Semi-Public Competitions *

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Abstract

The process of innovation is driven by two main factors: new inventions and institutions supporting the transformation of inventions into marketable innovations. This paper proposes a new institution, called a *semi-public competition*, that has been neglected by the economic literature but exists frequently in practice. I show how semi-public competitions can mitigate a dilemma that arises at an early stage of innovative activity and specify the conditions under which a semi-public competition can increase welfare. The results suggest that governments promote knowledge about the semi-public competition mechanism but refrain from direct public funding of competitions.

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1 Introduction

To foster innovation two main ingredients are necessary: new inventions and institutions supporting the transformation of inventions into marketable innovations (Scotchmer, 2004). This paper proposes a new institution that has been neglected by the economic literature but exists frequently in practice. It shows how this institution, called a *semi-public competition*, can mitigate a dilemma that arises at a very early stage of innovative activity.

I analyze a situation where entrepreneurs, who can be interpreted as inventors endowed with project ideas of uncertain value, have to be matched with investors, each of whom owns financial resources and has the relevant expertise to innovate but lacks ideas. Matching is modeled as an auction, where entrepreneurs sell their projects to investors, who bid for them. If matching is not preceded by screening of the project quality, all investors will have the same expectation and, thus, compete away any profit to be made in bidding. Moreover, if investors have to bear a market entry cost before bidding, the zero profit from the auction 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. This situation is related to a hold-up problem. Moreover, as entrepreneurs bear a cost for developing projects, the expected profit reduction can deter the development of innovations and, thus, reduce welfare. In this paper I model a mechanism (or institution) that exists in practice and can mitigate this dilemma.

According to this mechanism, an investor outsources screening to a jury of experts that produces a ranking of projects voluntarily entered by entrepreneurs. Participation is costly for both sides. The values of the winning projects 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 competition. The project values of competition losers, however, remain exclusive inside information of the competition sponsor.

Why would an investor sponsor a competition that exhibits a positive externality, as the sponsor pays all screening costs but competing investors also learn the values of winners' projects? The answer is that the sponsor benefits from exclusive inside information on competition losers, allowing 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 competition because they strive for the reputation and high payoff in case of winning. Thus, the sponsor is better off in equilibrium. His main trade-off arises when he determines the number of winning slots in his competition. If he increases this number, his competition becomes more attractive for entrepreneurs, which is especially important if other competitions are set up by competing investors. If he reduces the number of winning slots, ceteris paribus his competition produces more losers and, thus, increases the number of projects the sponsor has inside information about.

Although the institution is new to the economic literature, semi-public competitions are frequent phenomena in practice. For instance, 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. For example, one out of many business plan competitions is the "MIT $100K Entrepreneurship Competition", which "has facilitated the birth of over 120 companies with aggregate exit values of $2.5 billion captured and a market cap of over $10 billion. These companies have generated over 2,500 jobs and received $700 million dollars in Venture Capital funding."[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 and, hence, earn a high reputation and exposure to investors, some of whom (from diverse industries) sponsor the competition. Section 5 of this paper outlines the key features of the "Moot Corp Competition", the world's first business plan competition for MBA students, and shows how these features are reflected by the model's assumptions and findings.[2]

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

I also show that in equilibrium only one investor sponsors a given semi-public competition. Sponsoring is exclusive because the sponsor prefers not to share the inside information on losers' types, despite the potential to share screening costs with other investors. The market for semi-public competitions has characteristics of a natural monopoly. I specify the conditions under which a monopolistic competition exists in equilibrium. Moreover, depending on parameter values, it is possible that several competitions are

[1]See `http://www.mit100k.org/` for the quote and several resources on how to write a business plan.

[2]Other applications comprise TV casting shows for would-be pop stars such as "American Idol" (see section 5); talent competitions among young artists, software developers, or classical musicians (see Ginsburgh and van Ours, 2003); architecture competitions; and industry sponsored project grants for researchers or graduates.

organized simultaneously and compete for entrepreneurs' participation. I show, however, that in equilibrium every entrepreneur will not participate in more than one competition.

Summarizing, semi-public competitions can mitigate, yet not eliminate, a hold-up problem faced by entrepreneurs as, ex post, competition winners do not suffer from hold up but losers do. Non-exclusive private screening, where investors share inside information on a certain project value, is unprofitable for investors and, hence, does not exist in equilibrium. I show that a semi-public competition can serve as a welfare enhancing "compromise" between investors and entrepreneurs saving each side a positive expected payoff from matching.

The competition institution only exists if it is efficient compared to no screening and private screening. Depending on parameter values, it may even be socially optimal in general. As it is incentive compatible for entrepreneurs and investors and requires relatively little information ex ante as compared to potentially superior mechanisms, however, this model does not suggest that government authorities intervene directly with public funding. Instead, there is an indirect role for public policy. First, as semi-public competitions depend on active competition among investors, it is crucial that competition policy authorities safeguard competitive markets. Second, as the semi-public competition mechanism has been used selectively in practice but could potentially be used in many more fields, spreading information on how it works could make "investors" in some markets, who are feeling now that they only have the choice between private screening and no screening, consider using the semi-public competition mechanism to match with "entrepreneurs".

I endogenize the investors' choice of mechanism and the entrepreneurs' product development and competition 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 competition. In a competition, they also choose the number (not the identity) of winners. Third, each entrepreneur simultaneously chooses whether to participate in screening, if offered, and in which competition to participate, if more than one is offered. Competition winners' project values are publicized but the sponsor of a competition exclusively learns losers' values. Finally, every investor places a bid for every project in a first-price sealed bid auction.

The paper is organized as follows. Section 2 reviews the literature. Section 3 describes the model. Section 4 characterizes the conditions under which a semi-public competition exists in equilibrium and shows the main results. Section 5 features two applications of the model, business plan competitions and TV casting shows. Section 6 concludes. Appendix A presents several extensions and robustness checks. All proofs are in Appendix B.

2 Related Literature

The final stage of the game draws on the seminal article by 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 my 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 to study entrepreneur financing. 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 endogenize entrepreneurs' efforts. In their matching model, many sellers of a good meet many buyers. 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, I model a new institution that can mitigate a dilemma at the very beginning of the process of innovation, where ideas may be developed endogenously up to a stage where entrepreneurs can discuss them with investors.

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.

Related to stage 3 of my paper, Azmat and Möller (2009) endogenize the competitors' participation decisions if multiple contests compete for participants. They also endogenize the competitors' effort decisions and the contest organizers' prize structures. I abstract from both issues in this paper. For the same reason my paper has only weak links to the literature on contests and tournaments.[3] Instead, I endogenize participation of both market sides in the entire game, the screening technology of investors, and their bidding behavior.

[3] See Baye, Kovenock, and de Vries (1996) and Konrad (2009) for overviews of this literature.

My paper is also related to the literature on research contests.[4] In a research contest, suppliers of an innovation bid for a procurement contract that is offered by a monopsonistic buyer. In a semi-public competition, in contrast, first the suppliers (entrepreneurs) endogenously develop innovations. Next they have to be incentivized to participate in screening such that their project values are revealed—despite knowing that the inside buyer will exploit them later when bidding against less informed outside buyers. A semi-public competition can alleviate this problem because it serves as a buyer's commitment device to only exploit losers, not winners.

3 The Model

Entrepreneurs

On the seller side of a market there are N *entrepreneurs*, each of whom is endowed with one project idea and acting as inventor. N is common knowledge but, because the N entrepreneurs are drawn from a large population, their identities are unknown. The cost of development for entrepreneur i is D_i, which is a realization of the random variable $\tilde{D}_i$ with support $(0, \infty)$. All draws are i.i.d., hence, $\tilde{D}_i \equiv \tilde{D}$. $\tilde{D}$ is common knowledge but i learns his realization D_i privately before he decides whether to develop his project, or not. If i decides to spend D_i, he obtains a project with the potential value Z_i, which also represents i's talent and is a realization of the random variable $\tilde{Z}_i$ that has support $[0, \bar{Z}]$, no atoms, and expectation $E(\tilde{Z})$. All draws are i.i.d., hence, $\tilde{Z}_i \equiv \tilde{Z}$. I will omit the subscript i whenever there is no danger of confusion. $\tilde{Z}$ is statistically independent of $\tilde{D}$ and is common knowledge but nobody, including entrepreneur i, knows the realization Z_i. Consequently, every entrepreneur has the same expectation about his own Z_i. Every entrepreneur needs an investor to produce the value Z_i.

The independence of $\tilde{Z}$ and $\tilde{D}$ 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. In contrast, 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 better than the market value, which is determined on the demand side.[5] Moreover, i does not know his potential competitors. Thus, even if he gets feedback from his friends or colleagues that his idea is "good" or

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

[5] For instance, in life sciences D_i can be very high but the value Z_i of the project can be low because close substitutes exist and Bertrand competition among them is likely. Conversely, the development cost of a new business method on the internet can be low but its value can be high if a first mover advantage can be exploited.

"valuable", he does not know *how* valuable it is compared to other ideas.

Investors

On the buyer side of the market there are $m + 1$ identical *investors*, who may buy entrepreneurs' projects. They can be considered project developers who have both the necessary financial means and the knowledge to compare project values and to transform a project into a marketable product. However, they lack innovative ideas and, thus, need an entrepreneur's project to realize its value Z. 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, thus, expects $E(\tilde{Z})$.

Summarizing, at the beginning of the game an entrepreneur is endowed with an *idea* that just has a *potential value*. Only if he spends the development cost, he transforms his idea into a *project* that can be presented and sold to an investor. The investor, after buying a project, has to develop it further into a marketable *product*. This paper only offers a reduced form model of the product development process (by normalizing the net present value for the investor to Z_i). Instead its focus is on the process until an investor buys a project from an entrepreneur.

Screening

Each investor can hire an independent *jury* (see details below), which screens an entrepreneur's project for a unit cost k. When offered a screening, entrepreneur i can choose to collaborate for a cost c. Both k and c are specific to one screening instance. They reflect the time and the effort spent to interact with each other and to produce documents, etc. that are targeted at one specific screening. If a screening takes place, the jury learns the value of the entrepreneur's project, Z_i,[6] 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.

[6]The assumption of perfect value revelation is a shortcut. See Appendix A for a discussion of noisy screening by the jury. I could also assume that each entrepreneur must choose an effort level if he gets screened and assume that the cost of effort decreases in the Z_i of an entrepreneur. This could produce a sorting effort equilibrium and enable the jury to observe Z_i indirectly. Instead, as a short cut I assume that c is fixed and the jury observes Z_i directly.

Forms of Screening

Screening can take either of two forms: *exclusive private screening* or *semi-public competition*. After a private screening the jury reports the value Z_i of every project screened only to the investor who pays its screening cost.[7] Alternatively, if an investor j organizes a semi-public competition, he picks a number $n_j \leq N$ of winning slots. The independent jury declares the n_j entrepreneurs with the highest project values "winners" of the competition and publicizes their project values.[8]

Outsourcing the picking of winners to a jury serves as a commitment device of the competition sponsor that indeed the best entrepreneurs are declared winners. If the sponsor picked or publicized the competition 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 competition 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 it.[9]

Publicizing the identity of winners of a competition 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, where $\alpha_j \equiv \frac{n_j}{N_j} \in [0, 1]$ is the probability of winning the competition sponsored by investor j, n_j is the number of winning slots, and N_j is the total number of participants in competition j. I make the following assumption.

Assumption 1 (Reputation production function) $R(\alpha_j) \in [0, \bar{R}]$ *is the reputation production function of a semi-public competition, where:*

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

Assumption 1 implies that winning a competition is only valuable if not every participant wins and that the value of winning a competition increases in a convex way the less likely it is to win. R can be interpreted as the net present value of future earnings attributable to winning the competition, apart from getting higher bids when selling a project.[10] Alternatively, R can be interpreted as the non-pecuniary utility from the

[7] See Appendix A for a discussion of private screening by more than one investor.

[8] See Appendix A for a discussion of imprecise value revelation of winners.

[9] 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.

[10] 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 competition participation of each entrepreneur. In contrast,

esteem attached to winning a competition, which is enjoyed in other social situations.[11]

In both interpretations, the more exclusive it is to be a winner of a competitive competition the higher winning is valued. Note that private screening does not create a reputation because its results are not publicized and matching of an entrepreneur and a private screener cannot be taken as a positive signal from an outsider's perspective because all project values are nonnegative.

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

Besides private screening and semi-public competition, the third option of an investor is *no screening*. After (no) 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 nonnegative 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 (for the cost D_i), or not. Investors decide whether to become active (for the cost F) or not to enter the market. Second, investors are ordered randomly by nature. The first investor chooses among *exclusive private screening*, *semi-public competition*, and *no screening*. The other investors follow in the order of the random draw. The sponsor of a competition determines n_j, which is made public. Third, if private screening or a competition is chosen by an in-

winners can prove that they have actually won a competition by producing appropriate documents, etc. Hence, competition 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. As project values depend on entrepreneurs' talents, investors will believe that the probability that a former winner has a high project value is larger than the probability that another entrepreneur has a high value. This belief creates $R \geq 0$.

[11] To see that winning a competition indeed spends utility per se, apart from monetary gains, see Rablen and Oswald (2008), who show that winning the Nobel Prize, compared to merely being nominated, is associated with between 1 and 2 years of extra longevity. Delfgaauw et al. (2009) show in a field experiment that sales competitions among clerical workers have a large effect on sales growth even if no monetary rewards are associated with winning. In another field experiment, Blanes i Vidal and Nossol (2009) study the effects of revealing to workers their relative position in the distribution of pay and productivity. They find that merely providing this information leads to a large and long-lasting increase in productivity that is costless to the firm and interpret this such that workers' incipient concerns about their relative standing are activated by information about how they are performing relative to others.

vestor, 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 determines the price for which the entrepreneur sells the project to the highest bidder.[12] Figure 1 displays the timing of the endogenous decisions in the game.

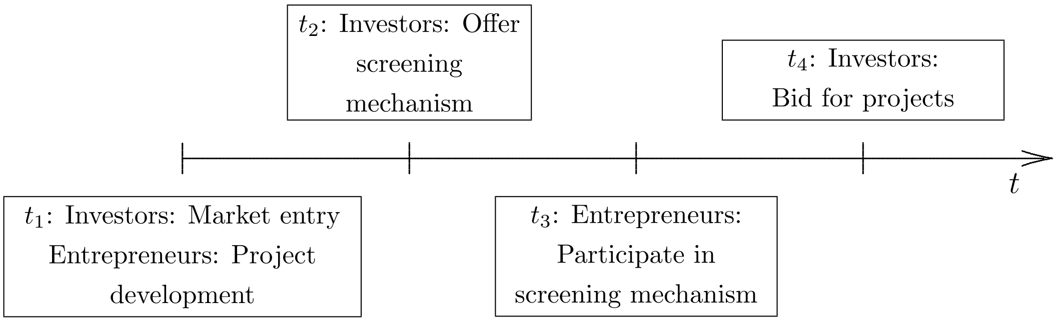

Figure 1: Time structure of the model

The solution concept used is Perfect Bayesian Equilibrium. As usual in such games, there are multiple equilibria, each sustained by its own beliefs. Due to the ex ante symmetry of entrepreneurs, on the one side, and investors, on the other, I focus on symmetric equilibria. 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 competition and show the conditions under which the existence of a competition and active participation of entrepreneurs therein characterize an equilibrium.

4 Analysis

The Benchmark: No Screening

If no screening of an entrepreneur takes place, at 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 $b = E(\tilde{Z})$ and expects $E(\pi) = 0$.*

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*.[13] Note that the

[12] The assumption of a complete sale of the project is made for simplicity. As long as Z_i is the net present value of the share sold by the entrepreneur to the investor, the results of the analysis below hold.

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

bidding strategies in Lemma 1 do not depend on the costs incurred by the investors in earlier stages, namely F, as these costs are sunk at stage 4. The situation of bidders is related to the one of sellers in Bertrand competition with homogenous goods.

Exclusive Private Screening

If exactly one investor has screened entrepreneur i, he is an insider with respect to i. Thus, at stage 4, I am looking for a Bayesian 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 $\beta(\tilde{Z})$ denote a pure strategy of the insider, in which he maps every value Z that he learns via screening onto a bid b.[14] 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.

Definition 1 (Expected payoffs from one auction) *Define $E(\pi_{OUT})$ as the expected payoff of an outsider, $E(\pi_{INS})$ as the expected payoff of the insider, and $E(\pi_i)$ as the expected payoff of the entrepreneur selling his project. Define the* expectation *of the insider's share in the total expected payoff as $(1-\theta)$ and the entrepreneur's share as θ.*

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:*

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

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

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

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 $[0, E(\tilde{Z})]$ and, thus, avoid the winner's curse in expectation. According to EMW, Theorem 4, the distribution of the total payoff $E(\tilde{Z})$ between the seller and the inside bidder only depends on the realization Z that the insider learns before bidding. Given that $\tilde{Z}$ is known, $\theta = \theta(\tilde{Z})$ is unambiguous, which is common knowledge. For the sake of brevity I will omit $\tilde{Z}$ in the notation of θ below.

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

The key insight from Lemma 2.(ii) for this model is that it pays for an investor to be an insider as he makes a positive expected payoff, unlike the symmetric information case of Lemma 1. Unavoidably, this comes at a cost for the entrepreneur selling his project because the project value is not influenced by screening but the insider can appropriate a share of it if he screens. However, if the entrepreneur does not agree to screening, this refusal cannot rationally be used as a signal for low ability from the investors' perspective because entrepreneurs do not know their own relative ability. Therefore, investors have to incentivize entrepreneurs to participate in screening. I will explore next how to achieve this.

Semi-Public Competitions

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 competition and determines a number of winning slots n^* for the best participants. The remaining m investors do not offer a competition. At stage 3, all N entrepreneurs participate in the competition and get screened by the jury. All investors observe the competition 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 for each winner of the competition. 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. As noted before, this equilibrium is not unique but it is efficient when compared to private screening and no screening, as we will see below. 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.

Definition 2 (Average values of competition winners and losers) *Consider competition j. I define Z_n as the expected lowest value of a winner's project, Z_w as the expected average value of a winner's project, and Z_l as the expected average value of a loser's project.*

By assumption, the identities of the best n_j entrepreneurs are publicized as winners together with their project values. Every investor also knows the distribution $\tilde{Z}$. Hence, he can guess Z_n, Z_w and Z_l. It follows that $Z_l < E(\tilde{Z}) < Z_w$ and that $0 < Z_l < Z_n < Z_w < \bar{Z}$ for $\alpha_j \in (0, 1)$.[15]

[15] For example, if project values are drawn from a uniform distribution over $[0, \bar{Z} = 100]$ and the sponsor sets $n_j = 10$ winning slots, then $E(\tilde{Z}) = 50, Z_n = 90, Z_w = 95, Z_l = 45$.

What is the bidding equilibrium for an entrepreneur's project at stage 4 if he is a competition 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. At stage 3, when the entrepreneur has to decide about competition 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 competition participants N_j (see details below). Hence, he can form a belief about α_j and use it, together with his knowledge on $\tilde{Z}$, to guess the average value of a winning project, Z_w.

What is the bidding equilibrium if an entrepreneur is a competition loser and there is only one insider knowing his type? 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) accordingly. 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, every entrepreneur has to make two decisions: (i) whether he wants to participate in a competition at all or whether he prefers private screening or no screening; (ii) conditional on competition participation, where he wants to participate if there are multiple competitions offered.[16]

Definition 3 (Entrepreneurs' beliefs) *From the perspective of entrepreneur i, $\hat{N}_j$ is the expected number of participants in competition j* before *i decides about his participation, and $\hat{\alpha}_j \equiv \frac{n_j}{\hat{N}_j+1}$ is the expected winning probability in competition j* after *i decided to participate in j.*

At stage 3, the development cost D_i is sunk. If he participates in competition j, entrepreneur i expects a payoff $E(\pi_i)$ of $\hat{\alpha}_j[R + Z_w] + (1 - \hat{\alpha}_j)[\theta Z_l] - c$. By using $E(\tilde{Z}) = \hat{\alpha}_j Z_w + (1 - \hat{\alpha}_j)Z_l$, this can be rewritten as:

$$E(\tilde{Z}) + \hat{\alpha}_j R(\hat{\alpha}_j) - (1 - \hat{\alpha}_j)(1 - \theta)Z_l(\hat{\alpha}_j) - c. \tag{4}$$

An entrepreneur can influence his expected payoff by choosing to participate in a certain competition j, which increases the expected number of participants in that competition by one and, thus, has an influence on the winning probability in j.

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

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

[16] As we are looking for an equilibrium with a unique competition, decision (ii) specifies out-of-equilibrium beliefs and behavior, as we will see below.

Lemma 3 implies that entrepreneurs face a trade-off when deciding in which competition to participate. If the winning probability in a competition is high, it comes at a cost because the reputation benefit of being a winner in that competition is small. In contrast, competition for the high reputation benefit that can be gained in a very exclusive competition is intense. However, there the winning probability is small, which reduces the expected utility from participation. Therefore, the expected payoff function of entrepreneurs from competition participation is hump-shaped in the expected winning probability; see Figure 2. This implies that, for $\hat{\alpha}_j > \alpha^*$, there is a positive externality, that is the expected utility of the participants in competition j increases if another entrepreneur participates in this competition. For $\hat{\alpha}_j \leq \alpha^*$, there is a negative externality because every additional participant drives $\hat{\alpha}_j$ 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 4 (Threshold winning probabilities)

$$\underline{\alpha} \equiv \frac{c + (1-\theta)Z_l(\underline{\alpha})}{R(\underline{\alpha}) + (1-\theta)Z_l(\underline{\alpha})} \leq \frac{c + (1-\theta)Z_l(\bar{\alpha})}{R(\bar{\alpha}) + (1-\theta)Z_l(\bar{\alpha})} \equiv \bar{\alpha}. \tag{5}$$

Lemma 4 (Entrepreneurs' preferred mechanism) *Let $E(\pi_i(\alpha^*)) \geq E(\tilde{Z})$ and $\hat{\alpha}_j > 0$. (i): From an entrepreneur's view, private screening is dominated by no screening and by a semi-public competition. (ii): If $\hat{\alpha}_j \in [\underline{\alpha}, \bar{\alpha}]$, an entrepreneur prefers a semi-public competition 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 competition can be entrepreneurs' most preferred mechanism if the expected winning probability of a competition lies in an intermediate range and thereby the expected reputation benefit from winning, $\hat{\alpha}_j R(\hat{\alpha}_j)$, 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 competition participation attractive for entrepreneurs. Only then it is possible that in expectation the reputation benefit conditional on becoming a competition 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 competition loser. Henceforth, I only consider cases where this holds:

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

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

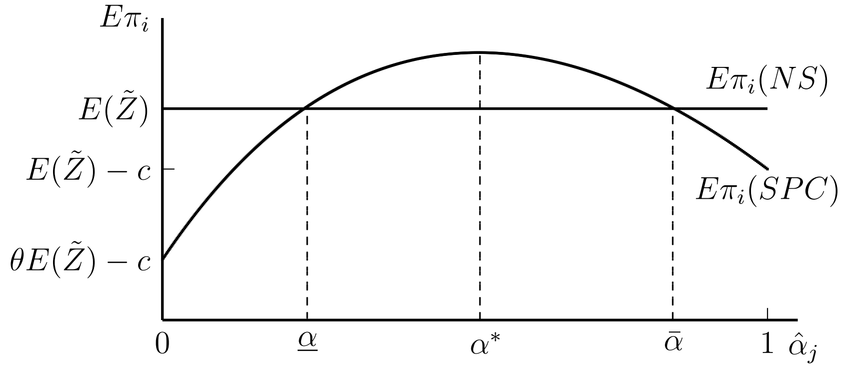

Figure 2: Expected payoffs from competition participation and no screening.

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

Lemma 5 (Competition participation equilibrium) *Let Q be the number of competitions that offer at least one winning slot, that is 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 $\hat{\alpha}_j(\phi_j^*) \in [\underline{\alpha}, \bar{\alpha}]$, 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 competition with probability ϕ_j^*, where:*

$$\phi_j^* = \frac{n_j(N + (Q - 1)) - \sum_{q=1}^{Q} n_q}{(N - 1)\sum_{q=1}^{Q} n_q}. \tag{6}$$

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

In a symmetric pure strategy Nash equilibrium, all entrepreneurs, by definition, participate in the same competition j. Thus, the expected winning probability in this competition is $\hat{\alpha}_j = \frac{n_j}{N}$. 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 the outside option, no screening, which secures them an expected payoff $E(\tilde{Z})$.

Lemma 5.(ii) starts from the fact that the expected winning probability of an entrepreneur in competition 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 competitions with some positive probability. 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 competition, that is 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:[17]

$$\hat{\alpha}_j(\phi_j^*) = \frac{\sum_{q=1}^{Q} n_q}{N + Q - 1} \quad \forall j \in \{1, ..., Q\}. \tag{7}$$

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. The pure strategy equilibrium and the mixed strategy equilibrium coincide if only one competition 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 competition. 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 $[(1-\theta)E(\tilde{Z}) - k]$ from each entrepreneur screened; see Lemma 2. If $\hat{\alpha}_j(\phi_j^*) \in [\underline{\alpha}, \bar{\alpha}]$, all entrepreneurs will participate in a competition. Then, he expects $[-k]$ from each winner and $[(1-\theta)Z_l - k]$ from each loser. In total, he expects:

$$(\phi_j^* N - n_j)(1-\theta)Z_l - \phi_j^* N k, \tag{8}$$

where $\phi_j^* N$ is the expected number of entrepreneurs participating in his competition. It is straightforward to observe from (8) that an investor will never organize a semi-public competition if the screening cost k is prohibitive. As the minimum number of winning slots in case a competition 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 competitions and investor payoff) *Conditional on offering a competition himself, the expected payoff of investor j decreases in the number of competitions offered:*

$$\frac{dE(\pi_j)}{dQ} < 0. \tag{9}$$

Lemma 6 implies that, if investor 1 offers a semi-public competition, his expected payoff decreases in the number of competing competitions. This is due to two effects.

[17] See the proof of Lemma 5 in Appendix B for a numerical illustration of the equilibrium strategies' mechanics.

First, because of the mixed strategy of entrepreneurs when deciding about competition participation (see Lemma 5.(ii)), investor 1 expects less participants in his competition for each additional competition that is offered. This also decreases the number of losers in his competition, who are the source of his positive expected payoff in the final auction. It also implies an increased winning probability $\hat{\alpha}_j$ for entrepreneurs, which reduces the average value of losers' projects, Z_l. Therefore, an investor is hurt twice for each additional competition that is offered.

Consequently, Lemma 6 implies that, given investor 1 offers a competition, he has an incentive to foreclose entry of other investors into the market of competitions 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 after investor 2 faces the same problem as investor 2 and will, thus, not enter the competition market.

How can investor 1 avoid that investor 2 offers a competition? 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 $n_1 \in (\underline{n}_1, \bar{n}_1)$.[18] This captures two *competitive constraints* of investor 1 when maximizing his own expected payoff (a lower constraint $\underline{n}_1$ and an upper constraint $\bar{n}_1$) and determines the boundaries of kind of a "limit pricing" strategy. In addition, he has to make sure that the two *demand constraints* defined in Lemma 5 hold for $Q = 1$:

$$\frac{n_1}{N} \in [\underline{\alpha}, \bar{\alpha}]. \tag{10}$$

Definition 5 (Threshold parameter values) *Define $\underline{n}, \bar{n}$ as investor 1's* binding con- straints*, $\bar{\bar{k}}$ 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 competition is profitable, and $\bar{c}_j$ as the prohibitive cost level of entrepreneurs in competition j:*

$$\underline{n} \equiv max\{\underline{n}_1, \underline{\alpha}N\}, \quad \bar{n} \equiv min\{\bar{n}_1, \bar{\alpha}N\}, \tag{11}$$

$$\bar{\bar{k}} \equiv \frac{(R(\underline{\alpha}) - c)(1-\theta)Z_l}{R(\underline{\alpha}) + (1-\theta)Z_l}, \quad \hat{k} \equiv min\{\bar{k}, \bar{\bar{k}}\} \tag{12}$$

$$\hat{c} \equiv \hat{\alpha}_2 R_2 + (1-\hat{\alpha}_1)(1-\theta)Z_l, \tag{13}$$

$$\bar{c}_j \equiv \hat{\alpha}_j R_j - (1-\hat{\alpha}_j)(1-\theta)Z_l. \tag{14}$$

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 demand constraints and competitive constraints.

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

Proposition 1 (Semi-public competition equilibrium) *If either (i): $c \leq \hat{c}$ or if (ii): $\underline{n} \leq \bar{n}$ and $k \leq \hat{k}$, then there is a unique equilibrium at stage 2 of the game, in which investor 1 organizes a semi-public competition with $n_1 = \underline{n} \equiv n^*$ winning slots. All other investors do not organize a competition.*

The proposition's intuition starts from the notion that some supported parameter realizations allow investor 1 to foreclose the market of semi-public competitions 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, as in Proposition 1.(i), the screening cost of entrepreneurs is low ($c \leq \hat{c}$), more than one competition could be organized but entrepreneurs would have an incentive to participate in two competitions. This would let the two insiders compete with symmetric information in the auction at stage 4, thereby increasing the expected bid and increasing the aggregate probability of the entrepreneur of being a competition winner. In turn, this behavior would make the net payoff from organizing the competition negative for both insiders. Knowing this, the second and all subsequent investors do not organize a competition. Hence, together with Assumption 3, $c \leq \hat{c}$ is a sufficient condition for the existence of a unique competition in equilibrium.

Alternatively, if $\bar{c}_1 \geq c > \hat{c}$, investor 1 can still profitably foreclose entry into the competition market by investor 2 if both demand constraints and both competitive constraints hold, that is if $\underline{n} \leq \bar{n}$; see Proposition 1.(ii). In this case he sets n_1 equal to the *lowest* level of the interval $[\underline{n}, \bar{n}]$. As $\underline{n}$ is defined as the maximum of the lower demand constraint and the lower competitive constraint, two cases arise.[19] In general, a monopolistic semi-public competition is more likely if the screening cost of investors (k) is low or if the share of the expected average value of a competition loser's project that investor 1 can appropriate ($(1-\theta)Z_l$) is high.

A main contribution of this paper is to show existence of a unique semi-public competition in equilibrium. Therefore, complementary to Proposition 1, I will only outline the conditions that lead to the existence of more than one competition in a less formal and more concise manner. If $\bar{c} \geq c > \hat{c}$, every entrepreneur would not participate in more than one competition voluntarily, even if it were organized. Hence, more than one competition *can* exist in equilibrium. In such a situation, if $\underline{n} > \bar{n}$, investor 1 cannot attract participation of entrepreneurs in his own competition and avoid that a second investor sets up a semi-public competition profitably. It depends on the parameters of the reputation production function R, the screening costs k and c, and the expected average value of a competition loser's project that an inside investor can appropriate, $(1-\theta)Z_l$, whether investors 1 and 2 can profitably prevent entry of a third, etc. investor.

[19] See the proof of Proposition 1 in Appendix B for a more detailed analysis of these cases and comparative statics effects on the equilibrium.

Every investor who offers a competition in equilibrium makes nonnegative payoff, while entrepreneurs make an extra expected payoff, on top of their no screening outside option $E(\tilde{Z})$, 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 competition will be offered. For $\hat{k} < k \leq \bar{k}$, investor* 1 *may offer* private screening *at stage 2. The other investors do neither offer a competition nor private screening. Whenever a semi-public competition is established in equilibrium, it has one exclusive sponsor.*

A private screener's net expected payoff is $(1-\theta)E(\tilde{Z}) - k$ per entrepreneur screened, as long as he is the only insider with respect to a certain entrepreneur. If investor 1 offers private screening because k is too high to offer a competition, 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 net payoff of $-k$, 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 competition is always exclusive and why mechanisms that assume sequential screening of the same entrepreneurs, for instance the losers, cannot exist 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 Q competitions exist in equilibrium and the expected winning probability in competition j is $\hat{\alpha}_j(\phi_j^*) = \frac{\sum_{q=1}^{Q} n_q^*}{N+Q-1}$. 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:*

$$\bar{D} \equiv E(\tilde{Z}) + \hat{\alpha}_j(\phi_j^*)R(\hat{\alpha}_j(\phi_j^*)) - (1-\hat{\alpha}_j(\phi_j^*))(1-\theta)Z_l - c \geq E(\tilde{Z}), \tag{15}$$

$$\bar{F} \equiv \sum_{q=1}^{Q} \frac{(\phi_q^* N - n_q^*)(1-\theta)Z_l - \phi_q^* N k}{m+2-q} > 0. \tag{16}$$

Proposition 2 states that at stage 1 of the game all entrepreneurs develop their ideas into projects whose development costs are not larger than the expected payoff from selling the project. Similarly, it states that investors will only enter the market as long as the market entry cost is not larger than the expected payoff from entering. Proposition 2 also implies the following corollary.

Corollary 2 (Competition and hold-up) *Competition among investors ($m > 0$) is necessary to establish a semi-public competition in equilibrium. The competition 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 competition or to bid more than ϵ is not subgame-perfect but cheap talk.

Abstracting from semi-public competitions 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 $E(\tilde{Z})$ 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 an investor organizes a competition, entrepreneurs can benefit from it and participate. In this situation, they voluntarily spend the relationship-specific cost as they uniquely provide the sponsor with inside information conditional on becoming a competition loser. The entrepreneurs are motivated to do so because of the very characteristic of a semi-public competition, that with a certain probability ($\hat{\alpha}_j$) they are among the winners of a competition and receive a high payoff from information revelation. Hence, the existence of a semi-public competition alleviates the entrepreneurs' hold-up problem faced in private screening.

Relative efficiency and social optimality

Corollary 3 (Positive expected payoffs) *If, according to Proposition 1, a semi-public competitions exists in equilibrium and the lower demand constraint is binding ($\underline{n} = \underline{\alpha}N$), the competition sponsor expects higher payoffs than under no screening. If the lower demand constraint is not binding ($\underline{n} > \underline{\alpha}N$), the sponsor and the entrepreneurs expect higher payoffs than under no screening.*

This corollary follows from the inequalities in (15) and (16), which compare expected payoffs in the competition 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 competitions 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 $E(\tilde{Z}) - D_i$ and develop his idea up to a cost of

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

Definition 6 (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, a semi-public competition exists in equilibrium, the competition mechanism is relatively efficient.*

The intuition of Proposition 3 is that, at stage 2 of the game, investor 1 organizes a competition 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 the one investor who organizes a competition profitably. Corollary 3 implies that the inclusion of the competition mechanism in investors' action sets at stage 1, on top of private screening and no screening, increases the expected payoffs of investors of the entire game.

In general, social optimality of the competition mechanism depends on the reputation production function, $R(\alpha)$. If the reputation utility created were zero or very small, it would be optimal to realize all projects without screening, due to the low costs of no screening and the assumption that project values are nonnegative. This, however, would restrict the number of developed projects to those whose development costs are $D_i \leq E(\tilde{Z})$.

In order to increase the number of developed projects, another source of entrepreneurs' utility has to be found. In this model R takes this role. As argued in section 3 and indicated by the literature in footnote 11, the creation of R is a natural characteristic of competitions that publicize the identities of the best competitors in a credible way; a characteristic private screening cannot achieve. As the determination of project values by some party—here: the jury—requires screening, the reputation produced must be large enough to compensate for the additional costs, c and k. Given that R is large enough, the socially optimal mechanism must be some kind of organized competition that realizes this additional value. A semi-public competition fulfills this requirement. Here, entrepreneurs are willing to develop projects whose development cost exceeds their expected gross payoff from no screening, $E(\tilde{Z})$, up to $\bar{D} \geq E(\tilde{Z})$. Thus, in a world with competitions more projects are developed than in a world without competitions. Many of them, for which $D_i < \bar{D}$, are welfare enhancing.

Does there exist another mechanism that achieves the development of even more projects thereby driving up welfare even higher? Bearing in mind the hump shape of the expected reputation payoff function, $\hat{\alpha}_j R(\hat{\alpha}_j)$, a socially optimal mechanism may determine the number of winning slots, n_{opt}, and the resulting optimal winning probability, $\alpha_{opt} \equiv \frac{n_{opt}}{N}$, such that the aggregate reputation created for all winners is maximized. This is not necessarily achieved by the semi-public competition mechanism because the sponsor has an incentive to reduce the number of winning slots to $\underline{n}$; see Proposition 1. Given that $\underline{n} \neq n_{opt}$, the alternative mechanism, however, reduces the sponsor's payoff as compared to the semi-public competition mechanism; see Proposition 2. Consequently, the alternative mechanism may be beneficial for entrepreneurs but detrimental to investors. Which mechanism is optimal depends on the parameter values.

Moreover, the alternative mechanism installing n_{opt} would have to be implemented by a dictator's fiat, who would have to know all parameters of all players precisely and before the game is played. This is the great advantage of the semi-public competition mechanism: It is not only relatively efficient when compared to no screening and to private screening but it also provides incentives for both entrepreneurs and investors to participate in the market in their own self-interest and, thus, does not require any kind of knowledgeable central planner.

5 Applications

How "realistic" is the theory of semi-public competitions presented above? In the following section I will outline two applications that fit the model well. Thereafter, in the concluding section I will condense the key characteristics of these applications into a set of general conditions for economic situations, in which the use of semi-public competitions may increase welfare.

Business Plan Competitions

A business plan is a document in which an entrepreneur lays out all aspects of a business idea that are relevant for potential investors. A business plan competition is an organized competition to which entrepreneurs send their business plans. Experts evaluate the business ideas sent in, 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. Below I will describe the key features of the "Moot Corp Competition" (MCC), which was set up in 1984 and is, according to its website,[20] "[...] 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.' "

[20] This and the subsequent quotes were taken from `http://www.mootcorp.org/index.asp` on April 17th, 2008.

MCC describes the typical entrepreneurs, jury members, and procedure of the competition 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 may 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, that is the finalists, are winners in the sense of this 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.[21] Due to the broad nature of the MCC, investors can be expected to have differentiated investment interests with respect to the industry or the investment stage of entrepreneurial projects. Thus, the diversification of judges in a given jury, as reported on the website, ensures exclusivity of every judge with a unique background.[22] Judges may use their inside knowledge as investor or convey it to another investor: "[...] we will not ask judges, reviewers, staff or the audience to agree to or sign non-disclosure statements for any participant."

The following quotes serve as evidence for the matching objective between entrepreneurs (also as potential employees) 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."

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 competition (in the sense of this 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

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

[22] See also the discussion of multidimensional types in Appendix A.

"compete" publicly become 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 may 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.[23]

To exemplify the appropriateness of the model to this application, I will outline some key features of "American Idol" below, which is, according to its website, "Television's No. 1 show" in the U.S. and has developed several franchises in other countries.[24] This statement and the following one indicate a high level of public awareness of the competition and a high prize both in money and in reputation of 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 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."[25] This procedure implies that information on losers' talents remains unpublicized; only the jury learns it. To motivate the sponsor's participation the judges may choose to forward it to the sponsor exclusively.

The following quote 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:[26] "In an interview [...] on the CBS TV current affairs show 60 Minutes on March 17, 2007 [...] judge Simon Cowell 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

[23]Moreover, there may be legal restrictions for competition 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 candidates "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 they are put at a disadvantage.

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

[25]Note that "tens of thousands" of applicants compete for 36 semifinal slots, as of season 8 taking place in 2009. Hence, the number of competition losers is very high.

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

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 competition 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 competition 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 competition.

Finally, recall that the model predicts (i) that competition winners are attractive for all investors, including non-sponsoring investors, and (ii) that the sponsor has private information on the talent of competition losers, which is valuable to him. There is evidence for both cases. (i): In 2004, two finalists (that is competition winners) signed record contracts with Universal Records in the Philippines and Japan (Jasmine Trias) and with Motown Records (Camile Velasco), competitors of the competition sponsor Sony/BMG.[27] (ii): 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. 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.[28] Thus, a "loser" can still be attractive for the sponsor.

6 Conclusion

In this paper I have characterized a mechanism, semi-public competitions, that can solve a dilemma occurring when entrepreneurs with ideas of uncertain value and investors with complementary resources have to be matched. I have shown the conditions under which such a competition exists in equilibrium and that it only exists if it is efficient compared to private screening and no screening, two alternative mechanisms.

Consequently, as long as the assumption holds that there are no positive spillovers from innovation on third parties besides entrepreneurs and investors, I can find no justification for direct government intervention in favor of or against semi-public competitions. In particular, this paper does not advocate public funding of such competitions. This point is important as the market for newly developed innovations is characterized by several information problems. There is no reason to assume that a central planner would understand the specifics of each project better than the entrepreneurs and investors involved. However, there is an indirect role for public policy. First, as existence of semi-public com-

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

[28]See `http://en.wikipedia.org/wiki/Mario_Vazquez`.

petitions depends on active competition among investors, it is crucial that competition policy authorities safeguard competitive markets. Second, as the semi-public competition mechanism has only been used selectively in practice but could be used in many more fields (see below), governments should promote its potential as an institution supporting innovation. If more "investors" in many industries know about it, they might not feel anymore that they are restricted to choosing between private screening and no screening. This can lead to more efficient matches with "entrepreneurs" and increase innovation and welfare.

More generally, my model can be applied to economic situations that are characterized by a strong complementarity of inputs and a high degree of hidden information on the value of one of the inputs, where even the owner of this input does not know its true value. The initial creation of the input's value should depend on some kind of ability or talent of its creator—a notion of human capital—which can be tested by screening. 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 product or service. Both private equity investors and public patrons that are specializing in funding start-ups are typical "investors".

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. The artist or scientist often requires financial resources and complementary knowledge of others 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 contracting the artists can support financing and match him with the right co-workers. They serve as "investors". Section 5 has presented one example for each of these categories, business plan competitions and TV casting shows. Ginsburgh and van Ours (2003) outline the case of a classical music competition.

The conditions listed above may point on untested applications of the semi-public competition mechanism. For instance, assume an employer faces a very competitive labor market for certain highly skilled workers, say engineers or software developers. Instead of increasing wages more and more, he could set up a semi-public competition 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 competition sufficiently attractive. As the best workers are most likely to win the competition and the winners would be publicized, competing employers would probably offer them high salaries, thereby free-riding on the sponsor's investment. However, the sponsor could employ a row of second-best workers, about whose talent he gained inside information, for relatively modest salaries, thereby making an economic profit.

Appendix

A Robustness and Extensions

Multidimensional types of entrepreneurs and private values of investors: In this model an entrepreneur's ability is only specified in one dimension captured by $\tilde{Z}$. In practice, entrepreneurs might be endowed with a multidimensional type vector. For instance, in the case of TV Casting Shows, one candidate may be better in singing, another one may be better in performing live on stage. It can occur that one investor values one dimension of entrepreneurs' types higher but another investor values another dimension higher. Related to multidimensional types, one investor may 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 amongst 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, two, and three of the game. Moreover, multidimensional types require additional assumptions to ensure well-behaving bidding functions because investors' preferences may not be single-peaked, anymore.

Most importantly, however, additional complexity would not deliver spectacularly new insights. Assume that each entrepreneur i is characterized by a two-dimensional type drawn from the joint distribution $(\tilde{Z}, \tilde{X})$. Moreover, assume as a shortcut that one group of investors, named z, is only interested in ability $\tilde{Z}$ whereas the other group, named x, is only interested in ability $\tilde{X}$. Let an investor's group affiliation be common knowledge. This would allow for two sponsors of a given competition 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 (along the lines of Lemma 2) and the fact that there is another insider interested in the second type-dimension.

For instance, assume that $(\tilde{Z}, \tilde{X})$ follows a uniform distribution in both dimensions, where both $\tilde{Z}$ and $\tilde{X}$ have support $[0, 20]$. Insiders observe an entrepreneur i's ability vector $(Z_i, X_i) \equiv (12, 8)$. If there were no second insider, the z-insider would bid $\beta(Z_i = 12) = E[\tilde{Z}|\tilde{Z} < Z_i] = 6$, according to Lemma 2. The aggregate of z-outsiders would bid a mixed strategy based on a uniform distribution over $[0, E(\tilde{Z})] = [0, 10]$. Now let a second investor sponsor the same competition and assume that he is from group x. An upper threshold for any rational equilibrium bidding strategy of the entrant is $\beta(X_i = 8) = 8$. Thus, if the z-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 payoff because $Z_i = 12 > 8 + \epsilon$.[29]

It follows that the expected payoff from becoming an insider 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. However, the key result holds, that being an insider creates an informational rent in the auction with respect to competing outsiders interested in the same type-dimension.

Noisy screening and publication of precise project values: 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 competition mechanism relies on the characteristic that exclusive inside information is valuable for an investor. The cruder the correlation between the insider's signal and the real value of entrepreneurs' projects is—that is the larger σ^2—the lower is the value of inside information. Thus, the upper threshold for existence of a semi-public competition in equilibrium, $\hat{k}$, decreases if σ^2 increases. For sufficiently small σ^2, the quality of the above results remains the same.

Akin to this argumentation, I assumed that the jury publicizes the *precise* project values of the winners, thereby allowing for Bertrand competition amongst investors in the final auction. In practice this may hardly be possible due to incomplete knowledge of the jurors about the future. Instead, the typical practical solution to this problem is to publicize a ranking of winners, detailing who is the first, the second, ..., the n_j'th winner. As long as the investors have some knowledge about the distribution of project values, they can form (positively correlated) beliefs about the value of a given winning project. Thus, competition winners can expect higher bids than competition losers and gain valuable reputation for their further careers. This may motivate them to participate in a competition.

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 competition winners have projects of high value, are confirmed in equilibrium. Publicity can be endogenized by assuming that the sponsor of competition 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 competition to investors and potentially to a wider audience. Then, a competition 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

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

semi-public competitions that create different reputation levels for winners in the same industry.[30] 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.

B Proofs

Proof of Lemma 1

Assume that at least one investor bids $E(\tilde{Z})$. Then, any $b < E(\tilde{Z})$ of another investor will lose and generate zero expected payoff. Any $b > E(\tilde{Z})$ 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 $\tilde{Z}$-distributions.[31]

(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 $\tilde{Z}$ and any $(m+1)$-tuple of bids, the seller's revenue plus the insider's profits in expected terms sum to $E(\tilde{Z})$. According to EMW, Theorem 4, the distribution of $E(\tilde{Z})$ between the seller and the inside bidder exclusively depends on the realization Z_i that the insider learns before bidding. Hence, there is a one-to-one mapping from $\tilde{Z}$ onto $\theta(\tilde{Z})$. This shows Lemma 2.(ii).[32]

Proof of Lemma 3

Preliminaries: The total derivative of (4) with respect to $\hat{\alpha}_j$ produces the following first-order condition (FOC):

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

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

[31] 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.

[32] 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 my model.

Assumption 1 states that R is decreasing and convex in α. Hence, the same holds with respect to $\hat{\alpha}_j$. To understand how the average value of competition losers, Z_l, depends on $\hat{\alpha}_j$ note that, for $\hat{\alpha}_j = 0$, all competition participants are losers. Hence, $lim_{\hat{\alpha}_j \to 0} Z_l = E(\tilde{Z})$. For $\hat{\alpha}_j = 1$, all competition participants are winners. Hence, $lim_{\hat{\alpha}_j \to 1} Z_l = 0$. Because, by definition, increasing the expected share of winners $\hat{\alpha}_j$ decreases Z_n, the threshold value between winners and losers, and because the distribution $\tilde{Z}$ is continuous, we have in expectation:

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

At stage 3 of the game n_j is fixed. Hence, $\hat{\alpha}_j$ can only decrease via increasing $\hat{N}_j$, the expected number of participants. With probability $\frac{(1-\hat{\alpha}_j)}{2}$, a new participant has value $Z \in [0, Z_l]$. With probability $\frac{(1-\hat{\alpha}_j)}{2}$, 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 $\hat{\alpha}_j$, a new participant has value $Z \in (Z_n, \bar{Z}]$, which increases Z_n and, hence, also increases Z_l. Summarizing, the larger $\hat{\alpha}_j$ before a new participant entered the competition, the *larger* the probability that his entry will have an effect on Z_l or:

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

Proof: Because of (1) and (B.2), the left hand side (LHS) and the right hand side (RHS) of (B.1) are positive for $\hat{\alpha}_j > 0$. For $\hat{\alpha}_j \to 1$, by definition, $R \to 0$, hence $Z_l \to 0$ and $(1 - \hat{\alpha}_j) \to 0$; hence, $LHS \to 0$. But in this case, $\frac{dR}{d\hat{\alpha}_j} \to -\infty$; hence, $RHS \to +\infty$. It follows that, for $\hat{\alpha}_j \to 1$, $LHS < RHS$. In contrast, for $\hat{\alpha}_j \to 0$, by definition, $R > 0$, hence $Z_l \to E(\tilde{Z})$ and $\frac{dZ_l}{d\hat{\alpha}_j} \to 0$; hence, $LHS > 0$, whereas $RHS \to 0$. It follows that, for $\hat{\alpha}_j \to 0$, $LHS > RHS$. Because R and Z_l are continuous and monotonic in $\hat{\alpha}_j$, the intermediate value theorem applies. It follows that there exists a unique optimum of (4), at α^*. The second-order condition (SOC) of (4) is given by:

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

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 (4) 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 $E(\tilde{Z})$ if there is no screening. Following Lemma 2, he expects $\theta E(\tilde{Z}) - c < E(\tilde{Z})$ from private screening. Private screening is also dominated by a semi-public competition if, drawing on (4), $\hat{\alpha}_j[R + Z_w] + (1 - \hat{\alpha}_j)[\theta Z_l] - c > \theta E(\tilde{Z}) - c$. By using $E(\tilde{Z}) = \hat{\alpha}_j Z_w + (1 - \hat{\alpha}_j) Z_l$, this can be rewritten as:

$$\hat{\alpha}_j(R + (1 - \theta)Z_w) > 0, \tag{B.5}$$

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

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

$$\hat{\alpha}_j[R + Z_w] + (1 - \hat{\alpha}_j)[\theta Z_l] - c \geq E(\tilde{Z}) \tag{B.6}$$

$$\Leftrightarrow \hat{\alpha}_j R \geq c + (1 - \hat{\alpha}_j)(1 - \theta)Z_l. \tag{B.7}$$

Lemma 3 implies that the expected utility from competition participation is hump-shaped in $\hat{\alpha}_j$. As the expected utility from no screening is independent of $\hat{\alpha}_j$, it implies that (B.7) holds with equality either for two $\hat{\alpha}_j$-levels or for one or for none. To see this note that in a competition, according to (B.6), $lim_{\hat{\alpha}_j \to 0} E(\pi_i) = \theta E(\tilde{Z}) - c$ and that $lim_{\hat{\alpha}_j \to 1} E(\pi_i) = Z_w(\hat{\alpha}_j = 1) - c = E(\tilde{Z}) - c$. Both values are smaller than $E(\tilde{Z})$. Hence, if $E(\pi_i|\alpha^*) > E(\tilde{Z})$, which depends on R and on $\tilde{Z}$ and on c, (B.7) holds with equality for $\underline{\alpha}$ and $\bar{\alpha}$, as defined in (5). These two levels converge in α^* for $E(\pi_i|\alpha^*) = E(\tilde{Z})$. Hence, $0 < \underline{\alpha} \leq \alpha^* \leq \bar{\alpha} < 1$. It follows that $\forall \hat{\alpha}_j \in [\underline{\alpha}, \bar{\alpha}]$, entrepreneurs prefer participation in competition j over no screening, as long as $E(\pi_i(\alpha^*)) \geq E(\tilde{Z})$. *Q.E.D.*

Proof of Lemma 5

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

$$\frac{d\hat{\alpha}_j}{d\hat{N}_j} < 0, \quad \frac{d^2\hat{\alpha}_j}{d\hat{N}_j^2} > 0. \tag{B.8}$$

In a symmetric pure strategy Nash equilibrium every i makes the same choice and participates in the competition that maximizes $E(\pi_i)$. Thus, expected utility of i is larger than under no screening if (B.7) holds for $\hat{\alpha}_j = \frac{n_j}{N}$ or:

$$\frac{n_j}{N} \in [\underline{\alpha}, \bar{\alpha}], \tag{B.9}$$

which is possible for $R(\frac{n_j}{N})$ sufficiently high or c sufficiently low. Given that (B.9) holds and entrepreneur i deviates unilaterally from choosing j, say by participating in competition s, he will be the only candidate there. Hence, $\hat{\alpha}_s = 1$, and the reputation benefit is $R(\hat{\alpha}_s = 1) = 0$, which creates an expected payoff strictly less than from participating in j. Thus, in a unique symmetric pure strategy Nash equilibrium every entrepreneur participates in the same competition j.

(ii): Let ϕ_j be the probability that entrepreneur i assigns to participation in each competition 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 competitions. (B.8) states that the marginal effect of i's entry on the winning probability in competition j decreases in $\hat{N}_j$. 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 competition, independent of the total number of competitions, Q, and independent of the number of winning slots in a competition, $n_j, \forall j \in \{1, ..., Q\}$. This is accomplished if the expected ex post winning probability in competition j, assuming that i participates in j, is equal $\forall j \in \{1, ..., Q\}$. Recall that this probability is defined as $\hat{\alpha}_j \equiv \frac{n_j}{\hat{N}_j+1}$ with $\hat{N}_j = \phi_j(N-1)$ as the expected number of entrepreneurs *other* than i participating in j. The mixed strategy equilibrium is found by solving the following system, where j and s are two arbitrary competitions:

$$\frac{n_j}{\phi_j(N-1)+1} = \frac{n_s}{\phi_s(N-1)+1} \quad \forall s \in \{1, ..., j-1, j+1, ..., Q\}, \tag{B.10}$$

$$\sum_{q=1}^{Q} \phi_q = 1. \tag{B.11}$$

(B.10) states $Q-1$ *indifference conditions*: the winning probability $\frac{n_j}{\phi_j(N-1)+1}$ that i faces *after* his entry in one of the Q competitions must be the same in every single competition. (B.11) closes the equation system by stating that all entry probabilities that i assigns to the Q competitions 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.10). This gives (7). It follows that, if the other $N-1$ entrepreneurs play $\Phi(\phi_j^*)$, i cannot change his expected utility from competition 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 competition, j. Due to $(B.11)$, this implies a reduction of the participation probability in another competition, $s \neq j$: $\phi_s' < \phi_s^*$. Thus, $\hat{\alpha}_j < \hat{\alpha}_s$, 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 $\hat{N}_j$) on the winning probability $\hat{\alpha}_j$, see (B.8), the only alternative equilibrium is one where all entrepreneurs choose the same competition with probability one. Hence, there $\hat{\alpha}_j = \frac{n_j}{N}$. If $\frac{n_j}{N} \notin [\underline{\alpha}, \bar{\alpha}]$, Lemma 5.(i) rules out this alternative and $\Phi(\phi_j^*)\forall i$ is the *unique* symmetric mixed strategy equilibrium.[33]

[33] *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 competition and a lower probability $\phi_s' < \phi_s^*$ to another competition, and another entrepreneur $g \neq i$

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

Illustration: Consider the following example. There are $N = 50$ entrepreneurs who face $Q = 5$ competitions, 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 competitions 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.11) holds. Substituting values in $\hat{\alpha}_j = \frac{n_j}{\phi_j(N-1)+1}$ results in $\hat{\alpha}_j = \frac{1}{2} \quad \forall j \in \{1, 2, 3, 4, 5\}$. 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 competitions. Consequently, i cannot increase his expected utility by deviating from $\Phi(\phi_j^*)$.

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

Proof of Lemma 6

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

$$\frac{d(\sum_{q=1}^{Q} n_q)}{dQ} = n_q \geq 1. \tag{B.12}$$

We can use this and (7) in:

$$\frac{d\hat{\alpha}_j(\phi_j^*)}{dQ} = \frac{(N+Q-1)\frac{d(\sum_{q=1}^{Q} n_q)}{dQ} - \sum_{q=1}^{Q} n_q}{(N+Q-1)^2} > 0. \tag{B.13}$$

Using (B.2) and (B.13), it follows that:

$$\frac{dZ_l(\hat{\alpha}_j(\phi_j^*))}{dQ} = \frac{dZ_l}{d(\hat{\alpha}_j(\phi_j^*))} \frac{d\hat{\alpha}_j(\phi_j^*)}{dQ} < 0. \tag{B.14}$$

From (6) and (B.12), we obtain:

$$\frac{d\phi_j^*}{dQ} = \frac{n_j \sum_{q=1}^{Q} n_q - n_j(N+Q-1)\frac{d(\sum_{q=1}^{Q} n_q)}{dQ}}{(N-1)(\sum_{q=1}^{Q} n_q)^2} < 0. \tag{B.15}$$

does the reverse. If deviations from ϕ_j^* are symmetric, such that, from the perspective of i, $\hat{\alpha}_j$ is the same $\forall j \in \{1, ..., Q\}$, this strategy combination constitutes a mixed strategy Nash equilibrium. However, this requires some coordination among the entrepreneurs: who participates in which competition 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 $\hat{\alpha}_j$ is the same $\forall j \in \{1, ..., Q\}$. But what should constitute such balancing asymmetric beliefs among ex ante identical players? Therefore, I focus on *symmetric* mixed strategy Nash equilibria in this paper.

Finally, we can take the total derivative of (8) with respect to Q:

$$\frac{dE(\pi_j)}{dQ} = \big(N((1-\theta)Z_l(\hat{\alpha}_j(\phi_j^*)) - k)\big)\frac{d\phi_j^*}{dQ} + (\phi_j^* N - n_j)(1-\theta)\frac{dZ_l(\hat{\alpha}_j(\phi_j^*))}{dQ}. \quad \text{(B.16)}$$

Due to (B.15) and Assumption 3, the first term of (B.16) is negative. It follows from (8) that, in order to avoid losses, an investor must offer less winning slots than the expected number of participants in his competition: $n_j < \phi_j^* N$. Because of this and (B.14), the second term of (B.16) is negative, too. (9) follows. *Q.E.D.*

Proof of Proposition 1

(i): Assumption 3 and Definition 5 imply that competitions can only exist in equilibrium if $k \leq \bar{k} \wedge c \leq \bar{c}_j$. When is exactly one competition offered? Two possibilities exist to rule out more than one competition in equilibrium. First, assume that two competitions, 1 and 2, are organized and entrepreneur i unilaterally participates in *both* of them whereas all other entrepreneurs only participate in one competition each. Investors 1 and 2 would obtain the same information on Z_i. Thus, i would expect perfectly competitive bidding and a payoff of $E(\tilde{Z}) + \hat{\alpha}_1 R_1 + \hat{\alpha}_2 R_2 - 2c$. If i participates in competition 1 only, he expects a payoff according to (4), with $j = 1$. Comparing expected payoffs shows that an entrepreneur prefers participation in two competitions over one if and only if:

$$c \leq \hat{\alpha}_2 R_2 + (1-\hat{\alpha}_1)(1-\theta)Z_l \equiv \hat{c}. \quad \text{(B.17)}$$

If i participates in two competitions, however, bidding is very competitive and the expected investor payoff from screening reduces to $-k$. Thus, given investor 1 already entered the market, investor 2 has no incentive to enter and will not organize a competition, too, if (B.17) holds.

(ii): If $c > \hat{c}$, it is still possible that exactly one competition is offered in equilibrium. Substituting (6) in (8) 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:

$$n_2(n_1) = \frac{\sqrt{n_1 N(N^2-1)(1-\theta)Z_l((1-\theta)Z_l - k)}}{(N-1)(1-\theta)Z_l} - n_1. \quad \text{(B.18)}$$

Substituting (B.18) in (8) for $j = 2$ produces investor 2's expected *Stackelberg follower payoff* from offering a competition and depending on n_1:

$$\frac{(n_1(N-1) + N^2)(1-\theta)Z_l - kN^2 - 2\sqrt{n_1 N(N^2-1)(1-\theta)Z_l((1-\theta)Z_l - k)}}{N-1}. \quad \text{(B.19)}$$

If the Stackelberg leader sets n_1 such that (B.19) is negative, investor 2 will not enter. Analyzing the first-order and second-order conditions of (B.19) with respect to n_1 reveals that (B.19) has a well-defined minimum level, which leads to a negative expected Stackelberg follower payoff.[34] Solving (B.19) for zero shows that investor 2's expected payoff is negative for all $n_1 \in (\underline{n}_1, \bar{n}_1)$, where:

$$\underline{n}_1 = \frac{\left(N(N+N^2-2)(1-\theta)Z_l((1-\theta)Z_l-k)-2\sqrt{(N-1)^2N^2(N+1)(1-\theta)^2Z_l^2((1-\theta)Z_l-k)^2}\right)}{(N-1)^2(1-\theta)^2Z_l^2} \quad \text{(B.20)}$$

$$\bar{n}_1 = \frac{\left(N(N+N^2-2)(1-\theta)Z_l((1-\theta)Z_l-k)+2\sqrt{(N-1)^2N^2(N+1)(1-\theta)^2Z_l^2((1-\theta)Z_l-k)^2}\right)}{(N-1)^2(1-\theta)^2Z_l^2} \quad \text{(B.21)}$$

$\underline{n}_1$ 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 $\underline{n} \leq \bar{n}$.[35]

Given the competitive constraints hold, it follows that $Q = 1$ and, thus, $\phi_1^* = 1$; see (6). Hence, investor 1 maximizes $(N - n_1)(1 - \theta)Z_l - Nk$, which yields, by total differentiation:

$$\frac{dE(\pi_1(Q = 1))}{dn_1} = -(1 - \theta)Z_l + (N - n_1)(1 - \theta)\frac{dZ_l}{dn_1}. \quad \text{(B.22)}$$

By definition, $\frac{d\hat{\alpha}_1}{dn_1} > 0$; by (B.2), $\frac{dZ_l}{d\hat{\alpha}_1} < 0$. 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: $n_1 = \underline{n}$. 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.20) in investor 1's expected payoff function,

$$E(\pi_1(Q = 1, \underline{n}_1)) = (N - n_1)(1 - \theta)Z_l - Nk, \quad \text{(B.23)}$$

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 valid parameter values.

Second, assume the *lower demand constraint* is binding: $\underline{n} = \underline{\alpha}N$. Substituting this in (B.23), setting it equal to zero, and rearranging yields:

$$E(\pi_1(Q = 1, \underline{\alpha}N)) \geq 0 \quad \forall k \leq \frac{(R(\underline{\alpha}) - c)(1 - \theta)Z_l}{R(\underline{\alpha}) + (1 - \theta)Z_l)} \equiv \bar{\bar{k}}, \quad \text{(B.24)}$$

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 realizations of R, c, and $\tilde{Z}$. Which of the two lower constraints is binding, i.e. whether $\underline{n}_1$ is larger or smaller than $\underline{\alpha}N$, also depends on the realizations

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

[35] 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 possible. It would not add value to the main contribution of this paper, which is to show that a semi-public competition can exist in equilibrium, to specify the threshold levels of k, $R(\alpha)$, or c.

of the parameters. As can be seen from (5), $\underline{\alpha}N$ 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 competition, satisfying the competitive constraints makes sure the best-response of investor 2 (and subsequent investors) is not to offer a competition. If investor 1 does not offer a competition because k is too large, all other investors have the same incentives not to do so since they are identical ex ante. *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 competitions and winning slots. 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 competition and expect a payoff of $(N-n^*)(1-\theta)Z_l - Nk$ in this case. If there are two competitions 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 competitions can be foreseen, investor j's expected net payoff from market entry is:

$$E\pi_j = \sum_{q=1}^{Q} \frac{(\phi_q^* N - n_q^*)(1-\theta)Z_l - \phi_q^* Nk}{m+2-q} - F \equiv \bar{F} - F. \tag{B.25}$$

Hence, investor j enters the market if and only if $F \leq \bar{F}$.

Entrepreneur i's security value is his payoff from no screening, $E(\tilde{Z})$. In case one or more competitions are offered in equilibrium, which implies that i's participation constraint holds, according to (B.7) and (7), i expects:

$$E\pi_i(\hat{\alpha}_j(\phi_j^*)) = E(\tilde{Z}) + \hat{\alpha}_j(\phi_j^*)R(\hat{\alpha}_j(\phi_j^*)) - (1-\hat{\alpha}_j(\phi_j^*))(1-\theta)Z_l - c, \tag{B.26}$$

where $\hat{\alpha}_j(\phi_j^*) = \frac{\sum_{q=1}^{Q} n_q^*}{N+Q-1}$ and $E\pi_i(\hat{\alpha}_j(\phi_j^*)) \geq E(\tilde{Z})$. 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 $D_i \leq \bar{D} \equiv E\pi_i(\hat{\alpha}_j(\phi_j^*))$. *Q.E.D.*

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 $E(\tilde{Z})$ (not larger than $\theta E(\tilde{Z}) - c$). It follows that $N_{PS} < N_{NS} < N$. If projects are developed, welfare in the no screening and private screening cases is:

$$W_{NS} = N_{NS}(E(\tilde{Z}) - D_i) - (m+1)F. \quad (B.27)$$

$$W_{PS} = N_{PS}(E(\tilde{Z}) - D_i - c - k) - (m+1)F. \quad (B.28)$$

Clearly, $W_{NS} > W_{PS}$. Define N_{SPC} as the number of entrepreneurs whose development cost in expectation is not larger than than $\bar{D}$. 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 competition case is:

$$W_{SPC} = N_{SPC}(E(\tilde{Z}) + \hat{\alpha}_j(\phi_j^*)R - D_i - c - k) - (m+1)F. \quad (B.29)$$

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

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