) are welfare enhancing.

4 Discussion and Extensions

Multidimensional types of entrepreneurs and private values of investors: In this model an entrepreneur's ability is only specified in one dimension, $\mathbf{Z}$. In practice, entrepreneurs might be endowed with a multidimensional type vector. For instance, in the case of TV Casting Shows, one candidate might be better in singing, another one might be better in performing live on stage. It might occur that one investor values one dimension of entrepreneurs' types higher but another investor values another dimension higher. Related to multidimensional types, one investor might be better endowed to create value from an entrepreneur's project than another one, due to higher complementarity of resources. This could lead to heterogenous values for a certain project among investors.

Despite these caveats, there are two reasons to model unidimensional entrepreneur types and common values. The first is reduction of complexity. Multidimensional types lead to private or affiliated values among investors in the final auction for an entrepreneur's project, not to common values as assumed here. Affiliated values create more complex bidding strategies; see Milgrom and Weber (1982). This also complicates the analysis in stages one and two. Moreover, multidimensional types would require additional assumptions to ensure well-behaving bidding functions because investors' preferences might not be single-peaked, anymore.

Most importantly, however, additional complexity would not deliver new insights. Assume that each entrepreneur i is characterized by a two-dimensional type drawn from the joint distribution $(\mathbf{Z}, \mathbf{X})$. Moreover, assume as a shortcut that one group of investors is only interested in ability $\mathbf{Z}$ while the other group is only interested in ability $\mathbf{X}$, and that an investor's group affiliation is common knowledge. This would allow for two sponsors of a given contest in equilibrium, one from each group of investors. In the auction of a certain entrepreneur's project each insider would bid a strategy that takes into account both the bids of outsiders interested in the same type-dimension (according to Lemma 2) and the fact that there is another insider interested in the second type-dimension.

For instance, assume that $(\mathbf{Z}, \mathbf{X})$ follows a uniform distribution in both dimensions, where $Z \in [0, 20], X \in [0, 20]$. Insiders observe an entrepreneur i's ability vector $(Z_i, X_i) \equiv (12, 8)$. If there were no second insider, the insider interested in dimension Z would bid $\beta(Z_i = 12) = E[\mathbf{Z}|\mathbf{Z} < Z] = 6$, according to Lemma 2, while the aggregate of outsiders interested in Z would bid a mixed strategy based on a uniform distribution over $[0, 10]$. Let a second investor sponsor the same contest and assume that he is entirely interested in dimension X. An upper threshold for any rational equilibrium bidding strategy of the entrant is $X_i = 8$. Thus, if the Z-interested insider bids $8 + \epsilon$ instead of 6, the probability that he wins the auction does not decrease compared to the situation without entrant but he still makes a positive expected profit as $Z_i = 12 > 8+\epsilon$.[10]

[10]Note that I do not claim that bidding $8 + \epsilon$ is an equilibrium strategy, but in equilibrium the Z-interested insider cannot do worse.

It follows that the expected payoff from becoming an insider, which is crucial for the contest equilibrium, has to be discounted by the probability of having a higher valuation for the entrepreneur's project than the second insider, who is interested in the other type-dimension. This makes becoming a sponsor less attractive for investors. The key result, however, that being an insider creates an informational rent in the auction with respect to competing outside investors interested in the same type-dimension, remains unchanged.

Noisy screening: What if the jury cannot observe entrepreneurs' project values perfectly but only observes $\hat{Z}_i = (Z_i + \epsilon)$, where ϵ is drawn from a distribution with mean zero and variance σ^2? The contest mechanism relies on the characteristic that exclusive inside information is valuable for an investor because it leads to a positive expected auction payoff. The cruder the correlation between the insider's signal and the real value of entrepreneurs' projects is—i.e. the larger σ^2—the lower is the value of inside information. Thus, the threshold for existence of a semi-public contest in equilibrium, $\hat{k}$, decreases if σ^2 increases. For sufficiently small σ^2, the quality of the above results remains the same.

Endogenous publicity: The production of valuable reputation, where $R > 0$ is possible, depends on two factors: credibility and publicity. Credibility is endogenous in this paper as the outsiders' beliefs, that contest winners have projects of high value, are confirmed in equilibrium. Publicity can be endogenized by assuming that the sponsor of contest j bears total costs of $(N_j k + K(R_j))$, where $K(R_j)$ is increasing in R_j and denotes the cost of marketing the contest to investors and potentially to a wider audience. Then, a contest sponsor has two tools, n_j and R_j, to maximize his payoff, subject to the demand and competitive constraints. This might explain why we observe semi-public contests that create different reputation levels for winners in the same industry.[11] Because one tool of investors, n_j, is sufficient for the results of this paper to hold, there is no value added to endogenize publicity, though.

[11] In the case of business plan competitions, there are several contests that are targeting the same set of entrepreneurs but are supported by different sponsors. See, `http://www.mootcorp.org/competitions.asp` > *Eligibility*, for a list of competing business plan contests that send their winners to the Moot Corp Competition in order to compete for even higher reputation, amongst other prizes.

5 Conclusion

In this paper I have characterized a mechanism, semi-public contests, that can solve a dilemma occurring when entrepreneurs with ideas of uncertain value and investors with the necessary complementary resources have to be matched. I showed the conditions under which such contests exist in equilibrium and the characteristic that they only exist if they are efficient compared to private screening and no screening, two fundamental alternatives.

Consequently, as long as the assumption used in this model holds, that there are no positive spillovers from innovation on third parties apart from entrepreneurs and investors, I can find no justification for direct government intervention in favor of or against the contest mechanism. However, there is an indirect role for public policy. First, as existence of semi-public contests depends on active competition among innovators, it is crucial that competition policy authorities safeguard competitive markets. Second, as the semi-public contest mechanism has only been used selectively in practice but could be used in many more fields (see below), spreading information on how it works could let "investors" in some markets, who are feeling now that they only have the choice between private screening and no screening, contemplate about a new mechanism to match with "entrepreneurs".

More generally, the model presented in this paper can be applied to economic situations that are characterized by complementarity of inputs and a high degree of hidden information on the value of one of the inputs, such that even the owner of this input does not know its true value. Furthermore, the initial creation of the input's value must depend on some kind of ability, talent, or ingenuity of its creator—a notion of human capital—which can be tested by screening. The input's value should also be characterized by a high degree of common value, such that investors interested in bidding face a high degree of price competition.

These conditions are regularly met in the context of innovation: an inventor or innovator features the idea of a new, valuable product or process but often requires financial resources and expertise on how to transform the initial idea into a marketable good or service. Both private equity investors and public patrons that are specializing in funding start-ups are natural "investors" here.

The required conditions are also often met in an art or science context, in which the "project" value is embodied in an artist's talent or in a scientist's genius. In such a situation, the artist or scientist often requires financial resources and complementary knowledge of other artists or scientists to develop his talent or idea to its full value. Distributors of art or science, who are interested in the development of a certain technology or in maximizing their profits by contracting the artist's human capital, can support financing and match him with the right co-workers. They serve as "investors". In Appendix A, I explain the functioning of one application of the mechanism in the field of innovation, business plan competitions, and one application in the field of art, TV casting shows, in more detail.

The characterizations made might point on untested applications of the semi-public contest mechanism. For instance, assume an employer faces a very competitive labor market for certain highly skilled workers. Instead of increasing wages more and more, he could set up a semi-public contest testing participants' required capabilities. He could invite several widely accepted industry experts to serve as jury judges and attract many workers' participation by making winning the contest sufficiently attractive. As the best workers are most likely to win the contest, and the winners would be publicized, competing employers could offer them high salary packages ex post, thereby free-riding on the sponsor's investment. However, the sponsor could employ a row of second-best workers for relatively modest salaries, thereby making an economic profit.

A Applications

Business Plan Competitions

A business plan is a document in which an entrepreneur or a team of entrepreneurs describe all aspects of a business idea or start-up business that are relevant for potential investors. A business plan competition is an organized contest to which entrepreneurs send their business plans. Experts evaluate the business ideas described, sometimes in several rounds, and choose the set of winners who are typically awarded prizes in a public ceremony, followed by a lot of media attention.

Many business plan competitions are organized by business schools. To exemplify the appropriateness of my model's main assumptions I describe the key features of the Moot Corp Competition (MCC), which was set up in 1984 and is, according to its website,[12] "[...] the first competition of its kind for MBA students and is still considered the most prestigious in the world. The Moot Corp Competition has been crowned 'the Super Bowl of world business plan competition.' "

[12] This quote and the following ones were taken from `http://www.mootcorp.org/index.asp` on April 17th, 2008.

MCC describes the typical entrepreneurs, jury members, and procedure of the contest as "[...] a competition in which MBAs working in teams would conceive an idea for a new business, develop the idea in a written business plan, and present the plan to a panel of entrepreneurs, venture capitalists, accountants and lawyers." This indicates that judges are experts who have the ability to correctly evaluate the projects described in business plans and oral presentations.

A high reputation of winners is secured by the following rule: "All public sessions of the competition, including but not limited to oral presentations and question/answer sessions, are open to the public at large. Any and all of these public sessions may be broadcast to interested persons through media which may include radio, television and the Internet." Notice that this implies that *all* entrepreneurs appearing in public sessions of the competition, i.e. the finalists, are winners in the sense of my model. Every non-sponsoring investor can learn their types too but only the jury learns the types of entrepreneurs who did not make it to the final round.

In the opening rounds each jury consists of about five judges, each with a slightly different professional background.[13] If I assume that, due to the broad nature of the MCC, investors have differentiated investment interests with respect to the industry or the investment stage of entrepreneurial projects, the diversification of judges in a given jury, as reported on the website, ensures exclusivity of a judge with a certain background.[14] Because of the following rule, a judge may use his inside knowledge himself if he is an investor or he may convey it (potentially exclusively) to another investor: "[...] we will not ask judges, reviewers, staff or the audience to agree to or sign non-disclosure statements for any participant."

Finally, the following quotes serve as evidence for the matching objective between entrepreneurs and investors/sponsors: "Participation in the Moot Corp Competition offers MBAs the following opportunities: [...] To make contact with venture capitalists and other investors." "Why Should You Participate [as a sponsor]? - The opportunity to meet and employ the best entrepreneurial MBAs in the world. The opportunity to learn about, invest in and partner with new ventures emerging from the best business schools in the world."

[13] On `http://www.mootcorp.org/GMCJudges07.htm`, the names and employers of every judge in the 2007 competition are mentioned.

[14] See also the discussion on multidimensional types in section 4.

TV Casting Shows

In TV casting shows, the "project value" of an entrepreneur is the net present value that can be generated by the singing/dancing talent of would-be pop stars. Singers have to prepare themselves specifically for a certain show. It is important to understand that the crucial contest (in the sense of the model) in such a show takes place in private before a subset of applicants appear on TV screen. While the talents of those singers who "compete" publicly becomes common knowledge among all investors, usually record labels, only the jury, which may inform the sponsor, learns about the talent of singers who did not make it to the public final round. As the number of singers appearing on TV screen is fixed but the number of applicants is not, there might be applicants with relatively high talent among the losers. If the sponsor offers one of them a record contract, competition is less intense because other investors have less information on that singer.[15]

To exemplify the appropriateness of the model to this application I describe some key features of "American Idol", which is, according to its website, "Television's No. 1 show" in the U.S. and has developed several franchises in other countries.[16] Taking this statement together with the following one indicates a high level of public awareness of the contest and a high prize both in money and in reputation for winners: "The judges have their say after every performance, but it's the viewing public that determines who will advance to the next round of the competition and who will go home. [...] Eventually the competition is narrowed down to two finalists who compete for a major recording contract and the American Idol title. Past winners [...] already have risen to the top of the recording industry."

The following statement indicates that information on losers' talents remains unpublished; only the jury learns it. To motivate the sponsor's participation,

[15]Moreover, there may be legal restrictions for contest participants to be matched with a non-sponsoring investor: According to `http://www.realityblurred.com/realitytv/archives/american_idol_5/2006_Feb_16_top_24`, the contract signed by American Idol contestants "bans them from signing '... any talent management agreement, talent agency agreement, recording contract, songwriting contract, acting contract, modeling contract, sponsorship contract, or any merchandising contract ... until three months following the date of the first broadcast of the final episode announcing the winner of the competition.´ They can, however, ask for 'prior written consent.´" This indicates that non-sponsoring investors are not excluded from bidding for entrepreneurs but that they are put at a disadvantage, by construction of the mechanism.

[16]This quote and the subsequent ones, unless otherwise stated, were taken on April 18th, 2008, from `http://www.americanidol.com/about/`.

the judges might want to forward it exclusively to the sponsor, who pays their salaries: "The show's judges [...] winnow down the competitors to a select group of semifinalists who sing their hearts out each week for the studio audience and the television viewers."

The following quote from Wikipedia indicates that American Idol is sponsored by exactly one record company, J Records (a subsidiary of industry giant Sony/BMG), just as predicted by Corollary 1:[17] " In an interview [...] on the CBS TV current affairs show 60 Minutes on March 17, 2007 [...] judge [...] openly declared that the underlying primary purpose of the Idol franchise (including American Idol) was for 19 Entertainment (the parent corporation that produces the Idol TV shows) to discover new singing talent that can be signed to recording agreements that the corporation maintains with a major record company (Sony/BMG), and benefit from the record sales of contestants and winners who are exposed to the worldwide marketplace through the TV shows."

I have not modeled a profit objective of the jury explicitly, but it is straightforward to adjust the model in a way, such that the sponsor's cost of setting up a given contest j is not $N_j k$ but a share of his gross payoff being paid to the jury. This does not change the quality of the results. It is important in this application, though, that the contest organizer, 19 Entertainment, has an incentive to produce a credible signal on winners' talents as this ensures the high reputation of winners and, hence, the incentive for singers to participate and, hence, the incentive for the sponsor to pay for the contest.

Finally, recall that, on the one hand, the model predicts that contest winners should be attractive for all investors, including non-sponsoring investors, and that, on the other hand, the sponsor has private information on the talent of contest losers. There is evidence for both cases.[18]

[17]See `http://en.wikipedia.org/wiki/American_Idol`.

[18]According to `http://en.wikipedia.org/wiki/American_Idol`, two finalists (= contest winners) in 2004 signed record contracts with Universal Records in the Philippines and Japan (Jasmine Trias) and with Motown Records (Camile Velasco), competitors of Sony/BMG.
In 2005, singer Mario Vazquez dropped out of the competition just days before the top 12's first (public) performance. This makes him a loser in the sense of the model. According to `http://en.wikipedia.org/wiki/Mario_Vazquez`, in August 2005, Vazquez nevertheless signed a record contract with Arista Records, also a subsidiary of Sony/BMG and also founded by Clive Davis, the founder of J Records. A "loser" can still be attractive for the sponsor.

B Proofs

Proof of Lemma 1

Assume that at least one investor bids $E(\mathbf{Z})$. Then, any $b < E(\mathbf{Z})$ of another investor will lose and generate zero expected payoff. Any $b > E(\mathbf{Z})$ has a positive probability of winning but conditional on winning creates $E(\pi) < 0$. *Q.E.D.*

Sketch of Proof of Lemma 2

(i): See the proof of EMW, Theorem 1, for the case of atomless $\mathbf{Z}$-distributions.[19]

(ii): The proof of EMW, Theorem 1, shows that $E(\pi_{OUT}) = 0$. The proof of EMW, Theorem 4, shows that for any realization of $\mathbf{Z}$ and any $(m+1)$-tuple of bids, the seller's revenue plus the insider's profits in expected terms sum to $E(\mathbf{Z})$. According to EMW, Theorem 4, the distribution of $E(\mathbf{Z})$ between the seller and the inside bidder depends on the realization Z_i that the insider learns before bidding. Define the *expectation* of the insider's share in total expected payoffs as $(1-\theta)$ and the entrepreneur's share as θ. Then θ only depends on the distribution $\mathbf{Z}$, which is common knowledge and omitted in the notation of θ henceforth. This shows Lemma 2.(ii).[20]

Proof of Lemma 3

Preliminaries: The total derivative of (5) with respect to $\tilde{\alpha}_j$ produces the following first-order condition (FOC):

$$R + (1-\theta)Z_l - (1-\tilde{\alpha}_j)(1-\theta)\frac{dZ_l}{d\tilde{\alpha}_j} = -\tilde{\alpha}_j\frac{dR}{d\tilde{\alpha}_j}. \tag{B.1}$$

Assumption 1 states that R is decreasing and convex in α. Hence, the same hods with respect to $\tilde{\alpha}_j$. To understand how the average value of contest losers, Z_l, depends on $\tilde{\alpha}_j$ note that, for $\tilde{\alpha}_j = 0$, all contest participants are losers. Hence, $lim_{\tilde{\alpha}_j \to 0} Z_l = E(\mathbf{Z})$. For $\tilde{\alpha}_j = 1$, all contest participants are winners.

[19] Dubra (2006) shows that the original proof of uniqueness is slightly incorrect. He does not criticize the validity of EMW, Theorem 1, though, and provides a correct proof instead.

[20] Note that Campbell and Levin (2000) criticize the result that the existence of an inside bidder unambiguously decreases a seller's revenue if compared to the case of symmetric bidder information. They argue (p.107/8), "when bidders' private information is affiliated, the public release of a signal makes their information less private, prompting stronger competition. This is the so-called 'linkage effect.' " As in my model there is only one bidder with inside information on a given project, there is no affiliated private information and, hence, no linkage effect. It follows that the critique of Campbell and Levin does not apply to this model.

Hence, $lim_{\tilde{\alpha}_j \to 1} Z_l = 0$. Because, by definition, increasing the expected share of winners $\tilde{\alpha}_j$ decreases Z_n, the threshold value between winners and losers, and because the distribution $\mathbf{Z}$ is continuous, we have in expectation:

$$\frac{dZ_l}{d\tilde{\alpha}_j} < 0. \tag{B.2}$$

In stage 3 of the game n_j is fixed. Hence, $\tilde{\alpha}_j$ can only decrease via increasing $\tilde{N}_j$, the expected number of participants. With probability $\frac{(1-\tilde{\alpha}_j)}{2}$, a new participant has value $Z \in [0, Z_l]$. With probability $\frac{(1-\tilde{\alpha}_j)}{2}$, a new participant has value $Z \in (Z_l, Z_n]$. These two effects on the expected level of Z_l cancel out. With probability $\tilde{\alpha}_j$, a new participant has value $Z \in (Z_n, \bar{Z}]$, which increases Z_n and, hence, also increases Z_l. Summarizing, the larger $\tilde{\alpha}_j$ before a new participant entered the contest, the *larger* the probability that his entry will have an effect on Z_l. This corresponds to the relation:

$$\frac{d^2 Z_l}{d\tilde{\alpha}_j^2} < 0. \tag{B.3}$$

Proof: Because of (1) and (B.2), the left hand side (LHS) and the right hand side (RHS) of (B.1) are positive for $\tilde{\alpha}_j > 0$. For $\tilde{\alpha}_j \to 1$, by definition, $R \to 0$, hence $Z_l \to 0$ and $(1 - \tilde{\alpha}_j) \to 0$; hence, $LHS \to 0$. But in this case, $\frac{dR}{d\tilde{\alpha}_j} \to -\infty$; hence, $RHS \to +\infty$. It follows that, for $\tilde{\alpha}_j \to 1$, $LHS < RHS$. In contrast, for $\tilde{\alpha}_j \to 0$, by definition, $R > 0$, hence $Z_l \to E(\mathbf{Z})$ and $\frac{dZ_l}{d\tilde{\alpha}_j} \to 0$; hence, $LHS > 0$, whereas $RHS \to 0$. It follows that, for $\tilde{\alpha}_j \to 0$, $LHS > RHS$. Because R and Z_l are continuous and monotonic in $\tilde{\alpha}_j$, the median value theorem applies. It follows that there exists a unique optimum of (5), at α^*.

The second-order condition (SOC) of (5) is given by:

$$\frac{dR}{d\tilde{\alpha}_j} + (1-\theta)\frac{dZ_l}{d\tilde{\alpha}_j} + \left(1 + \tilde{\alpha}_j \frac{d^2 R}{d\tilde{\alpha}_j^2}\right)\frac{dR}{d\tilde{\alpha}_j} + \left((1-\theta) - (1-\tilde{\alpha}_j)(1-\theta)\frac{d^2 Z_l}{d\tilde{\alpha}_j^2}\right)\frac{dZ_l}{d\tilde{\alpha}_j} \tag{B.4}$$

Because of (1) and (B.2), the first three terms of (B.4) are negative. Because of (B.3) and (B.2), the fourth term is also negative. Hence, $SOC < 0$. It follows that the optimum of (5) at α^* is a maximum. *Q.E.D.*

Proof of Lemma 4

(i): Abstracting from development cost D_i and following Lemma 1, an entrepreneur expects $E(\mathbf{Z})$ if there is no screening. Following Lemma 2, he expects $\theta E(\mathbf{Z}) - c < E(\mathbf{Z})$ from private screening. Private screening is also dominated by a semi-public contest if, drawing on (4):

$$\tilde{\alpha}_j [R + Z_w] + (1 - \tilde{\alpha}_j)[\theta Z_l] - c > \theta E(\mathbf{Z}) - c. \tag{B.5}$$

By using $E(\mathbf{Z}) = \tilde{\alpha}_j Z_w + (1 - \tilde{\alpha}_j) Z_l$, this can be rewritten as:

$$\tilde{\alpha}_j (R + (1 - \theta) Z_w) > 0, \tag{B.6}$$

which holds $\forall\ \tilde{\alpha}_j > 0$.

(ii): An entrepreneur prefers a semi-public contest over no screening if:

$$\begin{aligned} \tilde{\alpha}_j [R + Z_w] + (1 - \tilde{\alpha}_j)[\theta Z_l] - c &\geq E(\mathbf{Z}) && \text{(B.7)} \\ \Leftrightarrow \tilde{\alpha}_j R &\geq c + (1 - \tilde{\alpha}_j)(1 - \theta) Z_l. && \text{(B.8)} \end{aligned}$$

Lemma 3 implies that the expected utility from contest participation is hump-shaped in $\tilde{\alpha}_j$. As the expected utility from no screening is independent of $\tilde{\alpha}_j$, it implies that (B.8) holds with equality either for two $\tilde{\alpha}_j$-levels or for one or for none. To see this note that in a contest, according to (B.7), $lim_{\tilde{\alpha}_j \to 0} E(\pi_i) = \theta E(\mathbf{Z}) - c$ and that $lim_{\tilde{\alpha}_j \to 1} E(\pi_i) = Z_w(\tilde{\alpha}_j = 1) - c = E(\mathbf{Z}) - c$. Both values are smaller than $E(\mathbf{Z})$. Hence, if $E(\pi_i | \alpha^*) > E(\mathbf{Z})$, which depends on the distribution of R and Z and on c and is well defined, (B.8) holds with equality for $\underline{\alpha}$ and $\bar{\alpha}$, as defined in (6). These two levels converge in α^* for $E(\pi_i | \alpha^*) = E(\mathbf{Z})$. Hence:

$$0 < \underline{\alpha} \leq \alpha^* \leq \bar{\alpha} < 1. \tag{B.9}$$

It follows that $\forall \tilde{\alpha}_j \in [\underline{\alpha}, \bar{\alpha}]$, entrepreneurs prefer participation in contest j over no screening, as long as $E(\pi_i(\alpha^*)) \geq E(\mathbf{Z})$. *Q.E.D.*

Proof of Lemma 5

(i): Consider a pure strategy of entrepreneur i, according to which he participates in some contest j with probability one. The marginal impact of i's participation in contest j on $\tilde{\alpha}_j$ depends on the expected number of other participants in that contest, $\tilde{N}_j$. By the definition of $\tilde{\alpha}_j$, it follows that:

$$\frac{d\tilde{\alpha}_j}{d\tilde{N}_j} < 0, \quad \frac{d^2\tilde{\alpha}_j}{d\tilde{N}_j^2} > 0. \tag{B.10}$$

Hence, in a symmetric pure strategy candidate Nash equilibrium every i will make the same unique choice and participate in the contest such that $E(\pi_i)$ of that contest is maximized. This creates larger expected utility for i than under no screening if (B.8) holds for $\tilde{\alpha}_j = \frac{n_j}{N}$ or:

$$\frac{n_j}{N} \in [\underline{\alpha}, \bar{\alpha}] \wedge E(\pi_i(\alpha^*)) \geq E(\mathbf{Z}), \tag{B.11}$$

which is possible for $R(\frac{n_j}{N})$ sufficiently high or c sufficiently low. Given that (B.11) holds and entrepreneur i deviates unilaterally from choosing j, say by participating in contest s, he will be the only candidate there. Hence, $\tilde{\alpha}_s = 1$, and the reputation benefit is $R(1) = 0$, which creates an expected payoff strictly less than from participating in j. Hence, in a unique symmetric pure strategy Nash equilibrium every entrepreneur participates in the same contest j.

(ii): Let ϕ_j be the probability that entrepreneur i assigns to participation in each contest j that offers $n_j \geq 1$ winning slots. Let $\Phi : \phi_j \to j \quad \forall j \in \{1, ..., Q\}$ be the associated mixed strategy of i for all contests. Contests without winning slots are not regarded ($\phi_j(n_j = 0) = 0$). (B.10) shows that the marginal effect of i's entry on the winning probability in contest j decreases in the expected number of other participants, $\tilde{N}_j$. In a symmetric mixed strategy equilibrium, the strategy Φ of each of the other $N-1$ entrepreneurs has to make entrepreneur i indifferent between participating in this or in that contest, independent of the total number of contests, Q, and independent of the number of winning slots in a contest, $n_j, \forall j \in \{1, ..., Q\}$. This is reached if the expected ex post winning probability in contest j, i.e. assuming that i participates in j, is equal $\forall j \in \{1, ..., Q\}$. Recall that this probability is defined as $\tilde{\alpha}_j \equiv \frac{n_j}{\tilde{N}_j+1}$, where $\tilde{N}_j = \phi_j(N-1)$ is the expected number of entrepreneurs *other* than i participating in j.

The mixed strategy equilibrium can be found by solving the following system of Q equations, where j and s are two arbitrary contests:

$$\frac{n_j}{\phi_j(N-1)+1} = \frac{n_s}{\phi_s(N-1)+1} \quad \forall s \in \{1, ..., j-1, j+1, ..., Q\}, \tag{B.12}$$

$$\sum_{q=1}^{Q} \phi_q = 1. \tag{B.13}$$

(B.12) states $Q-1$ *indifference conditions*: the winning probability $\tilde{\alpha}_j$ that i faces *after* his entry in one of the Q contests must be the same in every single contest. (B.13) closes the equation system by stating that all entry probabilities that i assigns to the Q contests must sum up to one. There are Q unknown variables, $\{\phi_1, ..., \phi_Q\}$, and Q equations. The solution to the system is given by ϕ_j^*, as stated in Lemma 5.(ii). To see this, substitute ϕ_j^* for ϕ_j and ϕ_s into (B.12). This gives:

$$\tilde{\alpha}_j(\phi_j^*) = \frac{\sum_{q=1}^{Q} n_q}{N+Q-1} \quad \forall j \in \{1, ..., Q\}. \tag{B.14}$$

It follows that, if the other $N-1$ entrepreneurs play $\Phi(\phi_j^*)$, i cannot change his expected utility from contest participation whatever strategy he plays. It follows that $\Phi(\phi_j^*)\forall i$ constitutes a mixed strategy Nash equilibrium. Note that Lemma 5.(i) characterizes the special case of 5.(ii) for $Q = 1$.

Uniqueness: Assume a symmetric mixed strategy that puts a weight $\phi_j' > \phi_j^*$ on participation in one contest, j. Due to $(B.13)$, this implies a reduction of the participation probability in another contest, $s \neq j$: $\phi_s' < \phi_s^*$. Thus, $\tilde{\alpha}_j < \tilde{\alpha}_s$, which makes either j or s more attractive for all other entrepreneurs. However, because of the different marginal effects of entry (by n_j and by $\tilde{N}_j$) on the winning probability $\tilde{\alpha}_j$, see (B.10), the only alternative equilibrium is one where all entrepreneurs choose the same contest with probability one, hence there $\tilde{\alpha}_j = \frac{n_j}{N}$. If $\frac{n_j}{N} \notin [\underline{\alpha}, \bar{\alpha}]$, Lemma 5.(i) rules that alternative out and $\Phi(\phi_j^*)\forall i$ is the *unique* symmetric mixed strategy equilibrium.

Asymmetric mixed strategies or beliefs: Note that it is possible to construct multiple asymmetric Nash equilibria in mixed strategies, in which one entrepreneur i assigns a higher probability $\phi_j' > \phi_j^*$ to one contest and a lower probability $\phi_s' < \phi_s^*$ to another contest, and another entrepreneur $g \neq i$ does the reverse. If deviations from ϕ_j^* are symmetric, such that, from the perspective of i, $\tilde{\alpha}_j$ is the same $\forall j \in \{1, ..., Q\}$, this strategy combination constitutes a mixed strategy Nash equilibrium. However, this depends on some coordination among the entrepreneurs, who participates in which contest with which probability. Alternatively, asymmetric beliefs among the entrepreneurs about the other $N - 1$ entrepreneurs' behavior could also support an asymmetric mixed strategy equilibrium, as long as $\tilde{\alpha}_j$ is the same $\forall j \in \{1, ..., Q\}$. However, the question arises where such balancing asymmetric beliefs should come from among ex ante identical players. Therefore, I perceive the concept of *symmetric* mixed strategy Nash equilibrium as more appropriate for this model.

Finally, $\Phi(\phi_j^*)$ dominates no screening only if $\tilde{\alpha}_j(\phi_j^*) \in [\underline{\alpha}, \tilde{\alpha}]$; see Lemma 4.(ii). *Q.E.D.*

Illustration: Consider the following example. Assume there are $N = 50$ entrepreneurs who face $Q = 5$ contests, named $\{1, 2, 3, 4, 5\}$, which offer the following number of winning slots: $n_1 = 2, n_2 = 3, n_3 = 5, n_4 = 8, n_5 = 9$.

$\Phi(\phi_j^*)$ dictates that every entrepreneur participates in the contests with the following probabilities: $\phi_1^* = \frac{3}{49}, \phi_2^* = \frac{5}{49}, \phi_3^* = \frac{9}{49}, \phi_4^* = \frac{15}{49}, \phi_5^* = \frac{17}{49}$. It follows that $\sum_{q=1}^{Q} \phi_q = 1$; hence (B.13) holds. Substituting values in $\tilde{\alpha}_j = \frac{n_j}{\phi_j(N-1)+1}$ results in $\tilde{\alpha}_j = \frac{1}{2} \quad \forall j \in \{1, 2, 3, 4, 5\}$. Hence, every i cannot change the expected winning probability that he faces after entry despite the fact that the number of winning slots is different across the five contests. Consequently, i cannot increase his expected utility by deviating from $\Phi(\phi_j^*)$.

Note that $\tilde{\alpha}_j = \frac{1}{2} > \frac{1}{N}\sum_{q=1}^{Q} n_q = \frac{27}{50}$. This is due to the fact that $\tilde{\alpha}_j$ simulates i's participation in *every* contest, whereas $\frac{1}{N}\sum_{q=1}^{Q} n_q$ captures the "objective" expected winning probability, given that every i can just enter *one* contest.

Proof of Lemma 6

(9) depends on Q in three ways: via ϕ_j^*, via $\sum_{q=1}^{Q} n_q$, and via $Z_l(\tilde{\alpha}_j(\phi_j^*))$. Ceteris paribus, if there is one additional contest offered, say contest q, the total number of winning slots increases by $n_q \geq 1$. Hence:

$$\frac{d(\sum_{q=1}^{Q} n_q)}{dQ} = n_q \geq 1. \tag{B.15}$$

We can use this and (8) in:

$$\frac{d\tilde{\alpha}_j(\phi_j^*)}{dQ} = \frac{(N+Q-1)\frac{d(\sum_{q=1}^{Q} n_q)}{dQ} - \sum_{q=1}^{Q} n_q}{(N+Q-1)^2} > 0. \tag{B.16}$$

Using (B.2) and (B.16), it follows that:

$$\frac{dZ_l(\tilde{\alpha}_j(\phi_j^*))}{dQ} = \frac{dZ_l}{d(\tilde{\alpha}_j(\phi_j^*))}\frac{d\tilde{\alpha}_j(\phi_j^*)}{dQ} < 0. \tag{B.17}$$

From (7) and (B.15), we obtain:

$$\frac{d\phi_j^*}{dQ} = \frac{n_j\sum_{q=1}^{Q} n_q - n_j(N+Q-1)\frac{d(\sum_{q=1}^{Q} n_q)}{dQ}}{(N-1)(\sum_{q=1}^{Q} n_q)^2} < 0. \tag{B.18}$$

Finally, we can take the total derivative of (9) with respect to Q:

$$\frac{dE(\pi_j)}{dQ} = \big(N((1-\theta)Z_l(\tilde{\alpha}_j(\phi_j^*)) - k)\big)\frac{d\phi_j^*}{dQ} + (\phi_j^* N - n_j)(1-\theta)\frac{dZ_l(\tilde{\alpha}_j(\phi_j^*))}{dQ} \tag{B.19}$$

Due to (B.18) and Assumption 3, the first term of (B.19) is negative. It follows from (9) that, in order to avoid losses, an investor must offer less winning slots than the expected number of participants in his contest: $n_j < \phi_j^* N$. Because of this and (B.17), the second term of (B.19) is negative, too. It follows that:

$$\frac{dE(\pi_j)}{dQ} < 0 \quad \forall j \quad Q.E.D. \tag{B.20}$$

Proof of Proposition 1

(i): Assumption 3 and Definition 4 imply that contests can only exist in equilibrium if $k \leq \bar{k} \wedge c \leq \bar{c}_j$. When is exactly one contest offered? Two possibilities exist to rule out more than one contest in equilibrium. First, assume that two contests, 1 and 2, are organized and entrepreneur i unilaterally participates in *both* of them whereas all other entrepreneurs only participate in one contest each. Investors 1 and 2 would obtain the same information on Z_i. Thus, i would expect perfectly competitive bidding and payoff:

$$E(\mathbf{Z}) + \tilde{\alpha}_1 R_1 + \tilde{\alpha}_2 R_2 - 2c. \tag{B.21}$$

If he participates in contest 1 only, he expects payoff according to (5) with $j = 1$. Combining these two functions reveals that an entrepreneur prefers participation in two contests over one if and only if:

$$c \leq \tilde{\alpha}_2 R_2 + (1 - \tilde{\alpha}_1)(1 - \theta) Z_l \equiv \hat{c}. \tag{B.22}$$

If i participates in two contests, however, bidding is very competitive and the expected investor payoff from screening reduces to $-k$. It follows that, given investor 1 already entered the market, investor 2 has no incentive to enter and will not organize a contest, too, if (B.22) holds.

If $c > \hat{c}$, it is still possible that exactly one contest is offered in equilibrium. Substituting (7) in (9) for $j = 2$, and rearranging the FOC of this expression with respect to n_2 yields investor 2's *best-response function* depending on the number of winning slots set by investor 1:

$$n_2(n_1) = \frac{\sqrt{n_1 N (N^2 - 1)(1 - \theta) Z_l ((1 - \theta) Z_l - k)}}{(N - 1)(1 - \theta) Z_l} - n_1. \tag{B.23}$$

Substituting (B.23) in (9) for $j = 2$ produces investor 2's expected *Stackelberg follower payoff* from offering a contest and depending on n_1:

$$\frac{(n_1(N - 1) + N^2)(1 - \theta) Z_l - kN^2 - 2\sqrt{n_1 N (N^2 - 1)(1 - \theta) Z_l ((1 - \theta) Z_l - k)}}{N - 1} \tag{B.24}$$

If the Stackelberg leader can set n_1 such that (B.24) is negative, investor 2 will not enter. Inspecting the first-order and second-order conditions of (B.24) with respect to n_1 reveals that (B.24) has a well-defined minimum level, which leads to a negative expected Stackelberg follower payoff.[21] Solving (B.24) for zero

[21] The calculations are standard and omitted for the sake of brevity.

shows that investor 2's expected payoff is negative for all $n_1 \in (\underline{n}_1, \bar{n}_1)$, where:

$$\underline{n}_1 = \frac{\left(N(N+N^2-2)(1-\theta)Z_l((1-\theta)Z_l-k)-2\sqrt{(N-1)^2N^2(N+1)(1-\theta)^2Z_l^2((1-\theta)Z_l-k)^2}\right)}{(N-1)^2(1-\theta)^2Z_l^2} \tag{B.25}$$

$$\bar{n}_1 = \frac{\left(N(N+N^2-2)(1-\theta)Z_l((1-\theta)Z_l-k)+2\sqrt{(N-1)^2N^2(N+1)(1-\theta)^2Z_l^2((1-\theta)Z_l-k)^2}\right)}{(N-1)^2(1-\theta)^2Z_l^2} \tag{B.26}$$

$\underline{n}_1$ and $\bar{n}_1$ are investor 1's *competitive constraints* when maximizing his own expected payoff. Both decrease in k. In addition, investor 1 has to make sure that the two *demand constraints* defined in Lemma 5 hold for $Q = 1$: $\frac{n_1}{N} \in [\underline{\alpha}, \bar{\alpha}]$. If and only if the intervals $(\underline{n}_1, \bar{n}_1)$ and $[\underline{\alpha}N, \bar{\alpha}N]$ overlap, then $\underline{n} \leq \bar{n}$.[22]

Given the competitive constraints hold, it follows that $Q = 1$ and, thus, $\phi_1^* = 1$; see (7). Hence, investor 1 maximizes $(N - n_1)(1 - \theta)Z_l - Nk$, which yields, by total differentiation:

$$\frac{dE(\pi_1|Q=1)}{dn_1} = -(1-\theta)Z_l + (N-n_1)(1-\theta)\frac{dZ_l}{dn_1}. \tag{B.27}$$

By definition, we have $\frac{d\bar{\alpha}_1}{dn_1} > 0$, and, by (B.2), $\frac{dZ_l}{d\bar{\alpha}_1} < 0$. It follows that $\frac{dZ_l}{dn_1} < 0$. Hence, $\frac{dE(\pi_1|Q=1)}{dn_1} < 0$ as long as the demand constraints hold, too. This implies that investor 1 sets n_1 to the *lowest* level that lets all constraints hold, i.e. to set $n_1 = \underline{n}$. When does this lead to nonnegative expected payoff for investor 1?

First, assume the *lower competitive constraint* is binding: $\underline{n} = \underline{n}_1$. Substituting (B.25) in investor 1's expected payoff function,

$$E(\pi_1(Q=1,\underline{n}_1)) = (N-n_1)(1-\theta)Z_l - Nk, \tag{B.28}$$

setting it equal to zero, and rearranging yields that $E(\pi_1(Q = 1, \underline{n}_1)) \geq 0 \quad \forall k \leq (1-\theta)Z_l$. Due to Assumption 3 this holds for all supported parameter values.

Second, assume the *lower demand constraint* is binding: $\underline{n} = \underline{\alpha}N$. Substituting this in (B.28), setting it equal to zero, and rearranging yields that

$$E(\pi_1(Q=1,\underline{\alpha}N)) \geq 0 \quad \forall k \leq \frac{(R(\underline{\alpha})-c)(1-\theta)Z_l}{R(\underline{\alpha})+(1-\theta)Z_l)} \equiv \bar{\bar{k}}, \tag{B.29}$$

where $\bar{\bar{k}}$ is increasing in $R(\underline{\alpha})$ and decreasing in c. Whether $\bar{\bar{k}}$ is smaller or larger than $\bar{k}$ depends on the realization of R, c, and $\mathbf{Z}$. Which of the two lower constraints is binding, i.e. whether $\underline{n}_1$ is larger or smaller than $\underline{\alpha}N$, also

[22]Note that whether $\underline{n} \leq \bar{n}$, or vice versa, depends on the parameter realizations. Since $\underline{n}_1$ and $\bar{n}_1$ (but not $\underline{\alpha}N$ and $\bar{\alpha}N$) depend on k and only $\underline{\alpha}N$ and $\bar{\alpha}N$ (but not $\underline{n}_1$ and $\bar{n}_1$) depend on $R(\alpha)$ and c, both cases are supported. It would not add value to the main contribution of this paper, which is to show that semi-public contests can exist in equilibrium, to specify the threshold levels of k, $R(\alpha)$, or c. Hence, I omit it here for the sake of brevity and formalize part (ii) of the proposition in a qualitative way.

depends on the realization of the parameters. As can easily be seen from (6), $\underline{\alpha}N$ increases in c and decreases in $R(\underline{\alpha})$. Hence, the larger $R(\underline{\alpha})$ or the smaller c, the smaller the probability that the demand constraint is binding.

If investor 1 offers a contest, satisfying the competitive constraints makes sure the best-response of investor 2 (and subsequent investors) is not to offer a contest. If investor 1 does not offer a contest because k is too large, all other investors have the same incentives not to do so since they are identical ex ante.

(ii): If $c > \hat{c}$, every entrepreneur i voluntarily does not participate in more than one contest, even if it is organized. Hence, more than one contests *could* exist. i's contest participation constraint as compared to no screening (see (B.8)) shows that in equilibrium Q contests can only attract participation of a positive number of entrepreneurs each if $c \leq \tilde{\alpha}_j R_j - (1-\tilde{\alpha}_j)(1-\theta)Z_l \equiv \bar{c} \quad \forall j \in \{1, ..., Q\}$. The set of c-values for which $\bar{c} \geq c > \hat{c}$ is nonempty if:

$$2(1-\tilde{\alpha}_1)(1-\theta)Z_l \leq \tilde{\alpha}_1 R_1 - \tilde{\alpha}_2 R_2. \tag{B.30}$$

The LHS strictly decreases and the RHS strictly increases in $\tilde{\alpha}_1$. Hence, the larger the ex ante probability of winning contest 1, the easier (B.30) holds and, consequently, the more likely it is that more than one contest exist in equilibrium and each attracts participation of a distinct subset of entrepreneurs according to Lemma 5.(ii).

If $\bar{c} \geq c > \hat{c}$, the demand constraints hold, by definition. Still, if $\underline{n} > \bar{n}$, investor 1 cannot make sure at the same time that participation in his contest is attractive for entrepreneurs and discourage investor 2 (and potentially investor 3, etc.) from setting up a contest, too. In this case $Q \geq 2$ and consequently, $\tilde{\alpha}_1(\phi_1^*) > \frac{n_1}{N}$. Given that $\tilde{\alpha}_1(\phi_1^*), \tilde{\alpha}_2(\phi_2^*) \in [\underline{\alpha}, \bar{\alpha}]$, which is possible for supported parameter values, the foreclosure argument of part (i) of the proposition can be repeated. Hence, it depends on the parameter realizations of R, c, and k whether investors 1 and 2 can avoid profitable entry of investor 3 while satisfying entrepreneurs' demand constraints at the same time.[23] *Q.E.D.*

Proof of Proposition 2

At stage 1, all parameter realizations that are relevant to determine the equilibria in stages 2, 3, and 4 are common knowledge. Hence, all players can determine the equilibrium number of contests and contest slots, depicted in Proposition 1.

[23] As the focus of this paper is not on detailing the conditions under which 2, 3, etc. contests co-exist in equilibrium, I do not proceed further in this direction.

Investor j knows that the probability that he is determined by nature to act as the first investor in stage 2 is $\frac{1}{m+1}$. Given the conditions in Proposition 1.(i) hold, he will organize a contest and expect a payoff of $(N - n^*)(1-\theta)Z_l - Nk$ in this case. If there are two contests offered in equilibrium, investor j expects $(\phi_1^* N - n_1^*)(1-\theta)Z_l - \phi_1^* Nk$ with probability $\frac{1}{m+1}$ and $(\phi_2^* N - n_2^*)(1-\theta)Z_l - \phi_2^* Nk$ with probability $\frac{1}{m}$. In general, if the profitable existence of Q contests can be foreseen, according to Proposition 1, investor j's expected net payoff from market entry is:

$$E\pi_j = \sum_{q=1}^{Q} \frac{(\phi_q^* N - n_q^*)(1-\theta)Z_l - \phi_q^* Nk}{m+2-q} - F. \tag{B.31}$$

Hence, investor j enters the market if and only if:

$$F \leq \bar{F} \equiv \sum_{q=1}^{Q} \frac{(\phi_q^* N - n_q^*)(1-\theta)Z_l - \phi_q^* Nk}{m+2-q} > 0. \tag{B.32}$$

Entrepreneur i's security value is his payoff from no screening, $E(\mathbf{Z})$. In case one or more contests are offered in equilibrium, which implies that entrepreneurs' participation constraint holds, according to (B.8) and (8), i expects:

$$E\pi_i(\tilde{\alpha}_j^*(\phi_j^*)) = E(\mathbf{Z}) + \tilde{\alpha}_j^*(\phi_j^*)R(\tilde{\alpha}_j^*(\phi_j^*)) - (1-\tilde{\alpha}_j^*(\phi_j^*))(1-\theta)Z_l - c, \tag{B.33}$$

where $\tilde{\alpha}_j^*(\phi_j^*) = \frac{\sum_{q=1}^{Q} n_q^*}{N+Q-1}$ and $E\pi_i(\tilde{\alpha}_j^*(\phi_j^*)) \geq E(\mathbf{Z})$. The latter inequality holds strictly if the lower demand constraint is not binding.

It follows that i develops his idea into a project if and only if:

$$D_i \leq \bar{D}_i \equiv E\pi_i(\tilde{\alpha}_j^*(\phi_j^*)). \quad Q.E.D. \tag{B.34}$$

Proof of Proposition 3

The benchmark solution with which each mechanism has to be compared is market breakdown, which yields welfare $W_{BD} = 0$. Define N_{NS} (and N_{PS}) as the number of entrepreneurs whose development cost in expectation is not larger than $E(\mathbf{Z})$ (not larger than $\theta E(\mathbf{Z}) - c$). It follows that $N_{PS} < N_{NS} < N$. Assuming that projects are developed, in the no screening and private screening cases, welfare is:

$$W_{NS} = N_{NS}(E(\mathbf{Z}) - D_i) - (m+1)F. \tag{B.35}$$

$$W_{PS} = N_{PS}(E(\mathbf{Z}) - D_i - c - k) - (m+1)F. \tag{B.36}$$

Clearly, $W_{NS} > W_{PS}$. Define N_{SPC} as the number of entrepreneurs whose development cost in expectation is not larger than than $E(\mathbf{Z}) + \tilde{\alpha}_j^* R - (1 - \tilde{\alpha}_j^*)(1-\theta)Z_l - c$. Because of Corollary 3, $N_{SPC} > N_{NS}$ if the lower demand constraint is not binding and $N_{SPC} = N_{NS}$ if it is binding. Welfare in the contest case is:

$$W_{SPC} = N_{SPC}(E(\mathbf{Z}) + \tilde{\alpha}_j^* R - D_i - c - k) - (m+1)F. \qquad \text{(B.37)}$$

Because of Corollary 3, entrepreneurs and investors are never worse off in a contest if it exists but in many cases they are better off. Hence, in expectation, $W_{SPC} > W_{NS}$. *Q.E.D.*

References

Biais, B. and E. Perotti (2008), Entrepreneurs and new ideas, *RAND Journal of Economics*, 39, 4, 1105-1125.

Campbell, C.M. and D. Levin (2000), Can the Seller Benefit from an Insider in Common-Value Auctions?, *Journal of Economic Theory*, 91, 106-120.

Che, Y.-K and I. Gale (2003), Optimal Design of Research Contests, *The American Economic Review*, 93, 3, 646-671.

Dubra, J. (2006), A correction to uniqueness in 'Competitive Bidding and Proprietary Information', *Journal of Mathematical Economics*,42,56–60.

Engelbrecht-Wiggans, R., Milgrom, P.R. and R.J. Weber (1983), Competitive Bidding and Proprietary Information, *Journal of Mathematical Economics*, 11, 161-169.

Felli, L. and K. Roberts (2002), Does competition solve the hold-up problem?, CEPR Discussion Paper 3535.

Fullerton, R.L., Linster, B.G., McKee, M. and S. Slate (2002), Using Auctions to Reward Tournament Winners: Theory and Experimental Investigations, *RAND Journal of Economics,* 33, 1, 62-84.

Fullerton, R.L. and R.P. McAfee (1999), Auctioning Entry into Tournaments, *The Journal of Political Economy,* 107, 3, 573-605.

Milgrom, P.R. and R.J. Weber (1982), A Theory of Auctions and Competitive Bidding, *Econometrica*, 50, 5, 1089-1122.

Rajan, R.G. (1992), Insiders and Outsiders: The Choice between Informed and Arm's-Length Debt, *The Journal of Finance*, 47, 4, 1367-1400.

Scotchmer, S. (2004), *Innovation and Incentives*, MIT Press.

Taylor, C.R. (1995), Digging for Golden Carrots: An Analysis of Research Tournaments, *The American Economic Review*, 85, 4, 872-890.