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Agency and Anxiety

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Abstract

In this paper, we introduce the psychological concept of *anxiety* into agency theory. An important benchmark in the anxiety literature is the *inverted-U hypothesis* which states that an increase in anxiety improves performance when anxiety is low but reduces it when anxiety is high. We consider a version of the Holmström-Milgrom linear principal-agent model where the agent conforms to the inverted-U hypothesis and investigate the nature of the optimal linear contract. We find that although high-powered incentives can be demotivational, a profit-maximizing principal never offers them. In contrast, the principal may optimally engage in a demotivational level of monitoring. Moreover, since risk can be motivational, the principal may refrain from eliminating it even when monitoring is costless. Indeed, the principal may even add pure noise to the contract in order to motivate the agent, contradicting the *informativeness principle*. Finally, incentives and monitoring can be strategic substitutes or complements in our model.

> 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

Some fundamental assumptions and predictions of standard principal-agent theory seem to be at odds with a significant and growing body of empirical and experimental evidence.

Incentives

There is little doubt that monetary incentives can be a powerful motivational force. For example, 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).

In contrast, the claim that incentives are always motivational, in all contexts and circumstances, is highly controversial in management, psychology, sociology, and the broader social sciences, and the non-economic literature is replete with evidence that incentives can undermine intrinsic motivation and even reduce performance. Furthermore, recent experimental work by economists support these findings; see Gneezy and Rustichini (2000), Gneezy (2003), Ariely, Gneezy, Loewenstein, and Mazar (2005), and the survey by Frey and Jegen (2001). If incentives can have "hidden costs" or even be counterproductive, this may help to explain why extensive piece rate systems like the well-known case of Lincoln Electric[1] seem to be the

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

exception rather than the norm, as well as the widespread view, articulated in Baker, Jensen, and Murphy (1988) and Jensen and Murphy (1990), that incentives often appear weak in real-world organizations.

A nascent but growing theoretical literature attempts to explain how and under what circumstances incentives can be demotivational. Gibbs (1991) informally argues that a contingent reward can signal that the probability of promotion is high, dulling promotion incentives. Bénabou and Tirole (2003) show that incentives can have hidden costs when they signal that a task is difficult or distasteful or the agent's skill is low. In Bénabou and Tirole (2006), extrinsic incentives can "crowd out" intrinsic motivation and reputational concerns when the agent initially engages in prosocial behavior (e.g., giving blood or volunteering) to signal prosocial preferences to herself or others. The previous two papers formalize and extend certain aspects of *motivation crowding theory* surveyed in Frey and Jegen (2001). Casadesus-Masanell (2004) shows that it may be in the agent's best interest to develop intrinsic motivation in the form of norms, ethical standards, or altruism. In that context, extrinsic incentives can reduce effort, performance, and total surplus.

Risk-Reward Tradeoff and Monitoring

A central feature of principal-agent theory is the familiar risk-reward tradeoff. In the standard linear model (SLM) of Holmström and Milgrom (1987, 1991) and the textbook version in Milgrom and Roberts (1992), optimal incentives are decreasing in the variance of the performance measure (risk) when the latter is exogenous. If the principal has access to a monitoring technology which can reduce the variance at some cost, then risk is endogenous and incentives and monitoring are strategic complements. Although the agent's optimal effort is independent of monitoring and risk, an increase in monitoring allows for greater incentives, which in turn induce higher effort, so all three should be positively related.

In his influential survey, however, Prendergast (1999, p. 19) characterizes the evidence for the existence of a risk-reward tradeoff as being "rather mixed."

Furthermore, Barkema's (1995) empirical results using data on top managers at medium-sized Dutch firms suggests that monitoring can be *demotivational* when the principal-agent relationship is close. In accordance with motivation crowding theory, his explanation is that monitoring can signal distrust and thereby reduce intrinsic motivation.

The Psychology of Uncertainty and Inverted-U Hypothesis

In economics, the concept of *risk aversion* captures a basic attitude towards risk, while the concept of *risk premium* measures the cost of risk, both of which are reflected in the curvature of the utility function. Likewise, uncertainty and human reactions to it are also important in psychology, where the corresponding concept is that of *anxiety*. Given their common focus, it is not surprising that there is some overlap between these two concepts. For example, anxiety is a "negative emotion" connected with uncertainty and, similarly, the risk premium measures the cost of risk and enters negatively in the agent's expected utility [see equation (5) below]. There are some differences, however, between these concepts. In particular, anxiety explicitly incorporates a variety of cognitive processes such as worry which are at most implicit in its economic counterparts. In the next section, we provide a brief introduction to the anxiety literature in psychology.

An important benchmark in the anxiety literature is the *inverted-U hypothesis* or *Yerkes-Dodson Law*, which simply states that the relationship between anxiety and performance (e.g., athletic performance, information processing, reaction times, test scores, etc.) takes the form of an inverted-U: an increase in anxiety improves performance when anxiety is low, but decreases it when anxiety is high. Although the empirical psychology literature is mixed, numerous studies support the inverted-U hypothesis [for a survey of the evidence, see Zaichkowsky and Baltzell (2001)].

Following seminal contributions by Loewenstein (1987) and Caplin and Leahy (2001), there now exists a small but growing anxiety literature in economics. The former paper uses a reduced form representation to investigate some implications of anticipatory emotions (including anxiety) for consumption decisions, while the latter paper and a related contribution by Rauh and Seccia (2006) attempt to provide decision-theoretic foundations for the anxiety concept. Ariely, Gneezy, Loewenstein, and Mazar (2005) specifically invoke the inverted-U hypothesis to explain their experimental results.

Given the relative importance of the inverted-U hypothesis, the central question of the present paper is: what are the implications for the principal's optimal choice of incentives and monitoring when the agent's behavior conforms to it? To investigate these issues, we consider a reduced-form representation where the agent's disutility of effort depends on the variance of income, so that an increase in income risk is motivational (i.e., reduces the marginal cost of effort) when income risk is low, and is demotivational when income risk is high. Although we do not model the underlying psychological processes, this formalization is broadly consistent with the *processing efficiency theory* from cognitive psychology and the endogenous learning-by-doing model in Rauh and Seccia (2006), which focus on the implications of anxiety for the agent's optimal choice of effort (we briefly discuss these theories in the next section). Moreover, the agent's maximization problem is a special case of the Caplin and Leahy (2001) *psychological expected utility* framework.

After incorporating the effects of anxiety in this way, the agent's behavior conforms to the inverted-U hypothesis. In particular, high-powered incentives and intense monitoring can be demotivational as found by Ariely, Gneezy, Loewenstein, and Mazar (2005) and Barkema (1995). As Prendergast (1999, p. 18) points out, however, there is little conclusive evidence for the existence of counterproductive incentives in actual workplace settings. In this paper, we reconcile these two strands of the literature by showing that although *exogenously* determined high-powered incentives can be demotivational, a profit-maximizing principal never *endogenously* offers them.

In contrast, we show that the principal optimally engages in a demotivational level of monitoring when the agent is sufficiently risk averse, in line with Barkema's (1995) empirical findings. Furthermore, the traditional risk-reward relationship breaks down in our model in the sense that optimal incentives can be non-monotonic in risk when the latter is exogenous. If the principal has access to a costly monitoring technology, so that both incentives and risk are endogenous, then incentives and monitoring can be strategic *substitutes* as well as complements in our model. These results may help explain the aforementioned mixed evidence for the existence of a risk-reward tradeoff. Finally, since risk can be motivational, the principal may want to manipulate it in ways that are at odds with the SLM. In particular, the principal may refrain from eliminating it even when monitoring is costless and may even want to add extraneous noise to motivate the agent, which violates the well-known *informativeness principle.*

The plan for the rest of the paper is as follows. In section 2, we briefly survey the anxiety literature in both economics and psychology. In section 3, we present the model and results. Section 4 concludes. All proofs are in the appendix.

2. The Anxiety Literature in Economics and Psychology

The main purpose of this section is to orient the reader to what is perhaps an unfamiliar subject and to provide a basis for assessing to what extent our reduced-form representation of anxiety is consistent with the anxiety literatures in economics and psychology. For further information, see Caplin and Leahy (2001) and Rauh and Seccia (2006) in the economics literature and the surveys by Woodman and Hardy (2001) and Zaichkowsky and Baltzell (2001) in the sports psychology literature.

Definition of Anxiety

According to Woodman and Hardy (2001, p. 290-291),

> 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.*
> (italics in the original).

Anxiety is therefore a multi-dimensional construct. The first component, cognitive anxiety, is 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)].

Like the economic concepts of risk aversion and risk premium, cognitive anxiety is associated with uncertainty, but unlike them it has an explicitly cognitive character. The second component, somatic anxiety or physiological arousal, is connected with physical symptoms such as an elevated heart rate and shaky hands: "indications of autonomic arousal and unpleasant feeling states such as nervousness and tension" [Morris, Davis, and Hutchings (1981, p. 541)]. Although physiological arousal can be a major factor in the heat of the moment and for tasks with a significant motor component, it seems less important for the study of incentive mechanisms, where the time horizon is longer and the physical aspects of most tasks are relatively minor. We therefore focus exclusively on cognitive anxiety from now on.

The benchmark inverted-U hypothesis (discussed in the introduction) is an empirical generalization, like the Phillips curve in macroeconomics. We now turn to psychological theories which have the potential to explain and justify it.

The Processing Efficiency Theory

The starting point for most anxiety theories in psychology is that the agent's initial reaction to uncertainty is negative, since 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.
> Eysenck and Calvo (1992, p. 410).

It is therefore clear how anxiety could reduce performance. What is not clear, however, is how it could *improve* it, which was the initial motivation for the development of the *processing efficiency theory* by Eysenck and Calvo (1992).

> 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).
> (*ibid*, p. 410).

The main contribution of the processing efficiency theory is the hypothesis that anxiety can serve a *motivational function*, inducing the agent to increase effort:

> Worry about task performance has a second effect within the [processing efficiency] theory. It serves a motivational function... 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).

Whether or not the agent responds with increased effort depends on the probability of success:

> Thus, unless the likelihood or the estimated intensity of aversive consequences is higher if one continues on the task than if one avoids the task, subjects will generally proceed with the task with increased effort.
> *ibid*, p. 413.

An increase in anxiety can therefore improve performance if the agent is motivated to increase effort to such an extent that it outweighs the initial negative impact of worry. In contrast, the agent may avoid the task (reduce effort) when anxiety is sufficiently high and may even "give up" altogether (reduce effort to zero). In that case, the overall impact of anxiety is unambiguously negative.

Reversal Theory

Another theory that has the potential to explain the inverted-U hypothesis is *reversal theory* due to Apter (1982). In this theory, an agent can pass through distinct "meta-motivational" states characterized by different reactions to uncertainty. For example, in a *paratelic* state the agent is risk-loving (to use economic terminology) and interprets uncertainty as excitement or exhilaration, whereas in a *telic* state the agent is risk averse and perceives uncertainty as anxiety. Presumably, an increase in uncertainty would improve performance in the former state and reduce it in the latter. Although much broader in scope, these aspects of reversal theory are similar to the familiar economic context of an agent whose cubic utility function is initially convex and then concave.

To our knowledge, the only formal theories of anxiety are in economics. Among economists, anxiety research was pioneered by Loewenstein (1987) and Caplin and Leahy (2001). We now sketch the latter, since the agent's decision problem in our model can be viewed as a special case.

Psychological Expected Utility Theory

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

$$u_1[\phi(z_1, l_2)] + E_{l_2}[u_2(z_2)], \tag{1}$$

where u_1 and u_2 are the 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, as opposed to the more familiar case of economic outcomes. The first period outcome $\eta(s_1, \alpha_1)$ is determined by the first period action α_1 and first period state s_1, while the second period lottery $\lambda(\alpha_1, \pi_2|s_1)$ is induced by the latter, as well as the agent's second period policy function π_2. The agent's objective function is obtained by substituting these terms into (1):

$$u_1[\phi(\eta(s_1, \alpha_1), \lambda(\alpha_1, \pi_2|s_1))] + E_{\lambda(\alpha_1, \pi_2|s_1)}[u_2(z_2)]. \tag{2}$$

The advantage of this framework is that it can incorporate in a very general way a wide range of anticipatory emotions, including anxiety. What it possesses in terms of generality, however, it lacks in terms of detail. In particular, anxiety remains a "black box" in this theory, since the map ϕ is exogenous and completely general, with no structure apart from continuity.

Endogenous Learning-By-Doing Model

In an attempt to provide a more structured anxiety concept, Rauh and Seccia (2006) consider a two-period decision problem where performance

$$\pi_t = \theta e_t + \epsilon_t \tag{3}$$

in period t depends on the agent's skill θ, effort e_t, and a productivity shock ϵ_t. Although the agent is uncertain about the level of θ, at the start of the second period she can observe her own first period performance π_1 and Bayesian update. The agent's first period effort e_1 therefore has an important informational role since the signal is partly endogenous (endogenous learning-by-doing). Anxiety is then defined as the difference between expected utility with zero uncertainty and expected utility evaluated at optimal first period effort. As such, it is the opposite of the usual *value of information* concept and can be interpreted as the "disutility of residual uncertainty."

An advantage of the endogenous learning-by-doing model is that anxiety is an endogenous construct consistent with expected utility theory. Moreover, the agent's optimal effort and expected performance exhibit aspects of the inverted-U hypothesis, reversal theory, and the processing efficiency theory. In particular, an increase in the volatility of ϵ_t garbles the signal π_1 and the agent reacts by increasing e_1 to restore some its informativeness when the volatility is low. In contrast, informativeness is restored by reducing effort when the volatility of ϵ_t is sufficiently high, so the agent's optimal effort can conform to the inverted-U hypothesis.

3. Model and Results

We consider a generalization of the SLM in Holmström and Milgrom (1987, 1991) and the textbook version in Milgrom and Roberts (1992). Assume output is given by $q = e + \epsilon$, where e is the agent's effort and ϵ is a normally distributed productivity shock with mean zero and variance V_ϵ. We assume the latter is bounded above: $0 \leq V_\epsilon \leq \overline{V}_\epsilon$. As usual, we restrict attention to linear compensation rules of the form $I = \alpha + \beta q$, where I is the agent's income, α is a fixed payment (or receipt), and β is the incentive parameter or piece rate. We denote the variance of income as $V_I = \beta^2 V_\epsilon$. As is well-known, linear compensation rules are generally suboptimal, but are assumed for tractability and because they are fairly realistic and relatively easy to administer. For further discussions of this issue, see Holmström and Milgrom (1987, 1991).

In the SLM, the agent's utility function is

$$-\exp\{-r[I - C(e)]\}, \tag{4}$$

where r is the coefficient of absolute risk aversion and $C(e)$ is the disutility of effort. As is well-known [see Bolton and Dewatripont (2005, p. 137-139)], under these assumptions the agent's certainty equivalent is

$$\text{CE}_A = \alpha + \beta e - C(e) - (1/2) r \beta^2 V_\epsilon, \tag{5}$$

where the final term is the agent's risk premium.

In this paper, the aim is to derive properties of the optimal linear contract when the agent's behavior conforms to the inverted-U hypothesis. To do this, we recall that most anxiety theories in psychology assume the initial reaction to uncertainty is worry, which uses up scarce attentional resources and leads to a deterioration in performance. What happens next, according to the processing efficiency, reversal, and endogenous learning-by-doing theories, depends on how anxiety influences the agent's choice of effort: if uncertainty is perceived as a positive emotion (reversal theory) and/or acts as a spur, motivating the agent to increase effort (processing efficiency and endogenous learning-by-doing theories), then performance may be improved, whereas if uncertainty is perceived negatively and/or demoralizes the agent, performance will decline. What emerges from this literature, therefore, is the importance of the relationship between anxiety and optimal effort. To incorporate these effects, we assume a reduced-form expression $C(\phi e)$ for the agent's disutility of effort, under the following assumptions.

Assumptions 1. *(i) C and $\phi(V_I)$ are twice continuously differentiable on $[0, \infty)$. (ii) $C', C'' > 0$ on $[0, \infty)$. (iii) $\phi(0) = 1$, there exists $\hat{V}_I > 0$ such that $\phi' < 0$ on $[0, \hat{V}_I)$ and $\phi' > 0$ on $(\hat{V}_I, \infty)$, $\phi(\hat{V}_I) > 0$, and $\phi'' > 0$.*

The function ϕ is illustrated in Figure 1 below.

Figure 1 Goes Here

We first note that $C(\phi e)$ is a standard disutility of effort function when $V_I = 0$, since $\phi = 1$ in that case. For all $V_I > 0$, the marginal cost of effort $\phi C'$ is positive and increasing in effort as usual. The derivative of the marginal cost of effort with respect to V_I is $\theta \phi'$, where $\theta = C' + \phi e C'' > 0$. It follows that the marginal cost of effort, an important component of the agent's motivation, is decreasing in V_I up to $V_I = \hat{V}_I$ and increasing in V_I thereafter, which captures the basic idea of the inverted-U hypothesis. Moreover, the total cost of effort $C(\phi e)$ follows the same pattern, in accordance with reversal theory: the agent interprets uncertainty positively when it is low and negatively when it is high.

Under these assumptions, the agent's certainty equivalent is

$$\mathrm{CE}_A = \alpha + \beta e - C(\phi e) - (1/2) r \beta^2 V_\epsilon, \tag{6}$$

and the only difference between (5) and (6) is that ϕ appears in the latter.

Psychological Expected Utility Theory

In the above interpretation of the model, the agent's certainty equivalent (6) was derived assuming exponential utility (4), a normally distributed productivity shock, and linear compensation rules. Given the reduced form ϕ, (6) is therefore consistent with expected utility theory. We now provide a completely different interpretation based on the Caplin-Leahy psychological expected utility theory.

We consider the model as a game with four periods. In the first period, the principal makes a take-it-or-leave-it offer with respect to the contract. In the second, the agent accepts or rejects. If she rejects, she receives her opportunity cost $\overline{u}$. If she accepts, she chooses effort in period three. In period four, output and the agent's income are realized and both parties receive their payoffs. In this context, we assume the agent is risk neutral in the usual sense that $u_1(x) = u_2(x) = x$ [cf. equation (1)]. In the third period, there is no state s_1 (the productivity shock occurs in the fourth period) and the agent's effort e corresponds to α_1 in Caplin and Leahy (as distinguished from the fixed component α of income). The economic outcome is $\eta(e) \equiv e$, so in our model η is simply the identity map. The lottery l_2 corresponds to the agent's stochastic income I,[2] so

$$\lambda(\alpha_1) = \lambda(e) = \alpha + \beta q. \tag{7}$$

[2] Formally, l_2 equals the probability distribution of I rather than the random variable I itself, but this distinction is unimportant.

We now define the function ϕ^{CL} (the superscript CL distinguishes it from our ϕ) that maps the economic outcome and second period lottery to the agent's psychological state as follows:

$$\phi^{CL}(\eta(\alpha_1), \lambda(\alpha_1)) = \phi^{CL}(e, I) = -C[\phi(V_I)e] - (1/2)rV_I. \tag{8}$$

The advantage of the Caplin-Leahy framework is that it allows us to give a precise definition for anxiety in this context: anxiety is the psychological state given by the expression in (8). Note that anxiety includes the second term in (8), which is similar to the risk premium in (6), so anxiety is the broader concept in that sense. In this context, however, r is a parameter of the ϕ^{CL} map and cannot be interpreted as the coefficient of absolute risk aversion. Indeed, the agent is risk neutral. Nevertheless, throughout the paper we use the usual terminology. The first term in (8) is the agent's disutility of effort. Although normally we do not think of the latter as having psychological connotations, in our model the disutility of effort includes the reduced-form ϕ that captures the unmodeled motivational/demotivational effects of anxiety referred to in the processing efficiency, reversal, and endogenous learning-by-doing theories. As such, it falls under the anxiety concept. Anxiety is therefore a "negative emotion" consisting of two components: the first term captures the motivational/demotivational effects of anxiety, while the second reflects the direct negative impact of uncertainty (e.g., worry).

Since the agent is risk neutral, expected second period utility is simply $\alpha + \beta e$ and (2) becomes (8).

Let $p > 0$ denote the marginal benefit of the agent's effort to the principal, who therefore sets β such that $0 \leq \beta \leq p$. As in Milgrom and Roberts (1992), we assume the principal has access to a monitoring technology which can reduce V_ϵ at some cost. Specifically, the principal incurs the cost $M(V_\epsilon)$, where $M' < 0$ and $M'' > 0$. A complete specification of the contract is therefore $(\alpha, \beta, V_\epsilon)$.

Given the contract, the agent chooses effort to maximize (6). Note that (6) is strictly concave and eventually decreasing in effort, so a solution exists, is unique, and the first-order condition is both necessary and sufficient. Lemma 1 below is mainly a technical result which shows that the principal must incur a fixed cost $\underline{\beta}(V_\epsilon) > 0$ to induce positive effort because $C'(0) > 0$ (see Assumptions 1). Although anxiety can act as a second source of motivation for the agent, compared with the SLM, she is *not* intrinsically motivated in the sense that she will not work for free or even for sufficiently small but positive incentives.

Lemma 1. *(i) If*

$$(\hat{V}_I/\overline{V}_\epsilon)^{1/2} \geq \phi(\hat{V}_I)C'(0) \tag{9}$$

then for each $V_\epsilon \in [0, \overline{V}_\epsilon]$ *there exists a unique* $\underline{\beta}(V_\epsilon) > 0$ *such that the agent's optimal effort is zero for all* $0 \leq \beta \leq \underline{\beta}(V_\epsilon)$ *and positive for all* $\beta > \underline{\beta}(V_\epsilon)$. *(ii) Furthermore,* $\underline{\beta}$ *is continuous and strictly decreasing on* $[0, \overline{V}_\epsilon]$ *and*

$$0 < \phi(\hat{V}_I)C'(0) \leq \underline{\beta}(V_\epsilon) \leq C'(0) \tag{10}$$

for all $V_\epsilon \in [0, \overline{V}_\epsilon]$.

From now on, we assume $p > C'(0)$ to ensure that the principal's problem is nontrivial for all $V_\epsilon \in [0, \overline{V}_\epsilon]$.

We now turn to the comparative statics of the agent's problem, with particular focus on conditions under which incentives and monitoring are demotivational. Throughout the paper, partial derivatives are indicated by subscripts. Demotivational monitoring occurs when $e_{V_\epsilon} > 0$, so that a reduction in monitoring would result in an increase in V_ϵ and therefore an increase in optimal effort. Note that we can give an explicit expression for the agent's optimal effort

$$e^* = \frac{1}{\phi}(C')^{-1}(\beta/\phi). \tag{11}$$

Proposition 1. *(i) For all* $\beta > \underline{\beta}(V_\epsilon)$,

$$e_\beta = \frac{1 - 2\beta V_\epsilon \phi' \theta}{\phi^2 C''} \quad \text{and} \quad e_{V_\epsilon} = -\frac{\beta^2 \phi' \theta}{\phi^2 C''}. \tag{12}$$

(ii) There exists a nonempty open set involving β and V_ϵ sufficiently small where incentives are motivational and monitoring demotivational. (iii) There also exists a nonempty open set involving β and V_ϵ sufficiently large where incentives are demotivational and monitoring is motivational.

For purposes of comparison, we note that $e_\beta = 1/C'' > 0$ and $e_{V_\epsilon} = 0$ in the SLM [see (5)]. According to (ii), incentives are motivational when β and V_ϵ are small, but monitoring is demotivational. In contrast, monitoring has no effect on effort in the linear model. According to (iii), incentives are eventually demotivational for any fixed $V_\epsilon \in [0, \overline{V}_\epsilon]$, which corresponds to the experimental results in Ariely, Gneezy, Loewenstein, and Mazar (2005).

We illustrate these results in Figure 2 below, which is similar to Figure 1 in Frey and Jegen (2001).

Figure 2 Goes Here

For some fixed $V_\epsilon \in [0, \overline{V}_\epsilon]$, we assume the marginal cost of effort is MC_1 when the principal sets $\beta = \beta_1$ and the agent's optimal effort is e_1. Now consider an increase in β from β_1 to β_2, so the variance of income increases from $\beta_1^2 V_\epsilon$ to $\beta_2^2 V_\epsilon$. In the SLM, the marginal cost of effort is independent of the variance of income, so the agent would respond by increasing effort from e_1 to e_2. In the present model, however, the increase in uncertainty is interpreted positively by the agent (the disutility of effort falls) and is motivational (the marginal cost of effort also falls) when the variance of income is initially small. As a result, the marginal cost of effort shifts down to MC_2 and there is a further increase in effort from e_2 to e_3. Incentives have "hidden rewards" in this range and are *more* powerful than in standard theory.

On the other hand, if the variance of income is already sufficiently large at $\beta = \beta_1$ then the increase in uncertainty is interpreted negatively (anxiety) and the agent reacts by at least partially avoiding the task. In this range, incentives have "hidden costs" since anxiety is debilitating and demoralizing and the marginal cost of effort shifts up to MC_2, causing the agent to reduce effort from e_2 to e_4, for an overall decline in effort from e_1 to e_4.

Since the agent's "performance" is q and expected performance equals optimal effort, we can also relate these results to the inverted-U hypothesis. For example, if

$$\phi(V_I) = aV_I^2 + bV_I + 1 \quad \text{and} \quad C(\phi e) = (1/2)(\phi e)^2 \tag{13}$$

then a simple exercise shows that

$$e^* = \frac{\beta}{[1 + V_I(b + aV_I)]^2} \tag{14}$$

at an interior optimum. We plot this expression as a function of both β and V_ϵ in Panel A of Figure 3 below.[3]

Figure 3 Goes Here

Panel B depicts a cross-section in β when $V_\epsilon = 1/10$ and Panel C a cross-section in V_ϵ when $\beta = 3$. Expected performance is therefore hill-shaped in incentives and the variance of the productivity shock, in accordance with the inverted-U hypothesis.

We now turn to the principal's problem. Given the agent's optimal effort $e^* = e(\beta, V_\epsilon)$, the principal chooses incentives and monitoring to maximize

$$\mathrm{TCE} = pe^* - C(\phi e^*) - (1/2)r\beta^2 V_\epsilon - M(V_\epsilon) \tag{15}$$

subject to $0 \leq \beta \leq p$ and $V_\epsilon \in [0, \overline{V}_\epsilon]$. As usual, we need not concern ourselves with the agent's participation constraint, since α will be set such that it always binds. A solution to the principal's problem clearly exists, since optimal effort is continuous.[4]

Is it ever optimal for the principal to offer demotivational incentives or engage in demotivational monitoring? According to (i) of Proposition 2 below, incentives

[3] In this example, $C'(0) = 0$ but we still obtain the indicated results. In Figure 3, $a = 6/5$ and $b = -2$ and small changes in these parameters have no qualitative effect.

[4] Examples reveal that (15) is not necessarily strictly concave, so the first-order conditions are only necessary, not sufficient. Fortunately, that is all our results require.

are never demotivational when the principal wishes to induce a positive level of effort $\underline{\beta}(V_\epsilon) < \beta$ and does not sell the firm to the agent $\beta < p$. In contrast, (ii) states that the principal does engage in demotivational monitoring when the agent is sufficiently risk averse. Recall that Barkema (1995) provides empirical evidence that real-world monitoring can indeed be demotivational when the principal-agent relationship is close. This is consistent with (16) below, since a close principal-agent relationship should entail a relatively low marginal cost of monitoring.

Proposition 2. *(i) The principal never offers demotivational incentives at any optimum where the principal operates the firm and the agent supplies positive effort. (ii) At any optimum where $0 < V_\epsilon < \overline{V}_\epsilon$, a necessary condition for demotivational monitoring is*

$$r > -2\left[\frac{M'}{\beta^2} + \frac{\phi' C'}{\phi}(C')^{-1}(\beta/\phi)\right]. \tag{16}$$

In particular, there exists $\bar{r} > 0$ such that monitoring is demotivational at all such optima for all $r > \bar{r}$.

In our model, the principal only offers low-powered incentives (high-powered incentives are demotivational by Proposition 1), which seems consistent with some researchers' views on the character of real-world compensation practices, such as Baker, Jensen, and Murphy (1988) and Jensen and Murphy (1990).

Recall that Lazear (2000) found a strong positive relationship between incentives and output using real-world data from an actual firm (Safelite Glass Corporation) which is presumably interested in maximizing profits. In contrast, numerous experimental studies in economics and psychology have either failed to find such a relationship or found a negative one. These two strands of the literature are often juxtaposed, as when Lazear writes that "Claims by sociologists and others that monetizing incentives may actually reduce output are unambiguously refuted by the data" (cited in the introduction). In fact, what our paper shows is that these two literatures are *complementary*, in the sense that *exogenously* set incentives can be demotivational as in Proposition 1, whereas real-world principals should never *endogenously* set counterproductive incentives as in Proposition 2. In other words, there is nothing inherently inconsistent with observing demotivational incentives in the lab but motivational incentives in the field, since the former are not generally determined in a profit-maximizing way.

Of course, Proposition 2 assumes a profit-maximizing, well-informed principal. If these assumptions are not met, then a real-world principal might very well set counterproductive incentives. In fact, Gneezy and Rustichini (2000, Section III) found that the vast majority (87% in the IQ experiment and 76% in the donation experiment) of subjects acting as principals did indeed set demotivational incentives.

At first glance, it may seem counterintuitive that the principal would refrain from setting demotivational incentives but optimally engage in demotivational monitoring. The explanation is that, although intense monitoring is costly and reduces the agent's effort, it also reduces the agent's risk premium. When the agent is sufficiently risk averse, so that r is relatively high, the latter consideration becomes the overriding one.

In the SLM, if monitoring were costless then the principal would immediately set $V_\epsilon = 0$ and sell the firm to the agent ($\beta = p$). This is clear from (15) with $\phi = 1$, because in that case the only effect of V_ϵ is to increase the agent's risk premium since $e_{V_\epsilon} = 0$. Together with the result that the principal does not use mixed strategies, this is one facet of what Milgrom and Roberts (1992, p. 219) call the *informativeness principle.*

Informativeness Principle. *In designing compensation formulas, total value is always increased by factoring into the determinant of pay any performance measure that (with the appropriate weighting) allows reducing the error with which the agent's choices are estimated and by excluding performance measures that increase the error with which effort is estimated (for example, because they are solely reflective of random factors outside the agent's control).*

In contrast, a central theme of the anxiety literature in both economics and psychology is that anxiety can be motivational. If so, the principal will want to indirectly manipulate it through her choices of β and V_ϵ. In particular, if incentives have hidden rewards through their effects on the agent's anxiety level, the principal's optimal setting of them will reflect this. In Proposition 3 below, we show that this also applies to the principal's optimal choice of V_ϵ: if anxiety is motivational then the principal might not want to eliminate it. In that case, she would choose an incomplete level of monitoring ($V_\epsilon > 0$) even if monitoring were costless. In fact, the principal might even *introduce* pure noise into the contract, in violation of the informativeness principle.

Proposition 3. *Assume positive effort at the optimum. (i) If*

$$r < 2\left[\frac{|M'(0)|}{p^2} + p(C')^{-1}(p)|\phi'(0)|\right] \tag{17}$$

then the principal chooses incomplete monitoring at the optimum. (ii) In particular, if r is sufficiently small relative to $|\phi'(0)|$ then there is incomplete monitoring at the optimum even when monitoring is free.

Intuitively, the benefits of complete monitoring are the elimination of the agent's risk premium and perhaps a reduction in the disutility of effort. The costs are the direct costs of monitoring, as well as the lost output which occurs as a result of removing a prime source of the agent's motivation. When the agent is insufficiently risk averse relative to the marginal cost of monitoring $|M'(0)|$ and the initial motivational power of anxiety $|\phi'(0)|$, then monitoring will be incomplete. If $|\phi'(0)|$ is sufficiently large, this will be so even when monitoring is costless.

The link between Propositions 2 and 3 is that the former establishes conditions under which monitoring will be demotivational, whereas the latter considers the extreme case where the principal goes all the way and completely eliminates all uncertainty. According to (16), if r is sufficiently high then the principal will engage in a high level of monitoring, which will be demotivational. If r is not too high, however, (17) indicates that monitoring will be less than complete.

Our final result concerns the risk-reward tradeoff, a central feature of standard principal-agent theory. In the SLM, the optimal β is decreasing in V_ϵ when the latter is exogenous, since an increase in V_ϵ increases the marginal impact of β on the risk premium, inducing the principal to reduce incentives. If the principal has access to a costly monitoring technology then risk is endogenous and incentives and monitoring are strategic complements. For example, an increase in p will induce the principal to offer stronger incentives and, subsequently, to engage in further monitoring to keep the agent's risk premium from rising too much. As Prendergast (1999) points out, the empirical evidence for these predictions is mixed.

In contrast, Proposition 4 below shows that in our model incentives and risk are actually strategic *complements* on a region where β and V_ϵ are sufficiently small and $\beta > \underline{\beta}(V_\epsilon)$. In other words, incentives and monitoring are strategic substitutes on that region. Recall that a real-valued function defined on a Euclidean space is *strictly supermodular* in its variables and parameters if all cross-partial derivatives are strictly positive. For more information on lattice programming and supermodular games, see Milgrom and Roberts (1990), Topkis (1979, 1998), and Vives (1990, 1999).

Proposition 4. *Assume*

$$r < \frac{[p - C'(0)]\,|\phi'(0)|\,C'(0)\,[2C''(0) + \gamma(0)]}{C''(0)^3}, \tag{18}$$

where

$$\gamma = 2C''^2 - C'C'''. \tag{19}$$

(i) There exists $\tilde{\beta}, \tilde{V}_\epsilon > 0$ such that the TCE is strictly supermodular on the region defined by $0 \le V_\epsilon < \tilde{V}_\epsilon$, $\underline{\beta}(V_\epsilon) < \beta < \tilde{\beta}$, and $\tilde{\beta} \le p$. (ii) The optimal (second best) β and V_ϵ are increasing in p whenever they fall within this region.

To get a clearer picture, we return to the example in (13) and (14) and plot $\partial^2\text{TCE}/\partial\beta\partial V_\epsilon$ in Figure 4 below.[5]

Figure 4 Goes Here

We observe that incentives and monitoring are strategic complements in the middle region of Figure 4 where the cross-partial is negative, but strategic substitutes when incentives and risk are both relatively large or both small, as stated in Proposition 4. These results suggest that optimal incentives could be non-monotonic in risk when the latter is exogenous, which is confirmed in Figure 5 below.[6]

Figure 5 Goes Here

A linear regression using the data in Figure 5 might not pick up any statistically significant relationship between incentives and risk, which might help explain the mixed nature of the evidence on the risk-reward tradeoff. Of course, a *nonlinear* regression might reveal the true relationship.

4. Summary and Conclusions

In this paper, we introduced the psychological concept of anxiety into the standard linear principal-agent model (SLM) of Holmström and Milgrom (1987, 1991) and Milgrom and Roberts (1992). We began with a brief survey of the anxiety literature in economics and psychology, including decision-theoretic foundations provided by the processing efficiency, reversal, psychological expected utility, and endogenous learning-by-doing theories. An important benchmark in that literature is the inverted-U hypothesis, supported by numerous experimental and field studies including Ariely, Gneezy, Loewenstein, and Mazar (2005).

[5] In Figure 4, $p = 11/10$, $r = 1/10$, and a and b are as in Figure 3. Note that we do not need to specify monitoring costs for this cross-partial derivative.

[6] Figure 5 was generated using the same parameter configuration as Figure 4.

To formally model the effects of anxiety, we added the map $\phi(V_I)$ into the agent's disutility of effort to capture the motivational/demotivational aspects of the variance V_I of income. If $\phi \equiv 1$ then our model is identical to the SLM, so the model in this paper generalizes the latter. We showed that ϕ can be interpreted as a reduced-form representation of unmodeled psychological processes or arising out of the Caplin-Leahy psychological expected utility framework.

After incorporating ϕ into the SLM, the agent's behavior becomes consistent with the inverted-U hypothesis. In particular, high-powered incentives and intense monitoring can be demotivational in line with the experimental evidence in Ariely, Gneezy, Loewenstein, and Mazar (2005) and empirical work by Barkema (1995). In contrast, in the SLM optimal effort is monotonically increasing in incentives and independent of monitoring.

As Prendergast (1999, p. 18) points out, there is little conclusive evidence that real-world firms actually use counterproductive incentives, despite the experimental evidence. In this paper, we reconciled this apparent discrepancy by showing that although high-powered incentives are demotivational, a profit-maximizing principal never offers them. Moreover, the fact that the principal only offers low-powered incentives is consistent with the view expressed in Baker, Jensen, and Murphy (1988) and Jensen and Murphy (1990) that incentives often appear weak in real-world organizations.

On the other hand, the principal does engage in demotivational monitoring when the agent is sufficiently risk averse relative to the marginal cost of monitoring and the motivational effects of anxiety. We used this result to re-interpret Barkema's (1995) empirical evidence in support of demotivational monitoring, since a close principal-agent relationship should also entail relatively low monitoring costs.

If monitoring were costless, then in the SLM the principal would eliminate all risk and sell the firm to the agent since in that model risk only increases the agent's risk premium and cannot serve any positive role. In contrast, in our model anxiety can be motivational so monitoring will be incomplete even when the latter is costless, as long as the agent is not too risk averse. Indeed, the principal may even want to *introduce* additional risk in settings where it is initially negligible, which violates the *informativeness principle*.

Finally, in the SLM there is a negative relationship between incentives and risk and incentives and monitoring are strategic complements. In our model, however, the former relationship can be non-monotonic, which may help explain the mixed nature of the evidence on the risk-reward tradeoff as characterized by Prendergast (1999, p. 19). Moreover, in our model incentives and monitoring can be strategic substitutes when incentives and risk are both relatively low or high, and strategic complements otherwise.

Appendix

Proof of Lemma 1

To prove (i), fix $V_\epsilon \in [0, \overline{V}_\epsilon]$. Since the agent's first-order condition is necessary and sufficient, optimal effort is zero iff $\beta/\phi \leq C'(0)$. If $V_\epsilon = 0$ then $\phi = 1$ and the condition becomes $\beta \leq C'(0)$ so $\underline{\beta}(0) = C'(0)$. Assume $V_\epsilon > 0$. The function β/ϕ is continuous and strictly increasing on $0 \leq \beta \leq (\hat{V}_I/V_\epsilon)^{1/2}$ and takes the value zero at the left endpoint and

$$\frac{(\hat{V}_I/V_\epsilon)^{1/2}}{\phi(\hat{V}_I)} \geq \frac{(\hat{V}_I/\overline{V}_\epsilon)^{1/2}}{\phi(\hat{V}_I)} \geq C'(0) \tag{A.1}$$

at the right endpoint. It follows that $\underline{\beta}(V_\epsilon)$ exists and is unique. It is clearly continuous in V_ϵ, and since an increase in the latter pivots β/ϕ upwards about the origin, it is also strictly decreasing on $[0, \overline{V}_\epsilon]$. To prove (10), we note that

$$\underline{\beta}(V_\epsilon) = \phi(\underline{\beta}(V_\epsilon)^2 V_\epsilon) C'(0) \geq \phi(\hat{V}_I) C'(0) > 0, \tag{A.2}$$

which completes the proof. ∎

Proof of Proposition 1

(i) is a simple exercise. To prove (ii) and (iii), define the continuous functions $h_1(\beta, V_\epsilon) = \beta - \underline{\beta}(V_\epsilon)$ and $h_2(\beta, V_\epsilon) = \beta^2 V_\epsilon$. Let $\mathbf{R}_+$ denote the nonnegative real numbers. The set

$$h_1^{-1}((0,\infty)) \cap h_2^{-1}([0, \hat{V}_I)) \tag{A.3}$$

is open in $\mathbf{R}_+$ and nonempty, since it contains $(\beta, V) = (p, 0)$ [recall $p > C'(0)$]. On this open set, optimal effort is interior and (12) is valid. Furthermore, $\phi' < 0$ because $0 \leq V_I < \hat{V}_I$. It follows that $e_\beta, e_{V_\epsilon} > 0$ on the open set defined by (A.3). Similarly, $e_{V_\epsilon} < 0$ on

$$h_1^{-1}((0,\infty)) \cap h_2^{-1}((\hat{V}_I, \infty)). \tag{A.4}$$

Since ϕ' is strictly increasing and θ is bounded from below by $C'(0) > 0$, the term $1 - 2\beta V_\epsilon \phi' \theta$ diverges to $-\infty$ as $\beta, V_\epsilon \to \infty$. ▮

Proof of Proposition 2

The derivative of (6) with respect to β is

$$(p - \phi C')e_\beta - 2\beta V_\epsilon e \phi' C' - r\beta V_\epsilon. \tag{A.5}$$

Using the agent's first-order condition, we must have

$$(p - \beta)e_\beta = \beta V_\epsilon (r + 2e\phi' C') \tag{A.6}$$

at an interior optimum for β. An optimum involving demotivational incentives would require $e_\beta < 0$ and ϕ' sufficiently positive, which is inconsistent with (A.6). Similarly, the first-order condition for V_ϵ can be written

$$(p - \beta)e_{V_\epsilon} = \beta^2 [e\phi' C' + (1/2)r] + M'. \tag{A.7}$$

The right-hand side of (A.7) is positive iff (16) holds, using (11). Note that β is uniformly bounded away from zero because effort is positive by hypothesis and from

(10). Finally, the right-hand side of (16) is a continuous function on the nonempty compact set defined by the constraints $V_\epsilon \in [0, \overline{V}_\epsilon]$ and $\underline{\beta}(V_\epsilon) \leq \beta \leq p$. Monitoring is therefore always demotivational if r exceeds its maximum. ▮

Proof of Proposition 3

Suppose there is an optimum with positive effort and $V_\epsilon = 0$. From (12), $e_\beta > 0$ and (A.5) reduces to $(p-\beta)e_\beta$, which is strictly positive for all $\underline{\beta}(V_\epsilon) < \beta < p$. The principal therefore sets $\beta = p$ when $V_\epsilon = 0$ (i.e., she sells the firm to the agent). The first-order condition for V_ϵ

$$(p-\beta)e_{V_\epsilon} - \beta^2[e\phi'(0)C'(e) + (1/2)r] - M'(0) \leq 0 \tag{A.8}$$

can therefore be written as

$$-p^2[p(C')^{-1}(p)\phi'(0) + (1/2)r] - M'(0) \leq 0 \tag{A.9}$$

using (11) and the agent's first-order condition $p = \beta = C'$. After re-arranging, we get the opposite of (17). ▮

Proof of Proposition 4

Using the agent's first-order condition, a straightforward calculation shows that

$$e_{\beta V_\epsilon} = \frac{\beta}{\phi^3 C''^3}\left\{2\theta C''^2\left[\beta^2 V_\epsilon(2\phi'^2 - \phi\phi'') - \phi\phi'\right] - \gamma\beta\phi'(1 - 2\beta V_\epsilon\phi' C')\right\} \tag{A.10}$$

for all $V_\epsilon \in [0, \overline{V}_\epsilon]$ and $\beta > \underline{\beta}(V_\epsilon)$. Substituting $\beta = \phi C'$ into (A.5) and differentiating with respect to V_ϵ,

$$(p-\beta)e_{\beta V_\epsilon} - r\beta - 2\beta V_\epsilon \theta\phi' e_{V_\epsilon} - 2\beta e\left[\phi' C' + \beta^2 V_\epsilon(\phi'' C' + e\phi'^2 C'')\right]. \tag{A.11}$$

The sign of (A.11) evaluated at the point $\beta = \underline{\beta}(0) = C'(0)$ and $V_\epsilon = 0$ (where optimal effort is zero) equals the sign of

$$\frac{[p - C'(0)]\,|\phi'(0)|\,C'(0)\,[2C''(0) + \gamma(0)]}{C''(0)^3} - r. \tag{A.12}$$

If (18) holds, then $\partial^2\text{TCE}/\partial V_\epsilon \partial\beta > 0$ for $V_\epsilon \geq 0$ and $\beta > \underline{\beta}(V_\epsilon)$ in a neighborhood of that point. In other words, incentives and monitoring are strategic substitutes. According to Proposition 1,

$$\frac{\partial^2\text{TCE}}{\partial p \partial\beta} = e_\beta > 0 \qquad (A.13)$$

and

$$\frac{\partial^2\text{TCE}}{\partial p \partial V_\epsilon} = e_{V_\epsilon} > 0 \qquad (A.14)$$

for $V_\epsilon \geq 0$ and $\beta > \underline{\beta}(V_\epsilon)$ in a neighborhood of the same point for all $p > C'(0)$. Claim (i) follows and (ii) is an application of theorem 2.3 in Vives (1999, p. 26). ∎

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Figure 1. Shape of ϕ

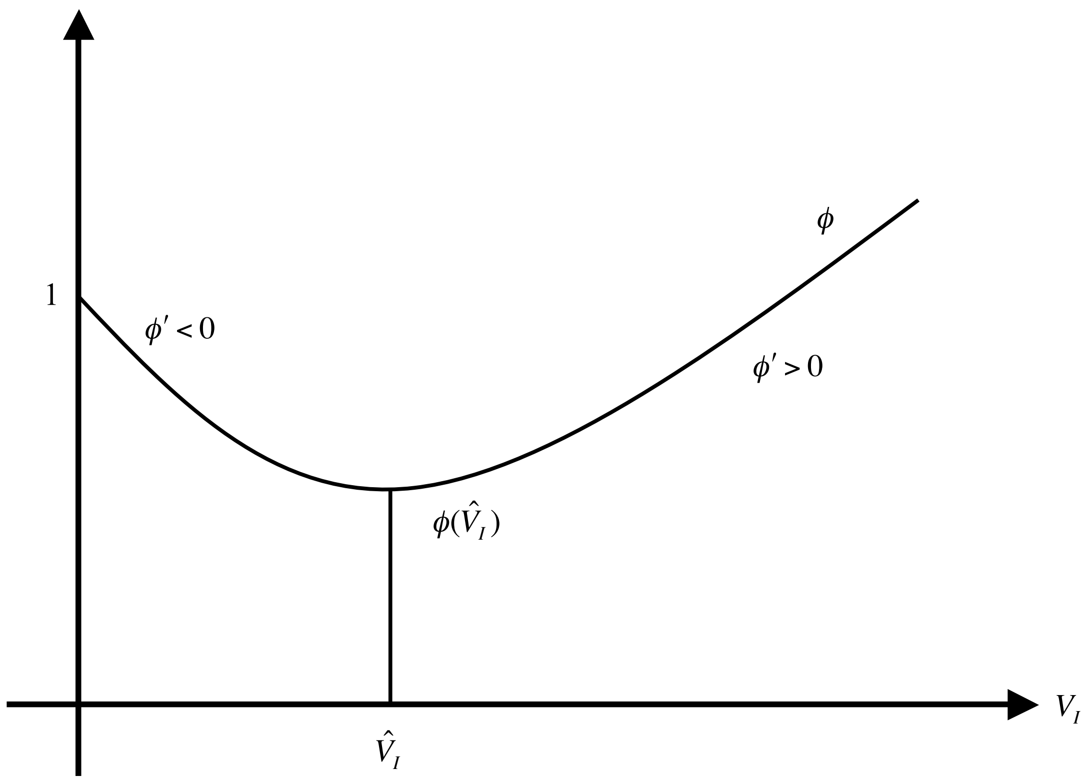


Figure 2

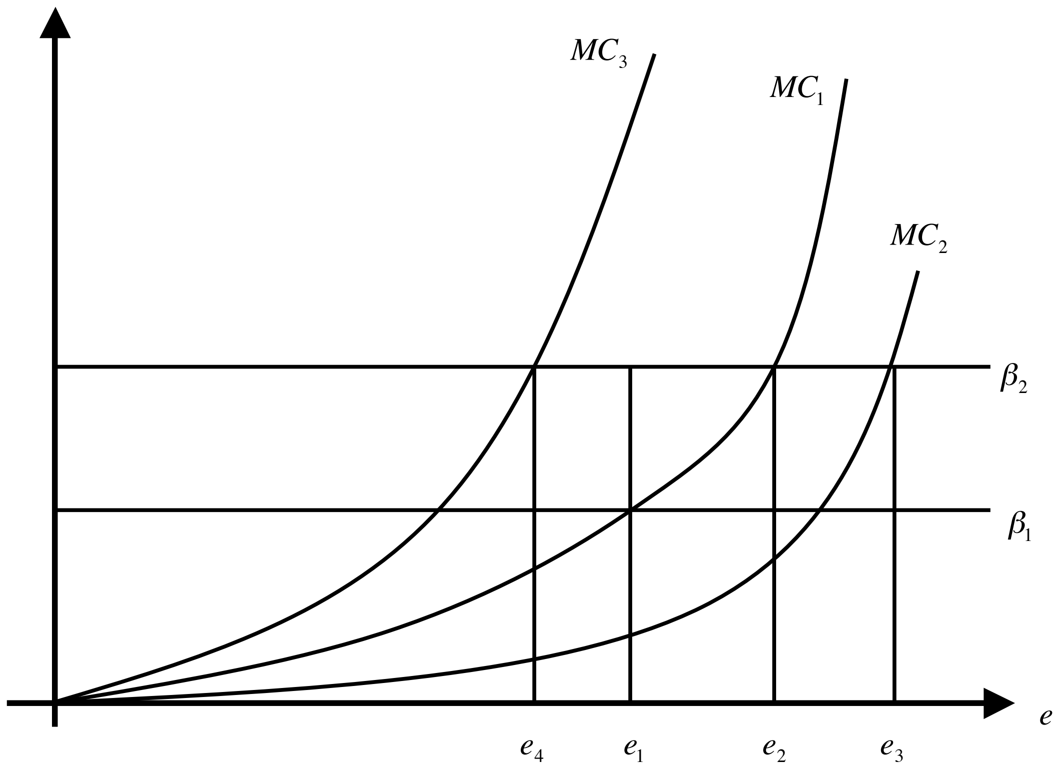
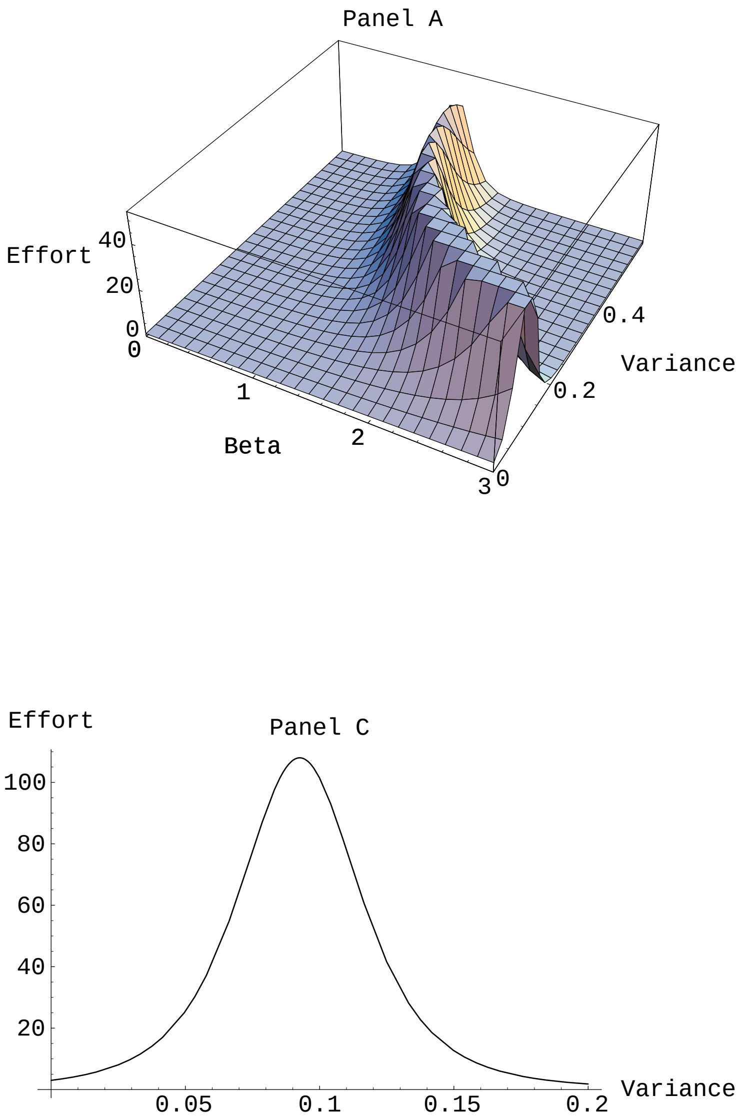


Figure 3



Panel A
Effort
40
20
0
0
1
2
3
Beta
0
0.2
0.4
Variance
Panel B
Effort
100
80
60
40
20
1
2
3
4
5
Beta
Panel C
Effort
100
80
60
40
20
0.05
0.1
0.15
0.2
Variance

Figure 4

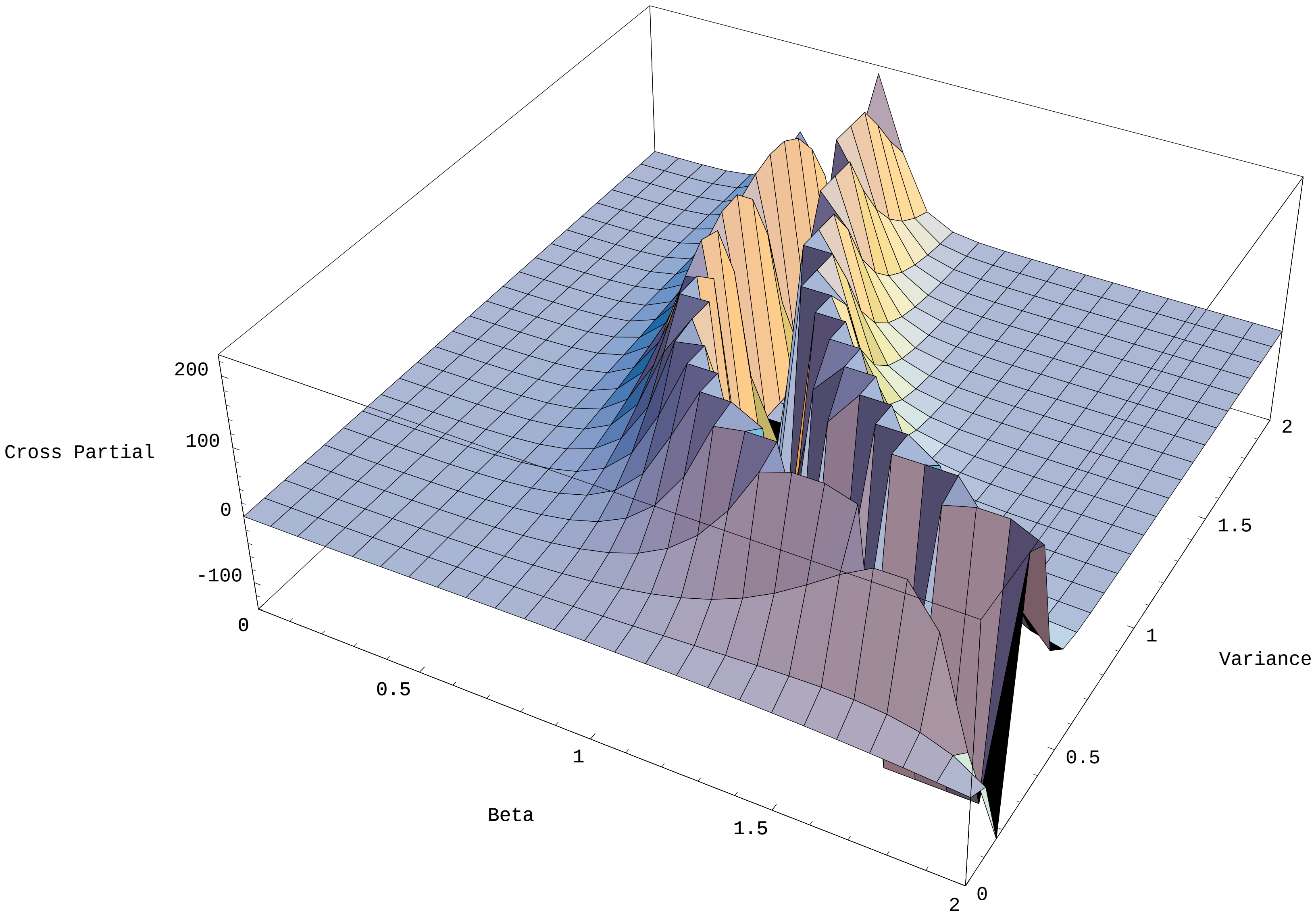


Figure 5