Incentives, Monitoring, and Motivation

June 2005

Michael T. Rauh
Kelley School of Business
Indiana University
Bloomington, IN 47405-1701 USA
mtrauh@indiana.edu

Giulio Seccia
Department of Economics
University of Southampton
Southampton, S017 1BJ UK
giulio.seccia@soton.ac.uk

Abstract

In this paper, we introduce the psychological concept of *anxiety* into conventional principal-agent theory. In doing so, we are motivated by experimental and econometric evidence which suggests that incentives and monitoring can be counterproductive. A distinctive feature of the anxiety construct, which has both empirical and theoretical support, is that anxiety can improve or reduce performance, depending on its effect on effort. An increase in incentives or reduction in monitoring which increases anxiety can therefore be motivational or demotivational. An optimizing principal, however, will never offer counterproductive incentives in equilibrium, which reconciles the experimental evidence on the existence of counterproductive incentives with econometric work indicating that incentives can be motivational in practice. Since anxiety can be motivational, the principal might not want to eliminate it, and may choose incomplete monitoring even when monitoring is costless. Moreover, the principal may even want to introduce extraneous noise in order to generate anxiety. Finally, since monitoring can be directly motivational, incentives and monitoring can be substitutes or complements in our theory.

> Most of economics can be summarized in four words: “People respond to incentives.” The rest is commentary.
>
> Landsburg (1993, p. 3)

> Ultimately, it may be that psychologists, behaviorists, human resource consultants, and personnel executives understand something about human behavior and motivation that is not yet captured in our economic models.
>
> Baker, Jensen, and Murphy (1988, p. 615)

1. Introduction

Do people really respond to incentives? Standard economic theory assumes so, but until recently this question has received relatively little attention in the economic literature. At the empirical level, Lazear (2000) reports that productivity increased by about 44% when the Safelite Glass Corporation switched from hourly wages to piece rates:

> Some conclusions are unambiguous. Workers respond to prices just as economic theory predicts. Claims by sociologists and others that monetizing incentives may actually reduce output are unambiguously refuted by the data.
>
> Lazear (2000, p. 1347).

As Lazear notes, however, some social scientists have questioned the effectiveness of monetary incentives, and the non-economic literature contains a substantial body of experimental evidence which suggests that contingent rewards can undermine intrinsic motivation and even reduce performance. Moreover, recent experimental work by economists support these findings; see Gneezy and Rustichini (2000), Gneezy (2003), and the survey by Frey and Jegen (2001). If incentives can have “hidden costs” or even be counterproductive, this may help explain why extensive piece rate systems like the well-known case of Lincoln Electric[1] seem to be the exception rather than the norm, as well as Jensen and Murphy’s (1990) finding that the pay-performance relationship for CEOs seems very weak, albeit positive and statistically significant.

A nascent but growing theoretical literature attempts to explain how incentives can be demotivational. Gibbs (1991) informally argues that a contingent reward can signal to the

[1] “The Lincoln Electric Company,” Case 376-028, Harvard Business School.

agent that the probability of promotion is high, dulling promotion incentives. *Motivation crowding theory*, surveyed in Frey and Jegen (2001), posits that extrinsic incentives can "crowd out" intrinsic motivation. Bénabou and Tirole (2003), which can be viewed as formalizing certain aspects of motivation crowding theory, demonstrate that incentives can have hidden costs by signaling that a task is difficult or distasteful, or the agent's skill is low. Although their model helps explain the prevalence of low-powered incentive systems, it seems unable to explain the aforementioned experimental evidence, since the agent's optimal effort is still nondecreasing in incentives. The formal literature on trust, including Casadesus-Masanell (2004), shows that psychological contracts can outperform extrinsic incentive contracts. In particular, switching from the former to the latter can reduce performance, although switching from a low-powered incentive contract to a high-powered one always increases effort and performance.

Standard economic theory also conflicts with some empirical evidence on the effects of monitoring. In efficiency wage theory, an increase in monitoring is modeled as an increase in the probability of detecting shirking, and incentives and monitoring are substitutes. In principal-agent theory, monitoring is a costly technology which reduces the noise associated with the principal's performance measure. In the standard linear principal-agent model (SLM),[2] monitoring has no *direct* effect on effort. Instead, it reduces the agent's risk premium, permitting stronger incentives, which in turn induce greater effort. Incentives and monitoring are therefore complements. In both classes of models, monitoring is associated with greater effort and expected performance. However, econometric work by Barkema (1995) [see also the evidence cited in Frey (1993)] suggests that monitoring can be counterproductive when the principal-agent relationship is close. Their explanation is that monitoring can signal distrust and thereby reduce intrinsic motivation, in accordance with motivation crowding theory.

In this paper, we address the growing experimental and econometric evidence on the demotivational effects of incentives and monitoring by introducing the psychological construct of *anxiety* into conventional principal-agent theory. Specifically, we consider a version of the SLM where we replace the agent's usual risk premium with a formalization

[2] E.g., see Milgrom and Roberts (1992, Ch. 7) and Bolton and Dewatripont (2005, Ch. 4).

of anxiety based on Caplin and Leahy's (2001) *psychological expected utility theory* and the more structured anxiety concept in Rauh and Seccia (2006). In the next section, we provide a brief overview of the economic and psychological literatures on anxiety and show that anxiety and the risk premium are substantively similar conceptualizations of subjective evaluation of uncertainty.

A distinctive feature of the anxiety construct, which has both empirical and theoretical support, is that anxiety can either improve or reduce performance, depending on its effect on effort. The idea that anxiety can induce greater effort and expected performance is formalized in Rauh and Seccia (2006), where an increase in anxiety induces the agent to expend more effort in an attempt to obtain more information. It is also a central element in the *processing efficiency theory* from cognitive psychology, which posits that anxiety can serve a positive *motivational function*. The *inverted-U hypothesis*, an important benchmark in the psychology literature, is even more specific: anxiety improves performance when anxiety is low, but reduces it when anxiety is high. This is supported by many empirical studies, although the evidence is mixed.

In our theory, incentives directly encourage greater effort, but also generate anxiety by increasing the variance of income. This mirrors the usual trade-off between incentives and efficient risk-sharing. The difference is that anxiety can be motivational or demotivational, so incentives can have hidden rewards or hidden costs, respectively. When anxiety is sufficiently debilitating, effort and expected performance actually decline. However, a well-informed optimizing principal will never offer such counterproductive incentives in equilibrium, which reconciles the experimental evidence on the existence of demotivational incentives with econometric work such as Lazear (2000), who found a strong positive effect. In experiments, incentives are determined by an experimenter for scientific purposes, whereas real-world data may be generated in part by principals who are interested in profit-maximization.

Likewise, monitoring reduces anxiety by lowering the variance of the productivity shock and can therefore be motivational or demotivational. Unlike incentives, the principal may choose a demotivational level of monitoring in equilibrium, in order to reduce the agent's anxiety to satisfy the participation constraint. Since anxiety can be motivational, the principal might not want to eliminate it, and may choose incomplete monitoring (non-zero variance for the productivity shock) even when monitoring is costless. Indeed, the principal may want to *introduce* extraneous noise in order to generate anxiety for motivational purposes, which violates the well-known *informativeness principle* due to Holmström (1979) and Grossman and Hart (1983). The fact that monitoring can be directly motivational in our model suggests that incentives and monitoring can be substitutes or complements, which we confirm through simulations. This blurs the usual dichotomy between efficiency wage and principal-agent models, where incentives and monitoring are substitutes and complements, respectively. Moreover, simulations reveal that the agent's optimal effort and expected performance may conform to the inverted-U hypothesis.

The plan for the rest of the paper is as follows. In the next section, we briefly discuss the anxiety literature in economics and psychology. In sections 3 and 4, we develop the general model and present our comparative statics results. Unless otherwise stated, all proofs are in the appendix. Section 5 presents simulations showing that incentives and monitoring can be complements or substitutes. Section 6 concludes.

2. The Anxiety Literature in Economics and Psychology[3]

In economics, agents' subjective evaluation of uncertainty is typically formalized by the usual concepts of *risk aversion* and *risk premium*. In the univariate case, the former can be measured by the curvature of the utility function, while the latter is defined as the maximum amount of money the agent would pay to have a certain income $\bar{I}$ instead of a random income with mean $\bar{I}$. In the SLM, where compensation is linear in output, utility is exponential, and the productivity shock is normally distributed, the risk premium is given by

$$RP(r, V) = (1/2)rV, \tag{1}$$

where r is the coefficient of absolute risk aversion (CARA) and V is the variance of income. Note that the risk premium is increasing in r and V. Under much more general conditions,

[3] This section is strongly tailored for the purposes of this paper. For more extensive surveys, see Caplin and Leahy (2001), Woodman and Hardy (2001), and Rauh and Seccia (2006).

the risk premium can be approximated by

$$RP(r, V) = (1/2)r(\bar{I})V, \tag{2}$$

where the CARA depends on expected income.[4]

In contrast, the anxiety concept is a much broader and richer approach to the subjective evaluation of uncertainty. In this paper, we replace the risk premium in the agent's objective function with a formalization of anxiety $A(e, V)$ which is increasing in V like the risk premium and decreasing in the agent's effort e. This will have unique properties which will generate results inconsistent with the SLM, but consistent with the empirical evidence discussed in the introduction.

Definition of Anxiety

The concepts and terminology in anxiety research have not been standardized, but the following is a representative definition:

> Anxiety is generally accepted as being an unpleasant emotion... Researchers in mainstream psychology have suggested that anxiety might have at least two distinguishable components: a mental component normally termed *cognitive anxiety* or *worry*, and a physiological component normally termed *somatic anxiety* or *physiological arousal*.
>
> Woodman and Hardy (2001, p. 290-291) (italics in the original).

The first component, *cognitive anxiety*, can be further described as follows:

> Worry is a cognitive phenomenon, it is concerned with future events where there is uncertainty about the outcome, the future being thought about is a negative one, and this is accompanied by feelings of anxiety.
>
> MacLeod, Williams, and Bekerian (1991, p. 478)
>
> [as quoted in Caplin and Leahy (2001)].

As such, cognitive anxiety is substantively very similar to the economic concepts of risk aversion and risk premium. The second component, *physiological arousal* can induce such physical symptoms as an elevated heart rate and shaky hands: "indications of autonomic arousal and unpleasant feeling states such as nervousness and tension" [Morris, Davis, and

[4] See the appendix to Chapter 7 in Milgrom and Roberts (1992).

Hutchings (1981, p. 541)]. Although physiological arousal can affect motor performance, it seems relatively unimportant in the context of this paper, which is focused on incentive mechanisms. We henceforth focus exclusively on cognitive anxiety.

Inverted-U Hypothesis

An important benchmark is the *inverted-U hypothesis* or *Yerkes-Dodson Law*, which posits that performance is increasing in anxiety when anxiety is low, but decreasing when anxiety is high. One advantage of the anxiety concept is that there is a substantial empirical psychology literature on the relationship between anxiety and performance (athletic performance, information processing, reaction times, etc.) based on direct measures of anxiety, including objective measures of physiological conditions such as heart rate and blood pressure, as well as subjective self-report scales. In contrast, economists tend to study the relationship between attitudes towards risk and behavior only indirectly, backing out values for risk premia by comparing theoretical predictions with the data. Although the empirical psychology literature is mixed, many studies support the inverted-U hypothesis, which is also a feature of the Rauh and Seccia (2006) formalization of anxiety under certain parameter configurations.[5] Nevertheless, it has been severely criticized by some psychologists as being overly simplistic and because it does not have any associated explanation for the supposed relationship: it is merely a hypothesis, not a theory.

The Processing Efficiency Theory

The anxiety literature in psychology includes several theories about the effects of anxiety on behavior, performance, and well-being, but the most relevant for the present paper is the *processing efficiency theory* of Eysenck and Calvo (1992), who were motivated by the

[5] For a survey of the empirical psychology literature, see Zaichkowsky and Baltzell (2001). Other well-known hypotheses are that performance is monotonically declining in anxiety or that the 3-dimensional relationship between performance, cognitive anxiety, and physiological arousal is a standard cusp catastrophe; see Woodman and Hardy (2001).

diversity of findings in the empirical psychology literature:

> One is concerned with the explanation of the relationship between anxiety and performance, taking into account not only the data regarding the negative effects of anxiety, but also trying to reconcile them with those findings indicating a lack of effect (or even a positive one).
>
> Eysenck and Calvo (1992, p. 410).

As in most anxiety theories, the negative effect of anxiety is that it induces worry:

> Worrisome thoughts interfere with attention to task-relevant information, thus reducing the cognitive resources available for task-processing activities. As a consequence, performance is impaired.
>
> (*ibid*, p. 410).

The novel aspect and cornerstone of the processing efficiency theory is that anxiety can serve a *motivational function*, inducing the agent to increase effort, provided that the probability of success is perceived to be sufficiently high.

> In order to escape from the state of apprehension associated with worrisome thoughts and to avoid the likely aversive consequences of poor performance, anxious subjects try to cope with threat and worry allocating additional resources (i.e. effort) and/or initiating processing activities (i.e. strategies).
>
> (*ibid*, p. 415).

Hence, an increase in anxiety can either improve or reduce performance, depending on the probability of success and the agent's effort adjustment. Like most anxiety theories in psychology, the processing efficiency theory is descriptive, rather than deductive.

The Economic Literature

Anxiety research in economics was pioneered by Loewenstein (1987) and Caplin and Leahy (2001). We now sketch the latter, since it turns out that the agent's decision problem in our model is a special case.

Caplin and Leahy (2001) consider a general two-period decision problem under uncertainty. The novel element in their *psychological expected utility theory* (PEUT) is an exogenous map $\phi(z_1, l_2)$ which assigns a psychological state to the first period outcome z_1 and lottery l_2 over second period outcomes z_2. The agent's overall utility function is

$$u_1[\phi(z_1, l_2)] + E_{l_2}[u_2(z_2)], \tag{3}$$

where u_1 and u_2 are the first and second period utility functions and E_{l_2} denotes the expectation with respect to the lottery l_2. Note that u_1 is defined over psychological states. Given the first period state s_1 and first period action α_1, the first period outcome is $\eta(s_1, \alpha_1)$. The second period lottery $\lambda(\alpha_1, \pi_2|s_1)$ is determined by α_1, the agent's second period policy function π_2, and s_1. We obtain the agent's objective function by substituting these terms into (3)

$$u_1[\phi(\eta(s_1, \alpha_1), \lambda(\alpha_1, \pi_2|s_1))] + E_{\lambda(\alpha_1, \pi_2|s_1)}[u_2(z_2)]. \quad (4)$$

Although the PEUT is a powerful framework for modeling situations involving uncertainty, which Caplin and Leahy illustrate with a natural application to the equity premium puzzle, anxiety remains a "black box" in their theory, since ϕ is completely general, with no structure apart from continuity.

To put more structure on $A(e, V)$, we appeal to Rauh and Seccia (2006),[6] which develops a formalization of anxiety consistent with expected utility maximization. In that paper, we consider a two-period decision problem where performance $\pi_t = \theta e_t + \epsilon_t$ in period t depends on the agent's skill θ, effort e_t, and productivity shock ϵ_t. The agent is uncertain about θ, and makes inferences about it by observing her own first period performance π_1. Hence, first period effort not only increases expected first period performance, it also affects the amount of information in the second period via the signal π_1. Anxiety is defined as the difference between expected utility with zero uncertainty and expected utility evaluated at optimal effort. It is therefore the opposite of the *value of information*; i.e., the disutility of uncertainty. The resulting formalization of anxiety is a function $A(e, R, a)$ of the agent's effort e, a parameter R measuring the volatility of θ, and another parameter a measuring the volatility of ϵ.

We show that when the distribution of ϵ satisfies the monotone likelihood ratio property, anxiety is decreasing in e, since an increase in effort is informative, and increasing in a, since an increase in noise reduces the informativeness of the signal. Furthermore, optimal effort and expected performance conform to the inverted-U hypothesis under certain parameter configurations. In particular, anxiety can serve a motivational function as in the

[6] The paper can be downloaded from http://home.insightbb.com/∼mtrauh/index.html.

processing efficiency theory: increases in anxiety can induce greater effort and expected performance. Based on these results, in this paper we assume $A(e, V)$ is decreasing in e and increasing in V. In the next section, we show that the approximation in (2) also has these properties.

3. The General Model

We consider a version of the SLM with particular reference to Milgrom and Roberts (1992, Ch. 7). We assume a linear compensation rule $I = \alpha + \beta q$, where I is income, α is a lump-sum payment, β is the incentive parameter, and q is output. The latter is determined by $q = e + \epsilon$, where e is the agent's effort and ϵ is a productivity shock with mean 0 and variance V_ϵ. The variance of income is given by $V = \beta^2 V_\epsilon$.

In the SLM, the agent's certainty equivalent is given by

$$CE_A = \alpha + \beta e - C(e) - RP(r, V), \tag{5}$$

where C is the disutility of effort expressed in monetary terms and RP was defined in (1). In this paper, the agent's expected utility is given by

$$U = \alpha + \beta e - C(e) - A(e, V), \tag{6}$$

where A is anxiety. Note that anxiety is an "unpleasant emotion" (recall the inset quotation in the previous section) in the sense that increased anxiety reduces expected utility. It is also important to note that the agent has no intrinsic motivation in the sense that $\beta = 0$ induces zero effort.

PEUT Foundations

The Caplin-Leahy PEUT can be used to justify (6) as follows. We consider the model as a game with 3 periods: 0, 1, 2. In period 0, the principal makes a take-it-or-leave-it offer (α, β, V) to the agent, which the latter can accept or reject. If she rejects, she gets $\bar{u}$. If she accepts, she chooses effort in period 1. Since there is no first period state, the period one outcome is $C(e)$, which corresponds to $\eta(s_1, \alpha_1)$ in the PEUT. The second period lottery is the wage distribution $\lambda(e)$ induced by the agent's choice of effort, which corresponds to $\lambda(\alpha_1, \pi_2|s_1)$. We then define $u_1(x) = x$ and

$$\phi[C(e), \lambda(e)] = -C(e) - A(e, V), \tag{7}$$

so ϕ transforms the *economic* state consisting of the disutility of effort and the wage distribution into the *psychological* state which is the former minus the anxiety generated by the latter, which depends on the variance of income V. In period 2, the agent's income is realized. She has no decision to make and $u_2(x) = x$, so her expected second period utility equals her expected income $\alpha + \beta e$. Substituting all of this into (4), we get (6). ∎

Let $e_{\max} > 0$ denote maximum feasible effort. Throughout the paper, partial derivatives are indicated by subscripts.

Assumptions 1. *(i) C and A are twice continuously differentiable. (ii) $C' > 0$ and $C'' > 0$ on $(0, e_{\max})$. (iii) $C'(0) = 0$ and $C'(e_{\max}) = \infty$. (iv) $A_e < 0$, $A_{ee} > 0$, and $A_V > 0$ on $[0, e_{\max}] \times (0, \infty)$. (v) For some constant k, $A(e, 0) = k$ for all $e \geq 0$.*

The partial $A_e < 0$ is the change in anxiety due to a small change in effort, so we call its absolute value the *marginal ability to cope* (MAC). As usual, we assume diminishing returns to effort, $A_{ee} > 0$, and the rest of the assumptions on the partials of A were discussed in the previous section; c.f. propositions 3 and 7(i) in Rauh and Seccia (2006). If $V = 0$, there is no uncertainty and the constant k in (v) represents minimum or baseline anxiety ("trait anxiety"). Given these assumptions, the sub-problem

$$\max_{0 \leq e \leq e_{\max}} \alpha + \beta e - C(e) \tag{8}$$

has a unique global maximizer $\hat{e}(\beta)$, which satisfies $0 < \hat{e}(\beta) < e_{\max}$ when $\beta > 0$. Clearly, the agent will never choose an effort level less than $\hat{e}(\beta)$, so optimal effort $e(\beta, V_\epsilon) \in [\hat{e}(\beta), e_{\max})$.

Recall that in principal-agent theory, monitoring is a costly technology which reduces the noise V_ϵ associated with the principal's performance measure, q. Proposition 1 below concerns the effects of incentives and monitoring on the agent's optimal effort and expected performance (which equals effort). An increase in incentives or a reduction in monitoring increases the variance of income, and hence increases anxiety. It follows that the net effect on effort and expected performance hinges on whether the increased anxiety is motivational or not. Clearly, this depends on A_{eV}: the effect of a change in the variance of income on the MAC. The proof of the following is standard and omitted.

Proposition 1. *(i) When $\beta > 0$ the agent's maximization problem in (6) has a unique positive global maximizer $e(\beta, V_\epsilon) \in [\hat{e}(\beta), e_{\max})$. (ii) When $A_{eV} < 0$, optimal effort and expected performance are increasing in V_ϵ, so monitoring is demotivational. When $A_{eV} > 0$, the opposite holds. (iii) When $A_{eV} < 1/(2\beta V_\epsilon)$, effort and expected performance are increasing in incentives, but when $A_{eV} > 1/(2\beta V_\epsilon)$, incentives are counterproductive. (iv) In particular,*

$$e_{V_\epsilon} = -\frac{\beta^2 A_{eV}}{C'' + A_{ee}} \tag{9}$$

$$e_\beta = \frac{1 - 2\beta V_\epsilon A_{eV}}{C'' + A_{ee}}. \tag{10}$$

In comparison with the SLM, the risk premium in (1) does not depend on effort, so $RP_{ee} = RP_{eV} = 0$. Setting $A_{ee} = A_{eV} = 0$ in (9) and (10), we recover the usual results that $e_{V_\epsilon} = 0$ and $e_\beta = 1/C'' > 0$, so monitoring has no direct effect on effort and incentives are always motivational in the SLM.

In contrast, in our theory, monitoring has a direct impact on the agent's effort. In particular, a reduction in monitoring increases V_ϵ, the variance of income, and anxiety. If $A_{eV} < 0$, the MAC increases and the agent reacts by increasing effort, which improves expected performance. In this case, anxiety is motivational and is associated with higher effort and expected performance as in the processing efficiency theory and Rauh and Seccia

(2006). The opposite scenario occurs when $A_{eV} > 0$. Likewise, incentives increase the direct reward to effort but also affect the MAC. If A_{eV} is sufficiently negative to outweigh $A_{ee} > 0$ in (10), then $e_\beta > 1/C''$, so the positive effect of incentives is greater than in the SLM. In other words, incentives have "hidden rewards" since the corresponding increase in the MAC reinforces the direct incentive effect, making incentives even more effective than in standard theory. In contrast, when $A_{eV} > 0$ incentives have "hidden costs" since the reduction in the MAC conflicts with the direct incentive effect, so incentives are relatively less effective. The novel aspect of our theory, compared with Bénabou and Tirole (2003) and Casadesus-Masanell (2004), is that incentives can actually be counterproductive when the negative effect on the MAC outweighs the direct incentive effect.

The Principal's Problem

Let $p > 0$ be the agent's constant marginal revenue product (MRP) and $M(V_\epsilon)$ the cost of monitoring, where $-M' > 0$ and $-M'' < 0$. The principal's problem is

$$\max_{e,\beta,V_\epsilon \geq 0} pe - \alpha - \beta e - M(V_\epsilon) \tag{11}$$

subject to the agent's first-order condition (which is necessary and sufficient by proposition 1) and the participation constraint $U \geq \bar{u}$. As in the SLM, the sole purpose of α is to make the latter bind. Substituting $U = \bar{u}$ into (11),

$$\max_{e,\beta,V_\epsilon \geq 0} \Pi = pe - C(e) - A(e, \beta^2 V_\epsilon) - M(V_\epsilon) - \bar{u}, \tag{12}$$

which is similar to equation 7.8 in Milgrom and Roberts (1992, p. 226).

Although proposition 1 shows that counterproductive incentives are possible under certain conditions, an optimizing principal will never offer them in equilibrium according to proposition 2 below. An important implication of these results is that econometric work such as Lazear (2000) using data generated by presumably profit-maximizing principals *cannot* refute the experimental evidence on demotivational incentives, where incentives are determined by the experimenter and are likely to be sub-optimal. Moreover, our results are predicated on a fully optimizing principal who has a great deal of information about the agent. An inexperienced or uninformed principal could offer counterproductive incentives by mistake, which may explain why subjects acting as principals did indeed choose demotivational incentives in Gneezy and Rustichini (2000).

In contrast, demotivational monitoring *can* occur in equilibrium, when the marginal cost of monitoring is small compared to the marginal benefit $\beta^2 A_V$ in terms of anxiety reduction. This is supported by Barkema's (1995) econometric work, which suggests that monitoring can indeed induce lower effort when the principal-agent relationship is close. Frey (1993) cites further evidence on this point. Their findings are also consistent with our results, since a close principal-agent relationship should also imply relatively low monitoring costs.

Proposition 2. *(i) At an interior solution, $e_\beta > 0$ and*

$$\text{sign } e_{V_\epsilon} = \text{sign } (\beta^2 A_V + M'). \tag{13}$$

(ii) Furthermore,

$$\frac{\beta}{p-\beta} = \frac{1 - 2\beta V_\epsilon A_{eV}}{2V_\epsilon A_V (C'' + A_{ee})} \tag{14}$$

$$-M' = \frac{\beta^2 A_V}{1 - 2\beta V_\epsilon A_{eV}}. \tag{15}$$

Comparison with the SLM

We now compare (14) and (15) with their counterparts in the SLM

$$\frac{\beta}{p-\beta} = \frac{1}{2V_\epsilon A_V C''} \tag{16}$$

$$-M' = \beta^2 A_V, \tag{17}$$

which we recover by setting $A_{ee} = A_{eV} = 0$. In our model, when $A_{eV} > 0$ monitoring is motivational and incentives have hidden costs, so one would expect the principal to offer fewer incentives and more monitoring relative to the SLM, which follows from (14) and (15). When A_{eV} is sufficiently negative to overcome $A_{ee} > 0$ in (10) and (14), monitoring is demotivational and incentives have hidden rewards, so the principal offers more incentives and less monitoring. Since $RP_V = (1/2)r$, A_V corresponds to the CARA in the SLM. Hence, the usual result that higher r implies fewer incentives and greater monitoring has a similar statement in our model in terms of A_V.

Incomplete Monitoring

In the SLM, the principal always wants to reduce V_ϵ subject to any costs of doing so, because noise increases the agent's RP, requiring additional compensation to satisfy the participation constraint (higher α) without any off-setting benefit. In particular, the principal should set $V_\epsilon = 0$ if monitoring is costless. In contrast, in our theory anxiety can serve a motivating function, and proposition 3 below shows that the principal may not want to eliminate it.

Proposition 3. *Assume monitoring is costless and $A_{eV}(e, 0) < 0$ for all $e > 0$. If $\beta > 0$ and*

$$\frac{(p-\beta)|A_{eV}(\hat{e}(\beta), 0)|}{C''(\hat{e}(\beta))} > A_V(\hat{e}(\beta), 0) \tag{18}$$

then $V_\epsilon > 0$ in equilibrium.

Indeed, when anxiety is motivational the principal may want to *increase* the variance of the productivity shock, by measuring output less precisely, issuing vague instructions to the agent, etc.

Wealth Effects

Until now, we have compared our results with those of the SLM, which assumes no wealth effects. When wealth effects are present, the risk premium can be approximated by (2), where $\bar{I} = \alpha + \beta e$. In that case, the risk premium depends on effort, so it is natural to inquire whether the results in this paper carry over to standard principal-agent models with wealth effects. If we make the usual assumption that the CARA is decreasing in expected income $r' < 0$ and $r'' > 0$ then $RP_e < 0$ and $RP_V, RP_{ee} > 0$ as in assumptions 1. However, RP_{eV} can only be negative, so incentives are always motivational.

4. Detailed Comparative Statics

The previous section highlighted the importance of A_{eV}, which determines whether or not anxiety is motivational. To investigate this term more closely, and to obtain sharper comparative statics results, in this section we assume $A(e,V) = \bar{A}f(e/V)$, where $\bar{A} > 0$.[7]

Assumptions 2. *(i) $f(x)$ is thrice continuously differentiable on $[0,\infty)$, with $f' < 0$, $f'' > 0$, and $f''' < 0$. (ii) $f'(x) + xf''(x)$ has a finite limit as $x \to 0$.*

Since

$$A_e = \frac{\bar{A}}{\beta^2 V_\epsilon} f' < 0, \quad A_V = -\frac{\bar{A}e}{\beta^2 V_\epsilon^2} f' > 0, \quad \text{and} \quad A_{ee} = \frac{\bar{A}}{\beta^4 V_\epsilon^2} f'' > 0, \tag{19}$$

assumptions 1 are satisfied. An example satisfying assumptions 2, as well as all subsequent assumptions, is $f(x) = \exp(-x)$.

The effect of monitoring on the agent's optimal effort is determined by

$$A_{eV} = -\frac{\bar{A}}{\beta^2 V_\epsilon^2}[f'(x) + xf''(x)], \tag{20}$$

where $x \equiv e/\beta^2 V_\epsilon$. Let $r(x) = -f'(x)/f''(x)$, the inverse of the usual absolute curvature measure. Proposition 4 identifies a condition on $r(x)$ (and hence on f) which ensures that $A_{eV} < 0$ and $e_{V_\epsilon} > 0$ when V_ϵ is low and $A_{eV} > 0$ and $e_{V_\epsilon} < 0$ when V_ϵ is high, consistent with the inverted-U hypothesis.

Proposition 4. *Assume there exists $\bar{x} > 0$ such that*

$$\mathit{sign}[r(x) - x] = \mathit{sign}(\bar{x} - x); \tag{21}$$

i.e., $r(x)$ crosses the $45°$ line at a unique point (e.g., in the exponential case $\bar{x} = 1$). Then for any fixed $\beta > 0$, there exists $0 < V_\epsilon^-(\beta) < V_\epsilon^+(\beta) < \infty$ such that optimal effort is increasing in V_ϵ on $[0, V_\epsilon^-(\beta)]$ and decreasing on $[V_\epsilon^+(\beta), \infty)$.

In the previous section, we showed that incentives are counterproductive when A_{eV} is positive and sufficiently large. Proposition 5 identifies sufficient conditions on f and

[7] Separable functional forms $A(e,V) = \bar{A}g(e)h(V)$ are uninteresting, since $A_{eV} = \bar{A}g'(e)h'(V) < 0$.

$s(x) = -2f''(x)/f'''(x)$ such that mid-level incentives are demotivational. It follows that an optimizing principal will only offer low-powered or high-powered incentives in equilibrium.

Proposition 5. *Assume there exists $\tilde{x} > \bar{x}$ such that*

$$sign[s(x) - x] = sign(\tilde{x} - x). \tag{22}$$

Furthermore, assume

$$2x^2 f''' + 5xf'' + f' = 0 \tag{23}$$

at a unique point $\hat{x}$ on $(0, \bar{x})$ [e.g., $\tilde{x} = 2$ and $\hat{x} = (5 - \sqrt{17})/4$ in the exponential case]. Given any fixed $V_\epsilon > 0$, when $\bar{A}$ is large enough (see the proof) there exist $0 < \beta_-(V_\epsilon) < \beta_+(V_\epsilon) < \infty$ such that $e_\beta < 0$ on $(\beta_-(V_\epsilon), \beta_+(V_\epsilon))$.

Proposition 4 shows that optimal effort is increasing in V_ϵ when V_ϵ is low, and decreasing when V_ϵ is high, but does not say what happens for medium values of V_ϵ. Similarly, proposition 5 establishes that mid-level incentives are demotivational, but does not say what happens for low-powered and high-powered incentives. To get a more complete picture, we simulate the model assuming $f(x) = \exp(-x)$ and

$$C(e) = \frac{1}{1-e} - e, \tag{24}$$

so $e_{\max} = 1$.[8] In panel A of Figure 1 below, $\bar{A} = 10$ and $V_\epsilon = 1$.

Figure 1 Goes Here

In panel A, optimal effort is increasing, decreasing, then increasing again in β, clearly illustrating the three regions in proposition 5, where incentives are demotivational in the middle region. In panel B, $\bar{A} = 10$ and $\beta = 1$ and the relationship between optimal effort and V_ϵ is an inverted-U. Since expected performance equals effort and anxiety is

[8] We used the FindRoot routine in Mathematica 5 on an Apple iMac G5 to numerically solve the first-order condition

$$1 + \beta + \frac{\bar{A}}{\beta^2 V_\epsilon} \exp\left(-\frac{e}{\beta^2 V_\epsilon}\right) - \frac{1}{(e-1)^2} = 0. \tag{25}$$

increasing in V_ϵ, a plot of expected performance versus anxiety would indeed conform to the inverted-U hypothesis. In panel C, $\bar{A} = 10$ and we plot the complete 3-dimensional relationship.

In proposition 3, we showed that for a given $\beta > 0$, monitoring remains incomplete ($V_\epsilon > 0$ at the optimum) as the marginal cost of monitoring goes to zero, which shows that the principal prefers that anxiety exceed its baseline level, for motivational purposes. In proposition 6 below, we show that given non-zero monitoring costs, the optimal V_ϵ is bounded from below as $\beta \to \infty$ (implicitly assuming $\beta \leq p$ and $p \to \infty$). This shows that incentives and monitoring are not strongly complementary in our theory for large β, because monitoring is eventually demotivational. In contrast, $V_\epsilon \to 0$ (complete or infinite monitoring) as $\beta \to \infty$ in the SLM when $-M'(0) = \infty$.

Proposition 6. *Assume $-M'(0) = \infty$ and $-M'(\infty) = 0$. Furthermore, assume*

$$-M'(V_\epsilon) = \frac{\bar{A} e_{\max} |f'(0)|}{V_\epsilon^2} \tag{26}$$

has a unique solution $V_\epsilon^\infty > 0$. Then for any $\delta > 0$, there exists $\bar{\beta} > 0$ such that for all $\beta > \bar{\beta}$, there exists a solution $V_\epsilon(\beta)$ to (15) such that $|V_\epsilon(\beta) - V_\epsilon^\infty| < \delta$. Furthermore, $V_\epsilon(\beta) \to V_\epsilon^\infty$ as $\beta \to \infty$.

5. Simulations

In the SLM, monitoring reduces the agent's risk premium and allows the principal to offer stronger incentives. It does not directly affect the agent's effort. In contrast, in our theory monitoring can be motivational, which suggests that incentives and monitoring may be substitutes, especially when β is large as in proposition 6. In this section, we simulate the model to show that incentives and monitoring can be either complements or substitutes, blurring the usual distinction between efficiency wage models and principal-agent theory.

We assume

$$A(e, V) = \begin{cases} \bar{A}\left(1 - \frac{e}{\beta^2 V_\epsilon}\right)^2 & 0 \leq e \leq \beta^2 V_\epsilon \\ 0 & e > \beta^2 V_\epsilon. \end{cases} \tag{27}$$

Although this specification does not satisfy some of our previous assumptions, we do have $A_e < 0$, $A_{ee} > 0$, and $A_V > 0$ on $0 \leq e < \beta^2 V_\epsilon$. Furthermore,

$$A_{eV} = \frac{2\bar{A}}{\beta^2 V_\epsilon^2}\left(1 - \frac{2e}{\beta^2 V_\epsilon}\right), \tag{28}$$

so

$$\text{sign } A_{eV} = \text{sign } \left(\frac{\beta^2 V_\epsilon}{2} - e\right). \tag{29}$$

Hence, A_{eV} can be positive or negative, which is crucial for our results. Assuming $C(e) = (1/2)e^2$, the agent's objective function is piecewise quadratic, and routine calculations give the agent's optimal effort

$$e(\beta, V_\epsilon, \bar{A}) = \begin{cases} \beta & \beta V_\epsilon \leq 1 \\ \frac{\beta^2 V_\epsilon(\beta^3 V_\epsilon + 2\bar{A})}{\beta^4 V_\epsilon^2 + 2\bar{A}} & \beta V_\epsilon > 1. \end{cases} \tag{30}$$

If $\beta V_\epsilon > 1$,

$$\frac{\partial e}{\partial V_\epsilon} = \frac{2\bar{A}\beta^2[2\bar{A} + \beta^3 V_\epsilon(2 - \beta V_\epsilon)]}{(2\bar{A} + \beta^4 V_\epsilon^2)^2}, \tag{31}$$

so the relationship between optimal effort and V_ϵ is an inverted-U, as in the previous example. Although the expression for $\partial e/\partial \beta$ is not very informative, we obtain the same qualitative relationship as in panel A of Figure 1 when $\bar{A}$ and V_ϵ are sufficiently large.

We now turn to the principal's problem, assuming $M(V_\epsilon) = 1/V_\epsilon$. We first consider the case $\beta V_\epsilon \leq 1$ (relatively low incentives, high monitoring), where $e = \beta$. Since anxiety is zero, the principal's problem is

$$\max p\beta - (1/2)\beta^2 - \frac{1}{V_\epsilon} \tag{32}$$

subject to $\beta V_\epsilon \leq 1$. The solution to this trivial maximization problem is $\beta = p - 1$ and $V_\epsilon = 1/(p-1)$ provided $p > 1$, which we henceforth assume. In this case, the principal's profits are $(1/2)(p-1)^2$. If $\beta V_\epsilon > 1$, then substituting the relevant expressions into (12) and simplifying, we obtain

$$\frac{\beta^4 V_\epsilon^2(2p\beta V_\epsilon - \beta^2 V_\epsilon - 2) + 2\bar{A}(2p\beta^2 V_\epsilon^2 - \beta^4 V_\epsilon^3 - 2)}{4\bar{A}V_\epsilon + 2\beta^4 V_\epsilon^3}. \tag{33}$$

The principal's profit is therefore

$$\Pi(\beta, V_\epsilon, \bar{A}, p) = \begin{cases} (1/2)(p-1)^2 & \beta V_\epsilon \leq 1 \\ \frac{\beta^4 V_\epsilon^2(2p\beta V_\epsilon - \beta^2 V_\epsilon - 2) + 2\bar{A}(2p\beta^2 V_\epsilon^2 - \beta^4 V_\epsilon^3 - 2)}{4\bar{A}V_\epsilon + 2\beta^4 V_\epsilon^3} & \beta V_\epsilon > 1. \end{cases} \tag{34}$$

This maximization problem cannot be solved analytically, so we used numerical methods to investigate its solutions.[9]

In Figure 2, we fix $\bar{A} = 10$ and plot the maximizers $\beta(p)$ and $V_\epsilon(p)$ of (34) as a function of the agent's MRP over the range $3 \leq p \leq 19$. (We obtained the same qualitative behavior for other nearby values of $\bar{A}$.)

Figure 2 Goes Here

In Panel A, incentives are increasing in the MRP as in standard theory (the relationship is actually nonlinear), while in Panel B $V_\epsilon(p)$ is U-shaped, so monitoring is increasing then decreasing in the MRP.

For illustrative purposes, we discuss these results in the context of management hierarchies. Assuming more senior managers have higher MRPs, the pattern in Figure 2 is that junior managers receive weak incentives and are monitored very little. At that level, incentives and monitoring are complements, so as they move up the hierarchy they receive stronger incentives and are subjected to greater monitoring. At some point, however, incentives and monitoring become substitutes, so more senior positions (e.g., CEOs) are associated with greater incentives, but less monitoring. Empirically, Kahn and Sherer (1990) present evidence that senior managers receive stronger incentives than junior ones, but we are unaware of any studies on similar differences in the intensity of monitoring. Clearly, Bebchuk and Fried (2003) and others are of the general view that internal monitoring mechanisms for CEOs are very weak.

[9] A plot of (34) when $\bar{A} = 10$ and $3 \leq p \leq 19$ shows that the unconstrained maximizers of (33) solve the problem in (34). We therefore used the FindRoot routine in Mathematica 5 to numerically solve the unconstrained first-order conditions for (33), and then checked that those solutions satisfied the unconstrained second-order conditions and the constraint $\beta V_\epsilon > 1$. Finally, we verified that our solutions were more profitable than $\beta = p - 1$ and $V_\epsilon = 1/(p-1)$, the relevant solutions when $\beta V_\epsilon \leq 1$.

6. Conclusion

In this paper, we considered a version of the standard linear principal-agent model where the agent experiences anxiety, rather than the usual economic aversion to risk. We derived the basic framework from the psychological expected utility theory of Caplin and Leahy (2001), and used the processing efficiency theory of Eysenck and Calvo (1992) and the experimentation model in Rauh and Seccia (2006) to motivate more specific comparative statics assumptions. In particular, a distinctive feature of the anxiety construct, which is supported by the empirical psychology literature, is that anxiety can be motivational or demotivational, so incentives can have hidden rewards or hidden costs, respectively. In contrast, the direct incentive effect of contingent rewards can only be accentuated when the agent's subjective evaluation of uncertainty is expressed as a risk premium, under the standard assumption that the CARA is decreasing in expected income. If incentives can have hidden costs, this may help explain why extensive high-powered incentive systems are relatively rare, as well as empirical findings such as Jensen and Murphy (1990). In comparison with Bénabou and Tirole (2003), in our theory mid-level incentives can actually be counterproductive, although an optimizing principal never offers them in equilibrium.

Likewise, monitoring reduces anxiety by lowering the variance of the productivity shock, and can therefore be motivational or demotivational. Unlike incentives, monitoring can be demotivational in equilibrium, as in Frey (1993) and Barkema (1995), who found that monitoring is demotivational when the principal-agent relationship is close. Their findings are also consistent with our theory, since close principal-agent relationships should entail low monitoring costs. Since anxiety can be motivational, the principal may choose incomplete monitoring even when monitoring is costless, and may introduce extraneous noise for motivational purposes. The fact that monitoring can be directly motivational in our theory suggests that incentives and monitoring may be substitutes or complements, which we confirmed via simulations. The simulations also revealed that optimal effort and expected performance may conform to the inverted-U hypothesis, which is supported by many studies in the empirical psychology literature.

A major contribution of conventional principal-agent theory has been the identification of a fundamental trade-off between incentives and optimal risk-sharing. The present paper has shown the continuing relevance of that contribution, even when explaining seemingly contrary experimental and econometric evidence on the demotivational effects of incentives and monitoring, provided that anxiety is used to represent the subjective evaluation of uncertainty, rather than the usual risk premium concept. In particular, one need not invoke aspects of intrinsic motivation such as trust, altruism, or sociological norms. On the other hand, we acknowledge the importance of intrinsic motivation for real-world contracting, and in our view the present paper should be considered as complementing that emerging literature.

Appendix

Proof of Proposition 2

At an interior solution,

$$\Pi_\beta = (p - C' - A_e)e_\beta - 2\beta V_\epsilon A_V = 0 \tag{A1}$$

$$\Pi_{V_\epsilon} = (p - C' - A_e)e_{V_\epsilon} - M' - \beta^2 A_V = 0. \tag{A2}$$

Substituting (9) and (10) and rearranging,

$$p - C' - A_e = \frac{(2\beta V_\epsilon A_V)(C'' + A_{ee})}{1 - 2\beta V_\epsilon A_{eV}} \tag{A3}$$

$$p - C' - A_e = \frac{(-M' - \beta^2 A_V)(C'' + A_{ee})}{\beta^2 A_{eV}}. \tag{A4}$$

From the agent's first-order condition, $\beta = C' + A_e$. Substituting this into (A3) and rearranging gives (14). Equating (A3) and (A4) gives (15). Since $1 - 2\beta V_\epsilon A_{eV} > 0$, $e_\beta > 0$. Since $p - C' - A_e > 0$, the sign of e_{V_ϵ} is governed by (A2). ∎

Proof of Proposition 3

The proof is a standard Kuhn-Tucker argument. Since $A(e, 0)$ is constant for all $e > 0$, $A_e(e, 0) = A_{ee}(e, 0) = 0$ for all $e > 0$. From the agent's first-order condition, $e = \hat{e}(\beta)$. The necessary condition for $V_\epsilon = 0$ is

$$(p - \beta)e_{V_\epsilon} - \beta^2 A_V \leq 0 \tag{A5}$$

when $-M'$ is identically zero. Substituting in (9),

$$-(p - \beta)\frac{\beta^2 A_{eV}}{C'' + A_{ee}} \leq \beta^2 A_V. \tag{A6}$$

Since $e = \hat{e}(\beta) > 0$, $A_{eV}(\hat{e}(\beta), 0) < 0$, and $A_{ee}(\hat{e}(\beta), 0) = 0$, this reduces to

$$\frac{(p - \beta)|A_{eV}(\hat{e}(\beta), 0)|}{C''(\hat{e}(\beta))} \leq A_V(\hat{e}(\beta), 0), \tag{A7}$$

which completes the proof. ▮

Proof of Proposition 4

If $x < \bar{x}$ then $f' + xf'' < 0$, $A_{eV} > 0$, and $e_{V_\epsilon} < 0$. Now, $x < \bar{x}$ iff $e/\beta^2\bar{x} < V_\epsilon$ and a sufficient condition for this is $e_{\max}/\beta^2\bar{x} < V_\epsilon$. Hence, $V_\epsilon^+(\beta) \equiv e_{\max}/\beta^2\bar{x}$. Similarly, $V_\epsilon^-(\beta) \equiv \hat{e}(\beta)/\beta^2\bar{x}$. ▮

Proof of Proposition 5

Fix $0 \leq e \leq e_{\max}$ and $V_\epsilon > 0$. From (10), $e_\beta < 0$ iff $2\beta V_\epsilon A_{eV} > 1$. From (20), this reduces to $g > 1$, where

$$g \equiv -\frac{2\bar{A}}{\beta V_\epsilon}(f' + xf''). \tag{A8}$$

Now,

$$g \geq 0 \iff f' + xf'' \leq 0 \iff x \leq \bar{x} \iff \beta \geq \sqrt{e/\bar{x}V_\epsilon} \equiv \beta_p(e, V_\epsilon). \tag{A9}$$

At $\beta_p(e, V_\epsilon)$, g switches from negative to positive values, so $g_\beta > 0$ at $\beta = \beta_p(e, V_\epsilon)$. Since $0 \leq e/\beta^2 V_\epsilon \leq e_{\max}/\beta^2 V_\epsilon$, $x \to 0$ as $\beta \to \infty$. Since $\lim_{x\to 0} f' + xf''$ is finite, $\lim_{\beta\to\infty} g = 0$

for any given $0 \leq e \leq e_{\max}$ and $V_\epsilon > 0$. Differentiating with respect to β and simplifying, we get

$$g_\beta = \frac{2\bar{A}}{\beta^2 V_\epsilon}(2x^2 f''' + 5xf'' + f'). \tag{A10}$$

Since g_β is continuous as a function of β and $g_\beta = 0$ uniquely at $\hat{x}$ on $(0, \bar{x})$, the behavior of g on $[\beta_p(e, V_\epsilon), \infty)$ is that it increases to a unique global maximum at $\beta = \sqrt{e/\hat{x}V_\epsilon}$ and then asymptotes to zero as $\beta \to \infty$. Differentiating g with respect to e and simplifying, we get

$$g_e = -\frac{2\bar{A}}{\beta^3 V_\epsilon^2}(2f'' + xf'''). \tag{A11}$$

Since $\tilde{x} > \bar{x}$, $2f'' + xf''' > 0$ and $g_e < 0$ on $[\beta_p(e, V_\epsilon), \infty)$, so increases in e uniformly lower g as in Figure A below.

Figure A Goes Here

For the rest of the proof, we fix $e = e_{\max}$. At $\beta = \sqrt{e_{\max}/\hat{x}V_\epsilon}$, the maximum of g is positive and equals the expression in (A8). Hence, the maximum of g will be greater than 1 when $\bar{A}$ is sufficiently large, as in Figure A. It follows that there exist $0 < \beta_-(V_\epsilon) < \beta_+(V_\epsilon) < \infty$ such that $g > 1$ on $(\beta_-(V_\epsilon), \beta_+(V_\epsilon))$. Since effort is bounded above by $e_{\max}$, $g > 1$ on $(\beta_-(V_\epsilon), \beta_+(V_\epsilon))$ for optimal effort as well. ▮

Proof of Proposition 6

Choose V_ϵ^m, V_ϵ^M such that $0 < V_\epsilon^m < V_\epsilon^\infty < V_\epsilon^M < \infty$ and define $\Sigma = [V_\epsilon^m, V_\epsilon^M]$. Throughout the proof, we consider only $V_\epsilon \in \Sigma$. Define $x(\beta, V_\epsilon) = \frac{e(\beta, V_\epsilon)}{\beta^2 V_\epsilon}$, where the numerator is optimal effort. Since

$$0 \leq x(\beta, V_\epsilon) \leq \frac{e_{\max}}{\beta^2 V_\epsilon^m}, \tag{A12}$$

$x(\beta, V_\epsilon)$ converges uniformly on Σ to zero as $\beta \to \infty$. Now consider

$$1 - 2\beta V_\epsilon A_{eV} = 1 + \frac{2\bar{A}}{\beta V_\epsilon}[f'(x) + xf''(x)]. \tag{A13}$$

Given assumption 2(ii), $f'(x) + xf''(x)$ converges uniformly on Σ to a constant as $\beta \to \infty$. Since

$$0 \leq \frac{2\bar{A}}{\beta V_\epsilon} \leq \frac{2\bar{A}}{\beta V_\epsilon^m}, \tag{A14}$$

the middle term converges uniformly to zero, so the expression in (A13) converges uniformly to 1. Now consider

$$\beta^2 A_V = \frac{\bar{A} e(\beta, V_\epsilon)}{V_\epsilon^2} \left| f'\left(\frac{e(\beta, V_\epsilon)}{\beta^2 V_\epsilon}\right)\right|. \tag{A15}$$

Since $f'' > 0$ and $0 < \hat{e}(\beta) \leq e(\beta, V_\epsilon)$,

$$\bar{A}\hat{e}(\beta)\left| f'\left(\frac{e_{\max}}{\beta^2 V_\epsilon^m}\right)\right| \leq \bar{A} e(\beta, V_\epsilon)\left| f'\left(\frac{e(\beta, V_\epsilon)}{\beta^2 V_\epsilon}\right)\right|$$

$$\leq \bar{A} e_{\max}\left| f'\left(\frac{\hat{e}(\beta)}{\beta^2 V_\epsilon^M}\right)\right|. \tag{A16}$$

Given assumptions 1(iii), $\hat{e}(\beta) \to e_{\max}$ as $\beta \to \infty$. Hence, both the left and right sides of (A16) are converging to $\bar{A} e_{\max}|f'(0)|$ as $\beta \to \infty$, so the middle term is converging there uniformly on Σ as well. Hence, $\beta^2 A_V$ converges uniformly to

$$\frac{\bar{A} e_{\max}|f'(0)|}{V_\epsilon^2}. \tag{A17}$$

It follows that the expression on the right-hand side of (15) is converging uniformly to (A17) as well. Since (A17) is strictly decreasing, it follows that for large β, any solution $V_\epsilon(\beta)$ to (15) will be closely approximated by V_ϵ^∞, and that $V_\epsilon(\beta) \to V_\epsilon^\infty$ as $\beta \to \infty$. ∎

References

Baker, G.P., M.C. Jensen, and K.J. Murphy, "Compensation and Incentives: Practice vs. Theory," *Journal of Finance: Papers and Proceedings* 43(3) (1988), 593-616.

Barkema, H.G., "Do Top Managers Work Harder When They Are Monitored?," *Kyklos* 48(1) (1995), 19-42.

Bebchuk, L.A. and J.M. Fried, "Executive Compensation as an Agency Problem," *Journal of Economic Perspectives* 17(3) (2003), 71-92.

Bénabou, R. and J. Tirole, "Intrinsic and Extrinsic Motivation," *Review of Economic Studies* 70(3) (2003), 489-520.

Caplin, A.S. and J. Leahy, "Psychological Expected Utility Theory and Anticipatory Feelings," *Quarterly Journal of Economics* 116(1) (2001), 55-79.

Casadesus-Masanell, R., "Trust in Agency," *Journal of Economics and Management Strategy* 13(3) (2004), 375-404.

Eysenck, M.W. and M.G. Calvo, "Anxiety and Performance: the Processing Efficiency Theory," *Cognition and Emotion* 6 (1992), 409-434.

Frey, B.S., "Does Monitoring Increase Work Effort? The Rivalry with Trust and Loyalty," *Economic Inquiry* 31(4) (1993), 663-670.

Frey, B.S. and R. Jegen, "Motivation Crowding Theory," *Journal of Economic Surveys* 15(5) (2001), 589-611.

Gibbs, M.J., "An Economic Approach to Process in Pay and Performance Appraisals," working paper, (1991).

Gneezy, U. and A. Rustichini, "Pay Enough or Don't Pay At All," *Quarterly Journal of Economics* 115(3) (2000), 791-810.

Gneezy, U., "The W Effect of Incentives," working paper, (2003).

Grossman, S.J. and O.D. Hart, "An Analysis of the Principal-Agent Problem," *Econometrica* 51 (1983), 7-46.

Holmström, B., "Moral Hazard and Observability," *Bell Journal of Economics* 10(1) (1979), 74-91.

Jensen, M.C. and K.J. Murphy, "Performance Pay and Top-Management Incentives," *Journal of Political Economy* 98(2) (1990), 225-264.

Kahn, L.M. and P.D. Sherer, "Contingent Pay and Managerial Performance," *Industrial and Labor Relations Review* 43(3) (1990), 107-120.

LANDSBURG, S.E., *The Armchair Economist: Economics and Everyday Life* (New York: Simon and Schuster, 1993).

LAZEAR, E.P., "Performance Pay and Productivity," *American Economic Review* 90(5) (2000), 1346-1361.

LOEWENSTEIN, G., "Anticipation and the Valuation of Delayed Consumption," *Economic Journal* 97(387) (1987), 666-684.

MACLEOD, A., J. WILLIAMS, AND D. BEKERIAN, "Worry is Reasonable: The Role of Explanations in Pessimism about Future Personal Events," *Journal of Abnormal Psychology* 100 (1991), 478-486.

MILGROM, P. AND J. ROBERTS, *Economics, Organization, and Management* (Englewood Cliffs, New Jersey: Prentice-Hall, 1992).

MORRIS, L., D. DAVIS, AND C. HUTCHINGS, "Cognitive and Emotional Components of Anxiety: Literature Review and Revised Worry-Emotional Scale," *Journal of Educational Psychology* 75 (1981), 541-555.

RAUH, M. AND G. SECCIA, "Anxiety and Performance: An Endogenous Learning-by-Doing Model," *International Economic Review* (forthcoming), (2006).

WOODMAN, T. AND L. HARDY, "Stress and Anxiety," in R.N. Singer, H.A. Hausenblas, and C.M. Janelle, eds., *Handbook of Sport Psychology*, 2nd edition (New York: Wiley, 2001), 290-318.

ZAICHKOWSKY, L.D. AND A. BALTZELL, "Arousal and Performance," in R.N. Singer, H.A. Hausenblas, and C.M. Janelle, eds., *Handbook of Sport Psychology*, 2nd edition (New York: Wiley, 2001), 319-339.

Figure 1

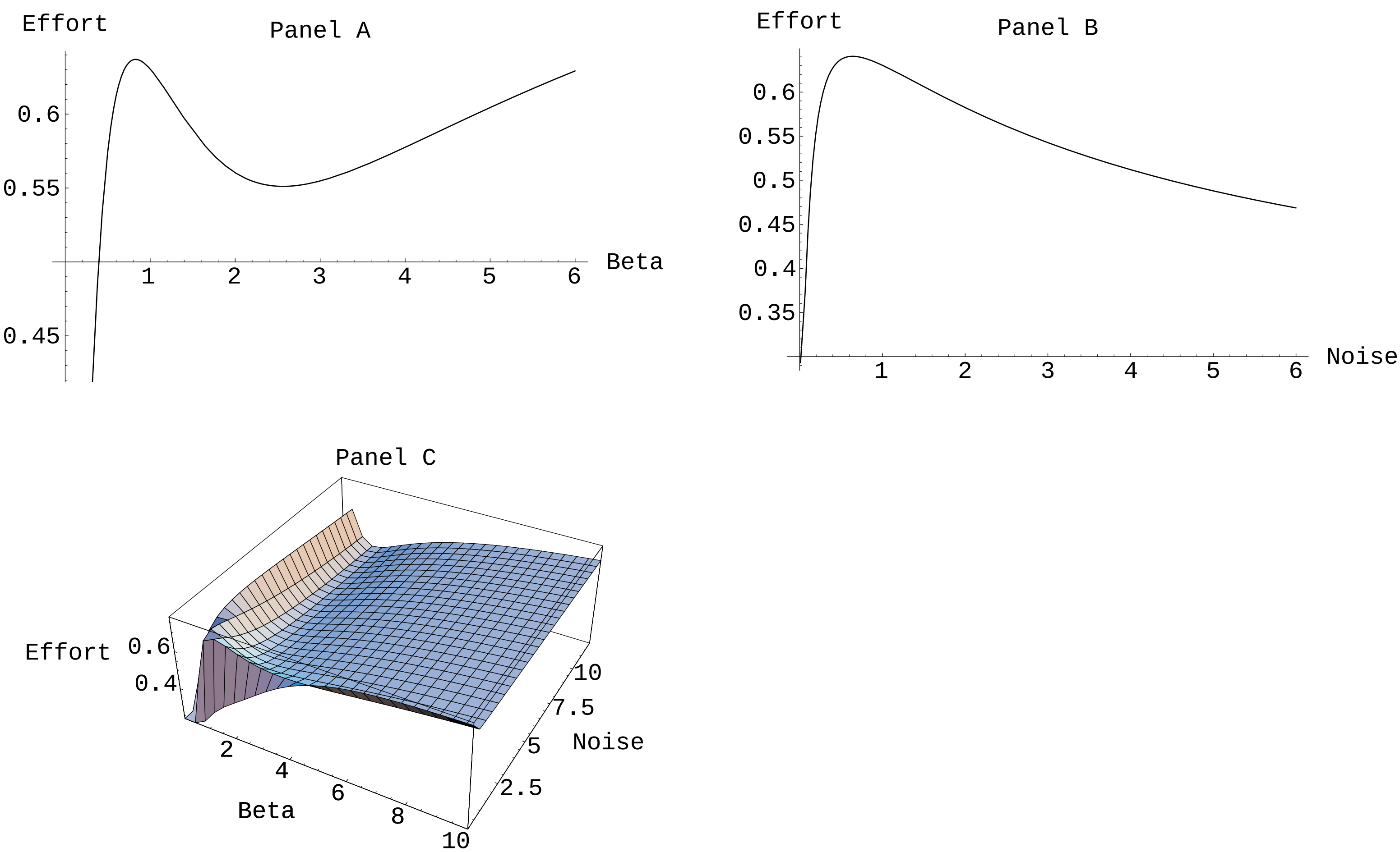
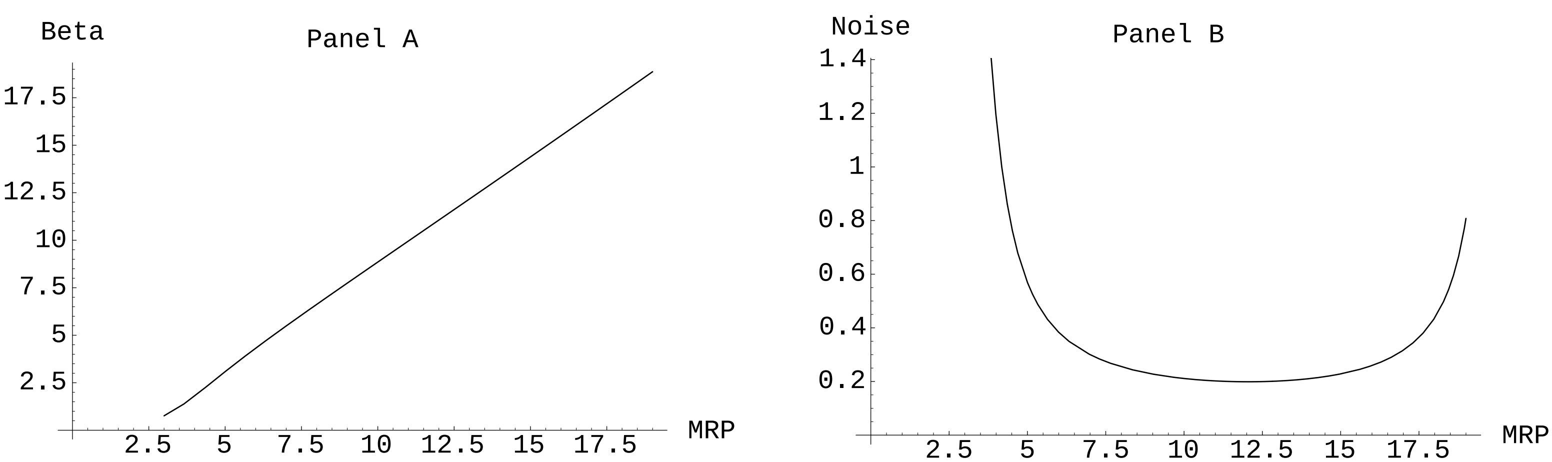

Panel A
Effort
0.6
0.55
0.45
Beta
1
2
3
4
5
6
Panel B
Effort
0.6
0.55
0.5
0.45
0.4
0.35
Noise
1
2
3
4
5
6
Panel C
Effort
0.6
0.4
2
4
6
8
10
Beta
2.5
5
7.5
10
Noise

Figure 2



Panel A
Beta
17.5
15
12.5
10
7.5
5
2.5
2.5
5
7.5
10
12.5
15
17.5
MRP
Panel B
Noise
1.4
1.2
1
0.8
0.6
0.4
0.2
2.5
5
7.5
10
12.5
15
17.5
MRP

Figure A