Overconfidence in a Career-Concerns Setting

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CESIFO WORKING PAPER NO. 2405
CATEGORY 4: LABOUR MARKETS
SEPTEMBER 2008

PRESENTED AT CESIFO VENICE SUMMER INSTITUTE 2008,
WORKSHOP ON EXECUTIVE PAY

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CESifo *Working Paper No. 2405*

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Abstract

We study the effects of overconfidence in a two-period investment-decision agency setting. Under common priors, agent risk aversion implies inefficiently low first-period investment. In our model, principal and agent disagree about the profitability of the investment decision conditional on a given public signal. An overconfident agent believes that the principal will update her beliefs upwards more often than not. As a consequence, the agent overestimates the benefits of learning from first-period investment. This implies that agent overconfidence mitigates the agency problems arising from the agent's career concerns, even though an overconfident agent bears more project and reputational risk in equilibrium.

JEL Code: D83, D84, D86.

Keywords: overconfidence, heterogenous beliefs, career concerns.

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First version: May 2007
This version: September 1, 2008
An early version of this paper is part of my Ph.D. dissertation at the University of California at Berkeley. I am very grateful to Patrick Bolton, Peter Ove Christensen, Benjamin Hermalin, Botond Kőszegi, Terrance Odean, Matthew Rabin, participants at the 3rd SFB Workshop in Bonn, at the Incentives in Economics BGPE Conference, at the Venice Summer Institute sponsored by CESifo, and seminar participants at the University of Copenhagen and the University of Munich for helpful comments and discussion.

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1 Introduction

The presence of career concerns—concerns for the effect of present outcomes on future compensation—affects the incentive structure underlying an agency relationship. Present outcomes affect the agent's future compensation when there is uncertainty about some of the agent's characteristics (which we will refer to as his "ability") that affect the future expected productivity of the agency relationship. The principal updates her beliefs about the agent's ability after observing each period's outcome. This may lead to efficiency costs, as noted by, e.g., Holmström and Ricart i Costa (1986) and Hermalin (1993) in an investment-decision setting. A risk-neutral principal is concerned with maximizing expected profits, and would like for the agent to choose investment projects accordingly. When making an investment decision, however, the agent must take into account the reputational risk that it entails: his future compensation likely depends on the outcome following his investment decision. If a risk-averse agent cannot be fully insured against reputational risk following initial outcomes, he will be willing to forego profitability in favor of self-insurance. In the case of Holmström and Ricart i Costa (1986), this translates into excessively cautious investing; in the case of Hermalin (1993) it translates into choosing noisy rather than profitable projects. To see the main intuition take, as a cynical example, that of a student who received a bad grade in an exam. The student might argue that the result is particularly noisy and uninformative about "ability" because of special circumstances that hindered his performance. If this is true, a Bayesian grader should correct the grade upwards towards the prior mean. An average risk-averse student has thus clear incentives to make sure that circumstances which hinder performance are in fact present before or during the exam, which is, of course, inefficient.

Research in psychology, however, suggests that individuals tend to overestimate their skills and abilities, as well as the likelihood of favorable outcomes.[1] Allowing for heterogeneous beliefs in a model of career concerns, we show that the effect of overconfidence on equilibrium investment decisions is reverse to the effect of reputational risk.[2] In our model, the agent's ability affects the outcome distribution following investment in a given project. In a common-priors setting,

[1] See Taylor and Brown (1988) for a survey this research.

[2] We will refer to an overconfident agent as one who is relatively optimistic about his own ability. Although other authors refer to this as optimism, that term seems to overlook the fact that the agent is actually instrumental in the outcome. Excessive self-confidence (thus the choice of "overconfidence") is more telling of the self-enhancing bias that I wish to introduce in the model.

there is little upside to the reputational risk the agent faces: investing introduces risk in future compensation, and the principal's beliefs about the agent's ability are not expected to deviate, on average, from their common prior. An overconfident agent, on the other hand, expects the principal to update her beliefs about his ability upwards more often than not: according to his beliefs, the principal holds overly pessimistic prior beliefs. So even though a risk-averse agent will generally shun investment because of the reputational risk he bears in terms of future compensation, an overconfident one expects investment to bring, on average, positive news about his ability and thus higher future average compensation. As a consequence, agent overconfidence alleviates the incentive problem arising from risk aversion in a repeated investment-decision setting.

Career concerns were initially studied within the framework of moral hazard. Holmström (1982) showed that career concerns alleviate the moral hazard problem: the implicit incentives in future remuneration are a partial substitute for explicit incentives when these are not available. Because of career concerns, an agent is willing to take a costly action in early stages (e.g. exert a high level of effort) in an attempt to increase the market's perception of his ability and with it his future compensation. Gibbons and Murphy (1992) allow for explicit incentives in such a setting, and show that the implicit incentives permit the principal to lower the (costly) explicit incentives in early stages. They also review empirical evidence which suggests that young executives do receive lower-powered incentives than executives who are close to retirement. Allowing for overconfidence in such a setting would affect contracting through its effect on both moral hazard and on career concerns *per se*. The effects of overconfidence in a moral-hazard setting have been studied by Adrian and Westerfield (2007), de la Rosa (2007), and Santos-Pinto (2007); in this paper we will focus on the effects of overconfidence in a career-concerns setting *without* moral hazard.

This paper is related to the recent strand of literature which studies the effects of agent overconfidence in different principal-agent settings. The three papers cited above study the effects of overconfidence in a moral-hazard setting; Goel and Thakor (2007) and Santos-Pinto (2008) in tournaments; Gervais and Goldstein (2007) in a model of teams with complementarities; Gervais, Heaton, and Odean (2003) in a model of information acquisition. This paper is, to my knowledge, the first to analyze the effects of overconfidence on contracting in the presence of career concerns.

Section 2 introduces a simple two-period investment-decision model. Several principals compete to hire an agent by making contract offers, which consist of a payment schedule and an investment rule which maps the realization of an observable signal to the decision "invest" or "do not invest." The agent is paid at the beginning of each period, so his payment cannot be contingent on same-period outcomes; it will likely depend, however, on past performance. After the agent is paid, the participants observe a (public) signal that is correlated with the revenue distribution of a given investment project. This signal is verifiable, and thus contractible.[3] The revenue distribution also depends on the agent's ability, which is unknown to both principal and agent.

Section 3 recursively solves for the equilibrium in a setting in which neither agent nor principal can bind themselves to the agency relationship across periods. Principals offer a new fixed-salary contract at the beginning of each period. The agent thus bears all of the reputational risk implicit in learning about ability following first-period investment. In the second period the agent no longer has any career concerns, so that the principal will implement the investment rule she believes to be optimal. Payment to the agent at the beginning of the period is a sunk cost from the principal's point of view, so she simply invests whenever expected profits from the project are non-negative. The agent's second-period compensation is thus his expected productivity according to the principal's (posterior) beliefs, taking into account the principal's efficient investment rule. The expectation about the agent's productivity in the second period depends on first-period outcomes, so the agent takes the reputational risk of first-period investment into account. Given that the agent receives his first-period payment before investment decisions are made and that he is not bound to remain in the agency relationship in the following period, the equilibrium investment rule must maximize the agent's *ex-ante* expectation of second-period utility. Absent agent risk aversion, the first-period investment rule would maximize financial returns for the principal (like the second-period investment rule) plus the agent's perception of benefits from learning about ability that investment provides (through its effect on second-period remuneration). The benefits from learning about ability are the gains from optimally revising the second-period investment rule after updating beliefs about agent ability. Because the agent is risk averse, however, the reputational risk of first-period investment associated with second-period remuneration is costly to him, so with risk aversion there is less first-period investment than socially optimal. At the extreme, if the cost of investment in terms of reputational risk to the agent is greater than the expected benefit from learning, there will be no investment in the first period independent of how high expected revenues may be after receiving a particularly good signal. An overconfident agent overestimates the benefits from learning about ability, so agent overconfidence reduces the agency cost arising from risk aversion in a career-concerns setting.

Section 4 discusses the effects of overconfidence when both agent and principal can bind themselves to the agency relationship across periods. Because the principal can commit to remain in the

[3] The setup in Holmström and Ricart i Costa (1986) served as a blueprint for the setup in this paper. The most notable difference between the two is that we will not allow the agent to withhold information from the principal. In their model, the agent is given *de facto* veto power which he exercises by withholding information. Such extension implies that the equilibrium contract might include a bonus for investment to the agent, but does not otherwise affect the results and would rather cloud the intuition of our model.

agency relationship, she is able to fully insure the agent against reputational risk. In a common-priors setting, the agent would in fact be fully insured in equilibrium: he would receive the same payment in both periods, independent of whether investment is undertaken or not and independent of outcome following first-period investment. The investment rule that is implemented by the principal in equilibrium maximizes financial returns to investing in the second period, and the sum of financial and learning returns to investing in the first period. Therefore, there is no agency cost arising from career concerns in this case, since full insurance makes them innocuous.

When allowing for disagreement, recall that an overconfident agent overestimates the returns to learning following first-period investment. For this reason, he disagrees with the principal regarding the distribution of outcomes conditional on investment: an overconfident agent expects to see higher project revenue following investment, on average, than the principal does. The agent's second-period payment will thus be contingent on first-period outcome; principal and agent will optimally wager on outcomes because of their disagreement. Both principal and agent find it beneficial to accept a lower payment following outcome realizations she/he deems relatively unlikely in return for higher payment following outcome realizations she/he deems relatively more likely.[4] As a consequence, the first-period investment rule is distorted from the principal's perceived optimal investment rule. Because the agent's well being is directly affected by the investment rule, de la Rosa (2006) shows that he is willing to "pay" the principal for control—for them to set a rule that is more in line with his perception of the benefits of first-period investment. Also, since an overconfident agent overestimates his expected second-period utility when signing the contract, he will receive higher first-period payment compared to the common-priors case because of intertemporal-insurance motives.

Section 5 allows for the agent to quit the agency relationship between periods. This introduces an additional constraint: the agent's second-period remuneration is bounded below by the principals' (posterior) expectation of agent productivity. In a common-priors setting, Holmström and Ricart i Costa (1986) show that the agent's first-period salary must be lower than his expected first-period productivity. This stems from the fact that in providing insurance the principal will pay him more than his expected productivity following unfavorable first-period outcome realizations, but cannot pay him less than his expected productivity following favorable realizations. As discussed

[4] Maximilian Rüger, my discussant at the Incentives in Economics BGPE Conference, noted that a risk-averse agent dislikes mean-preserving spreads, and that from the principal's point of view an overconfident agent disliked them less. This perspective is correct and the reader can find it helpful in interpreting the result, but it obscures the mechanism behind the result. Pareto-optimal wagering between two disagreeing parties actually allows each to receive a mean-*enhancing* spread according to their respective beliefs. So an overconfident agent is, in fact, accepting a riskier contract because it offers a higher expected value.

before, agent overconfidence alleviates the problems arising from career concerns for a risk-averse agent because he deems the benefits from learning to be high. In terms of second-period salary, higher agent overconfidence implies higher salary volatility. The effect of agent overconfidence on first-period remuneration is ambiguous in this case. An overconfident agent expects high remuneration in the second period after the principal updates her beliefs (which are overly pessimistic from the agent's point of view). Because of the intertemporal-insurance motive mentioned before, he will tend to prefer higher first-period salary. Because of the wagering effect, however, he is willing to trade lower first-period salary for higher second-period salaries following good outcome realizations that the agent believes are more likely than the principal does.

Section 6 concludes and discusses the results of the model in terms of the ongoing debate regarding executive compensation. Among other things, I argue that golden parachutes might be excessive if they are set by doing calculations based on common-prior models and that although equilibrium requires that some measure of control is passed on to the agent, full delegation might be problematic in a world with disagreement.

2 Model Setup

In our model there are two periods $t = 1, 2$ which are technologically identical and independent. Several principals compete to contract with the agent by making simultaneous contract offers, so that in equilibrium the agent's perceived expected utility is maximized subject to zero expected profits for the contracting principal. We will allow for different commitment horizons to the agency relationship. If the agent accepts a contract offer, at the beginning of each period he observes the signal $s_t \in S_t \subseteq \mathbb{R}$, which is public, verifiable, and correlated with (potential) net payoff from some given investment project in that period. The signal s_t is random, and has cumulative distribution function G. Net payoff from investment also depends on the realization of $\theta_t \in \Theta_t \subseteq \mathbb{R}$, a random variable independent of s_t whose distribution depends on the agent's ability. Specifically, net payoff from investment, q_t, is

$$q_t = s_t + \theta_t.$$

As in Holmström (1982), both principal and agent are uncertain about the agent's ability; there is no private information in this model. Deviating from most of the current literature on agency theory, we will allow for principals and agent to hold heterogeneous prior beliefs regarding the agent's ability. Furthermore, both principals and agent are aware of their disagreement (more on this below). Let F_t^P denote the cumulative distribution function of θ_t according to the principals' beliefs at time t. F_1^P depends solely on the principals' prior beliefs, while F_2^P incorporates the new information conveyed by θ_1 following first-period investment if it is undertaken. The agent's beliefs are denoted by a superscript A; according to his beliefs, θ_t has c.d.f. F_t^A. Principals and agent "agree to disagree" in their prior assessment regarding agent ability, and they both update their beliefs according to Bayes's rule after observing first-period outcomes.

The assumption that principals share the same beliefs while at the same time openly disagreeing with the agent may seem peculiar. If we were to allow for principals to disagree, the competition between them would resemble a public- or private-value auction depending on whether principals' beliefs are publicly or privately known—see de la Rosa (2007)—but the results and message of our model would not be affected. The idea that principal and agent do not update their prior beliefs after the communication implicit in the contracting game may raise even more eyebrows. For our purposes, the only crucial assumption to hold is that updating is not complete, which, as noted by Morris (1995), seems consistent with everyday observation. Some theoretical models of behavior give plausible explanations for such imperfect updating. Eyster and Rabin (2005) note that if players in a private-information game fail to interpret other players' actions as conveyors of private information, asymmetric posterior beliefs will survive even in fully-separating equilibria of the game (in our case, principals and agent could have played a previous game in which beliefs are shared, and the agent has some private information about ability). Gervais and Odean (2001) explore the possibility that agents do not update their beliefs in Bayesian fashion, so that successful agents develop overconfidence because they overweight the informative content of successful outcomes and underweight the content of failures (once again, previous rounds of observation under these assumptions would lead to principals and agent disagreeing about the agent's ability). For further motivation, consider the following thought experiment. The agent is a "new guy," so there are no previous observations of his actual ability. The principals hold as prior beliefs the average distribution of productivity, and they know that new guys tend to be overly optimistic about their ability. The agent knows very little about his own ability himself, but is overconfident. He might be aware of overconfidence, but as the psychology literature surveyed by Taylor and Brown (1988) suggests, does not completely correct for it. When principal and agent meet, the principal is not surprised to learn that the agent is overconfident, and the agent is not surprised to find out that the principal is not optimistic, since "everyone" tends to be overconfident. Principal and agent learn nothing from each other's beliefs in this case and there is no updating.

The principal is assumed to be risk neutral, and the agent risk averse. For notational simplicity, I assume that there is no intertemporal discounting, that both the principal's and the agent's utility are additively separable across periods, and that the agent cannot borrow or lend so that he fully consumes his salary in each period. The agent's two-period utility can thus be written as

$$u(w_1, w_2) = u(w_1) + u(w_2).$$

The principal's utility in period t is revenues from investment net of any payments made to the agent:

$$q_t - w_t.$$

Following Holmström and Ricart i Costa (1986), I assume that payment to the agent is made at the beginning of each period. In this setting, a general contract is characterized by a pair $(\mathbf{w}, \alpha)$ where $\mathbf{w} = (w_1, w_2(s_1, \theta_1))$ specifies the salaries paid to the agent, and $\alpha = (\alpha_1(s_1), \alpha_2(s_1, \theta_1, s_2))$ specifies the investment rule—either invest in the project or not—$\alpha_t \in \{1, 0\}$ that will be followed in each period. The investment rule is assumed to be enforceable.

3 Single-Period Contracts

Consider the case in which neither the agent nor the principal can bind themselves to the agency relationship for more than one period at a time. In such a setting, the agent is always paid his expected productivity at the beginning of each period, and thus receives all the benefits—and bears all the costs—from learning about ability when investment is undertaken in the first period. In this setting we can isolate the effects of overconfidence on the career-concerns problem.[5] We can find the equilibrium recursively, working backwards from the second period.

3.1 Second-Period Equilibrium Contract

In the second period the agent no longer has career concerns, given that his payment w_2 is received at the beginning of the period and is thus independent of that period's investment decision and outcome. The equilibrium contract maximizes the agent's perceived second-period expected utility—so it maximizes w_2—subject to non-negative expected profits for the principal. This constraint can be written as

$$\int_{\{s_2:\alpha_2(s_1,\theta_1,s_2)=1\}} \int_{\Theta_2} (s_2 + \theta_2)\, dF_2^P dG - w_2 \geq 0,$$

where s_1 and θ_1 are the actual realizations of these variables and F_2^P incorporates the information about agent ability conveyed by the realization of θ_1 if investment was undertaken in the first period

[5] Absent career concerns, overconfidence affects the equilibrium contract only when the agent's remuneration can be made contingent on same-period outcomes following investment. Restricting attention to single-period contracts, the outcome of the investment project affects contracting only insofar as investing provides information about the agent's ability (about the mean of θ), so studying single-period contracts allows us to isolate the effects of overconfidence through this channel alone.

(if no investment is undertaken, since s_t and θ_t are independent, $F_2^P = F_1^P$—the principals do not update their prior beliefs). This constraint clearly binds in equilibrium, so we have

$$w_2 = \int_{\{s_2:\alpha_2(s_1,\theta_1,s_2)=1\}} \left(s_2 + \mu_2^P(\theta_1)\right) dG,$$

where $\mu_2^P(\theta_1) \equiv \int_{\Theta_2} \theta_2 dF_2^P$, the mean of θ_2 according to the principals' (posterior) beliefs. Note that if no investment is made in the first period, $\mu_2^P |_{\alpha_1(s_1)=0} = \mu_1^P$, where μ_1^P denotes the mean of θ_1 according to the principal's prior beliefs: $\mu_1^P \equiv \int_{\Theta_1} \theta_1 dF_1^P$. In what follows, if there is no first-period investment, "$\mu_2^P(\theta_1)$" should be interpreted as μ_1^P.

Not surprisingly, the equilibrium is characterized by the agent receiving the full expected productivity and by an investment rule $\alpha_2^*(s_1,\theta_1,s_2)$ which maximizes it. The equilibrium investment rule is thus characterized by

$$\alpha_2^*(s_1,\theta_1,s_2) \in \arg\max_{\alpha_2} \int_{\{s_2:\alpha_2(s_1,\theta_1,s_2)=1\}} \left(s_2 + \mu_2^P(\theta_1)\right) dG.$$

Given that the principal can guarantee zero investment payoff by choosing not to invest, the equilibrium investment rule is the optimal investment rule according to the principal's beliefs: invest if and only if expected profits from investing are non-negative. That is, $\alpha_2^* = 1$ if and only if $s_2 + \mu_2^P(\theta_1) \geq 0$. Since q_2 is monotonic in s_2, the equilibrium investment rule can be expressed as a "hurdle rate" $s_2^*\left(\mu_2^P\right)$, so that investment is undertaken if and only if $s_2 \geq s_2^*\left(\mu_2^P\right)$. This hurdle rate is implicitly defined by

$$s_2^*\left(\mu_2^P\right) + \mu_2^P(\theta_1) = 0.$$

The following proposition summarizes these results.

Proposition 1 *If the agent is paid at the beginning of each period and only single-period contracts are feasible, the second-period contract is characterized by a hurdle rate $s_2^*\left(\mu_2^P\right)$—so that investment is undertaken if and only if $s_2 \geq s_2^*\left(\mu_2^P\right)$—implicitly defined by*

$$s_2^*\left(\mu_2^P\right) + \mu_2^P(\theta_1) = 0,$$

and by payment w_2 to the agent satisfying

$$w_2\left(\mu_2^P(\theta_1)\right) = \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} \left(s_2 + \mu_2^P(\theta_1)\right) dG,$$

where $S_2^*\left(\mu_2^P(\theta_1)\right) \equiv \left\{s_2 : s_2 \geq s_2^*\left(\mu_2^P(\theta_1)\right)\right\}$ and $\mu_2^P(\theta_1)$ denotes the posterior expected value of θ_2 according to the principal's beliefs after first-period outcomes have been observed.

Given that the principal receives the full marginal benefit from investing after paying w_2 to the agent at the beginning of the second period, it is intuitive that the equilibrium investment rule will be the optimal investment rule according to the principal's beliefs at the time of contracting.

3.2 First-Period Equilibrium Contract

In the first period, the equilibrium contract maximizes the agent's two-period expected utility (according to his beliefs), subject to non-negative profits for the principal during the first period (according to her beliefs), taking into account the second-period equilibrium contract characterized in Proposition 1. That is, the first-period equilibrium contract is the solution to

$$\max_{w_1,\alpha_1} u(w_1) + \int_{\Theta_1} u(w_2)\, dF_1^A$$

subject to

$$w_2\left(\mu_2^P\right) = \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} \left(s_2 + \mu_2^P(\theta_1)\right) dG, \text{ and}$$

$$w_1 \leq \int_{\{s_1:\alpha_1(s_1)=1\}} \int_{\Theta_1} (s_1+\theta_1)\, dF_1^P dG.$$

Note that the agent evaluates expected utility according to his (prior) beliefs, while it is the principals' beliefs that are relevant when evaluating the non-negative profits condition.

As in the second period, the non-negative expected profits constraint binds in equilibrium, so we can write

$$w_1 = \int_{\{s_1:\alpha_1(s_1)=1\}} \int_{\Theta_1} (s_1+\theta_1)\, dF_1^P dG.$$

The maximization problem is therefore reduced to choosing the first-period investment rule that maximizes the agent's perceived lifetime expected utility. Note that if investment is undertaken during the first period, then the agent's second-period salary depends on how the realization of θ_1 affects the principal's posterior beliefs regarding the distribution of θ_2.

Given that s_1 and θ_1 are independently distributed, and that the two periods are technologically independent, we can again express the equilibrium investment rule $\alpha_1(s_1)$ as a hurdle rate s_1^*, so that investment is undertaken in the first period if and only if $s_1 \geq s_1^*$. Let $S_1^* \equiv \{s_1 : s_1 \geq s_1^*\}$. We can rewrite the problem as

$$\max_{s_1^*} u\left(\int_{S_1^*}\int_{\Theta_1} (s_1+\theta_1)\, dF_1^P dG\right) + G(s_1^*)\, u\left(w_2\left(\mu_1^P\right)\right)$$
$$+ (1-G(s_1^*)) \int_{\Theta_1} u\left(w_2\left(\mu_2^P(\theta_1)\right)\right) dF_1^A.$$

Given some first-period investment rule, the agent judges the likelihood of each realization of θ_1 according to his prior beliefs and takes into account how the principal updates her beliefs after observing θ_1. The agent evaluates expected second-period utility according to his beliefs, but incorporates the fact that w_2 depends on the *principals'* updated beliefs about his ability.

Solving for the optimal hurdle rate in the maximization problem above, we find that it is implicitly defined by

$$s_1^* + \mu_1^P + \frac{1}{u'(w_1)} \left\{ \int_{\Theta_1} u\left(w_2\left(\mu_2^P(\theta_1)\right)\right) dF_1^A - u\left(w_2\left(\mu_1^P\right)\right) \right\} = 0.$$

The following proposition summarizes this result.

Proposition 2 *If the agent is paid at the beginning of each period and only single-period contracts are feasible, the first-period contract is characterized by a hurdle rate s_1^*—so that investment is undertaken if and only if $s_1 \geq s_1^*$—implicitly defined by*

$$s_1^* + \mu_1^P + \frac{1}{u'(w_1)} \left\{ \int_{\Theta_1} u\left(w_2\left(\mu_2^P(\theta_1)\right)\right) dF_1^A - u\left(w_2\left(\mu_1^P\right)\right) \right\} = 0$$

and payment w_1 to the agent satisfying

$$w_1 = \int_{S_1^*} \left(s_1 + \mu_1^P\right) dG.$$

It is useful to note that in the case of a risk-neutral agent, the equilibrium investment rule can be written as

$$s_1^* + \mu_1^P + v^A\left(F_1^A, F_1^P\right) = 0,$$

where

$$v^A\left(F_1^A, F_1^P\right) \equiv \int_{\Theta_1} \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} \left(s_2 + \mu_2^P(\theta_1)\right) dG dF_1^A - \int_{S_2^*\left(\mu_1^P\right)} \left(s_2 + \mu_1^P\right) dG \geq 0$$

can be interpreted as the value of learning about agent ability according to the beliefs of a risk-neutral agent. Learning has positive value because it allows for the second-period investment rule $s_2^*\left(\mu_2^P(\theta_1)\right)$ to be revised optimally following the first-period realization of θ_1. Note that $w_2(\cdot)$ is a convex function, so $\int_{\Theta_1} \mu_2^P(\theta_1)\, dF_1^A \geq \mu_1^P$ implies $v^A\left(F_1^A, F_1^P\right) \geq 0$. Holmström and Ricart i Costa (1986) identify the value of learning, and show that under common priors this first-period investment rule is socially optimal: setting $s_1^* = -\mu_1 - v(F)$ maximizes expected financial and "human-capital" (or learning) returns to investment.[6]

In the case of agent overconfidence—when he holds prior beliefs regarding θ_1 that are overly optimistic relative to the principal's—under fairly weak assumptions the agent overestimates the benefits from learning relative to the principal (see appendix for sufficient conditions). Note that the principal's posterior belief about agent productivity $\mu_2^P(\theta_1)$ is a function of her prior beliefs F_1^P and of the observed realization of θ_1. An overconfident agent overestimates the likelihood of realizations of θ_1 that are consistent with his prior beliefs relative to the likelihood of those

[6] We dropped the A and P superscripts in the last expression since they are superfluous under common priors.

realizations consistent with the principals' beliefs. Because of this, the agent believes that the principal will tend to update their beliefs about the agent's average productivity upwards given investment in the first period (again, see appendix). He therefore overestimates—relative to the principal's beliefs—the learning returns to first-period investment: $v^A\left(F_1^A, F_1^P\right) \geq v^P\left(F_1^A, F_1^P\right)$.

Consider now the case of a risk-averse agent. The first thing to note is that the presence of career concerns and agent risk aversion imply that the equilibrium investment rule will be more conservative than in the case of a risk-neutral agent.[7] When only single-period contracts are feasible, the agent receives all the benefits, and bears all the costs, of learning about ability. Given that he will be paid his expected productivity in the second period, it is only his perception about the value of learning that guides the decision regarding the first-period investment rule. His attitudes towards risk, his prior beliefs about the distribution of θ_1, and the principal's prior beliefs are thus all relevant in equilibrium.

The distortion introduced by the agent's risk aversion can be so strong that investment is never undertaken in the first period. In particular, if

$$\int_{\Theta_1} u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) dF_1^A < u\left(w_2\left(\mu_1^P\right)\right)$$

given any possible hurdle rate s_1^*, the equilibrium investment rule will dictate no investment independent of the realization of s_1—even though this implies that he will receive zero salary during the first period. Given the agent's risk aversion, he might prefer to eliminate reputational risk altogether and accept a contract with no investment (or simply not accept any offer and take his outside option). This result is parallel to the observation made by Hermalin (1993) that, under single-period contracting and up-front payments to the agent, if allowed to freely choose a project among many alternatives the agent will always choose the riskiest project available, independent of the project's expected returns. In that particular setting, this allows him to minimize his reputational risk by maximizing "noise" regarding his ability.

Agent overconfidence causes the equilibrium investment rule to be more liberal, opposite to the effect of agent risk aversion (see appendix). From the agent's perspective, the cost of first-period investment in terms of reputational risk (i.e. second-period payment risk) reduces the value of learning following investment. In the presence of agent overconfidence, the agent perceives the benefits of first-period investment in terms of learning about ability to be higher than in the common-priors case, since he expects the principals to update their beliefs favorably more often than not after observing θ_1.

[7] The fact that $\frac{1}{u'(w_1)}\left\{\int_{\theta_1} u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) dF_1^A - u\left(w_2\left(\mu_1^P\right)\right)\right\} < v^A\left(F_1^A, F_1^P\right)$ follows immediately from the proof of part (a) of Proposition 3 in (Holmström and Ricart i Costa, 1986, p. 850).

4 Long-term, bilaterally binding contracts

Now consider a situation in which both principal and agent can bind themselves to the agency relationship across periods (i.e. neither participant can "quit" after the first period). The results in a single-period contracting setting discussed above point to the fact that agent overconfidence affects the equilibrium contract in the presence of career concerns through the agent's perception about the benefits of investment (in terms of learning about ability). When principal and agent can bind themselves to the agency relationship, the principal can insure the agent against second-period payment risk following investment in the first period. The agent will not be fully insured, however, if he disagrees with the principal about the likelihood of some realizations of θ_1; agent and principal will wager on those realizations.

All payments to the agent are made by the beginning of period 2, so the second-period hurdle rate is optimal in terms of maximizing financial expected returns according to the principal's beliefs, as before:

$$s_2^*\left(\mu_2^P\right) + \mu_2^P\left(\theta_1\right) = 0,$$

and the agent always reports signal s_2 in the second period.

The equilibrium contract maximizes the agent's perceived lifetime expected utility, subject to non-negative perceived lifetime expected profits for the principal. Let $\hat{s}_1$ denote the equilibrium first-period hurdle rate, and $\hat{S}_1 = \{s_1 : s_1 \geq \hat{s}_1\}$. The equilibrium contract solves:

$$\max_{w_1, w_2\left(\mu_2^P(\theta_1)\right), \hat{s}_1} u\left(w_1\right) + \int_{\Theta_1} u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) dF_1^A$$

subject to

$$w_1 + \int_{\Theta_1} w_2\left(\mu_2^P\left(\theta_1\right)\right) dF_1^P \leq \int_{\hat{S}_1}\left(s_1 + \mu_1^P\right) dG + \int_{S_2^*\left(\mu_2^P(\theta_1)\right)}\left(s_2 + \int_{\Theta_1} \mu_2^P\left(\theta_1\right) dF_1^P\right) dG.$$

The equilibrium contract solves this maximization problem; it is characterized in the following proposition.

Proposition 3 *If the agent is paid at the beginning of each period and bilaterally binding contracts are feasible, the equilibrium contract is characterized by first-period hurdle rate $\hat{s}_1$ implicitly defined by*

$$\hat{s}_1 + \mu_1^P + \left\{v^P\left(F_1^A, F_1^P\right) - \left[\int_{\Theta_1} w_2\left(\mu_2^P\left(\theta_1\right)\right) dF_1^P - w_2\left(\mu_1^P\right)\right]\right\} + \frac{1}{u'\left(w_1\right)}\left\{\int_{\Theta_1} u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) dF_1^A - u\left(w_2\left(\mu_1^P\right)\right)\right\} = 0,$$

second-period hurdle rate $s_2^*\left(\mu_2^P\right)$ implicitly defined by

$$s_2^*\left(\mu_2^P\right)+\mu_2^P\left(\theta_1\right)=0,$$

and, if beliefs can be characterized by probability density functions f_1^A and f_1^P, payments w_1 and $w_2\left(\mu_2^P\left(\theta_1\right)\right)$ to the agent such that

$$u'\left(w_1\right)=u'\left(w_2\left(\mu_1^P\right)\right)=u'\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right)\frac{f_1^A\left(\theta_1\right)}{f_1^P\left(\theta_1\right)}\quad\forall\theta_1$$

and

$$w_1+\int_{\Theta_1}w_2\left(\mu_2^P\left(\theta_1\right)\right)dF_1^P=\int_{\hat{S}_1}\left(s_1+\mu_1^P\right)dG+\int_{S_2^*\left(\mu_2^P\left(\theta_1\right)\right)}\left(s_2+\int_{\Theta_1}\mu_2^P\left(\theta_1\right)dF_1^P\right)dG.$$

If principal and agent hold the same prior beliefs regarding the distribution of θ_1, then the equilibrium contract is very simple: the agent is fully insured, so that $w_1=w_2$ (and thus is indifferent between investment rules), and the hurdle rate is the one that the principal deems socially optimal: $s_1^*+\mu_1+v\left(\mu_1\right)=0$ —it maximizes both financial and human-capital returns to investment.

Allowing for heterogeneous beliefs, $w_2\left(\mu_2^P\left(\theta_1\right)\right)$ is not constant because principal and agent wager on some realizations of θ_1. Other than this *ex-ante* Pareto-optimal wagering, the agent is receiving as much insurance as possible; his marginal utility of consumption is constant both across periods and events. The investment rule is distorted by two factors.[8] First, the term

$$\left\{v^P\left(F_1^A,F_1^P\right)-\left[\int_{\Theta_1}w_2\left(\mu_2^P\left(\theta_1\right)\right)dF_1^P-w_2\left(\mu_1^P\right)\right]\right\}$$

reflects the value of learning about the agent's ability for the principal, net of the difference between expected payment to the agent conditional on first-period investment and payment to the agent conditional on no investment. The sign of $\left(\int_{\Theta_1}w_2\left(\mu_2^P\left(\theta_1\right)\right)dF_1^P-w_2\left(\mu_1^P\right)\right)$ is ambiguous in the general case. When the principal transfers a positive stake in the expected gains from learning to the agent, which would be the case if $\int_{\Theta_1}w_2\left(\mu_2^P\left(\theta_1\right)\right)dF_1^P\left(\theta_1\right)-w_2\left(\mu_1^P\right)>0$, the marginal benefit to the principal from first-period investment is reduced. The opposite is true if the principal transfers a negative stake to the agent. Second, if $\int_{\Theta_1}u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right)dF_1^A-u\left(w_2\left(\mu_1^P\right)\right)>0$ in equilibrium, then the agent believes he is strictly better off following a decision to invest in the first period than if no investment is undertaken, in which case he will be willing to give up some of his expected payment in return for a more liberal investment rule.

Disagreement is likely to cause the equilibrium investment rule to be more liberal than in the case of common priors (see discussion in the appendix). First-period investment allows principal and agent to wager on the realization of θ_1, so the value of first-period investment is deemed larger by both than in the case of common priors.

[8]See de la Rosa (2007) for a more elaborate exposition of this result.

5 Long-term, unilaterally binding contracts

Finally, consider the setting in which the agent is allowed to "quit" the agency relationship, but cannot be "fired" by the principal—the setting of interest for Holmström and Ricart i Costa (1986). This adds one more constraint to the maximization problem to which the equilibrium contract is a solution: second-period payment to the agent can never fall below the market expectation of his productivity. Given that the agent can quit after the first period and work for another principal during the second, he will never receive less than his second-period expected productivity (evaluated according to the principals' beliefs). The equilibrium contract thus solves the following problem:

$$\max_{w_1, w_2\left(\mu_2^P(\theta_1)\right), \hat{s}_1} u\left(w_1\right) + \int_{\Theta_1} u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) dF_1^P$$

subject to

$$w_1 + \int_{\Theta_1} w_2\left(\mu_2^P\left(\theta_1\right)\right) dF_1^P \leq \int_{\hat{S}_1}\left(s_1 + \mu_1^P\right) dG + \int_{S_2^*\left(\mu_2^P(\theta_1)\right)}\left(s_2 + \int_{\Theta_1} \mu_2^P\left(\theta_1\right) dF_1^P\right) dG$$

and

$$w_2\left(\mu_2^P\left(\theta_1\right)\right) \geq \int_{S_2^*\left(\mu_2^P(\theta_1)\right)}\left(s_2 + \mu_2^P\left(\theta_1\right)\right) dG \ \forall \theta_1.$$

It maximizes the agent's perceived lifetime expected utility subject to non-negative expected profits for the principal and the "no-quitting" constraint. This last constraint simply places a lower bound on the agent's second-period salary.

In a common-priors setting, as shown by Holmström and Ricart i Costa (1986), this unambiguously implies that the agent will be subject to a higher amount of risk in terms of remuneration than when bilaterally binding contracts are feasible[9]. Because the agent's second-period salary is never lower than his expected productivity and is actually higher for some bad realizations, on average the contracting principal pays the agent more than his expected productivity during the second period. For this reason, and because she cannot sustain negative lifetime expected profits in equilibrium, she pays the agent less than her expectation of agent productivity during the first period (using our notation and dropping the superscripts, $w_1 < \mu_1$ and $\int_{\Theta_1} w_2\left(\mu_2\left(\theta_1\right)\right) dF_1 > \int_{\Theta_1} \int_{S_2^*(\mu_2(\theta_1))}\left(s_2 + \mu_2\left(\theta_1\right)\right) dG dF_1$).

The latter result remains when we allow for heterogeneous beliefs. Compared to the bilaterally-binding-contracts setting we studied in Section 4 above, if the no-quitting constraint binds for some realizations of θ_1, the principal must pay less to the agent in the first period. It is also the case that she will pay the agent less in the event of no first-period investment and for those realizations

[9]Recall that the long-term bilaterally-binding contract under common priors fully insures the agent (i.e. $w_1 = w_2\left(\mu_2\left(\theta_1\right)\right) \forall \theta_1$).

of $\theta_1$under which the no-quitting constraint is slack. The possibility for the agent to accept outside offers implies

$$w_2\left(\mu_2^P\left(\theta_1\right)\right) \geq \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} \left(s_2 + \mu_2^P\left(\theta_1\right)\right) dG \; \forall \theta_1.$$

Recall that absent this constraint, the equilibrium contract under heterogeneous beliefs would satisfy

$$u'\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) \frac{f_1^A\left(\theta_1\right)}{f_1^P\left(\theta_1\right)} = \kappa \; \forall \theta_1$$

for some constant κ. Given that the agent now has the possibility to quit, it follows that

$$u'\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) \frac{f_1^A\left(\theta_1\right)}{f_1^P\left(\theta_1\right)}$$

is necessarily lower for those realizations of θ_1 under which the quitting constraint binds. Just as in the common-priors case, this implies that the agent's possibility to quit hinders the extent to which the principal can offer him intertemporal insurance. In the case of heterogeneous beliefs, the fact that the agent can quit the agency relationship after the first period implies that he will bear more risk given some realizations of θ_1 (for those under which the no-quitting constraint is binding), *but* it also limits the extent to which he can wager against the principal compared to the bilaterally-binding-contracts setting.

Proposition 4 *If the agent is paid at the beginning of each period and only the principal can commit to remain in the agency relationship, the equilibrium contract is characterized by first-period hurdle rate $\hat{s}_1$ implicitly defined by*

$$\hat{s}_1 + \mu_1^P + \left\{ v^P\left(F_1^A, F_1^P\right) - \left[\int_{\Theta_1} w_2\left(\mu_2^P\left(\theta_1\right)\right) dF_1^P - w_2\left(\mu_1^P\right) \right] \right\} + \frac{1}{u'\left(w_1\right)} \left\{ \int_{\Theta_1} u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) dF_1^A - u\left(w_2\left(\mu_1^P\right)\right) \right\} = 0,$$

second-period hurdle rate $s_2^*\left(\mu_2^P\right)$ implicitly defined by

$$s_2^*\left(\mu_2^P\right) + \mu_2^P\left(\theta_1\right) = 0,$$

and, if beliefs can be characterized by probability density functions f_1^A and f_1^P, and payments w_1 and $w_2\left(\mu_2^P\left(\theta_1\right)\right)$ to the agent such that

$$w_2\left(\mu_2^P\left(\theta_1\right)\right) = \begin{cases} \hat{w}_2\left(\mu_2^P\left(\theta_1\right)\right) \; \textit{if } \hat{w}_2\left(\mu_2^P\left(\theta_1\right)\right) \geq \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} \left(s_2 + \mu_2^P\left(\theta_1\right)\right) dG \\ \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} \left(s_2 + \mu_2^P\left(\theta_1\right)\right) dG \; \textit{otherwise,} \end{cases}$$

where $\hat{w}_2\left(\mu_2^P\left(\theta_1\right)\right)$ and w_1 are implicitly defined by

$$u'\left(w_1\right) = u'\left(\hat{w}_2\left(\mu_1^P\right)\right) = u'\left(\hat{w}_2\left(\mu_2^P\left(\theta_1\right)\right)\right) \frac{f_1^A\left(\theta_1\right)}{f_1^P\left(\theta_1\right)}$$

and

$$w_1 + \int_{\Theta_1} w_2\left(\mu_2^P(\theta_1)\right) dF_1^P = \int_{\hat{S}_1} \left(s_1 + \mu_1^P\right) dG + \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} \left(s_2 + \int_{\Theta_1} \mu_2^P(\theta_1)\, dF_1^P\right) dG.$$

It is still true that under weak assumptions an overconfident agent overestimates the value of learning relative to the principals' beliefs, and that, as a consequence, the equilibrium investment rule is more liberal.

An interesting question is regarding the effect of overconfidence on the level of pay. We know that the principal will, just as in the case of common priors, meet outside offers. Under other realizations of θ_1, the principal will pay the agent more than his expected productivity for two reasons. First, as under common priors, after particularly bad realizations of θ_1 the principal may pay more to the agent because of an insurance motive. Second, and confounded with the first, optimal insurance under heterogeneous beliefs is not a fixed wage but rather an optimal wagering schedule under which the agent receives higher pay after a realization of θ_1 that he deemed relatively more likely. What, then, can we say about the level of first-period pay? Given that the agent enjoys intertemporal insurance, and that an overconfident agent overestimates his expected second-period pay relative to the principals' beliefs, we should expect him to receive a higher initial pay. Accepting lower initial pay, however, would allow him to wager more strongly with the principal. Since competition among principals implies zero expected profits according to their beliefs, more wagering necessarily implies higher expected payment to the agent according to *his* beliefs. Through this channel, then, we should expect an overconfident agent to receive lower initial pay. The overall effect of overconfidence on first-period pay is thus ambiguous.

6 Conclusion

The setting in which we allow only the agent to quit the agency relationship seems to be the most realistic if we are to study incentive compensation schemes. Managers and other employees are prevented, by law, to bind themselves unconditionally to an employer. Firms, on the other hand, tend to offer very costly severance packages to their executives (usually referred to as a "golden parachute"), and law requires that every employee receive adequate compensation if they are fired without just cause, so that the firm is *de facto* binding itself to the agency relationship under many outcome realizations.

We can interpret some of the results of the models using the language of the ongoing debate regarding executive compensation. Under common priors, when the agent has the possibility to quit the agency relationship the principal simply "meets outside offers," which can be reminiscent of practices in both the corporate arena and in academia. Furthermore, the principal may provide the agent with a "golden parachute" by committing to give higher compensation than the agent's expected productivity after unfavorable first-period outcomes. Under heterogeneous beliefs, the agent gets compensation above his expected productivity not only following very bad realizations (because of insurance motives), but also following some particularly good realizations (because of wagering motives). Extraordinarily high executive pay is repeatedly discussed in the open arena (a news search for "executive pay" is thickly populated with discussions about excessive pay relative to performance; take for example Dobrzynski (1996) and Deutsch (2008)); optimal contracting with a "lucky" overconfident manager could be part of the explanation of the cases that are used as an example in these discussions.[10] If heterogeneous beliefs are relevant in setting executive compensation contracts, then we should expect to observe exceedingly high and variable salaries following good results. The second thing to note is that the model suggests that managers should receive more of a silver rather than a golden parachute: given that the manager receives pay above his expected productivity for some favorable realizations, he should only be insured against very unfavorable realizations, and the level of pay then should be lower than in the alternative common-priors setting.

Finally, there are some lessons to be drawn regarding delegation decisions. Under common priors, given that the only difference between principal and agent is regarding risk aversion, aligning incentives (e.g. giving a stock-option package to the agent á la Gervais, Heaton, and Odean (2003)) and then delegating investment decisions is optimal. Under heterogeneous beliefs, delegation can be very costly for the principal; an overconfident agent may pick investment projects based on beliefs about outcome distribution that are very far removed from the principal's beliefs. David Viniar, CFO of Goldman Sachs, is frequently quoted as saying "We were seeing things that were 25-standard deviation moves, several days in a row" (see, e.g. Larsen (2007)). The fact that their asset valuation models calculated the recent sub-prime mortgage crisis as a near impossibility, and that management went along with those estimates, is a telling anecdote. I venture a guess that, had Goldman Sachs's investors and owners been consulted a year or two before this quote, many would not have placed the likelihood of those events as 25 standard deviations away. There are gains to hiring overconfident managers, but shareholders and boards need to keep this in mind when deciding how much of the decision power to delegate.

[10] Studying whether it is in fact only the lucky ones, opposed to what many critics of excessive executive pay argue, might be enlightening. Note that one should not reduce the definition of "lucky" to high profits, and include any measure that affects pay.

A Appendix

In order to provide proofs of some of the statements in the text, we need to be more specific about the definition of overconfidence and assumptions regarding the underlying distributions.

Definition 1 (FOSD) *The distribution* $F(\cdot)$ first-order stochastically dominates $G(\cdot)$ *if, for every non-decreasing function* $u : \mathbb{R} \rightarrow \mathbb{R}$*, we have*

$$\int u(x)\, dF(x) \geq \int u(x)\, dG(x).$$

(Mas-Colell, Whinston, and Green, 1995, Definition 6.D.1).

Definition 2 (overconfidence) *We will say that the agent is* overconfident *(about his ability) relative to the principals if* F_1^A *first-order stochastically dominates* F_1^P*.*

By defining overconfidence in this way, we ensure that the agent's expectation about own ability will be higher than the principals' (i.e. that $\int_{\Theta_1} \theta_1 dF_1^A = \mu_1^A > \mu_1^P$).[11]

Assumption 1 (monotonicity) *We will assume that the principals' posterior expectation regarding agent ability* ($\mu_2^P(\theta_1) \equiv \int_{\theta_2} \theta_2 dF_2^P$) *is monotonically increasing in the first-period realization of ability.*

This is a very weak assumption to place on updating. It simply states that better ability realizations are good news in terms of expected future ability. Indeed, when considering many examples of conjugate families of distributions we find that this is the case:

- If θ_t is assumed to be normally distributed with unknown mean μ_θ and known precision h_θ, and the principals' prior belief about μ_θ is that it is normally distributed with mean μ_1^P and precision h_1^P, then

$$\mu_2^P(\theta_1) = \delta_1 \theta_1 + (1 - \delta_1)\mu_1,$$

[11] Note that our analysis could be extended to cover another type of overconfidence, defined as overestimating the precision of prior beliefs. We would then say that the agent is relatively overconfident in terms of precision if F_1^A second-order stochastically dominates F_1^P. This would require more stringent assumptions in order to reach general conclusions and the interpretation in terms of executive compensation would be slightly different; see de la Rosa (2006) for a one-period example of this type of overconfidence with normally-distributed priors. In that case, the agent will receive high payment for outcomes close to the average, but lower around the tails. In the current model and when the agent can quit, this would mean lower payment for very bad outcomes, matching outside offers after very good outcomes, and "excessive" compensation for results around the mean relative to the common-priors benchmark.

where $\delta_1 = \frac{h_\theta}{h_1^P + h_\theta}$.[12]

- If θ_t is assumed to follow a Poisson distribution with unknown mean μ_θ and the principals' prior belief about μ_θ is that it is distributed gamma with shape α^P and scale β^P so that $\mu_1^P = \frac{\alpha^P}{\beta^P}$, then

$$\mu_2^P(\theta_1) = \frac{\alpha^P + \theta_1}{\beta + 1}.$$

- If θ_t is assumed to be distributed negative binomial with unknown parameter p and known parameter r, and the principals' prior belief about p is that it is distributed beta with shape parameters α^P and β^P so that $\mu_1^P = \frac{r\beta^P}{\alpha^P}$, then

$$\mu_2^P(\theta_1) = \frac{r\left(\beta^P + \theta_1\right)}{\alpha^P + r}.$$

- If θ_t is assumed to be distributed exponentially with unknown rate parameter w, and the principals' prior belief about w is that it is distributed gamma with with shape α^P and scale β^P so that $\mu_1^P = \frac{\beta^P}{\alpha^P}$ ($\mu_\theta = \frac{1}{w}$ in this case), then

$$\mu_2^P(\theta_1) = \frac{\beta^P + \theta_1}{\alpha^P + 1}.$$

- If θ_t is assumed to be distributed Bernoulli with unknown probability of success μ_θ, and the principals' prior belief about μ_θ is that it is distributed beta with shape parameters α^P and β^P so that $\mu_1^P = \frac{\alpha^P}{\alpha^P + \beta^P}$, then

$$\mu_2^P(\theta_1) = \frac{\alpha^P + \theta_1}{\alpha^P + \beta^P + 1}.$$

- Finally, if θ_t is assumed to be distributed on the interval $(0, 2w)$ where w is unknown, and the principals' prior belief about w is that it is distributed Pareto with scale parameter w_0^P and shape parameter α^P so that $\mu_1^P = \frac{\alpha^P w_0^P}{\alpha^P - 1}$, then

$$\mu_2^P(\theta_1) = \frac{\left(\alpha^P + 1\right)\max\left\{w_0^P, \theta_1\right\}}{\alpha^P}.$$

See (DeGroot, 1970, Chapter 9) for the properties of posterior distributions that were used to derive the results about monotonicity of $\mu_2^P(\theta_1)$ above.

[12] Note that with a concrete example as this, it is clear that an overconfident agent believes that the principal will, more often than not, update his prior beliefs upwards: $\mu_1^A > \int_{\Theta_1} \mu_2^P(\theta_1)\, dF_1^A > \int_{\Theta_1} \mu_2^P(\theta_1)\, dF_1^P = \mu_1^P$ for $0 < h_1^P, h_\theta < \infty$.

Claim 1 (page 11) *An overconfident agent overestimates—relative to the principal's beliefs—the learning returns to first-period investment:* $v^A\left(F_1^A, F_1^P\right) \geq v^P\left(F_1^A, F_1^P\right)$.

Proof. Note that we can write

$$
\begin{aligned}
v^A\left(F_1^A, F_1^P\right) &= \int_{\Theta_1}\int_{S_2^*\left(\mu_2^P(\theta_1)\right)}\left(s_2+\mu_2^P(\theta_1)\right)dGdF_1^A - \int_{S_2^*\left(\mu_1^P\right)}\left(s_2+\mu_1^P\right)dG \\
&= \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} s_2 dG + \int_{\Theta_1}\mu_2^P(\theta_1)\,dF_1^A - \int_{S_2^*\left(\mu_1^P\right)} s_2 dG + \mu_1^P
\end{aligned}
$$

and similarly

$$
v^P\left(F_1^A, F_1^P\right) = \int_{S_2^*\left(\mu_2^P(\theta_1)\right)} s_2 dG + \int_{\Theta_1}\mu_2^P(\theta_1)\,dF_1^P - \int_{S_2^*\left(\mu_1^P\right)} s_2 dG + \mu_1^P.
$$

Under Assumption 1 and given Definitions 1 and 2, we know that

$$
\int_{\Theta_1}\mu_2^P(\theta_1)\,dF_1^A \geq \int_{\Theta_1}\mu_2^P(\theta_1)\,dF_1^P,
$$

and therefore

$$
v^A\left(F_1^A, F_1^P\right) \geq v^P\left(F_1^A, F_1^P\right).
$$

■

Claim 2 (page 11) *Agent overconfidence causes the equilibrium investment rule to be more liberal.*

Proof. For any given F_1^P, Definition 1 plus the fact that $u(\cdot)$ is assumed to be non-decreasing imply

$$
\int_{\Theta_1} u\left(w_2\left(\mu_2^P(\theta_1)\right)\right)dF_1^A \geq \int_{\Theta_1} u\left(w_2\left(\mu_2^P(\theta_1)\right)\right)dF_1^P.
$$

Therefore, the hurdle rate

$$
s_1^* = -\mu_1^P - \frac{1}{u'(w_1)}\left\{\int_{\Theta_1} u\left(w_2\left(\mu_2^P(\theta_1)\right)\right)dF_1^A - u\left(w_2\left(\mu_1^P\right)\right)\right\}
$$

will be lower when the agent is overconfident than when he shares the principals' beliefs.[13] ■

Claim 3 (page 13) *Disagreement is likely to cause the equilibrium investment rule to be more liberal than in the case of common priors.*

[13] Furthermore, if we refer to a "more overconfident" agent as one holding prior beliefs whose distribution first-order stochastically dominates that of the beliefs of a "less overconfident" agent, it follows that s_1^* is decreasing in overconfidence.

This is a speculative claim. My intuition tells me that we should expect that in equilibrium

$$\int_{\Theta_1} w_2\left(\mu_2^P\left(\theta_1\right)\right) dF_1^P\left(\theta_1\right) - w_2\left(\mu_1^P\right) < 0$$

and

$$\int_{\Theta_1} u\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right) dF_1^A - u\left(w_2\left(\mu_1^P\right)\right) > 0.$$

This is because each inequality above reflects the gains that the principal and the agent, respectively, expect from wagering after a decision to invest in the first period. Given that in this setting both are optimally wagering based on their disagreement, I would expect that both would rather wager than pay/receive the fixed $w_2\left(\mu_1^P\right)$. If this is the case, of course, the claim follows immediately from this observation.

Claim 4 (page 16) *An overconfident agent overestimates his expected second-period pay relative to the principals' beliefs.*

We need a further assumption regarding agent overconfidence to provide sufficient conditions for this claim to hold. This is because sufficiency requires that $w_2\left(\mu_2^P\left(\theta_1\right)\right)$ be a non-decreasing function of θ_1. Although this is the case when the no-quitting constraint binds (expected agent productivity is increasing in θ_1), when it does not bind $w_2\left(\mu_2^P\left(\theta_1\right)\right)$ is implicitly defined by

$$u'\left(w_2\left(\mu_2^P\left(\theta_1\right)\right)\right)\frac{f_1^A\left(\theta_1\right)}{f_1^P\left(\theta_1\right)} = \kappa$$

for some constant κ. This will be non-decreasing if and only if $\frac{f_1^A(\theta_1)}{f_1^P(\theta_1)}$ is non-decreasing in θ_1.

Assumption 2 (MLRP) *The agent's and the principals' beliefs exhibit the monotone likelihood ratio property:*

$$\frac{f_1^A\left(\theta_1\right)}{f_1^P\left(\theta_1\right)}$$

is monotonically increasing in θ_1*.*

Proof. Assumption 2 plus the fact that $w_2\left(\mu_2^P\left(\theta_1\right)\right) = \int_{S_2^*\left(\mu_2^P(\theta_1)\right)}\left(s_2 + \mu_2^P\left(\theta_1\right)\right) dG$ whenever the no-quitting constraint binds imply that $w_2\left(\mu_2^P\left(\theta_1\right)\right)$ is non-decreasing in θ_1. $\int_{\Theta_1} w_2\left(\mu_2^P\left(\theta_1\right)\right) dF_1^A\left(\theta_1\right) \geq \int_{\Theta_1} w_2\left(\mu_2^P\left(\theta_1\right)\right) dF_1^P\left(\theta_1\right)$ follows then immediately from Definition 1 (Assumption 2 implies overconfidence as defined in Definition 2). ■

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