Overconfidence and Moral Hazard

—Job-Market Paper—

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Abstract

This paper studies the effects of overconfidence on incentive contracts in a moral-hazard framework where principal and agent knowingly hold asymmetric beliefs regarding the probability of success of the enterprise. Agent overconfidence can have conflicting effects on the equilibrium contract. On the one hand, an overconfident agent disproportionately values success-contingent payments, and thus prefers higher-powered incentive contracts. On the other hand, if the agent is overconfident about the extent to which his actions affect the likelihood of success, lower-powered incentives are sufficient to induce effort. If the agent is moderately overconfident, the latter effect dominates; because the agent bears less risk, he actually benefits from his overconfidence in this case. If the agent is significantly overconfident, the former effect dominates; the agent is then exposed to an excessive amount of risk, which is harmful to him. An increase in overconfidence—either about the return to effort or the base probability of success—makes it more likely that high levels of effort are implemented.

Keywords: overconfidence, asymmetric beliefs, moral hazard.

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1 Introduction

Consider the problem that a business owner faces when hiring a manager. If the owner (the principal) cannot monitor the manager's actions and these affect profits, she will offer an incentive contract (e.g. consisting of a salary and a performance bonus). In the standard treatment of this moral-hazard problem, it is usually assumed either that the parties hold identical and accurate beliefs regarding the distribution of profits conditional on the manager's actions, or that asymmetries in beliefs arise solely from private information. Motivated by extensive psychological evidence that people are overconfident about their ability and future prospects, this paper introduces asymmetric beliefs that principal and agent are aware of; they "agree to disagree."[1]

Because of the parties' awareness about the asymmetry in beliefs, there are no signaling or screening concerns in my model, so the effects of overconfidence on optimal contract design are isolated from its consequences in terms of adverse selection. Agent overconfidence about the probability of success of his enterprise can have conflicting effects on the equilibrium contract. On the one hand, because an overconfident agent disproportionately values success-contingent payments, he finds high-powered contracts—those with a higher performance bonus and a lower base salary—more attractive than a "realistic" agent. Because the principal believes that she will pay the bonus infrequently, she finds such a contract an inexpensive way of hiring the agent. This consequence of the divergence in evaluating payments is the ***wager effect*** of overconfidence, and it pushes the equilibrium contract to exhibit higher-powered incentives. On the other hand, when the agent is overconfident in particular about the value of his effort, lower-powered incentives are sufficient to induce any given effort level. This is the ***incentive effect*** of overconfidence, and it pushes the equilibrium contract to exhibit lower-powered incentives. Conversely, if the agent is *underconfident* about the value of his effort (although overconfident overall about the probability of success), higher-powered incentives are necessary to induce effort, so the incentive effect then pushes towards

[1] Recent studies allow for asymmetric beliefs in principal-agent models, but the main focus has been on the effects of asymmetric beliefs in an adverse-selection framework. Fang and Moscarini (2005) allow for overconfident agents in an adverse selection model, and find that a principal might prefer not to differentiate wages to avoid the negative effects that revealing her private information about the agents' true ability has on morale. Koufopoulos (2002) suggests that bias in the perception of risk might explain some empirical observations related to asymmetric information in competitive insurance markets. Maskin and Tirole (1990) and (1992) introduce private information held by the principal regarding the extent to which she values the agency relationship in an adverse-selection model. Villeneuve (2000) considers the possibility that the principal is better informed than the agent in an insurance-market setting, which he refers to as "reverse adverse selection." Van den Steen (2005) considers asymmetric beliefs in the absence of private information (as this paper does) when there is disagreement about the best course of action (I consider disagreement about outcome distribution conditional on actions, but the parties agree about which one generates a better distribution).

higher-powered incentive contracts.

The degree of overall overconfidence determines which of these effects dominates in equilibrium. The incentive effect dominates when the agent is only slightly overconfident overall. When the agent is significantly overconfident, however, incentive provision becomes secondary to the fact that principal and agent value outcome-contingent payments differently. As a consequence, the wager effect dominates, and greater agent overconfidence always results in higher-powered incentives in equilibrium. Because of the potentially conflicting effects of overconfidence, the power of incentives of the equilibrium contract depends both on the type and the degree of agent overconfidence. In contrast, the level of effort implemented by the equilibrium contract unambiguously increases, *ceteris paribus*, with overconfidence on each dimension—about the value of effort or the base probability of success.[2]

Section 2 introduces the main assumptions of the model, devoting special attention to the assumption that principal and agent knowingly hold asymmetric beliefs, which implies there can be no further updating of beliefs upon observing each other's actions Taking into account psychological research regarding self-enhancing biases, I restrict attention to the case of agent overconfidence. Consistent with the standard treatment of moral hazard, assume that exerting effort is costly to the agent, and it cannot be observed by the principal—effort is non-contractible. Thus, to induce effort, the payments to the agent must be made contingent on project outcome. I assume that the possible outcome is binary: the project can either succeed or fail. The principal is risk neutral and the agent risk averse; the fact that his payoff is contingent on outcome is costly to the agent. There are two dimensions on which the asymmetry of beliefs is important in the model: an (overall) overconfident agent can be overconfident about the *base probability of success* of the project—over all possible choices of effort available to him—and he can be over- or underconfident about the *value of his effort*—the marginal contribution of his effort to the probability of success.[3] Distinct consequences arise from asymmetry of beliefs in each dimension.

Section 3 explores the effects of overconfidence when several principals compete to contract with the agent. The results regarding how contracts depend on overconfidence are strikingly similar in a more standard one-principal, one-agent framework; the equilibrium contract only differs

[2]This does not mean that more *overall* overconfident agents always exert more effort in equilibrium; it is very costly to induce effort from an agent who is very overconfident overall but who underestimates the marginal contribution of his effort to the probability of success of the project (he is underconfident about the value of effort, so high-powered incentives are necessary).

[3]Imagine, for example, an agent who believes he has the "Midas touch": just because he's involved, the enterprise must succeed. This agent is overall very overconfident, but underestimates the contribution of his effort to the probability of success.

in the level of expected payment to the agent, because his participation constraint depends on market structure.[4] Competition between principals will drive their expected profits down to zero in equilibrium.

The agent can choose whether or not to exert effort. To illustrate the main forces driving the results, first assume that "no effort" is implemented in equilibrium. Because incentives are not necessary in this case, if principal and agent held identical beliefs the equilibrium contract would specify an outcome-independent payment to the agent (a riskless contract). Consider an alternative risky contract that provides a success-contingent bonus to the agent. Suppose that both contracts yield zero expected profits for the offering principal, and thus the same expected payment to the agent, *according to the principal's beliefs*. Because the agent is relatively optimistic, *according to his beliefs* the risky contract offers a higher expected payment. Intuitively, the agent is willing to "bet on success" against the principal: there are first-order gains for the agent from a higher expected payment, and only second-order losses from bearing some risk. It follows that the equilibrium contract always exposes an overconfident agent to some risk.

Assume now that "effort" is implemented in equilibrium. Because effort is costly to the agent, a contract *must* provide him with a success-contingent bonus. The wager effect of overall overconfidence remains, pushing towards higher-powered incentives. Recall, however, that principal and agent can disagree about the value of effort. If the agent is overconfident in this respect, he believes that there is a greater likelihood of receiving the bonus *if* he exerts effort. A lower bonus is then sufficient to induce effort, so the incentive effect of overconfidence about the value of effort pushes towards lower-powered incentives. Conversely, if the agent is underconfident in this respect, the incentive effect makes higher-powered incentives necessary.

Because providing incentives for the risk-averse agent to exert effort is costly for the risk-neutral principal in terms of expected payment, the incentive effect of overconfidence about the value of effort dominates when the agent is only slightly overconfident overall. The incentive effect allows a principal to provide more insurance to an agent who is overconfident about the value of effort without destroying incentives, so it is less costly for her to implement effort. Intuitively, a contract that induces effort must expose the agent to a discrete amount of risk in order to provide him sufficient incentives to exert effort. Even though the wager effect implies that an overconfident

[4] Conventionally, moral hazard is studied in a framework in which a principal makes a take-it-or-leave-it contract offer to the agent. This assumption is naturally associated with the assumption that it is the principal who designs the contract. Studying the competing-principals case first, however, allows for a more intuitive exposition of the results, and the welfare effects of overconfidence are more striking in this framework. In a one-principal, one-agent model, the principal extracts all the surplus from the agency relationship, so agent overconfidence can only harm him and possibly benefit the principal. The one-principal, one-agent model is studied in Section 4.

agent is willing to bear some risk in equilibrium, this amount of risk is continuous in the degree of disagreement in beliefs. If the beliefs held by principal and agent differ only slightly, the amount of risk required by incentive provision is greater than the amount of risk the agent would willingly bear when contracting with the principal, so the incentive effect dominates the wager effect and the equilibrium contract does provide more insurance to an agent who is overconfident about the value of effort. The wager effect will dominate, however, if the beliefs held by principal and agent differ significantly. In that case the power of incentives always increases in overall overconfidence: the agent then judges the higher expected payment implicit in a contract with excessively-powerful incentives to compensate him for the additional risk he bears.

Overconfidence also affects whether effort is implemented in equilibrium. The incentive effect of overconfidence about the value of effort reduces the cost to the principal of implementing effort (she can offer more insurance to the agent). The wager effect of overall overconfidence makes higher-powered incentive contracts (e.g. those that implement effort) increasingly attractive for the agent compared to lower-powered contracts (e.g. those that do not implement effort). As a consequence, higher levels of overconfidence of either kind increase the likelihood that effort is implemented in equilibrium.

Subsection 3.1 discusses the welfare effects of overconfidence in the competing-principals framework. Independent of agent overconfidence, competition drives principals' expected profits to zero. To simplify the analysis, I initially assume that the principals hold accurate beliefs. Actual expected profits and actual expected payment to the agent are thus independent of agent overconfidence, as long as it does not affect the implemented level of effort. Therefore, the welfare of the risk-averse agent (the level of his actual expected utility) depends solely on his effort and the amount of risk he bears in equilibrium. Because an agent who is slightly overconfident about the value of effort receives more insurance than one holding realistic beliefs, he actually benefits from the principal's reaction to his overconfidence. An agent who is underconfident about the value of effort or significantly overconfident overall, in contrast, bears an excessive amount of risk; his overconfidence is therefore harmful to him.[5]

Subsection 3.2 is a brief discussion on how the results carry over when we allow the competing

[5] Relaxing the assumption that principals hold accurate beliefs, the welfare effects discussed above (i.e. the fact that the agent's actual expected utility decreases with the amount of risk he bears in equilibrium) are reinforced if principals are overly optimistic about the probability of success of the project, and weakened if they are overly pessimistic. Intuitively, in the extreme case that the principals are overly pessimistic and the agent holds accurate—thus relatively optimistic—beliefs, his actual expected utility is maximized, subject to zero expected profits according to the principals' beliefs, by the equilibrium contract. When principals are overly pessimistic, higher-powered incentive contracts yield in fact a higher expected payment to the agent.

principals to hold asymmetric beliefs amongst themselves. The main difference is that expected profits for the principal whose offer is accepted by the agent will, generically, be positive according to her beliefs. The effects of changes in overconfidence on the equilibrium contract remain, and a principal will tend to be better off when she holds accurate beliefs that allow her to design her contract offer optimally.

Subsection 3.3 simply notes that if the agent could design the contract and make a take-it-or-leave-it offer to a principal, the equilibrium contract would be identical to the one in the competing-principals case as long as he is aware of the principal's beliefs.

Section 4 studies the implications of the model when one principal can make a take-it-or-leave-it offer to an agent—the standard framework in the moral-hazard literature. Because an exogenous agent-participation constraint replaces the endogenous one generated by competing contract offers, the principal faces a remarkably similar problem to the one faced by a principal who competes with others. The qualitative effects of overconfidence on the equilibrium contract thus mirror the results discussed in the competing-principals framework. Because the principal extracts all the surplus from the agency relationship, however, the expected payment to the agent under the optimal contract is different than when competition drives the principals' expected profits to zero. The welfare effects of agent overconfidence are therefore different in the one-principal case. These are discussed in Subsection 4.1; agent overconfidence lowers the cost to the principal of satisfying the agent's participation constraint, so expected profits always increase with overconfidence on either dimension, and any degree of overconfidence is harmful to the agent. Subsection 4.2 discusses the implications of the model in a situation in which the principal can choose from a pool of agents with different ability and overconfidence levels. Interestingly, the principal will choose the most overconfident agent in some situations, and the least overconfident agent in others; her main concern is the agent's true ability, but among agents with equal underlying ability she prefers an overconfident one (because it is cheaper to satisfy his participation constraint).

Section 5 extends the one-principal, one-agent framework allowing the agent to choose from a continuum of possible effort levels. The incentive and wager effects of overconfidence carry over. A consequence of both effects is that, if the problem is well behaved, the implemented level of effort is (continuously) increasing in both dimensions of agent overconfidence. For this reason, however, the power of incentives of the optimal contract might increase with overconfidence about the value of effort even when the agent is only slightly overconfident overall.

Section 6 concludes; I mention some recent empirical observations about entrepreneurship and executive compensation that are consistent with the model, and discuss some potentially interesting avenues for further research.

2 Framework

The main assumption in the model that differs from those in conventional moral-hazard models is that principal and agent hold asymmetric beliefs regarding the distribution of outcomes, and both are completely aware of this asymmetry. Therefore, principal and agent do not update their beliefs upon play of the game (principal and agent simply "agree to disagree"). Because this assumption is crucial to the results of the paper, I pause here to discuss its validity.

There are both empirical and methodological reasons for assuming that parties do not fully update their beliefs upon learning the beliefs held by others. This assumption may be very appropriate in a moral-hazard framework; in relation to the agent's ability, arguments like "I know myself better than anybody else" for the agent and "everyone thinks they're better than average" for the principal would allow them both to rationalize not revising their beliefs. Consider, for example, the extreme situation in which the principal judges the agent's ability according to the population mean, knowing that agents tend to be overconfident. If she believes that agents' beliefs are independent of their underlying ability, she will disregard those beliefs as uninformative. In this scenario, the principal's beliefs are also independent of the individual agent's true ability, so he can also disregard them as uninformative. Principal and agent have nothing to teach each other in terms of the agent's true ability in a one-shot game. Furthermore, the assumption allows me to study the effects of overconfidence on the equilibrium incentive contract, isolating them from any signaling or screening concerns.

Asymmetric posterior beliefs can result from differing prior beliefs. Morris (1995) discusses the assumption of heterogeneous priors in the context of economic models, and makes a case for allowing this possibility. Asymmetric posterior beliefs can also result from errors in processing information. If players update their beliefs in a non-Bayesian way following the observation of a given signal (for example, each participant in a private-information game overestimates the informative value of their own private signal) their posterior beliefs will differ even if all private information is revealed in equilibrium. Eyster and Rabin (2005) explore another channel through which participants can maintain asymmetric posterior beliefs: if players in a private-information game fail to interpret other players' actions as signals of others' private information, asymmetric posterior beliefs will survive even in separating equilibria of the game.

Among the possible asymmetries in beliefs, I restrict attention to the case of *agent overconfidence*: the agent holds overly optimistic beliefs, relative to the principal, regarding the probability of success of the project. The general structure of the model would allow us to consider the possibility a relatively pessimistic agent, but the presentation of results focuses on the case of agent overconfidence. This assumption is consistent with research in psychology, suggesting that individuals tend to overestimate the probability of favorable events and such bias is more pronounced when they have some control over the likelihood of those events. Weinstein (1980) found that students were overly optimistic about the likelihood of good or bad events—such as enjoying their post-graduation job or attempting suicide—happening to them relative to same-gender students in their school. He also found that the degree of such "unrealistic optimism" depended, among other things, on a notion of control over the likelihood of a given event. Taylor and Brown (1988) present a review of psychology literature that supports the view that, in general, individuals' assessment of their own abilities, talents, and social skills are overly optimistic. Fiske and Taylor (1991), and Kunda (1999) also discuss the tendency of individuals to be overconfident, giving references to both theoretical and empirical studies in psychology.

Researchers in business and economics have also taken notice of the propensity of individuals to be overconfident. Larwood and Whittaker (1977) found company managers to be unrealistically optimistic about the future performance of their firms relative to the competition. Cooper, Woo, and Dunkelberg (1988), in a survey of nearly three thousand entrepreneurs, report that entrepreneurs are notably optimistic about their chances of success when setting up a business. Evidence from experimental economics supports the case for overconfidence as well: Camerer and Lovallo (1999), for example, find that there is excess entry into a hypothetical capacity-constrained market when participants' payoffs after entering depend on skill, but not when they depend on chance. This suggests that agents not only hold overconfident beliefs, but also *act* on them.[6]

The other assumptions in the model correspond to the standard treatment of moral hazard. Assume there is a project that can be undertaken by a principal and an agent if they decide to enter a contractual relationship. There are two possible outcomes: the project can succeed or fail. The project yields revenue x_0 if it fails, and revenue $x_1 > x_0$ if it succeeds. The probability of success of the project depends on a non-contractible action e chosen by the agent, which can be interpreted as his choice of effort.

The principal's utility is the expected revenue from the project net of any payments made to the agent (the principal is risk neutral). The agent's utility is separable in payments and effort choice, so that his utility after receiving payment s from the principal and exerting effort level e is $u(s) - c(e)$, where $c(e)$ denotes the disutility to the agent from exerting effort. I assume that $u : \mathbb{R} \to \mathbb{R}$ has full range, and that it is continuous and twice continuously differentiable, with

[6]There are also theoretical approaches to overconfidence in the economics literature. Gervais and Odean (2001) explain overconfidence in a dynamic framework in which agents overweight success and underweight failure when updating their beliefs about their own ability. Bénabou and Tirole (2002) model a self-deception game in which multiple equilibria regarding the level of overconfidence may arise. Goel and Thakor (2002) explore the costs and benefits of overconfidence in a "tournament" setting.

$u' > 0$ and $u'' < 0$ (the agent is risk averse).

As previously noted, principal and agent knowingly hold asymmetric beliefs regarding the probability of success of the project. The principal believes that, conditional on the agent choosing effort level e, the project will succeed with probability $\Pr(x_1 \mid e) = q + ve$. Let a tilde denote the agent's beliefs: he believes that the conditional probability of success is $\widetilde{\Pr}(x_1 \mid e) = \tilde{q} + \tilde{v}e$. This particular parametrization will prove to be subsequently useful for the analysis, because it highlights the two dimensions (levels and differences) on which the asymmetry in beliefs will be relevant in the model. The parameters q, $\tilde{q}$, v, and $\tilde{v}$ are assumed to be positive; the probability of success of the project is perceived by both parties to be increasing in effort. The agent's beliefs are restricted to $\tilde{q} + \tilde{v} < 1$.[7]

The beliefs held by principal and agent can differ on two dimensions. The agent is said to be *overconfident about the base probability of success* if $\tilde{q} > q$. The agent is said to be *overconfident about the value of his effort* if $\tilde{v} > v$; he believes that the marginal contribution of his effort to the probability of success is greater than what the principal believes. Conversely, if $\tilde{v} < v$ the agent is *underconfident about the value of effort.* The agent's beliefs about the value of effort affects his perception rewards to effort of a given incentive contract. I focus on the case that the agent is overconfident overall, i.e. $\tilde{q} > q$ and $\tilde{q} + \tilde{v} > q + v$. In light of research in psychology, both overconfidence and underconfidence about the value of effort seem consistent with overall overconfidence. Hoorens (1993) summarizes one common opinion by noting that "according to some authors, unrealistic optimism emerges because people overestimate the degree to which they can personally control the occurrence of a variety of events in their lives" (p. 126). This suggests that $\tilde{v} > v$. She also notes, however, that most self-enhancing biases seem to be motivated by a desire to see oneself as particularly "good," and consequently a perception of superiority (pp. 131–2). A sense of superiority might lead an agent to believe that the probability of success of a project which he engages is very high independent of effort level (a very high $\tilde{q}$), and therefore underestimate the value of his effort ($\tilde{v} < v$) given that $\tilde{q} + \tilde{v}$ is bounded above by 1.

I will consider both the case of many principals who compete to contract with an agent, and the case of one principal making a take-it-or-leave-it contract offer to an agent. The timing of the game is as follows: the principal(s) first make contract offer(s) to the agent. The agent then decides whether to accept one or reject all offers. If he accepts one, he then chooses how much effort to exert, the outcome of the project is realized, and payoffs are distributed according to the contract's terms, after which the agency relationship ends. The solution concept used is Subgame-Perfect Nash Equilibrium: at every decision node of the game, the relevant player chooses an optimal

[7] This assumption avoids the possibility of a trivial forcing contract—one that infinitely punishes the agent in case of project failure and thus trivially implements effort at first-best cost.

response, even if she had expected not to reach that node in equilibrium. I focus on pure-strategy equilibria of the game (in particular, each principal offers a given contract with probability 1 in equilibrium); this is a substantive assumption in terms of the equilibrium strategy, but does not affect the main message of the model.[8] Without loss of generality, I restrict attention to contract offers of the form $\langle s_1, s_0 \rangle$—a schedule of outcome-contingent payments to the agent—given that project outcome is the only mutually-observable signal in the model.[9]

3 Competing Principals

Consider the case of multiple principals who compete to contract with one agent. This setup is appropriate if agents are scarce in the sense that there are more principals who wish to hire an agent than there are qualified agents. If we are concerned with particularly talented or specialized agents (superstar occupations for example), this model will be more suitable than the standard one-principal, one-agent framework. This model is also useful when considering a situation in which the agent has proprietary rights over the project, rather than the principal. Imagine, for example, a risk averse entrepreneur deciding whether or not to set up a business. There are potential principals (a bank or venture capital fund) who would be willing to bear some of the risk inherent to the enterprise. Establishing an agency relationship in which the risk-neutral party absorbs some of this risk would be mutually beneficial.

[8] In the model with one principal, she always offers the optimal contract to the agent. In the case that principals compete to contract with the agent, it will be shown that in equilibrium principals receive zero expected profits. The principals will therefore be indifferent between offering what is characterized as the equilibrium contract, or any other contract that yields zero expected profits (e.g. one that is rejected by the agent). Equilibrium requires, however, that the agent accepts the characterized equilibrium contract with probability 1; if the agent accepted a different contract with positive probability, there would be a profitable deviation for some principal.

[9] See Holmstrom (1973) for a discussion about observability and contracting under moral hazard. Because of the agent's risk aversion, it is in general not optimal to introduce unnecessary "noise" to the payment structure. If signals besides project outcome are observable by both parties, the terms of the equilibrium contract may be contingent on those as well. Under asymmetric beliefs, if there is some signal that the agent believes to be correlated with his effort, the principal can reduce the cost of implementing effort by offering payments that are also contingent on this signal, even if she believes it to be completely uninformative. I assume that outcome is the only signal on which principal and agent can contract, mainly because a second, independent, contract dependent on other signals could always be written.

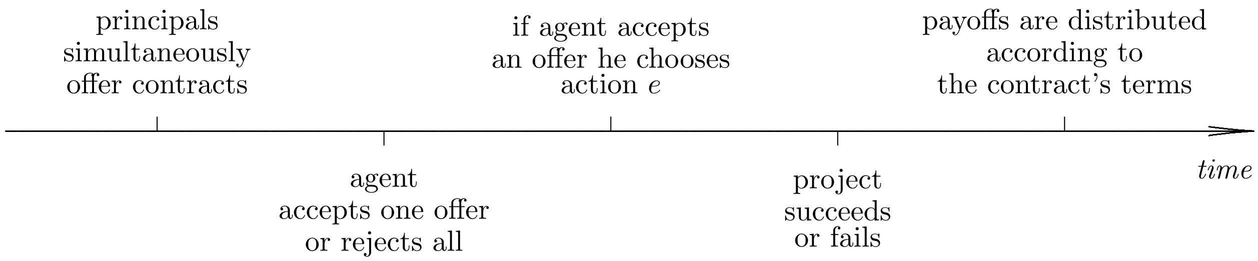

Figure 1: Timing of the model when principals compete

The timing of the model is as follows: first, principals make simultaneous contract offers to the agent. The agent then chooses which offer (if any) to accept. If the agent chooses to accept a contract offer, he chooses some action that affects the outcome distribution of the project. The outcome of the project is realized and observed by both parties. Payoffs are then distributed according to the provisions in the contract, and the agency relationship ends. If the agent chooses not to accept any contract, the project will not be undertaken, and the players receive payoffs according to some outside option. The participants' outside option is their opportunity cost of entering the contractual relationship. The outside option for each principal is not contracting with the agent, which yields zero profits. I assume that the outside option for the agent is low enough that he always accepts an offer in equilibrium, and thus the equilibrium contract is independent of his outside option.

Assume the agent has two actions to choose from; $e \in \{0, 1\}$.[10] A straightforward way to interpret this two-action space is that the agent can simply choose whether or not to exert effort. I normalize the cost of not exerting effort so that $c(0) = 0$ and $c(1) = c$.

Principals and agent evaluate any given contract according to their own beliefs. Assume that competing principals share the same beliefs about the probability of success of the project; I discuss the possibility of different principals holding different beliefs in Subsection 3.2 below. Each principal wishes to maximize her expected profits. Expected profits for the principal whose contract offer $\langle s_1, s_0 \rangle$ is accepted by the agent in equilibrium, conditional on each of the agent's possible effort levels, are:

$$\mathbb{E}[\pi \mid e = 1] = (q + v)(x_1 - s_1) + [1 - (q + v)](x_0 - s_0)$$
$$\mathbb{E}[\pi \mid e = 0] = q(x_1 - s_1) + [1 - q](x_0 - s_0).$$

The agent's objective is to maximize his expected utility when choosing which contract offer to

[10]Section 5 presents an extension of the model in which the agent can choose his action from the continuous interval $[0, 1]$.

accept and how much effort to exert once he engages the project. After accepting a given contract offer $\langle s_1, s_0 \rangle$, the agent's expected utility conditional on his choice of effort is:

$$\tilde{\mathbb{E}}\left[u\left(s_x\right) \mid e=1\right] - c = \left(\tilde{q}+\tilde{v}\right) u\left(s_1\right) + \left[1-\left(\tilde{q}+\tilde{v}\right)\right] u\left(s_0\right) - c$$
$$\tilde{\mathbb{E}}\left[u\left(s_x\right) \mid e=0\right] = \tilde{q} u\left(s_1\right) + \left[1-\tilde{q}\right] u\left(s_0\right).$$

Having set up the model, we can turn to characterizing the equilibrium contract. After accepting the contract offer that the agent finds most attractive, he chooses whichever action he believes will yield higher expected utility. The competing principals must take this into account when designing their contract offer. In particular, if a principal wants to induce effort, the contract must be "incentive compatible"; the contract terms must be such that if the agent accepts it, he maximizes his perceived expected utility by choosing to exert effort:

$$\left(\tilde{q}+\tilde{v}\right) u\left(s_1\right) + \left[1-\left(\tilde{q}+\tilde{v}\right)\right] u\left(s_0\right) - c \geq \tilde{q} u\left(s_1\right) + \left[1-\tilde{q}\right] u\left(s_0\right).$$

We can rewrite the incentive-compatibility constraint above as

$$\tilde{v}\left(u\left(s_1\right) - u\left(s_0\right)\right) \geq c. \tag{IC}$$

Intuitively, the perceived expected utility gain for the agent from exerting effort (receiving excess utility $u\left(s_1\right) - u\left(s_0\right)$ with additional probability $\tilde{v}$), must be no less than his disutility cost of exerting effort. I will refer to the utility differential $u\left(s_1\right) - u\left(s_0\right)$ as the contract's *power of incentives*. Note that the power of incentives necessary to induce effort is decreasing in $\tilde{v}$. It is, however, independent of $\tilde{q}$: bias about the base probability of success does not affect the agent's perception of the rewards to effort of a given incentive scheme.

An equilibrium contract is such that no other contract can *(i)* attract the agent by offering him terms that he strictly prefers and *(ii)* yield higher expected profits for the offering principal (i.e. there is no profitable deviation from the equilibrium contract). Because principals compete in offering contracts to the agent and they all evaluate profits based on the same beliefs, expected profits for the principal whose offer is accepted by the agent in equilibrium are zero (equal to the principals' outside option). This fact is stated in Lemma 1 below.

Lemma 1 *If principals share the same beliefs regarding outcome distribution conditional on the agent's actions, expected profits will be zero in equilibrium according to the principals' beliefs.*

All formal proofs are relegated to the appendix. Intuitively, if a principal made positive expected profits, another principal could outbid that contract—offer a slightly higher expected payment to the agent—without affecting incentives, thus attracting the agent and earning positive expected profits.

The equilibrium contract depends, among other things, on the effort level that is implemented in equilibrium. I will, in turn, characterize the equilibrium contract assuming that effort is not implemented and assuming that effort is implemented, and subsequently analyze the effect of overconfidence on the implemented level of effort in equilibrium.

Assume that effort is not implemented in equilibrium. If principals and agent held identical beliefs, the risk-neutral principal would absorb all the risk from the project, and offer a fixed payment to the agent—independent of project outcome. If the agent is overconfident about the base probability of success, however, he will be exposed to risk in equilibrium.

Proposition 1 *Assuming effort is not implemented in equilibrium, the only equilibrium contract* $\langle s_{1*}, s_{0*} \rangle$ *is characterized by the conditions*

$$\frac{\tilde{q}}{1-\tilde{q}} \frac{u'(s_{1*})}{u'(s_{0*})} = \frac{q}{1-q}$$

and $q(x_1 - s_{1*}) + [1-q](x_0 - s_{0*}) = 0$. *The agent bears risk in equilibrium if* $\tilde{q} > q$.

The intuition of Proposition 1 is that the agent, being relatively optimistic about the probability of success of the project, is willing to wager on success against the (relatively pessimistic) principal. Starting from a riskless contract (one that specifies $s_1 = s_0$), because the marginal cost for the agent from bearing additional risk is zero at that point, principal and agent evaluate marginal changes in payments based on their effect only in terms of expected payment. Consider, then, an increase in the success-contingent payment, coupled with a decrease in the failure-contingent payment, that leaves expected payment unchanged according to the principals' beliefs. The agent is relatively optimistic about receiving the success-contingent payment, so *according to his beliefs* such deviation yields a higher expected payment. When $\tilde{q} > q$, there is a first-order gain perceived by the agent from higher expected payment, and only a second-order loss from higher risk exposure, starting from a riskless contract. Therefore, an agent who is overconfident about the base probability of success bears some risk in equilibrium.

Because of the disagreement between principal and agent regarding the probability of success of the project, the agent is willing to be exposed to more risk in equilibrium than a "realistic" agent. This ***wager effect*** pushes the equilibrium contact towards higher-powered incentives.[11]

[11] Another way to think about the wager effect is from the viewpoint of asset trading under uncertainty. Principal and agent have the opportunity to trade payments in the "success" state of the world for payments in the "failure" state of the world. The principal, being risk neutral, is willing to trade infinitely at what she believes to be the

Note that if, under the contract characterized in Proposition 1, the agent would choose to exert effort then effort must be implemented in equilibrium. Whenever $\frac{\tilde{q}}{1-\tilde{q}}\frac{u'(s_1)}{u'(s_0)} > \frac{q}{1-q}$ and effort is not implemented, $\langle s_1, s_0 \rangle$ cannot be an equilibrium; because the agent is willing to give up more payment in the event of failure (in exchange for a higher success-contingent payment) than necessary to make the principal indifferent, a principal could deviate and offer a higher-powered incentive contract that will both attract the agent and yield positive expected profits. Competition could thus increase the power of incentives to the point that the agent is induced to exert effort.

Assume now that effort is implemented in equilibrium. If principals and agent held identical beliefs, the equilibrium contract offer would be characterized by zero expected profits for the offering principal and the binding (IC) constraint. There is a tradeoff between incentives and insurance: absent the incentive provision problem, efficiency gains would be possible from providing more insurance to the agent (reducing the power of incentives). When effort is implemented, incentive provision requires that the agent be exposed to a discrete amount of risk in equilibrium. The efficiency loss that arises (given the agent's risk aversion) is the *cost of agency*; if the agency relationship was not necessary (e.g. if the risk-neutral principal could undertake the project on her own and carry out the agent's task) this cost would be avoided.

Given the incentive-insurance tradeoff, the contract analogous to the identical-beliefs equilibrium contract is a natural candidate to consider as a potential equilibrium when allowing for asymmetric beliefs.

Definition 1 *Let $\langle \bar{s}_1, \bar{s}_0 \rangle$ denote the contract that satisfies (IC) with equality and yields zero expected profits according to the principals' beliefs;*

$$\tilde{v}\left(u\left(\bar{s}_1\right) - u\left(\bar{s}_0\right)\right) = c$$
$$(q+v)\left(x_1 - \bar{s}_1\right) + \left[1 - (q+v)\right]\left(x_0 - \bar{s}_0\right) = 0.$$

This contract will in fact be the equilibrium contract when the beliefs held by principals and agent differ only slightly. In other words, if the agent is only slightly overconfident overall, the contract with incentives just powerful enough to implement effort will be the equilibrium contract. The intuition from the identical-beliefs case carries over: a principal cannot decrease the expected

actuarially fair price of these securities. A trade that is evaluated by the principal to be actuarially fair will not be judged as actuarially fair according to the agent's beliefs. In particular, an increase in the payment to the agent conditional on success coupled with a decrease in the payment conditional on failure that the principal judges to be actuarially fair will be judged by the agent as better than actuarially fair. Because the agent is risk averse, he is not willing to trade infinitely at the price that the principal is willing to trade; only as long as he judges the higher expected payment to compensate him for bearing additional risk.

payment to the agent while providing more insurance, because that would destroy the incentives for the agent to exert effort.

Proposition 2 *Assuming effort is implemented in equilibrium,* $\langle \bar{s}_1, \bar{s}_0 \rangle$ *is the only equilibrium contract if* $\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})}\frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} \leq \frac{q+v}{1-(q+v)}$.

The condition $\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})}\frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} \leq \frac{q+v}{1-(q+v)}$ will hold whenever the agent is only slightly overconfident overall (i.e. if $\tilde{q}+\tilde{v} \ggg q+v$; recall that $\bar{s}_1 > \bar{s}_0$, so $\frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} < 1$). If it holds, there is no profitable deviation from $\langle \bar{s}_1, \bar{s}_0 \rangle$. Providing more insurance to the agent (by decreasing s_1 and increasing s_0) would destroy incentives. Increasing both payments would decrease expected profits, and a contract with lower payments would not draw the agent away from $\langle \bar{s}_1, \bar{s}_0 \rangle$. Consider an increase in s_1 coupled with a decrease in s_0, so that effort is still implemented. Providing less insurance to the agent would never be profitable in the identical-beliefs framework, but because of the wager effect such deviation could seem attractive to an overconfident agent. The condition in Proposition 2 illustrates how each party evaluates marginal changes in payments at $\langle \bar{s}_1, \bar{s}_0 \rangle$. The agent perceives that a marginal increase in s_1 increases his utility by $u'(\bar{s}_1)$ with probability $(\tilde{q}+\tilde{v})$, and a marginal decrease in s_0 decreases his utility by $u'(\bar{s}_0)$ with probability $[1-(\tilde{q}+\tilde{v})]$. The principal believes, on the other hand, that he will pay the marginal increase in s_1 with probability $(q+v)$, and save the marginal decrease in s_0 with probability $[1-(q+v)]$. If the condition holds, a principal cannot draw the agent away from $\langle \bar{s}_1, \bar{s}_0 \rangle$ and increase expected profits. Intuitively, it is too costly for the principal to compensate the agent for bearing more risk. Because marginal utility is assumed to be decreasing, the fact that there is no profitable marginal deviation from $\langle \bar{s}_1, \bar{s}_0 \rangle$ implies that there is no profitable discrete deviation either.

When the condition in Proposition 2 holds, agent overconfidence about the value of effort ($\tilde{v} > v$) allows principals to provide more insurance to the agent without destroying incentives than if he shared the principals' beliefs. This is the ***incentive effect*** of overconfidence. Any contract that implements effort must expose the agent to a discrete amount of risk in order to provide him with sufficient incentives to exert effort. Even though the wager effect implies that an overconfident agent is willing to bear some amount of risk when contracting with a principal, this amount is continuous in the degree of disagreement in beliefs. If the agent is only slightly overconfident overall, the amount of risk required by incentive provision is greater than the amount of risk he would willingly bear as a consequence of the wager effect. The incentive effect therefore dominates the wager effect in this case, and the power of incentives of the equilibrium contract depends solely on the agent's beliefs about the value of effort.

When the agent is only slightly overconfident overall, the incentive-insurance tradeoff present in the case of identical beliefs remains. Providing less insurance to the agent is too costly for a principal because of the agent's risk aversion, and providing more insurance would destroy incentives. Since the (IC) constraint binds in equilibrium, the power of incentives of the equilibrium contract depends exclusively on the agent's beliefs regarding the value of his effort. If the agent is overconfident in this respect, lower-powered incentives are sufficient to implement effort than if he held "realistic" beliefs; a principal can then offer a contract that provides more insurance (thus reducing the cost of agency) without destroying incentives. If, however, the agent is underconfident about the value of effort, the incentive effect implies that higher-powered incentives will be necessary to implement effort. Lemma 1 implies that $\frac{d\bar{s}_1}{d\tilde{v}} < 0$ and $\frac{d\bar{s}_0}{d\tilde{v}} > 0$. The agent's beliefs regarding the base probability of success ($\tilde{q}$) do not affect the equilibrium contract in this case. The principals' beliefs do not affect the power of incentives of the equilibrium contract either, but they do affect the agent's expected payment; if the principals judge the probability of success to be high, they believe the project's expected revenue is high and can offer a higher expected payment to the agent accordingly.

The degree of asymmetry in the beliefs held by principals and agent affects whether or not the condition in Proposition 2 holds. As the next proposition shows, if the agent is significantly overconfident overall, the equilibrium contract will exhibit excessively powerful incentives that increase with overconfidence. Because of the wager effect, a very overconfident agent substantially overestimates the probability of success, so he prefers a contract that rewards him handsomely for success and punishes him harshly for failure over $\langle \bar{s}_1, \bar{s}_0 \rangle$. He judges the higher expected payment from an excessively risky contract as sufficient to compensate him for the cost of bearing more risk.

Proposition 3 *Assuming effort is implemented in equilibrium, if* $\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})} \frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} > \frac{q+v}{1-(q+v)}$ *then* $\langle \bar{s}_1, \bar{s}_0 \rangle$ *is not an equilibrium contract. The only equilibrium contract* $\langle s_1^*, s_0^* \rangle$ *is characterized by*

$$\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})} \frac{u'(s_1^*)}{u'(s_0^*)} = \frac{q+v}{1-(q+v)}$$

and $(q+v)(x_1 - s_1^*) + [1-(q+v)](x_0 - s_0^*) = 0$. *The equilibrium contract has higher-powered incentives than necessary to implement effort.*

If the agent is significantly overconfident overall (i.e. if $\tilde{q}+\tilde{v} \gg q+v$), he is actually content to bear more risk in equilibrium than he would under the $\langle \bar{s}_1, \bar{s}_0 \rangle$ contract. Parallel to the analysis in the case of slight overconfidence, consider a deviation from $\langle \bar{s}_1, \bar{s}_0 \rangle$ contract that offers a marginal increase in s_1 and a marginal decrease in s_0. Recall that the agent perceives such a change as an increase in utility of $u'(\bar{s}_1)$ with probability $(\tilde{q}+\tilde{v})$ and a decrease in utility of $u'(\bar{s}_0)$ with probability $[1-(\tilde{q}+\tilde{v})]$. Because the agent considerably overestimates the likelihood of receiving the success-contingent payment, a principal can offer an excessively powerful incentive contract that attracts the agent and increases her expected profits. Since $\langle s_1^*, s_0^* \rangle$ maximizes the agent's perceived expected utility subject to the zero-expected-profits condition, there is no profitable deviation from this contract. Because of the wager effect, if the agent is significantly overconfident, he judges the $\langle s_1^*, s_0^* \rangle$ contract to yield a significantly higher expected payment than the $\langle \bar{s}_1, \bar{s}_0 \rangle$ contract; so much higher that it compensates him for the excessive amount of risk he bears.

The agent's bias in evaluating payments overshadows the incentive-insurance tradeoff present in the standard moral-hazard problem. In the case of identical beliefs, the principal is prevented from providing more insurance to the agent because of the need to provide appropriate incentives. When the agent is significantly overconfident, there is no such tradeoff in equilibrium. The agent's relative bias overrides his risk aversion when evaluating payoffs, so that incentive provision becomes secondary to the fact that the agent judges higher-powered incentive contracts (holding expected profits constant according to the principals' beliefs) to yield a higher expected payment.

In contrast to the effect of overconfidence about the value of effort on the power of incentives when the agent is slightly overconfident, $\frac{ds_1^*}{d\tilde{v}} > 0$ and $\frac{ds_0^*}{d\tilde{v}} < 0$. Likewise, $\frac{ds_1^*}{d\tilde{q}} > 0$ and $\frac{ds_0^*}{d\tilde{q}} < 0$. When the agent is significantly overconfident overall, the power of incentives increases with overconfidence on either dimension because it is the wager effect of overconfidence that dominates. The equilibrium contract exhibits excessively powerful incentives—more powerful than necessary to induce effort—independent of the type of agent overconfidence. As before, more optimistic principals will also offer higher expected payment to the agent. Given that in this case it is the degree of divergence in beliefs that drives contract design, however, the power of incentives is decreasing in both q and v: the divergence is smaller when principals are more optimistic.

Whether the equilibrium contract will in fact implement effort depends on which of the potential equilibrium contracts that we identified above gives the agent higher perceived expected utility (recall that principals always receive zero expected profits in equilibrium). A higher degree of overconfidence on either dimension makes the potential equilibrium contract that implements effort relatively more attractive to the agent. Therefore, higher levels of overconfidence on either dimension increase the likelihood that effort is implemented in equilibrium.

Proposition 4 *Higher levels of overconfidence on either dimension, ceteris paribus, increase the likelihood that effort is implemented in equilibrium: if effort is implemented given agent beliefs* $(\tilde{q}, \tilde{v})$*, then effort will be implemented when his beliefs are* $(\tilde{q}, \tilde{v}^*)$ *for any* $\tilde{v}^* \geq \tilde{v}$ *or* $(\tilde{q}^*, \tilde{v})$ *for any* $\tilde{q}^* \geq \tilde{q}$*.*

For different reasons, the potential equilibrium contract that implements effort becomes more attractive to the agent as overconfidence in either dimension increases, regardless of which of the two effects of overconfidence dominates. Recall that when the incentive effect dominates, higher overconfidence about the value of effort reduces the cost of implementing it. Because of the competition between principals, the agent enjoys the benefit of this efficiency gain. Higher overconfidence about the base probability of success increases the agent's perceived expected utility under the contract that *does not* implement effort; however, because he receives a higher success-contingent payment under the contract that *does* implement effort, there is a greater increase in his perceived expected utility under this contract. For the same reason, higher overconfidence on either dimension makes the contract that implements effort comparatively more attractive to the agent when the wager effect dominates.

Note that Proposition 4 does not imply that effort is more likely to be implemented, in general, when dealing with an overall more overconfident agent. Imagine, for example, a case in which effort would be implemented if the agent held "realistic" beliefs. Suppose that the agent is overall slightly overconfident, but underconfident about the value of effort. Because higher-powered incentives are then necessary to implement effort, the cost of agency might be too high for effort to be implemented.

3.1 Welfare Analysis

This section studies the welfare effects of agent overconfidence. I am allowing for principals and agent to knowingly hold asymmetric (and therefore incorrect for at least one of them) beliefs; the effects of this type of irrationality on the participants' well-being is not immediately clear. For most of this subsection, I assume that the principals' beliefs are accurate. This assumption is convenient because the zero-expected-profits condition implies that the agent's actual expected payment is independent of his overconfidence, so that I can identify the effect of changes in beliefs absent changes in the actual expected payment. After analyzing the implications under this assumption, I discuss how conclusions change when it is relaxed.

An overconfident agent will have a biased outlook on his expected utility; in what follows, I evaluate the agent's *actual expected utility* based on the true probabilities of success and failure. I believe that this is a good initial measure of the agent's *ex ante* well-being. If the agent cares solely about the actual payments that he receives (in addition to his cost of effort), this is the appropriate measure—it is the actual expected value of his future utility. Further considerations about factors that influence individuals' well-being have conflicting implications in terms of welfare analysis. If the agent derives utility from anticipating how richly he will be rewarded once the project succeeds, along the lines of Kőszegi (2005), an overconfident agent will enjoy higher utility than what I calculate as his actual expected utility. On the other hand, once payoffs are realized, the agent will be disappointed whenever he does not receive the success-contingent payment he so confidently anticipates. An agent could evaluate receiving the low failure-contingent payment not only for its own worth, but also as a loss relative to his "reference point" as introduced by Kőszegi and Rabin (2005). In this case, the agent would be worse off than what I calculate. One could also imagine a concept of welfare consistent with individual sovereignty: if we calculate each participant's expected utility based on their subjective beliefs, the equilibrium contract would be Pareto efficient when the beliefs of principals and agent differ significantly. Such analysis, however, ignores the fact that individuals do care about utility derived from actual consumption made possible by income, and not just their expectations about future utility.

Under the assumption that the principals hold accurate beliefs, social welfare depends solely on the agent's well being because competition drives principals' expected profits to zero, independent of agent overconfidence. When principals compete, the agent receives all the project's revenue in expectation. Given that the expected payment to the agent is then independent of the terms of the equilibrium contract given some implemented level of effort, his actual expected utility depends exclusively on his effort and the amount of risk he bears in equilibrium.

Following the same structure as in the previous section, I first identify the welfare effects of overconfidence assuming that effort is not implemented in equilibrium and that changes in overconfidence do not affect the implemented level of effort. In that case, zero expected profits and the assumption that principals hold accurate beliefs imply that actual expected payment to the agent is

$$qx_1 + (1-q)\,x_0,$$

the project's expected revenue. As shown in Proposition 1, as a consequence of the wager effect an agent who is overconfident about the base probability of success always bears risk in equilibrium, so any level of overconfidence on this dimension harms the agent.

Assume now that effort is implemented in equilibrium, and changes in overconfidence do not affect the implemented level of effort. Actual expected payment to the agent is always

$$(q+v)\,x_1 + [1-(q+v)]\,x_0.$$

When the agent is only slightly overconfident overall, the equilibrium contract is characterized by Proposition 2. In this case, the power of incentives depends solely on the agent's beliefs regarding the value of effort. Due to the incentive effect, an agent who is overconfident about the value of effort is exposed to less risk in equilibrium than he would be if he held realistic beliefs because lower-powered incentives are sufficient to induce effort. Thus, in this case the agent's well-being *increases* with overconfidence regarding the value of effort. Some level of overconfidence about the value of effort is therefore beneficial to the agent: he benefits from the efficiency gain of a lower cost of agency. The agent's beliefs about the base probability of success do not affect the equilibrium contract as long as the agent is only slightly overconfident overall.

When the agent is significantly overconfident overall, the equilibrium contract is characterized by Proposition 3; it exhibits excessively powerful incentives. As a consequence of the wager effect, the amount of risk that the agent is exposed to increases in overconfidence on either dimension. Thus, when the agent is significantly overconfident, his well-being *decreases* with overconfidence on either dimension. Higher levels of overconfidence hurt the agent: higher overconfidence increases his exposure to what is already an excessive amount of risk.

As shown by Proposition 4, another effect of higher overconfidence on either dimension is that it makes effort more likely to be implemented. If agent overconfidence drives effort to be implemented in equilibrium, the actual expected payment to the agent increases (by as much as expected revenue does) because effort exertion increases the probability of success of the project. A marginal increase in overconfidence that drives effort to be implemented might, therefore, benefit the agent. This will only be the case, however, if effort is in fact the first-best action (i.e. if the additional expected revenue covers the disutility cost to the agent of exerting effort: $v\left(x_1 - x_0\right) > c$) *and* the increase in expected payment truly compensates the agent for the additional risk he bears.

When principals compete to contract with the agent, because lower-powered incentives are sufficient to induce effort, some overconfidence about the value of effort benefits the agent. A risk-neutral principal can thus absorb more of the risk in the project without destroying incentives. In contrast, if the agent is underconfident about the value of effort or significantly overconfident overall, the agent bears an excessive amount of risk.

Allowing for principals to hold inaccurate beliefs, the effects of overconfidence outlined above are reinforced if principals are overly optimistic about the probability of success of the project. When this is the case, higher-powered incentive contacts that yield zero expected profits according to the principals' beliefs yield lower actual expected payment to the agent. The agent's welfare therefore decreases with the power of incentives of the equilibrium contract, even more sharply than in the case that principals hold accurate beliefs. Intuitively, if the principal contracting with the agent is overly optimistic, she suffers expected losses in equilibrium;[12] a higher-powered incentive contract reduces the principal's stake in the project, and with it her expected losses. The effects of agent overconfidence are therefore reinforced in this case: the agent benefits from moderate overconfidence

[12]This is true if $s_1 < x_1$ and $s_0 > x_0$. I assume that this is the case for the remainder of the paper, but briefly discuss the alternative in Subsection 3.2 below. Law (and common sense) could prevent the agent from signing a contract in which he takes on more risk than the intrinsic risk of the project.

about the value of effort because he bears less risk and receives a higher actual expected payment, whereas underconfidence about the value of effort or significant overall overconfidence harm the agent because he is exposed a higher amount of risk and receives a lower actual expected payment.

If the principals are overly pessimistic relative to the true probability of success, whether increasing overconfidence will benefit or harm the agent depends on the parameters of the model (the agent's degree of risk aversion, for instance). In this case, when expected profits are zero according to the principals' beliefs, higher-powered incentive contracts yield higher actual expected payment to the agent. When the contracting principal is overly pessimistic, her actual expected profits are positive. Higher-powered incentive contracts reduce the principal's stake in the project, and thus transfer more of the actual expected profits to the agent. In the case that the agent is moderately overconfident about the value of his effort, he benefits from being exposed to less risk but loses because of a lower expected payment. Conversely, if the agent is underconfident about the value of effort or significantly overconfident overall, he loses from being exposed to excessive risk but gains because his actual expected payment increases. A significantly overconfident agent may actually benefit from his overconfidence when contracting with an overly pessimistic principal, particularly if his beliefs are close to the true outcome distribution and he is not very risk averse.

3.2 Principals With Differing Beliefs

I derived the results of the model assuming that all competing principals hold identical beliefs. This simplified the analysis because competition turns into *de facto* Bertrand competition, so that expected profits are driven to zero when as few as two principals compete. In a world of asymmetric beliefs, however, this assumption seems particularly strong. If we allow for principals to hold disagreeing beliefs regarding the probability distribution of outcomes, two main complications arise.

First, so long as the number of competing principals is finite, expected profits according to the beliefs of the principal whose offer is accepted in equilibrium will generically be positive. The most optimistic principal needs only to ensure that her contract offer yields zero expected profits according to the beliefs of the second-most-optimistic principal. The second-most-optimistic principal is not willing to outbid some offers that yield positive expected profits to the most optimistic principal if they hold different beliefs.[13] When allowing for principals to hold different beliefs, generally

[13] The result of generically positive perceived expected profits for the principal whose offer is accepted in equilibrium does not depend on the assumption that principals are aware of each others' beliefs. Dropping this assumption (if principals are only aware of the agent's and their own beliefs), competition would resemble a first-price sealed-bid auction instead. If there are finitely many principals, each of them knows that some contract offers which yield strictly positive expected profits will be accepted by the agent with positive probability. Each principal will therefore offer

it is in each principal's best interest to hold accurate beliefs which allow her to design the truly optimal contract offer. If the second-most-optimistic principal overestimates the true probability of success, the most optimistic principal (whose contract is accepted in equilibrium) will suffer losses in expectation. Optimistic bias will therefore tend to harm the principal. An overly pessimistic principal, on the other hand, will be outbid by more optimistic principals. If all principals are pessimistic relative to the actual probability of success, any principal whose offer is rejected in equilibrium would benefit from correctly updating her beliefs; she could then attract the agent and earn positive expected profits.

The second, further, complication is finding which offer is actually accepted by the agent in equilibrium. If we assume monotonic bidding strategies by the principals, then the offer made by the most optimistic principal will tend to be accepted in equilibrium. There is, however, an extreme case in which the offer made by the most *pessimistic* principal could be accepted: if the agent is fairly risk neutral and is very overconfident relative to the most pessimistic principal, the $\langle s_1^*, s_0^* \rangle$ contract as characterized in Proposition 3 could be such that $s_1^* > x_1$ and $s_0^* < x_0$—the principal is betting on project failure.[14] If this is the case, the principal earns higher profits when the project fails than when it succeeds; the principal would have incentives to sabotage the project if possible, and the agent should be wary to accept such a contract. This possibility seems unrealistic. The reason is analogous to why we don't observe contracts with payments that are non-monotonic in the principal's objective variable (e.g. output): the agent would then have incentives to destroy output.

3.3 Comment on the Agent Designing the Contract

With a reinterpretation, the competing-principals framework can be used to predict what happens when it is the agent who designs the contract. If the agent makes a take-it-or-leave-it offer to a principal, he extracts all the surplus from the relationship as he does when principals compete. Recall that competition drives expected profits to zero, so the equilibrium contract maximizes the agent's perceived expected utility among those that yield non-negative expected profits for the principal. This is precisely the agent's objective when designing a take-it-or-leave-it contract offer. If the overconfident agent was oblivious about the fact that the principal holds different beliefs, he would instead offer a contract in line with the equilibrium of a standard identical-beliefs model.

a contract to the agent that, conditional on being accepted, gives the principal strictly positive perceived expected profits according to her beliefs.

[14]This case may be so extreme that holding excessively pessimistic beliefs could be better than holding accurate beliefs for a principal: she then "wins" and earns the chance to bilk the agent for profit, whereas the offer made by a principal holding accurate beliefs would be rejected.

The principal would reject such an offer if she is relatively pessimistic about the probability of success, judging it to yield negative expected profits.

4 One Principal and One Agent

Consider the more standard setting in which one principal can make a take-it-or-leave-it contract offer to an agent. Because of her bargaining position, the principal extracts all the surplus from the agency relationship. This framework is more appropriate than the competing-principals setting when the pool of potential agents is large relative to the number of principals. The case of salespeople in some industries could be an example of such a situation.

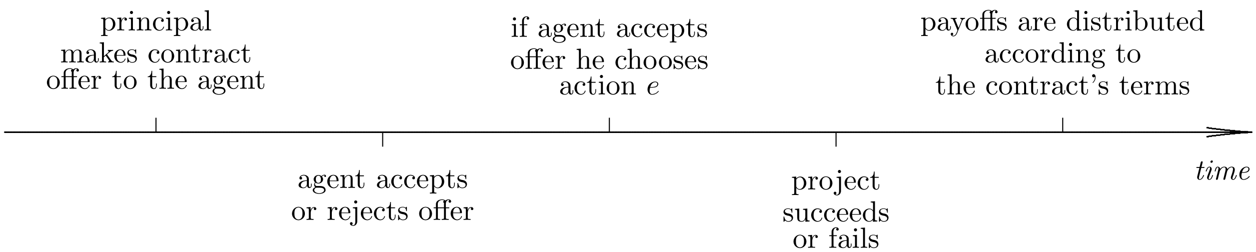

Figure 2: Timing of the model with one principal and one agent

The timing of the model is as follows: first, the principal makes a take-it-or-leave-it contract offer to the agent. The agent can accept or reject the offer. If he accepts it, he chooses whichever action maximizes his perceived expected utility. The outcome of the project is then realized, payoffs are distributed according to the terms of the contract, and the agency relationship ends. If the agent rejects the principal's offer, both will receive utility according to their outside option. I assume that the agent's outside option is exogenous and independent of his overconfidence.[15] The principal's outside option does not affect the equilibrium contract as long as the agency relationship yields sufficient surplus for her to engage in it; I assume this is the case.

Let $\underline{u}$ denote the agent's perceived expected utility from his outside option. The principal's contract offer, if it is to be accepted by the agent, must provide for the agent to receive perceived expected utility no less than $\underline{u}$. This participation, or "individual rationality," constraint restricts the possible optimal contract offers to those such that

$$(\tilde{q} + \tilde{v}e)\, u\,(s_1) + [1 - (\tilde{q} + \tilde{v}e)]\, u\,(s_0) - c \geq \underline{u}, \tag{IR}$$

[15]This assumption allows me to isolate the effect that overconfidence, only regarding the probability of success of the project, has on the equilibrium contract. If the agent was also overconfident about his outside option, he would demand a higher perceived expected utility in order to accept the principal's offer.

where e is the action (freely chosen by the agent) that the principal wishes to implement. The incentive compatibility constraint that must be satisfied if the principal wishes to implement effort remains unchanged:

$$\tilde{v}\left(u\left(s_1\right)-u\left(s_0\right)\right) \geq c. \tag{IC}$$

The principal's objective in designing the optimal contract offer is therefore to maximize expected profits taking the two constraints above into account:

$$\max_{e,s_1,s_0} \left(q+ve\right)\left(x_1-s_1\right)+\left[1-\left(q+ve\right)\right]\left(x_0-s_0\right)$$

subject to

$$\begin{aligned} \tilde{v}\left(u\left(s_1\right)-u\left(s_0\right)\right) &\geq c \text{ if } e=1 \\ \tilde{v}\left(u\left(s_1\right)-u\left(s_0\right)\right) &\leq c \text{ if } e=0 \\ \left(\tilde{q}+\tilde{v}e\right)u\left(s_1\right)+\left[1-\left(\tilde{q}+\tilde{v}e\right)\right]u\left(s_0\right)-c &\geq \underline{u}. \end{aligned}$$

Note that the problem of a given principal who competes with others to contract with the agent can be reinterpreted as follows: she wishes to maximize expected profits, taking into account that the agent chooses e optimally and that he will accept the offer only if it is better than the next-best contract offer. This maximization problem can be written as:

$$\max_{e,s_1,s_0} \left(q+ve\right)\left(x_1-s_1\right)+\left[1-\left(q+ve\right)\right]\left(x_0-s_0\right)$$

subject to

$$\begin{aligned} \tilde{v}\left(u\left(s_1\right)-u\left(s_0\right)\right) &\geq c \text{ if } e=1 \\ \tilde{v}\left(u\left(s_1\right)-u\left(s_0\right)\right) &\leq c \text{ if } e=0 \\ \left(\tilde{q}+\tilde{v}e\right)u\left(s_1\right)+\left[1-\left(\tilde{q}+\tilde{v}e\right)\right]u\left(s_0\right)-c &\geq U\left(\text{next-best offer}\right), \end{aligned}$$

where U (next-best offer) stands for the maximum perceived expected utility that the agent would receive by accepting the best alternative offer (and choosing his optimal effort level accordingly).

The only difference between these two problems is that the agent's participation constraint is exogenous when one principal makes a take-it-or-leave-it offer, and endogenously generated by competing offers in the case of many principals. All the results regarding the equilibrium contract (Propositions 1–4) remain, except that the expected payment to the agent is determined by his exogenous participation constraint (IR), rather than the zero-expected-profits condition. Intuitively, there is no profitable deviation from the equilibrium contract in the competing-principals setting—there is no other contract that attracts the agent (gives him higher perceived expected utility) and yields higher expected profits for the offering principal. The optimal contract when one principal makes a take-it-or-leave-it offer is such that no other contract retains the agent (gives him at least as much perceived expected utility as his outside option) and yields higher expected profits for the principal.

Because of the above correspondence between the two models, the effects of overconfidence carry over from the competing-principals model accordingly. If the agent is only slightly overconfident overall, the incentive effect dominates: if the agent is overconfident about the value of effort, lower-powered incentives are sufficient to induce effort, while if he is underconfident on this dimension higher-powered incentives are then necessary to implement effort. If the agent is significantly overconfident overall, the wager effect dominates: the optimal contract exhibits excessively powerful incentives that increase with agent overconfidence on either dimension. Finally, increases in overconfidence on either dimension, *ceteris paribus*, make effort more likely to be implemented under the optimal contract. The optimal contract is derived explicitly in section A.2 of the appendix.

4.1 Welfare Analysis

As before, assume that the principal's beliefs are accurate. Because the principal is able to extract all the surplus from the agency relationship, the welfare effects of overconfidence differ from those in the competing-principals setting. At the optimum, she offers the agent perceived expected utility only as high as the utility he would derive from his outside option. Because an overconfident agent is overly optimistic about the probability of receiving the success-contingent payment, agent overconfidence reduces the principal's cost of satisfying his participation constraint.

Recall that the agency cost is reduced when the agent is overconfident about the value of effort. The principal benefits from this efficiency gain because she captures all the surplus from the relationship. Furthermore, because the agent overestimates the probability of receiving the (higher) success-contingent payment, the principal can reduce his expected payment by more than is warranted by the lower risk he bears: an overconfident agent overestimates his expected utility, and therefore accepts contracts that give him lower actual expected utility than his outside option. For this same reason, even slight overconfidence about the value of effort hurts the agent.[16] Agent underconfidence about the value of effort increases the cost of agency; besides hurting the agent, who is exposed to more risk, it might also reduce the principal's expected profits.

When the agent is significantly overconfident overall, he bears an excessive amount of risk in

[16]The assumption that the agent's evaluation of his outside option is independent of his level of overconfidence is crucial for this result. In some instances, an overconfident agent may be overconfident about the opportunities that he passes by, just as he is about the project he actually engages.

equilibrium. This, coupled with lower actual expected payment (as a consequence of his overestimation of the probability of receiving the success-contingent payment), implies that his actual expected utility quickly decreases with overconfidence in this range. The principal's expected profits increase with agent overconfidence on either dimension in this range, because it is cheaper for her in expectation to provide the agent a perceived expected utility comparable to his outside option, whether or not effort is implemented in equilibrium.

4.2 Choosing From a Pool of Agents

Consider the problem that the principal faces when choosing an agent from a pool of applicants with different levels of overconfidence and true ability. This question is relevant when the pool of agents is large relative to the number of principals willing to hire an agent, the main motivation for considering the one-principal setting.

All else equal, the principal will prefer a more overconfident agent. Imagine a situation in which many potential agents share the same actual ability, but differ in their self-confidence; a group of individuals who pass several aptitude tests, for example. The principal will choose the most overconfident agent, because it is cheapest for her to satisfy his participation constraint.[17] Clearly, the assumption that the outside option is evaluated equally by agents with different beliefs is crucial for this result: less overconfident agents could become attractive if overconfidence also affected how they evaluate their outside option, since less overconfident agents would demand a lower perceived expected utility in order to accept a given contract.

The principal will hire the agent that she judges to be most able when facing a pool of agents who share the same beliefs about their ability. When applicants respond to a job announcement, for example, most probably believe to be well-suited for the position. Because choosing a higher-ability agent (i.e. an agent who generates a better outcome distribution) yields higher expected revenue and her cost of inducing any of these agents to exert effort is the same, she prefers the most able agent.

These considerations lead to the following conclusions about the hired agent's overconfidence. When the principal faces a pool of same-ability agents who differ only in their level of overconfidence, she will tend to hire the *most* overconfident agent. In contrast, when she faces a pool of applicants who share the same beliefs but differ in underlying ability, the principal will choose the *least* overconfident—most able—agent.

[17] As discussed before, if an agent is overconfident overall but underconfident about the value of effort, the cost of agency increases. The principal might choose a less (overall) overconfident agent if lower-powered incentives are sufficient to induce this second agent to exert effort.

5 Extension: The Continuous-Action Case

In this section, I generalize the one-principal, one-agent model by allowing the agent to choose from a continuum of possible effort levels. The purpose of this generalization is to explore which results of the two-action model generalize to a continuous-action framework (as it turns out, most of them do). The timing and other assumptions in this framework are identical to those in the one-principal, one-agent setting studied in the previous section, except that the agent has a continuum of possible effort levels to choose from: he will choose $e \in [0, 1]$ if he accepts the principal's contract offer. The disutility cost of effort is $c(e)$; assume that $c'(\cdot) > 0$ and $c''(\cdot) > 0$. This assumption implies that the agent's effort level choice will be proportionately related to the accepted contract's power of incentives as long as his choice is an interior solution to his perceived expected utility maximization problem. Assume that $c'(0) = 0$ and $\lim_{e \to 1} c'(e) = \infty$ so that it is, in fact, an interior solution whenever $s_1 > s_0$.[18]

As discussed before, because one principal who makes a take-it-or-leave-it offer to an agent faces a very similar problem to the one faced by a principal who competes with others, the results in a competing-principals setting and a one-principal setting differ only in the level of expected payment to the agent. I focus on a continuous-action-space extension of the model in a one-principal, one-agent setting; because at the optimum the agent receives perceived expected utility equal to that of his (exogenous) outside option, his two possible outcome-contingent utility levels have a fairly simple closed-form solution in this case.

The principal's problem when designing the optimal contract offer is to maximize her expected profits, taking into account that the agent will optimally choose the level of effort and that he will accept the offer only if he judges it to yield expected utility no lower than the utility he would receive from his outside option by rejecting it.

Given contract offer $\langle s_1, s_0 \rangle$, the agent chooses his effort level so as to maximize his perceived expected utility:

$$\max_{e \in [0,1]} (\tilde{q} + \tilde{v}e)\, u(s_1) + [1 - (\tilde{q} + \tilde{v}e)]\, u(s_0) - c(e);$$

the first-order condition for the agent's problem is

$$\tilde{v}\,[u(s_1) - u(s_0)] = c'(e),$$

which defines the agent's choice of effort after accepting contract offer $\langle s_1, s_0 \rangle$. The incentive effect is apparent from this condition: a lower-powered incentive contract is sufficient to implement

[18] Note that if the agent chose a corner solution $e = 0$ or $e = 1$, as long as his choice of effort remains at a given corner solution or shifts discretely to the other, the analysis reduces to the two-action model studied before.

any given effort level e when the agent is overconfident about the value of effort. The agent's participation constraint can be written as:

$$(\tilde{q}+\tilde{v}e)\,u(s_1)+[1-(\tilde{q}+\tilde{v}e)]\,u(s_0)-c(e)\geq \underline{u},$$

where e is chosen optimally by the agent. Note that it must be binding at the optimum. If not, the principal could marginally reduce both payments s_1 and s_0 while keeping the power of incentives $[u(s_1)-u(s_0)]$ constant (so as to implement the same effort level); the principal would then increase expected profits, contradicting optimality.

In order to characterize the relationship between overconfidence, the power of incentives and the implemented level of effort under the optimal contract, it is useful to reinterpret the principal's problem. Taking into account the agent's effort-choice problem, and that the principal will optimally set the participation constraint to bind, the best contract that implements effort level e, $\langle s_1(e), s_0(e)\rangle$, is characterized by

$$\begin{aligned} u(s_1(e)) &= \underline{u}+c(e)+[1-(\tilde{q}+\tilde{v}e)]\,\frac{c'(e)}{\tilde{v}} \\ u(s_0(e)) &= \underline{u}+c(e)-(\tilde{q}+\tilde{v}e)\,\frac{c'(e)}{\tilde{v}}. \end{aligned}$$

Taking this into account, we can reduce the principal's problem to

$$\max_{e\in[0,1]}\,(q+ve)\,(x_1-s_1(e))+[1-(q+ve)]\,(x_0-s_0(e))\,.$$

Clearly, the power of incentives of the optimal contract depends not only on the agent's beliefs but on the effort level that the principal implements, which in turn depends on all the parameters in the model (including the particular functional form of the agent's utility with respect to payments and disutility cost of effort). But while explicitly solving for the optimal implemented effort level seems fruitless, it is possible to study the qualitative effects of both types of overconfidence on it.

Assume that the principal's profit-maximization problem when choosing which effort level to implement is *well behaved*: it has a unique, interior, local and global maximum. Sufficient conditions for this are discussed in section A.3.1 of the appendix. Let e^* denote the effort level that solves the principal's profit maximization problem, at which the marginal revenue equals the marginal cost to the principal of implementing effort:

$$MR_{e^*}=MC_{e^*}.$$

Note that the marginal revenue of effort is constant:

$$MR_e=v\,(x_1-x_0)\,.$$

By marginally increasing the implemented level of effort, the additional revenue in the event of project success $(x_1 - x_0)$ will come about with marginally higher probability (how much higher depends on v).

The marginal cost of implementing effort, on the other hand, is

$$MC_e = v(s_1 - s_0) + (q + ve)\frac{ds_1(e)}{de} + [1 - (q + ve)]\frac{ds_0(e)}{de}$$

where (using the characterization of $\langle s_1(e), s_0(e)\rangle$ above)

$$\begin{aligned} \frac{ds_1(e)}{de} &= \frac{1}{u'(s_1(e))}[1 - (\tilde{q} + \tilde{v}e)]\frac{c''(e)}{\tilde{v}}, \text{ and} \\ \frac{ds_0(e)}{de} &= -\frac{1}{u'(s_0(e))}(\tilde{q} + \tilde{v}e)\frac{c''(e)}{\tilde{v}}. \end{aligned}$$

Note, in particular, that the marginal cost of implementing effort depends crucially on the agent's beliefs. It is clear that, for the principal's profit-maximization problem to be well behaved, it is sufficient that the marginal cost of implementing effort be an increasing function of effort level.

Consider the effect of marginally higher agent overconfidence about the base probability of success on the marginal cost of implementing effort, evaluated at the optimal e^*:

$$\frac{\partial MC_{e^*}}{\partial \tilde{q}} = -\frac{c''(e^*)}{\tilde{v}}\left[(q + ve^*)\frac{1}{u'(s_1(e^*))} + [1 - (q + ve^*)]\frac{1}{u'(s_0(e^*))}\right] < 0.$$

Given that the marginal revenue of implementing any effort level is constant, and that the marginal cost of implementing effort increases with effort level, it follows that the principal will choose to implement higher effort if dealing with an agent who is more overconfident about the base probability of success: $\frac{de^*}{d\tilde{q}} > 0$. This result is the analogue to part of Proposition 4 in the two-action case. As a consequence of the wager effect of overconfidence, because the agent prefers higher-powered incentive contracts, it is cheaper for the principal in the margin to implement higher effort levels.

Consider now the comparable effect of marginally higher agent overconfidence about the value of effort:

$$\begin{aligned} \frac{\partial MC_{e^*}}{\partial \tilde{v}} = -e^*\frac{c''(e^*)}{\tilde{v}}\left[(q + ve^*)\frac{1}{u'(s_1(e^*))} + [1 - (q + ve^*)]\frac{1}{u'(s_0(e^*))}\right] \\ - \frac{1}{\tilde{v}}v\left[(x_1 - s_1(e^*)) - (x_0 - s_0(e^*))\right] < 0. \end{aligned}$$

The first term of the equation above reflects the wager effect of overconfidence. Just as in the case of overconfidence about the base probability of success, it is less costly for the principal to implement higher effort levels. The second term of the equation reflects the incentive effect of overconfidence. The contract $\langle s_1(e^*), s_0(e^*)\rangle$ will implement some effort level greater than e^*

given an increase in the agent's overconfidence about the value of effort. This benefits the principal as long as $(x_1 - s_1(e^*)) \geq (x_0 - s_0(e^*))$.[19] Implementing a higher level of effort increases the expected revenue of the project. Given both effects of overconfidence, higher overconfidence about the value of effort results in a higher implemented effort level: $\frac{de^*}{d\tilde{v}} > 0$. This is analogous to part of the result exposed in Proposition 4, the part regarding overconfidence about the value of effort.

The effect of overconfidence about the base probability of success on the power of incentives of the optimal contract is straightforward. Given that a higher effort level is implemented, and that this type of overconfidence does not directly affect the incentive structure of the contract holding effort constant, it follows that overconfidence about the base probability of success always implies higher-powered incentives. The wager effect of overconfidence drives the optimal contract to exhibit higher-powered incentives in the continuous-action case, even if the agent is only slightly overconfident overall, because the implemented effort level (continuously) increases with overconfidence.

The effect of overconfidence about the value of effort on the power of incentives, on the other hand, is ambiguous. This is because, as in the two-action case, the incentive effect of overconfidence on this dimension pushes toward lower-powered incentives, while its wager effect pushes toward higher-powered incentives. Furthermore, both effects of overconfidence imply that the optimal contract implements a higher effort level, which also pushes toward higher-powered incentives. Intuitively, in the two-action model an increase in overconfidence about the value of effort could drive effort to be implemented, in which case such an increase in overconfidence would result in higher-powered incentives in the new equilibrium.

The actual change in the power of incentives of the optimal contract as a consequence of changes in agent overconfidence regarding the value of effort is formally derived in Subsection A.3.2 of the appendix. Whether there is some range of overall "slight" overconfidence over which the power of incentives decreases in overconfidence about the value of effort depends on all the parameters of the model. In general, if the agent is very risk averse such a range will in fact exist. Intuitively, because a small increase in the amount of risk born by the agent is sufficient to induce higher effort exertion, and lower-powered incentives are sufficient to implement any given effort level, the power of incentives of the optimal contract decreases with overconfidence about the value of effort. If, on the other hand, the agent's marginal cost of exerting effort increases sharply, the additional power

[19] As explained in footnote 12 and the discussion that follows it in the text, it seems much more reasonable to assume that in equilibrium $x_1 - x_0 \geq s_1(e^*) - s_0(e^*)$, so that the agent is not exposed to more risk than inherent in the project. If this assumption is violated, the principal would enjoy greater profits in the case of project failure than success, so may prefer to implement lower rather than higher effort levels. Such a contract seems unrealistic, since the principal would have incentives to sabotage the project in that case. Common sense, if not legal restrictions, should prevent the agent from accepting such a contract.

of incentives necessary to implement higher effort is large, so there is no such range and the power of incentives is everywhere increasing in overconfidence on either dimension.

6 Conclusion and Discussion

This paper attempts to give some insight into the effects of overconfidence in equilibrium within a moral-hazard framework (which include potential benefits and pitfalls). It gives one possible explanation to why we observe incentive contracts that seem excessively powerful in some situations, and surprisingly flat in others. It also helps explain why overconfidence can be valuable, not only for the agent, but also for a principal even though her main concern is the agent's underlying ability.

The results of the paper suggest that incentive contracts are sensitive to the *type* of overconfidence the agent has, not only to the presence of overconfidence per se. Because of this, experimental and field studies exploring how (besides whether or not) individuals are overconfident would shed some light on our understanding about how incentive contracts respond to changes in beliefs. For instance, if agents tend to be significantly overconfident overall and agent overconfidence is procyclical (as suggested by Gervais and Odean [2001]), this model predicts that fast-paced growth would be followed by more powerful incentive contracts being implemented. In contrast, if agents tend to be slightly overconfident about the value of effort less powerful incentives would follow.

Some recent empirical observations are consistent with the model. For example, in a survey of almost three thousand entrepreneurs, Cooper, Woo, and Dunkelberg (1988) find that entrepreneurs tend to overestimate the probability of success of their enterprise, and invest many hours in it (more than 60 hours a week according to many of the respondents). In Weinstein's (1980) terms, when entrepreneurs form expectations they compare themselves to a hypothetical entrepreneur who chooses to enter an industry with merely good prospects and puts little effort into making the enterprise succeed. Given that the average success rate of businesses is readily available information, entrepreneurs may use this average as their benchmark when forming expectations, failing to internalize the fact that most entrepreneurs, like them, also have a "brilliant idea" and work hard to "make it happen." The results of my model imply that entrepreneurs' choice of long hours arises from their overconfidence rather than, for instance, the idea that the cost of effort for entrepreneurs is particularly low or that they underestimate this cost.

Cooper, Woo, and Dunkelberg (1988) also find that the entrepreneurs' degree of overconfidence seems to be independent of factors that affect their actual probability of success (like experience in the industry and education level). This suggests an empirical test for the relevance of overconfidence in entrepreneurs' decisions: holding the beliefs of the entrepreneur constant, if the most overconfident agents are significantly overconfident (as implicitly defined by Proposition 3) then my model has opposite implications than a standard moral-hazard model does not allow for overconfidence. The most overconfident entrepreneurs (those with relatively low underlying ability) will "underinsure," and be willing to risk a higher proportion of their own funds in the project. They will tend to have a lower success rate than more able, less overconfident entrepreneurs who are not underinsured. Less overconfident entrepreneurs (who have a higher underlying probability of success) find the terms of the principals' offers (e.g. the terms of a bank loan) to be more in line with their own beliefs; because of a smaller wager effect of overconfidence, they face less powerful incentives in equilibrium (they invest a smaller proportion of their own funds). Thus, on average, the probability of success of an enterprise may be *negatively* correlated to the proportion of the entrepreneur's own funds invested in it. A standard identical-beliefs model would predict a positive correlation instead: entrepreneurs who invest a higher proportion of their own funds face more powerful incentives to exert effort; there is less of an agency problem, so the probability of success should always be *positively* correlated to the proportion of funds invested by the entrepreneur. Of course, even allowing for overconfidence, the effect of incentives on the effort that the entrepreneur exerts pushes towards a positive correlation. Observing a negative correlation would therefore strongly suggest that overconfidence is relevant in entrepreneurs' behavior.

Smith and Watts (1992) present an empirical study which discusses executive compensation. One of their observations is that firms with larger "investment opportunity sets" pay their CEOs more, and are more likely to use stock options and other forms of performance-contingent pay. They interpret this result in light of a standard moral-hazard framework; they argue that a manager's actions are less readily observable if the firm has more investment opportunities. In terms of overconfidence, it seems intuitive that a larger opportunity set will go together with higher CEO overconfidence about the chosen course of action, since he will choose the action he's more optimistic about. In this sense, my model is consistent with a positive correlation between larger investment opportunity sets and higher-powered compensation packages.

Moral hazard does not seem to be the main driving force behind optimal contract design in the context of executive compensation, however. A model in which the agent holds private information regarding the best course of action seems more appropriate to study this topic. Gervais, Heaton and Odean (2003) explore one such model and find that the power of incentives "should" be lower if a manager is overconfident than if is realistic. Their insight is that an overconfident manager will act in a less risk-averse manner, so lower-powered incentives are sufficient to align the agent's objectives to those of the principal. The wager effect of overconfidence identified in this paper, however, carries over to this setting. If the principal is aware that the agent tends to overestimate the probability of success after choosing a course of action, the wager effect pushes towards higher-powered incentives. An interesting question for further research is how these two forces interact to determine whether the equilibrium contract exhibits higher- or lower-powered incentives in the presence of manager overconfidence.

Another direction for further research that could yield interesting results is overconfidence in a self-selection (or sorting) setting. According to adverse-selection models that allow for overconfidence, the most overconfident agents are naturally attracted to riskier endeavors. This is consistent with the fact that some agents in dangerous jobs do underestimate the probability of a bad outcome, as noted by Akerlof and Dickens (1982). My model implies, however, that different types of overconfidence can have conflicting effects in terms of the amount of risk born by the agent in equilibrium. If this is the case, agents with similar degrees of overall overconfidence might sort themselves into very different positions.

A Appendix

A.1 Competing Principals

Lemma 1 *If principals share the same beliefs regarding outcome distribution conditional on the agent's actions, expected profits will be zero in equilibrium according to the principals' beliefs.*

Proof. Suppose not. Suppose that a principal offers, and the agent accepts, a contract $\langle s_1, s_0\rangle$ in equilibrium that it yields positive expected profits for the offering principal:

$$\Pr(x_1 \mid e)(x_1 - s_1) + [1 - \Pr(x_1 \mid e)](x_0 - s_0) > 0,$$

where e is chosen optimally by the agent. Other principals, whose contracts are not accepted by the agent, receive zero profits in equilibrium. Consider the following deviation by one of these principals: offer contract $\langle s_1 + \epsilon, s_0\rangle$ if $\langle s_1, s_0\rangle$ implements effort, and $\langle s_1, s_0 + \epsilon\rangle$ if $\langle s_1, s_0\rangle$ does not implement effort. In either case, the new contract makes the agent strictly better off, and will thus be accepted by the agent. For ϵ close enough to zero, the principal making the new contract offer enjoys positive expected profits. Given that there is a profitable deviation, $\langle s_1, s_0\rangle$ cannot be the equilibrium contract. ■

Proposition 1 *Assuming effort is not implemented in equilibrium, the only equilibrium contract* $\langle s_{1*}, s_{0*}\rangle$ *is characterized by the conditions*

$$\frac{\tilde{q}}{1-\tilde{q}}\frac{u'(s_{1*})}{u'(s_{0*})} = \frac{q}{1-q}$$

and $q(x_1 - s_{1*}) + [1-q](x_0 - s_{0*}) = 0$*. The agent bears risk in equilibrium if* $\tilde{q} > q$*.*

Proof. Assuming that effort is not implemented in equilibrium, $\langle s_{1*}, s_{0*}\rangle$ characterized by $\frac{q}{1-q} = \frac{\tilde{q}}{1-\tilde{q}} \frac{u'(s_{1*})}{u'(s_{0*})}$ and zero expected profits for the principal maximizes the agent's perceived utility subject to non-negative profits for the offering principal. It can be shown that, because of the agent's risk aversion, this contract is the unique global maximum. Any other contract that does not implement effort and gives non-negative expected profits to the offering principal therefore yields strictly lower perceived expected utility to the agent. Conversely, any other contract that does not implement effort and yields the same perceived expected utility to the agent yields strictly negative expected profits for the offering principal. Thus, there is no profitable deviation from $\langle s_{1*}, s_{0*}\rangle$. ■

Proposition 2 *Assuming effort is implemented in equilibrium,* $\langle \bar{s}_1, \bar{s}_0\rangle$ *is the only equilibrium contract if* $\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})} \frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} \leq \frac{q+v}{1-(q+v)}$*.*

Proof. We need to show there is no profitable deviation from this contract; i.e. that no other effort-implementing contract exists such that the agent receives higher expected utility, and the offering principal enjoys positive expected profits. This rules out contracts with higher payment to the agent both in the case of success and failure, and those with lower payment to the agent in both events. The perceived expected utility for the agent under $\langle \bar{s}_1, \bar{s}_0\rangle$ is

$$\tilde{\mathbb{E}}\left[u(\bar{s}_x) \mid e=1\right] = (\tilde{q}+\tilde{v})\, u(\bar{s}_1) + [1-(\tilde{q}+\tilde{v})]\, u(\bar{s}_0) - c.$$

A marginal change in payments that leaves the agent indifferent satisfies

$$(\tilde{q}+\tilde{v})\, u'(\bar{s}_1)\, ds_1 + [1-(\tilde{q}+\tilde{v})]\, u'(\bar{s}_0)\, ds_0 = 0$$

or

$$ds_0 = -\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})} \frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} ds_1$$

where necessarily $ds_1 > 0$ and $ds_0 < 0$, since the incentive compatibility constraint would be otherwise violated. Such a change implies that the agent would bear more risk under the new contract. Since the agent is risk-averse, he must be compensated with a higher expected payment, which is why the increase in s_1 must be more than actuarially fair *according to his beliefs*.

The change in expected profits for the offering principal from a marginal change in the payment structure that leaves the agent indifferent is

$$-(q+v)\, ds_1 - [1-(q+v)]\, ds_0 =$$
$$\left(-(q+v) + [1-(q+v)] \frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})} \frac{u'(\bar{s}_1)}{u'(\bar{s}_0)}\right) ds_1 \leq 0.$$

If $\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})}\frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} \leq \frac{q+v}{1-(q+v)}$, expected profits decrease for the principal offering the new contract that exposes the agent to more risk than $\langle \bar{s}_1, \bar{s}_0 \rangle$ does. It follows that there is no profitable marginal deviation from the $\langle \bar{s}_1, \bar{s}_0 \rangle$ contract. Given that $\frac{u'(s_1)}{u'(s_0)}$ falls as s_1 increases and s_0 decreases, discrete deviations from $\langle \bar{s}_1, \bar{s}_0 \rangle$ that implement effort and leave the agent indifferent also imply expected losses for the offering principal. Therefore, $\langle \bar{s}_1, \bar{s}_0 \rangle$ is the equilibrium contract. ■

Proposition 3 *Assuming effort is implemented in equilibrium, if* $\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})}\frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} > \frac{q+v}{1-(q+v)}$ *then* $\langle \bar{s}_1, \bar{s}_0 \rangle$ *is not an equilibrium contract. The only equilibrium contract* $\langle s_1^*, s_0^* \rangle$ *is characterized by*

$$\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})}\frac{u'(s_1^*)}{u'(s_0^*)} = \frac{q+v}{1-(q+v)}$$

and $(q+v)(x_1 - s_1^*) + [1-(q+v)](x_0 - s_0^*) = 0$. *The equilibrium contract has higher-powered incentives than necessary to implement effort.*

Proof. The proof is analogous to the proof of Proposition 1. Assuming that effort is implemented in equilibrium, $\langle s_1^*, s_0^* \rangle$ (uniquely) maximizes the agent's perceived utility subject to non-negative profits for the offering principal. It follows that any other contract that implements effort and yields the same perceived expected utility to the agent yields strictly negative expected profits for the offering principal. There is no profitable deviation from $\langle s_1^*, s_0^* \rangle$.

Given that by assumption $\frac{q+v}{1-(q+v)} < \frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})}\frac{u'(\bar{s}_1)}{u'(\bar{s}_0)}$, since $u''(\cdot) < 0$, and expected profits for the principal are zero under both $\langle \bar{s}_1, \bar{s}_0 \rangle$ and $\langle s_1^*, s_0^* \rangle$, it follows that $s_1^* > \bar{s}_1$ and $s_0^* < \bar{s}_0$. By construction, $\tilde{v}(u(\bar{s}_1) - u(\bar{s}_0)) = c$, and thus

$$\tilde{v}(u(s_1^*) - u(s_0^*)) > c;$$

$\langle s_1^*, s_0^* \rangle$ has higher-powered incentives than necessary to implement effort. ■

Proposition 4 *Higher levels of overconfidence on either dimension, ceteris paribus, increase the likelihood that effort is implemented in equilibrium: if effort is implemented given agent beliefs* $(\tilde{q}, \tilde{v})$*, then effort will be implemented when his beliefs are* $(\tilde{q}, \tilde{v}^*)$ *for any* $\tilde{v}^* \geq \tilde{v}$ *or* $(\tilde{q}^*, \tilde{v})$ *for any* $\tilde{q}^* \geq \tilde{q}$.

Proof. Overconfidence affects the implemented level of effort differently, depending on whether the incentive or the wager effect of overconfidence dominates.

First, consider changes in agent overconfidence regarding the value of effort.

If $\langle \bar{s}_1, \bar{s}_0 \rangle$ is the potential equilibrium contract that implements effort, the power of incentives decreases with overconfidence regarding the value of effort. Expected profits are zero in equilibrium, so a marginal increase in $\tilde{v}$ implies:

$$-(q+v)\frac{d\bar{s}_1}{d\tilde{v}} - [1-(q+v)]\frac{d\bar{s}_0}{d\tilde{v}} = 0,$$

where $\frac{d\bar{s}_1}{d\tilde{v}} < 0$ and $\frac{d\bar{s}_0}{d\tilde{v}} > 0$. The effect of such a change in the agent's perceived utility when $\langle \bar{s}_1, \bar{s}_0 \rangle$ is the potential equilibrium contract that implements effort is

$$u(\bar{s}_1) - u(\bar{s}_0) + (\tilde{q} + \tilde{v}) u'(\bar{s}_1) \frac{d\bar{s}_1}{d\tilde{v}} + [1 - (\tilde{q} + \tilde{v})] u'(\bar{s}_0) \frac{d\bar{s}_0}{d\tilde{v}} \geq c > 0,$$

taking into account that $\langle \bar{s}_1, \bar{s}_0 \rangle$ is the potential equilibrium contract only if $\frac{\tilde{q}+\tilde{v}}{1-(\tilde{q}+\tilde{v})} \frac{u'(\bar{s}_1)}{u'(\bar{s}_0)} \leq \frac{q+v}{1-(q+v)}$.

If $\langle s_1^*, s_0^* \rangle$ is the potential equilibrium contract that implements effort, the envelope theorem implies that the change in the agent's perceived utility from a marginal increase in $\tilde{v}$ is

$$u(s_1^*) - u(s_0^*) > c > 0.$$

There is no change in the agent's perceived utility under $\langle s_{1*}, s_{0*} \rangle$ from a marginal increase in $\tilde{v}$. Therefore, if effort is implemented given agent beliefs $(\tilde{q}, \tilde{v})$, then effort will be implemented when his beliefs are $(\tilde{q}, \tilde{v}^*)$ for any $\tilde{v}^* \geq \tilde{v}$.

Consider now changes in agent overconfidence regarding the base probability of success.

If $\langle \bar{s}_1, \bar{s}_0 \rangle$ is the potential equilibrium contract that implements effort, the power of incentives is independent from overconfidence regarding the base probability of success. A marginal increase in $\tilde{q}$ implies a change in agent's perceived utility of

$$u(\bar{s}_1) - u(\bar{s}_0) = c.$$

If $\langle s_1^*, s_0^* \rangle$ is the potential equilibrium contract that implements effort, the envelope theorem again implies that the change in the agent's perceived utility from a marginal increase in $\tilde{q}$ is

$$u(s_1^*) - u(s_0^*) > c.$$

The change in the agent's perceived expected utility following a marginal increase in $\tilde{q}$ under the potential equilibrium contract that does not implement effort is

$$u(s_{1*}) - u(s_{0*}) \leq c.$$

Therefore, if effort is implemented given agent beliefs $(\tilde{q}, \tilde{v})$, then effort will be implemented when his beliefs are $(\tilde{q}^*, \tilde{v})$ for any $\tilde{q}^* \geq \tilde{q}$. ■

A.2 One Principal and One Agent

Solving the principal's profit-maximization problem explicitly

Assume that effort is implemented in equilibrium. The principal's problem is

$$\max_{s_1, s_0} (q + v)(x_1 - s_1) + [1 - (q + v)](x_0 - s_0)$$

subject to

$$\tilde{v}\left(u\left(s_1\right)-u\left(s_0\right)\right) \geq c$$
$$\left(\tilde{q}+\tilde{v}\right) u\left(s_1\right)+\left[1-\left(\tilde{q}+\tilde{v}\right)\right] u\left(s_0\right)-c=\underline{u}$$

We can solve this problem by setting up a Lagrangian. Let λ denote the Lagrange multiplier associated with the IC constraint, and μ the multiplier associated with the IR constraint. Since the IR constraint binds in equilibrium, it follows that $\mu > 0$.

If the IC constraint binds in equilibrium as well, so that $\lambda > 0$, then the IR and IC constraints holding with equality define the equilibrium contract. This contract is analogous to the contract discussed in the previous section when the difference in beliefs held by principal and agent was small (which we denoted by $\langle \bar{s}_1, \bar{s}_0 \rangle$). As before, when the beliefs held by principal and agent do not diverge significantly, the IC constraint will in fact bind, and the contract with incentives just powerful enough to induce effort exertion is the equilibrium contract. This result is analogous to Proposition 2. The optimal contract is characterized by

$$u\left(s_0\right)=\underline{u}-\frac{\tilde{q}}{\tilde{v}} c$$
$$u\left(s_1\right)=\underline{u}+\frac{1-\tilde{q}}{\tilde{v}} c.$$

If the IC constraint binds, the incentive effect of overconfidence dominates. The power of incentives is, as in the case of competing principals, decreasing in the agent's estimation of the value of his effort ($\tilde{v}$). The power of incentives is independent of the agent's overoptimism ($\tilde{q}$), and of the principal's beliefs. An overoptimistic agent (who overestimates $\tilde{q}$) will, however, be paid less both in the event of success and failure. Overoptimism makes it cheaper for the principal to satisfy the agent's participation constraint, since the agent thinks it's more likely that he will receive the "high" payment s_1. The incentive effect of overconfidence will in fact dominate if the principal and agent hold beliefs that are not significantly divergent.

If the IC constraint is slack in equilibrium instead, so that $\lambda = 0$, the first-order conditions of the principal's maximization problem yield

$$\left(\tilde{q}+\tilde{v}\right) \mu u'\left(s_1\right)=\left(q+v\right)$$
$$\left[1-\left(\tilde{q}+\tilde{v}\right)\right] \mu u'\left(s_0\right)=\left[1-\left(\tilde{q}+\tilde{v}\right)\right]$$

which substituting for μ yields

$$\frac{q+v}{1-(q+v)}=\frac{\tilde{q}+\tilde{v}}{1-\left(\tilde{q}+\tilde{v}\right)} \frac{u'\left(s_1^{**}\right)}{u'\left(s_0^{**}\right)}.$$

This condition characterizes the power of incentives of the equilibrium contract when the beliefs held by principal and agent differ significantly. This result is analogous to Proposition 3 in the case of competing principals. The expected payment in this case is grounded by the IR constraint instead of the zero expected profits condition.

When the agent significantly overconfident, the power of incentives of the optimal contract offered by the principal is increasing in overconfidence on both dimensions.

Assume now that effort is not implemented in equilibrium. The wager effect of overconfidence implies that the agent will bear some risk in equilibrium. The equilibrium contract's power of incentives are characterized by the expression $\frac{q}{1-q} = \frac{\tilde{q}}{1-\tilde{q}} \frac{u'(s_1)}{u'(s_0)}$. This result is analogous to Proposition 1. The expected payment to the agent is determined by the IR constraint.

Finally, the likelihood that the principal will implement effort is increasing in either dimension of overconfidence. If the agent is moderately overconfident about the value of effort, the cost of agency when implementing effort is reduced, so the profits for the principal when implementing effort increase. Furthermore, given that an overconfident agent overestimates the probability of receiving the success-contingent payment, it is increasingly cheaper for the principal to satisfy the agent's participation constraint the higher this payment is; a contract that implements effort is increasingly cheaper to implement for the principal relative to a contract that does not implement effort. The likelihood that effort is implemented under the optimal contract is therefore increasing in both types of overconfidence. This result is analogous to Proposition 4.

A.3 The Continuous-Action Case

A.3.1 Conditions for the principal's profit-maximization problem to be well behaved

Recall that we can write the principal's profit-maximization problem as:

$$\max_{e \in [0,1]} (q + ve) (x_1 - s_1 (e)) + [1 - (q + ve)] (x_0 - s_0 (e)) .$$

subject to

$$u (s_1 (e)) = \underline{u} + c (e) + [1 - (\tilde{q} + \tilde{v}e)] \frac{c' (e)}{\tilde{v}}$$
$$u (s_0 (e)) = \underline{u} + c (e) - (\tilde{q} + \tilde{v}e) \frac{c' (e)}{\tilde{v}}.$$

Let e^* denote the solution to the first-order condition of this problem, the level of effort at which the principal's marginal revenue equals her marginal cost of implementing effort:

$$MR_{e^*} = MC_{e^*}.$$

Recall that

$$MR_e = v\left(x_1 - x_0\right),$$

and

$$MC_e = v\left(s_1 - s_0\right) + \left(q + ve\right)\frac{ds_1\left(e\right)}{de} + \left[1 - \left(q + ve\right)\right]\frac{ds_0\left(e\right)}{de},$$

where

$$\begin{aligned}\frac{ds_1\left(e\right)}{de} &= \frac{1}{u'\left(s_1\left(e\right)\right)}\left[1 - \left(\tilde{q} + \tilde{v}e\right)\right]\frac{c''\left(e\right)}{\tilde{v}}\\ \frac{ds_0\left(e\right)}{de} &= -\frac{1}{u'\left(s_0\left(e\right)\right)}\left(\tilde{q} + \tilde{v}e\right)\frac{c''\left(e\right)}{\tilde{v}}.\end{aligned}$$

This problem will have a unique, interior, local and global maximum if the marginal cost of implementing effort is strictly increasing in implemented level of effort.

The change in the marginal cost of increasing effort is:

$$\frac{dMC_e}{de} = v\left(\frac{ds_1\left(e\right)}{de} - \frac{ds_0\left(e\right)}{de}\right) + \left(q + ve\right)\frac{d^2 s_1\left(e\right)}{de^2} + \left[1 - \left(q + ve\right)\right]\frac{d^2 s_0\left(e\right)}{de^2}.$$

The first component of this expression is positive, since $\frac{ds_1(e)}{de} > 0$ and $\frac{ds_0(e)}{de} < 0$. Assuming for simplicity that $c''\left(e\right) = k$, a constant, the second and third components of the expression above are:

$$\begin{aligned}\frac{d^2 s_1\left(e\right)}{de^2} &= \frac{k}{u'\left(s_1\left(e\right)\right)}\left[-\frac{u''\left(s_1\left(e\right)\right)}{u'\left(s_1\left(e\right)\right)}\frac{\left[1 - \left(\tilde{q} + \tilde{v}e\right)\right]^2}{\tilde{v}^2}\frac{k}{u'\left(s_1\left(e\right)\right)} - 1\right],\\ \frac{d^2 s_0\left(e\right)}{de^2} &= \frac{k}{u'\left(s_0\left(e\right)\right)}\left[-\frac{u''\left(s_0\left(e\right)\right)}{u'\left(s_0\left(e\right)\right)}\frac{\left(\tilde{q} + \tilde{v}e\right)^2}{\tilde{v}^2}\frac{k}{u'\left(s_0\left(e\right)\right)} - 1\right].\end{aligned}$$

If both of these components are positive, it follows that the marginal cost of implementing effort will be strictly increasing in effort level. This will be the case if:

- $c''\left(e\right)$ is large enough

  If the cost to the agent of choosing higher levels of effort is convex enough, then the cost to the principal of implementing higher levels of effort will be convex as well.

- the agent is sufficiently risk averse

  A large coefficient of absolute risk aversion $-\frac{u''(s_x)}{u'(s_x)}$ also makes it increasingly costly to implement higher effort, since the principal must compensate the agent for the higher risk he must bear as higher levels of effort are implemented.

- the agent is wealthy

  It is increasingly costly to power-up incentives and implement higher levels of effort when changes in the payments have little effect on the agent's utility level. When the agent is wealthy, his marginal utility $u'(s_x)$ is relatively low.

A.3.2 The power of incentives and agent overconfidence regarding the value of effort

Recall that the solution to the agent's problem yields

$$[u(s_1(e^*)) - u(s_0(e^*))] = \frac{c'(e^*)}{\tilde{v}}.$$

The change in the power of incentives of the equilibrium contract is thus

$$\frac{d[u(s_1(e^*)) - u(s_0(e^*))]}{d\tilde{v}} = \frac{c''(e^*)}{\tilde{v}}\frac{de^*}{d\tilde{v}} - \frac{c'(e^*)}{\tilde{v}^2}.$$

Recall, as well, that the solution to the principal's problem e^* is such that

$$MR_{e^*} = MC_{e^*},$$

or

$$v(x_1 - x_0) = v(s_1 - s_0) + (q + ve^*)\frac{ds_1(e^*)}{de} + [1 - (q + ve^*)]\frac{ds_0(e^*)}{de}.$$

Assume that $c''(e) = k$, a constant. Taking the total derivative of the equation above with respect to $\tilde{v}$ yields

$$\begin{aligned}
0 = \frac{de^*}{d\tilde{v}} \Bigg(& \left\{ \frac{[1-(\tilde{q}+\tilde{v}e^*)]}{u'(s_1(e^*))} + \frac{(\tilde{q}+\tilde{v}e^*)}{u'(s_0(e^*))} \right\} v + \left\{ \frac{[1-(\tilde{q}+\tilde{v}e^*)]}{u'(u(s_1(e^*)))} + \frac{(\tilde{q}+\tilde{v}e^*)}{u'(u(s_0(e^*)))} \right\} v \\
& - \left\{ \frac{(q+ve^*)}{u'(u(s_1(e^*)))} + \frac{[1-(q+ve^*)]}{u'(u(s_0(e^*)))} \right\} \tilde{v} \\
& + \frac{k}{\tilde{v}} \left\{ -\frac{u''(u(s_1(e^*)))}{u'(u(s_1(e^*)))} \frac{(q+ve^*)[1-(\tilde{q}+\tilde{v}e^*)]^2}{u'(u(s_1(e^*)))} - \frac{u''(u(s_0(e^*)))}{u'(u(s_0(e^*)))} \frac{[1-(q+ve^*)](\tilde{q}+\tilde{v}e^*)^2}{u'(u(s_0(e^*)))} \right\} \Bigg) \\
& - \frac{1}{\tilde{v}} \left\{ \frac{(q+ve^*)[1-(\tilde{q}+\tilde{v}e^*)]}{u'(u(s_1(e^*)))} + \frac{[1-(q+ve^*)](\tilde{q}+\tilde{v}e^*)}{u'(u(s_0(e^*)))} \right\} \\
& - e^* \left\{ \frac{(q+ve^*)}{u'(u(s_1(e^*)))} + \frac{[1-(q+ve^*)]}{u'(u(s_0(e^*)))} \right\}.
\end{aligned}$$

Given that we are interested in the effect of overconfidence regarding the value of effort on the power of incentives when the agent is slightly overconfident, I evaluate the change in the power of incentives of the equilibrium contract at the point that principal and agent agree in their beliefs:

$$\left.\frac{d[u(s_1(e^*)) - u(s_0(e^*))]}{d\tilde{v}}\right|_{\tilde{v}=v,\tilde{q}=q} = \frac{k}{v}\frac{de^*}{d\tilde{v}} - \frac{c'(e^*)}{v^2}$$

$$= \frac{\left\{\frac{1}{\beta_1} - \frac{1}{\beta_0}\right\}\frac{\alpha}{v} + \left\{\frac{(q+ve^*)}{\beta_1} - \frac{[1-(q+ve^*)]}{\beta_0}\right\}e^*}{\left(\left\{\frac{[1-(q+ve^*)]}{u'(s_1(e^*))} - \frac{(q+ve^*)}{u'(s_0(e^*))}\right\} + \left\{\frac{1}{\beta_1} - \frac{1}{\beta_0}\right\}\right)v\left(\frac{v}{k}\right) + \left\{-\frac{u''(u(s_1(e^*)))}{u'(u(s_1(e^*)))}\frac{[1-(q+ve^*)]}{\beta_1} - \frac{u''(u(s_0(e^*)))}{u'(u(s_0(e^*)))}\frac{(q+ve^*)}{\beta_0}\right\}\alpha} - \frac{c'(e^*)}{v^2}$$

where

$$\alpha = (q+ve^*)\left[1-(q+ve^*)\right], \beta_1 = u'\left(u\left(s_1\left(e^*\right)\right)\right), \beta_0 = u'\left(u\left(s_0\left(e^*\right)\right)\right); \text{ note } \frac{1}{\beta_1} - \frac{1}{\beta_0} > 0.$$

The expression above shows that the power of incentives will be decreasing in overconfidence about the value of effort when the agent is moderately overconfident if the agent's action is very responsive to the power of incentives. This will be the case if the agent is very risk averse (as measured by $-\frac{u''(u(s_x))}{u'(u(s_x))}$, which resembles the coefficient of absolute risk aversion), or if the increase in the marginal cost of effort is sufficiently low (as measured by $k = c''(e^*)$). The power of incentives of the optimal contract will be everywhere increasing in both types of overconfidence if the agent is sufficiently risk neutral, or if the disutility cost of effort is high.

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