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WHY DOES IT MATTER THAT BELIEFS AND VALUATIONS BE CORRECTLY REPRESENTED?*

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This article contains an analysis of a simple principal–agent problem illustrating possible problems that may arise when the prinicpal ascribes to the agent subjective probabilities and utilities that are implied by the subjective expected utility model but do not represent the agent's beliefs and valuations. In particular, it is possible that an incentive contract designed by the principal induces the agent to choose an action that is not in the principal's best interest.

1. INTRODUCTION

Subjective expected utility theory is founded on the tacit notion that choice among alternative courses of action (acts) is governed by two separate cognitive processes: the assessment of the likelihood of various events, or the formation of beliefs, and the valuation of the consequences associated with those events. Moreover, beliefs are supposed to be coherent enough to allow their representation by a (subjective) probability measure, and the valuation of the consequences sufficiently structured to permit their representation by numerical utilities. Individual preferences on acts are represented by the expected values of the utilities of the consequences of these acts with respect to the subjective probability measure.

Choice-theoretic models of subjective expected utility, including Savage (1954) and Anscombe and Aumann (1963), derive the subjective probabilities and utilities from individuals' preference relations on the set of acts. These, and all similarly conceived models give rise to equivalent representations of preferences each involving a utility function and a corresponding subjective probability measure. To determine a unique subjective probability the choice-theoretic models invoke the convention, not implied by the axioms, that the utility function is state independent. Put differently, the axiomatic structures of the various choice-theoretic, subjective expected utility models require that the preference relations on acts be state independent (e.g., Savage's postulates P3 and P4 and Anscombe and Aumann state-independence, or monotonicity, axiom) but that does not imply that the utility function must be state independent. In fact, state-independent preferences, that is, state-independent risk attitudes, only require that the utility

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function representing the valuation of the consequences in different states be positive affine transformations of one another. Thus, the normalization of the utility functions to make them the same across states has no compelling choice-theoretic foundation. Moreover, the subjective probabilities are the normalized multiplicative coefficients of these utility functions. Hence, these subjective probabilities are inherently arbitrary (see Drèze, 1987, Schervish et al., 1990, Karni and Schmeidler 1993; Karni, 1996, 2003a). In particular, *it is possible that a decision maker's preference relation on acts satisfies the axioms of subjective expected utility theory and yet can be ascribed probabilities that do not represent his beliefs and utilities that do not represent his valuations*.

To remedy this problem and obtain a definition of subjective probability that quantifies the decision makers' beliefs it is necessary to extend the choice space. One possible extension, due to Karni and Schmeidler (1980), calls for the introduction of a second preference relation over hypothetical lotteries on the set of state–consequence pairs. The new preference relation is linked axiomatically to the preference relation on horse/roulette–lotteries acts in the framework of Anscombe and Aumann (1963). The original intent of Karni and Schmeidler was to model subjective expected utility theory with state-dependent preferences; however, Karni and Mongin (2000) recently noted that the probabilities thus obtained are, in fact, the unique correct representation of decision makers' beliefs. The model of Karni and Schmeidler, as well as the more general expected utility model explored in Karni (2003b) and the nonexpected utility theory developed in Grant and Karni (2004), in all of which the subjective probabilities represent decision makers' beliefs, rely on the use of objective probabilities on the set of states as a primitive concept. Adherents of the strict version of the revealed preference methodology would find the reliance of objective probabilities on the state space to describe the choice problem objectionable. Although we believe that strict adherence to revealed preference methodology is itself questionable, our main concern is not methodological. Instead, we are concerned with the potential implications of misrepresentation of decision makers' utilities and probabilities. In other words, we are concerned with the question: Why is it important, other than for philosophical reasons, to represent decision makers' beliefs and valuations correctly? Karni (1996) argued that such a representation is desirable because it renders the decision makers' observed choice behavior and their verbal exchange of information consistent. Our purpose, in this article, is to explore this issue further. In particular, in the context of principal–agent relations with moral hazard, we intend to examine the significance of ascribing to the agent the correct probabilities and utilities.

To pursue our investigation we adopt the subjective expected utility theory developed in Karni (2003a, 2005). In this theory decision makers are supposed to be able to choose among alternatives consisting of action–bet pairs. Actions affect the likely realizations of different effects and bets are monetary payoffs contingent on the different effects. For example, an action may be a choice of lifestyle, including diet and exercise regimens, and the effects will be future states of health. Bets in this case may be health insurance policies. This theory bypasses the need to specify a state space and yields a subjective expected utility representation with effect-dependent utility functions and action-dependent subjective probabilities.

The subjective probabilities represent the decision maker's beliefs regarding the likely realization of the alternative effects conditional on the choice of action, and the utilities represent his valuations of the effect–monetary payoff pairs. Like Savage (1954), Karni's theory does not involve the use of objective probabilities as a primitive concept but, unlike Savage, it accommodates decision situations involving moral hazard. In particular, Karni's (2003a) theory provides an axiomatic foundation of a subjective version of the parameterized distributions formulation of agency theory pioneered by Mirrlees (1974, 1976).

We assume that, for every given action, the principal can observe the agent's choices among alternative bets and, in addition, the principal can observe the agent's choices between two constant bets predicated on distinct actions. In other words, we assume that the principal is in a position to elicit utilities and conditional (on the action) subjective probabilities of the agent (using known elicitation methods) and, in addition, to elicit the subjective (dis)utility to the agent of the alternative actions. The principal is supposed to ascribe to the agent these utilities and probabilities and design the incentive contract accordingly. However, the principal does not *know* the agent's true preferences and may only infer these preferences from the agent's displayed pattern of choices specified above. In fact, we show that there is a whole set of conditional subjective probabilities and utilities that are consistent with the agent's choice behavior. Moreover, we show that if the principal ascribes to the agent utilities and/or subjective probabilities that are consistent with subjective expected utility theory but are not the agent's true conditional subjective probabilities and utilities, then she may fail to induce the agent to act in a way that best serves the interest of the principal. Specifically, we show that *a contract designed, on the basis of ascribed probabilities and utilities that are implied by the choice-theoretic subjective expected utility model, to motivate the agent to choose one action may motivate him, instead, to choose another action that is not in the principal's best interest. Moreover, even if the principal manages to induce the agent to choose the action that best serves the principal's interest, she does it at a cost to herself that exceeds the minimum cost required to attain her objective.*

2. AN EMOTIONAL AGENT PROBLEM

In classical economic theory self-interest seeking behavior is portrayed strictly as a quest to improve the individual's material well-being. This narrow view of human nature has recently been challenged and the possibility of incorporating emotions into the theory of choice is explored (see, for example, a survey by Elster, 1998, and discussions by Loewenstein, 2000; Romer, 2000). The interest in broadening the psychological basis underlying the conduct of economic agents is due, in part, to experimental evidence indicating a tendency of individuals to cooperate in situations in which maximization of material self-interest alone would imply noncooperative behavior (see Berg et al., 1995; Camerer, 1997). Against this backdrop, we next consider a principal–agent relation that may be influenced by emotions such as jealousy or magnanimity. Specifically, we analyze a principal–agent problem in which the agent's preferences incorporate emotions related to the principal's well-being, and yet are representable by a subjective expected utility functional. We show that the failure of the principal to detect the presence of such emotions results in contracts based on the principal's ascribed utilities and probabilities, which are suboptimal.

2.1. *An Advertising Campaign.* Consider the following principal–agent problem. A producer (the principal) engages an advertising agency to promote an event (e.g., a rock concert). The revenue is a random variable that depends on the effect which, in this instance, represents the "latent" demand. Specifically, suppose that there are three effects $X = \{H, M, L\}$, where H signifies high demand, M signifies moderate demand, and L signifies low demand.

The agent must choose between actively promoting the event, choosing the action a^1 and incurring the cost (disutility) $v(a^1) > 0$, and doing nothing, namely, choosing the costless default action a^0, (i.e., $v(a^0) = 0$). Assume that if the agent does not actively promote the event, then if the demand is high the producer will sell the concert hall capacity and attain a high level of revenue, r_H; if the demand is moderate she will sell half of the concert hall capacity and attain a revenue of r_M; and if the demand is low she will sell only 15% of the concert hall capacity and attain low revenue level, r_L. If the agent undertakes an active advertising campaign to reach a wide audience he can boost the demand to the point of ensuring that at least half of the concert hall's capacity is sold. In other words, he can prevent the situation in which only 15% of the capacity is sold, and so either half the concert hall's capacity or the entire concert hall's capacity will be sold. Assume that the nature of the advertising campaign (effort and cost invested to reach the potential audience) is private information of the agent.

We model the situation described above using the analytical framework of Karni (2003a). Let $\mathbf{A} = \{a^1, a^0\}$ denote the set of feasible actions. Suppose that both the agent and the principal agree on the effects of the alternative advertising campaigns. In other words, both parties believe that there is a mapping $F : \mathbf{A} \to \mathcal{X}$, where $\mathcal{X}$ is the set of all subsets of the set X, where $F(a)$ represents the set of effects that may obtain if the action a is implemented.[2] Thus the active advertising campaign a^1 corresponds to $F(a^1) = \{H, M\}$ and a^0 corresponds to $F(a^0) = \{H, M, L\}$. Let $B := \{b : X \to \mathbb{R}\}$ be the set of bets.

Assume that both the principal and the agent are expected utility-maximizing decision makers.[3] Let the principal's preference relation on $\mathbf{A} \times B$ be represented by a subjective expected utility functional

$$(a, b) \mapsto \sum_{x \in X} u^P(b(x); x)\pi^P(x; a)$$

where $\{\pi^P(\cdot\,; a)\}_{a \in \mathbf{A}}$ and u^P are the principal's (action-dependent) subjective probabilities and utilities.

[2] Note that the assumption that the agent and the principal agree on the effects of the alternative advertising campaigns is, in principle, verifiable. The effects that are supposed to be impossible are null effects in Karni (2005).

[3] The axiomatic foundations of the subjective expected utility theory used here are developed in Karni (2003a).

To depict the agent's choice behavior we extend the model somewhat and, following Anscombe–Aumann (1963), we assume that bets are functions from the relevant set of effects to the set of simple monetary lotteries. Namely, we define $H = \{h : X \to L\}$, where L denotes the set of simple probability distributions on $\mathbb{R}$. The agent's preference relation is an effect-independent, continuous weak order, $\succcurlyeq$ on $\mathbf{A} \times H$, that is representable by a subjective expected utility functional

$$(a, h) \mapsto \sum_{x\in X} U^A(h(x); x)\pi^A(x; a) - v(a) = \sum_{x\in X}\sum_{j=1}^{m} u^A(b_j; x)h_j(x)\pi^A(x; a) - v(a)$$

where $\{\pi^A(\cdot\,; a)\}_{a\in\mathbf{A}}$ are the agent's (action-dependent) subjective probabilities on X and U^A and u^A are his utilities on $L \times X$ and $\mathbb{R} \times X$, respectively.

Suppose that the principal and the agent have the same beliefs regarding the likely realization of the effects conditional on the actions. In other words, the principal's and the agent's beliefs are represented by the probability distribution $\{\pi(H; a), \pi(M; a), \pi(L; a)\}_{a\in\mathbf{A}}$. However, the principal and the agent are unaware of the uniformity of their beliefs.

Assume that the principal is risk neutral and her only concern regarding the demand is the revenue it induces. Thus, the principal's utility function is given by $u^P(b(x);\, x) = r_x - b(x)$, $x \in X$. Suppose also that the agent is risk averse and that his effect-dependent valuations of the payoff $w \in [0, 1]$ (where 1 corresponds to \$1 million) are depicted by effect-dependent utility functions $u^A(w;\, x) = \beta_x u(w) + \alpha_x$, $\beta_x > 0$, $x \in X$, where u is a strictly concave, continuously differentiable, real-valued function. Note that the agent's *preferences* are effect-independent even though his utility function is not. Put differently, the agent's attitudes toward monetary risks are the same across effects. Without loss of generality let $\sum_{x\in X}\pi(x; a^0)\beta_x = 1$ and $\sum_{x\in X}\pi(x; a^0)\alpha_x = 0$.

In this framework, if the principal could verify that the agent employed the action a^0 and observe his choice behavior she would ascribe to the agent's subjective probabilities, $p(a^0) = \{p(H;\, a^0),\ p(M;\, a^0),\ p(L;\, a^0)\}$ and an effect-independent utility function, $\hat{u}(w)$, implied by the choice-theoretic subjective expected utility model. For example, the principal can set $\hat{u}(0) := 0$ and $\hat{u}(1) := 1$. Then, for each $Y \subseteq X$, $p(Y;\, a^0)$ is the unique "probability" in [0,1] which, if the agent were to choose a^0 would render him indifferent between the constant bet $p(Y;\, a^0)\delta_1 + (1 - p(Y;\, a^0))\delta_0$ and the bet whose payoff is δ_1 if $x \in Y$ and is δ_0 if $x \in X - Y$, where δ_w denotes the degenerate monetary lottery that assigns to the payoff w the unit probability mass. Formally,

$$(1)\qquad \big(a^0, p(Y; a^0)\delta_1 + (1 - p(Y; a^0))\delta_0\big) \sim \left(a^0, \begin{bmatrix}\delta_1 & x \in Y\\ \delta_0 & x \notin Y\end{bmatrix}\right)$$

Hence, for each $x \in X$, we obtain

$$(2)\qquad p(x; a^0)\sum_{x\in X}\pi(x; a^0)(\beta_x + \alpha_x) = \pi(x; a^0)\beta_x + \sum_{x\in X}\pi(x; a^0)\alpha_x$$

But $\sum_{x\in X}\pi(x;a^0)\beta_x = 1$, and $\sum_{x\in X}\pi(x;a^0)\alpha_x = 0$; hence, if no active advertising campaign is undertaken by the agent, the principal ascribes to the agent the belief that the effect x obtains with probability $p(x;a^0) = \pi(x;a^0)\beta_x$.

Similarly, for each $w \in [0,1]$, $\hat{u}(w)$ is set equal to the unique probability u_w for which

$$\big(a^0, u_w\delta_1 + (1-u_w)\delta_0\big) \sim \big(a^0, \delta_w\big) \tag{3}$$

This implies

$$\begin{aligned} u_w[&\pi(H;a^0)(\beta^H u(1)+\alpha^H) + \pi(M;a^0)(\beta^M u(1)+\alpha^M) \\ &+\pi(L;a^0)(\beta^L u(1)+\alpha^L)] + (1-u_w)[\pi(H;a^0)(\beta^H u(0)+\alpha^H) \\ &+\pi(M;a^0)(\beta^M u(0)+\alpha^M) + \pi(L;a^0)(\beta^L u(0)+\alpha^L)] \\ =\ &\pi(H;a^0)(\beta^H u(w)+\alpha^H) + \pi(M;a^0)(\beta^M u(w)+\alpha^M) \\ &+\pi(L;a^0)(\beta^L u(w)+\alpha^L) \end{aligned} \tag{4}$$

Again using the fact that $\sum_{x\in X}\pi(x;a^0)\beta_x = 1$ and $\sum_{x\in X}\pi(x;a^0)\alpha_x = 0$ we obtain

$$\hat{u}(w) = \frac{u(w)-u(0)}{u(1)-u(0)} \quad \text{for all } w \tag{5}$$

Furthermore, for $x \in F(a^1) = \{H, M\}$, the principal ascribes to the agent the conditional belief $p(x;a^1)$, which is the unique "probability" in [0,1] that satisfies

$$\begin{aligned} &\left(a^1, p(x;a^1)\begin{bmatrix} \delta_1 & x' \in \{H,M\} \\ \delta_0 & x' = L \end{bmatrix} + (1-p(x;a^1))\delta_0\right) \\ &\quad\sim \left(a^1, \begin{bmatrix} \delta_1 & x' = x \\ \delta_0 & x' \in \{H,M\}-\{x\} \\ \delta_0 & x' = L \end{bmatrix}\right) \end{aligned} \tag{6}$$

That is, for $x \in F(a^1)$, we obtain

$$p(x;a^1)[\pi(H;a^1)\beta^H + \pi(M;a^1)\beta^M]\hat{u}(1) = \pi(x;a^1)\beta_x\hat{u}(1) \tag{7}$$

Thus,

$$p(x;a^1) = \frac{\pi(x;a^1)\beta_x}{\pi(H;a^1)\beta_H + \pi(M;a^1)\beta_M}, \quad x \in F(a^1) \tag{8}$$

Moreover, the principal will ascribe to the agent a disutility of undertaking an active advertising campaign of $\hat{v} = \hat{u}(\hat{w})$, where $\hat{w}$ satisfies

$$(a^0, \delta_0) \sim (a^1, \delta_{\hat{w}}) \tag{9}$$

In other words, $\hat{w}$ is the amount of money required to compensate the agent for undertaking the action a^1. Condition (9) implies that

$$\begin{aligned} u(0) = {} & \big[\pi(H; a^1)\beta_H + \pi(M; a^1)\beta_M\big]u(\hat{w}) \\ & + \pi(H; a^1)\alpha_H + \pi(M; a^1)\alpha_M - v(a^1) \end{aligned} \tag{10}$$

Note that if $\hat{w} \leq 0$, then the principal would conclude that the agent actually enjoys the active advertising campaign. In this case the principal may require the agent to pay her for the privilege of undertaking the advertising campaign. Clearly, this is not a typical situation and, henceforth, we assume that $\hat{w} > 0$. This assumption requires that the range of the parameters $(\alpha_x, \beta_x)_{x \in \{H,M\}}$ to be considered must satisfy the following inequality:

$$\begin{aligned} & u(\hat{w}) - u(0) = \\ & \frac{u(0)\big(1 - \big[\pi(H; a^1)\beta_H + \pi(M; a^1)\beta_M\big]\big) - \big[\pi(H; a^1)\alpha_H + \pi(M; a^1)\alpha_M - v(a^1)\big]}{\big[\pi(H; a^1)\beta_H + \pi(M; a^1)\beta_M\big]} > 0 \end{aligned} \tag{11}$$

Suppose that the principal knows the agent's outside option and let this option be earning an effect-independent wage $\bar{w}$. To simplify the exposition, with little essential loss in terms of the insight of the results, let $\bar{w} = 0$. This means that the principal ascribes to the agent a utility of the outside option equal to $\hat{u}(0) = 0$.

Thus the principal ascribes to the agent who undertakes the action a^1 for the contract $w = (w_H, w_M, w_L)$ that pays w_x if the effect $x \in \{H, M, L\}$ obtains, the subjective expected utility

$$p(H; a^1)\hat{u}(w_H) + p(M; a^1)\hat{u}(w_M) - \hat{v} \tag{12}$$

2.2. *The Principal–Agent Problem.* Let the effect-contingent revenue $\mathbf{r} = (r_H, r_M, r_L)$ satisfy $r_H > r_M > r_L$. A contract, $\mathbf{w}$, is a point in $\mathbb{R}^3_+$ representing the agent's effect-contingent pay. To simplify the exposition we assume that contracts stipulating a payment by the agent to the principal are not enforceable. It is well known that if such payments could be enforced it would be possible to penalize the agent to coerce him to avoid taking certain actions that may be detected, ex post. In our example, if a large penalty could be imposed in case the revenue r_L is realized it would be possible to force the agent to avoid the action a^0 for fear of being detected and penalized after the fact. Agency theory deals with this issue by assuming that all the probability distributions on effects conditional on the actions have the same support (see Salanié, 1997). We note that the conclusions of this article hold under the "full support" assumption.

Given the principal's subjective probabilities, $\{\pi(\cdot\,;a)\}_{a\in\mathbf{A}}$, and her perception of the agent's subjective probabilities, $\{p(\cdot\,;a)\}_{a\in\mathbf{A}}$, utility, $\hat{u}$, and the disutility of effort, $\hat{v}$, if the principal wants to induce the agent to undertake the advertising campaign, her problem may be stated as follows:

Choose $\mathbf{w} \in \mathbb{R}^3_+$ so as to maximize

$$\sum_{x\in X} \pi(x;a^1)(r_x - w_x) \tag{13}$$

subject to the participation constraint,

$$\sum_{x\in X} p(x;a^1)\hat{u}(w_x) - \hat{v} \geq 0 \tag{14}$$

and the incentive compatibility constraint,

$$\sum_{x\in X} p(x;a^1)\hat{u}(w_x) - \hat{v} \geq \sum_{x\in X} p(x;a^0)\hat{u}(w_x) \tag{15}$$

The principal will offer the contract $\mathbf{w}^*$ that solves this program if

$$\sum_{x\in X} \pi(x;a^1)\big(r_x - w^*_x\big) \geq \sum_{x\in X} \pi(x;a^0)r_x$$

The agent's problem may be stated as follows: Given the contract $\mathbf{w}^*$, choose $a \in \mathbf{A}$ so as to maximize

$$U(a;\mathbf{w}^*) = \sum_{x\in X} \pi(x;a)\big(\beta_x u\big(w^*_x\big) + \alpha_x\big) - v(a) \tag{16}$$

and implement the optimal action, a^*, if $U(a^*;\, \mathbf{w}^*) \geq u(0)$. Otherwise reject the contract.

Obviously, the principal's perception of the agent's beliefs and valuation of the payoffs may differ from the agent's true beliefs and valuations. We illustrate next the potential pitfalls of misconstrued assignment of utilities and probabilities to the agent. This requires a detailed analysis of the principal–agent problem stated above, which we undertake next.

2.3. *Analysis.* From the viewpoint of the principal the expected revenue if she does not induce the agent to undertake an active advertising campaign is $\pi(H;a^0)r_H + \pi(M;a^0)\,r_M + \pi(L;a^0)\,r_L$.

The principal perceives the incentive compatibility constraint to induce the agent to undertake an advertising campaign to be

$$[p(H;a^1) - p(H;a^0)]\hat{u}(w_H) + [p(M;a^1) - p(M;a^0)]\hat{u}(w_M) - \hat{v} \geq 0 \tag{17}$$

Moreover, the principal perceives the participation constraint to be

$$p(H;a^1)\hat{u}(w_H)+p(M;a^1)\hat{u}(w_M)-\hat{v}\geq 0 \tag{18}$$

Inequality (17) implies that the perceived participation constraint (18) is not binding.

Assume that the agent's disutility $\hat{v}$ from taking the action a^1, as perceived by the principal, is sufficiently small and r_H and r_M are sufficiently large so that the principal perceives it to be in her best interest to induce the agent to undertake the advertising campaign. That is,

$$\begin{aligned}\pi(H;a^1)\big(r_H-w_H^*\big)+\pi(M;a^1)\big(r_M-w_M^*\big)&\\ >\ \pi(H;a^0)r_H+\pi(M;a^0)r_M+\pi(L;a^0)r_L&\end{aligned} \tag{19}$$

Hence the principal's problem may be written as: Choose $\mathbf{w}$ so as to minimize

$$\pi(H;a^1)w_H+\pi(M;a^1)w_M$$

subject to inequality (17).

From the first-order conditions we obtain

$$\frac{\pi(H;a^1)}{\pi(M;a^1)}=\frac{[\pi(H;a^1)-\pi(H;a^0)]\beta_H\hat{u}'\big(w_H^*\big)}{[\pi(M;a^1)-\pi(M;a^0)]\beta_M\hat{u}'\big(w_M^*\big)} \tag{20}$$

where $\mathbf{w}^*=(w_H^*,w_M^*,0)$ denotes the optimal contract as perceived by the principal. Note that $\mathbf{w}^*$ satisfies (17) with equality.

Consider next the agent's choice between the action–act pairs $(a^1, \mathbf{w}^*)$ and $(a^0, \mathbf{w}^*)$. Let $U(a, \mathbf{w}^*)$ denote the agent's subjective expected utility corresponding to the action–act pair $(a, \mathbf{w}^*)$, $a \in \{a^1, a^0\}$. Then

$$\begin{aligned}U(a^1;\mathbf{w}^*)=\pi(H;a^1)\big(\beta_H u\big(w_H^*\big)+\alpha_H\big)&\\ +\pi(M;a^1)\big(\beta_M u\big(w_M^*\big)+\alpha_M\big)-v(a^1)&\end{aligned} \tag{21}$$

and, recalling that $\sum_{x\in X}\pi(x;a^0)\alpha_x=0$,

$$U(a^0,\mathbf{w}^*)=\pi(H;a^0)\beta_H u\big(w_H^*\big)+\pi(M;a^0)\beta_M u\big(w_M^*\big)+\pi(L;a^0)\beta_L u(0) \tag{22}$$

From the agent's perspective and the definition of $\hat{w}$ in Equation (10) we have

$$v(a^1)=\pi(H;a^1)[\beta_H u(\hat{w})+\alpha_H]+\pi(M;a^1)[\beta_M u(\hat{w})+\alpha_M]-u(0) \tag{23}$$

Thus, substituting for $v(a^1)$ in Equation (21), we get

$$U(a^1;\mathbf{w}^*) = \pi(H;a^1)\beta_H\big[u\big(w_H^*\big) - u(\hat{w})\big] + \pi(M;a^1)\beta_M\big[u\big(w_M^*\big) - u(\hat{w})\big] + u(0) \tag{24}$$

Hence,

$$\frac{[U(a^1;\mathbf{w}^*) - u(0)]}{[u(1) - u(0)]} = \pi(H;a^1)\beta_H\frac{\big[u\big(w_H^*\big) - u(\hat{w})\big]}{[u(1) - u(0)]} + \pi(M;a^1)\beta_M\frac{\big[u\big(w_M^*\big) - u(\hat{w})\big]}{[u(1) - u(0)]} \tag{25}$$

But, from the definition of $\hat{w}$, we have

$$\hat{v} = \pi(H;a^1)\beta_H[u(\hat{w}) - u(0)] + \pi(M;a^1)\beta_M[u(\hat{w}) - u(0)] \tag{26}$$

Substituting in Equation (25) we get

$$\frac{[U(a^1;\mathbf{w}^*) - u(0)]}{[u(1) - u(0)]} = \big[\pi(H;a^1)\beta_H + \pi(M;a^1)\beta_M\big] \times \big[p(H;a^1)\hat{u}\big(w_H^*\big) + p(M;a^1)\hat{u}\big(w_M^*\big) - \hat{v}\big] \tag{27}$$

Similarly, recalling that $\sum_{x\in X}\pi(x;a^0)\beta_x = 1$, Equation (22) implies that

$$\frac{[U(a^0;\mathbf{w}^*) - u(0)]}{[u(1) - u(0)]} = p(H;a^0)\hat{u}\big(w_H^*\big) + p(M;a^0)\hat{u}\big(w_M^*\big) > 0 \tag{28}$$

Hence, using the fact that the incentive compatibility constraint (17) is binding, Equations (27) and (28) imply that

$$\frac{[U(a^1;\mathbf{w}^*) - U(a^0;\mathbf{w}^*)]}{[u(1) - u(0)]} = [\pi(H;a^1)\beta_H + \pi(M;a^1)\beta_M - 1] \times \big[p(H;a^0)\hat{u}\big(w_H^*\big) + p(M;a^0)\hat{u}\big(w_M^*\big)\big] \tag{29}$$

Thus, the agent's choice of action depends on the sign of $[\pi(H;a^1)\beta_H + \pi(M;a^1)\beta_M - 1]$. We consider next some special cases.

2.4. *Agent's Types.* An agent is said to be *jealous of the principal* if his utility (and marginal utility) of income increases when the income of the principal decreases. In the principal–agent problem of the preceding subsection an agent is jealous of the principal if $\beta_H < \beta_M < \beta_L$. But $\sum_{x\in\{H,M,L\}}\pi(x;a^0)\beta_x = 1$ implies

$\beta_L > 1$; hence $[\pi(H; a^1)\beta_H + \pi(M; a^1)\beta_M] < 1$. Thus, Equation (29) implies that $U(a^1; \mathbf{w}^*) < U(a^0, \mathbf{w}^*)$. In this instance, under the contract that the principal perceives to be optimal and to induce the agent to undertake action a^1 the agent, in fact, undertakes the action a^0. In other words, under what the principal perceives to be the optimal contract, which the agent accepts since the participation constraint is satisfied, contrary to the wishes of the principal, the agent chooses *not* to incur the cost of undertaking the active advertising campaign. *Because she misconstrued the agent's subjective probabilities and utilities, the principal designed a contract that induced the agent to choose an action that is not in the principal's best interest.*

An agent is *magnanimous toward the principal* if his utility and marginal utility of income increase when the income of the principal increases, that is, if $\beta_H > \beta_M > \beta_L$. If the agent is magnanimous, then by the same argument as above, $\beta_L < 1$, $[\pi(H; a^1)\beta_H + \pi(M; a^1)\beta_M] > 1$, and $U(a^1; \mathbf{w}^*) > U(a^0, \mathbf{w}^*)$. In this case the agent undertakes the action desired by the principal. However, the true (as opposed to the perceived) incentive compatibility constraint is not binding. Consequently, *the principal pays the agent more than is needed to induce the agent to undertake the desired action.*

Finally, if $\beta_H = \beta_M = \beta_L = 1$, the principal's perception of the agent's utilities and probabilities agrees with the agent's true utilities and probabilities. In this instance, the optimal contract will be accepted and will induce the agent to undertake the action desired by the principal at the minimum possible cost to the latter.

Having stated the main conclusions it is instructive to interpret them in a more intuitive way. What our analysis shows is that the principal does not err in her estimate of the agent's marginal rates of substitution at the optimal contract. In other words,

$$\frac{p(x; a)\hat{u}'(w_x)}{p(x'; a)\hat{u}'(w_{x'})} = \frac{\pi(x; a)\beta_x u'(w_x)}{\pi(x'; a)\beta_{x'} u'(w_{x'})}$$

Thus, when faced with the incentive compatibility constraint the principal chooses a contract that equates her marginal rate of substitution to the trade-off implied by the incentive compatibility constraint (see Equation (20)). Where the principal does err is in her evaluation of the agent's disutility of undertaking the action a^1. In particular, if the agent is jealous of the principal the latter overestimates the agent's expected utility of the contract and, at the same time, as shown in Equation (26), she does not overestimate, to the same degree, the agent's disutility from choosing the desired action a^1 over the default action a^0. In other words, the principal is "overoptimistic" in her evaluation of the agent's overall benefits of undertaking the costly action a^1 instead of the default action, a^0 and will not provide the agent with sufficient incentive to do so. Thus the agent prefers to undertake the action a^0. By the same logic, if the agent is magnanimous, the principal underestimates the agent's expected utility of the contract relative to the disutility to the agent of choosing the desired action a^1. In this case, however, the optimal contract overcompensates the agent for undertaking the desired action. Thus, in this case, the agent enjoys an "informational rent."

2.5. *General Results.* The preceding discussion illustrates a more general result. Let $X = \{1, \ldots, n\}$ be ordered so that the payoff to the principal is monotonic increasing in the effects, that is, $r_{x+1} \geq r_x$ for all $x \in \{1, \ldots, n-1\}$. As before, an agent is said to be jealous of the principal if his effect-dependent utility function, $\beta_x u(\cdot) + \alpha_x$, displays the following property: $\beta_{x+1} < \beta_x$ for all $x = 1, \ldots, n-1$. Similarly, an agent is magnanimous if $\beta_{x+1} > \beta_x$ for all $x = 1, \ldots, n-1$. Let $a^0, a^1, \ldots, a^{n-1}$ be actions such that $F(a^j) = X - \{1, \ldots, j\}$, where $\{1, \ldots, 0\} = \emptyset$ and $v(a^{j+1}) > v(a^j)$ for all $j = 0, \ldots, n$. For $j = 0, \ldots, n-1$, let $\hat{w}^j$ be the amount of money required to "compensate" the agent for undertaking action a^j, in the sense that $\hat{w}^j$ satisfies $(a^0, \delta_0) \sim (a^0, \delta_{\hat{w}^j})$. When we say the agent's preferences are *private information*, that will entail assuming that $\hat{w}^{j+1} > \hat{w}^j$ for all $j = 0, \ldots, n-2$.

The principal–agent problem is said to have a nontrivial solution if the principal wants to induce the agent to take an action other than the default action a^0. We summarize our results in the following theorem:

THEOREM 1. *Suppose that the principal is risk neutral, the agent is risk averse, the agent's preferences and actions are private information, $\pi(x; a^j) > \pi(x; a^k)$ for all $x > j > k$, and the principal–agent problem has a nontrivial solution. Then:*

1. *If the agent is jealous, then, under the contract perceived by the principal to be optimal, the agent will undertake an action that is less costly to him than the one the contract is designed to implement (i.e., an action that is suboptimal from the viewpoint of the principal).*
2. *If the agent is magnanimous, then, under the contract perceived by the principal to be optimal, at the very least the agent will undertake the action that the contract is designed to implement but he may even take a higher cost action. The cost to the principal, however, is greater than would have been required if the principal knew the agent's true utilities and probabilities.*
3. *If updated beliefs conform to Bayes' rule (i.e., if $\pi(x; a^j) = \pi(x; a^0) / \sum_{y=j+1}^{n} \pi(y; a^0)$ for all $x > j$), then the contract, perceived by the principal to be optimal, stipulates a wage schedule as follows: $w_i^* = 0$ for $i = 1, \ldots, j$ and $(w_i^* - w_{i+1}^*)(\beta_i - \beta_{i+1}) > 0$.*

PROOF. Let $p(x; a^j)$, $\hat{u}$, and $\hat{v}^j$, $x, j \in \{1, \ldots, n\}$ denote the probabilities (conditional on a^j), the utility of wealth, and the disutilities of actions ascribed by the principal to the agent. In particular, $\hat{v}^j = \hat{u}(\hat{w}_j)$ and since $\hat{u}$ is monotonically increasing and the agent's preferences are private information it follows that $\hat{v}^{j+1} > \hat{v}^j$ for all $j = 0, \ldots, n-2$.

By the hypothesis, for all $k < j$ we have $p(x; a^j) > p(x; a^k)$ for all $x \in X - \{1, \ldots, j\}$. Let a^j be the optimal action from the point of view of the principal. Because the problem has a nontrivial solution, $n - 1 \geq j > 0$. Let $\mathbf{w}^*$ denote the optimal contract. The principal perceives the incentive compatibility constraints necessary to induce the agent to undertake the action a^j to be

$$(30) \qquad \sum_{x=1}^{n} p(x; a^j) \hat{u}(w_x^*) - \hat{v}^j \geq \sum_{x=1}^{n} p(x; a^k) \hat{u}(w_x^*) - \hat{v}^k, \quad k = 0, \ldots, n-1$$

Set

$$\varepsilon_k^j := \sum_{x=1}^{n}[p(x;a^j) - p(x;a^k)]\hat{u}(w_x^*) - \hat{v}^j + \hat{v}^k \geq 0, \quad k = 1, \dots, n-1 \tag{31}$$

Claim 1. *The perceived participation constraint is not binding.*

To prove Claim 1 consider the agent's choice between the action–contract pairs $(a^j, \mathbf{w}^*)$ and $(a^0, \mathbf{w}^*)$. The incentive compatibility constraints imply

$$\sum_{x=j+1}^{n}\left(1 - \frac{p(x;a^0)}{p(x;a^j)}\right)p(x;a^j)\hat{u}(w_x^*) > \hat{v}^j - \hat{v}^0 > 0 \tag{32}$$

But $p(x;a^j) > p(x;a^0)$ for all $x \geq j+1$ and, by assumption, $\hat{v}^0 = 0$. Hence,

$$\sum_{x=j+1}^{n} p(x;a^j)\hat{u}(w_x^*) > \frac{\hat{v}^j}{M} > 0 \tag{33}$$

where

$$M = \frac{\sum_{x=j+1}^{n}\left(1 - \frac{p(x;a^0)}{p(x;a^j)}\right)p(x;\, a^j)\hat{u}(w_x^*)}{\sum_{x=j+1}^{n} p(x;a^j)\hat{u}(w_x^*)} > 0$$

Inequality (33) implies that the perceived participation constraint is not binding.

Claim 1 implies that $w_x^* = 0$ for $x = 1, \dots, j$.

Claim 2. *For some $\bar{k} < j$ the perceived incentive compatibility constraint is binding, that is, $\varepsilon_{\bar{k}}^j = 0$.*

To prove Claim 2 suppose, by way of negation, that for all $k < j$ the perceived incentive compatibility constraints are not binding. Because, for $k < j$, $p(x;a^j) > p(x;a^{\bar{k}})$ for all $x \in X - \{1, \dots, j\}$, $\hat{v}^{\bar{k}} < \hat{v}^j$, and $w_x^* = 0$ for all $x = 1, \dots, j$, we get

$$\sum_{x=j+1}^{n} p(x;a^j)\hat{u}(w_x^*) - \hat{v}^j > \sum_{x=j+1}^{n} p(x;a^k)\hat{u}(w_x^*) - \hat{v}^k, \quad k = 1, \dots, j \tag{34}$$

Because the perceived participation constraint is not binding, there is another contract $\mathbf{w}^{**}$ such that $w_x^{**} = 0$ for all $x = 1, \dots, j$, and $w_x^{**} < w_x^*$ for all $x = j+1, \dots, n$ that induces the agent to implement a^j. This contradicts the optimality of $\mathbf{w}^*$.

Consider next the agent's evaluation of the action–contract pair $(a^k, \mathbf{w}^*)$. Let $B^k = \sum_{x=1}^{n} \pi(x;a^k)\beta_x$; then, from the viewpoint of the agent

$$U(a^k, \mathbf{w}^*) = \sum_{x=1}^{n} \pi(x; a^k)\big[\beta_x u\big(w_x^*\big) + \alpha_x\big] - v(a^k) \tag{35}$$

$$= B^k \sum_{x=1}^{n} p(x; a^k) u\big(w_x^*\big) + \sum_{x=1}^{n} \pi(x; a^k)\alpha_x - v(a^k)$$

From the agent's perspective and the definitions of $\hat{w}^k$ we have

$$v(a^k) = \sum_{x=1}^{n} \pi(x; a^k)\big[\beta_x u(\hat{w}^k) + \alpha_x\big] - u(0) \tag{36}$$

Substituting for $v(a^k)$ in Equation (35) $U(a^k, \mathbf{w}^*)$ yields

$$U(a^k, \mathbf{w}^*) = \sum_{x=1}^{n} \pi(x; a^k)\beta_x\big[u\big(w_x^*\big) - u(\hat{w}^k)\big] + u(0) \tag{37}$$

$$= B^k \sum_{x=1}^{n} p(x; a^k)\big[u\big(w_x^*\big) - u(\hat{w}^k)\big] + u(0)$$

Thus,

$$\frac{[U(a^k, \mathbf{w}^*) - u(0)]}{[u(1) - u(0)]} = B^k \sum_{x=1}^{n} p(x; a^k)\big[\hat{u}\big(w_x^*\big) - \hat{u}(\hat{w}^k)\big] \tag{38}$$

$$= B^k \sum_{x=1}^{n} p(x; a^k)\big[\hat{u}\big(w_x^*\big) - \hat{v}^k\big]$$

Hence, for the agent's choice among the action–contract pairs $(a^j, \mathbf{w}^*)$ and $(a^k, \mathbf{w}^*)$, we have

$$U(a^k, \mathbf{w}^*) - U(a^j, \mathbf{w}^*)$$

$$= [u(1) - u(0)]\left[B^k \sum_{x=1}^{n} p(x; a^k)\big[\hat{u}\big(w_x^*\big) - \hat{v}^k\big] - B^j \sum_{x=1}^{n} p(x; a^j)\big[\hat{u}\big(w_x^*\big) - \hat{v}^j\big]\right]$$

$$= [u(1) - u(0)]\left[(B^k - B^j)\left(\sum_{x=1}^{n} p(x; a^k)\hat{u}\big(w_x^*\big) - \hat{v}^k\right) + B^j \varepsilon_k^j\right]$$

where

$$\sum_{x=1}^{n} p(x; a^k)\hat{u}\big(w_x^*\big) - \hat{v}^{\bar{k}} > 0 \tag{39}$$

because the perceived participation constraint does not bind, and $\varepsilon_k^j \geq 0$, from the perceived incentive compatibility constraints (31).

For $\bar{k} < j$ the index for which the perceived incentive compatibility constraint is binding, that is, $\varepsilon_{\bar{k}}^j = 0$, if the agent is jealous, that is, $\beta_x > \beta_{x+1}$ for $x = 1, \dots, n-1$, then $B^{\bar{k}} > B^j$, and so from Equation (39) we have

$$U(a^{\bar{k}}, \mathbf{w}^*) - U(a^j, \mathbf{w}^*) = (B^{\bar{k}} - B^j)\left(\sum_{x=1}^{n} p(x; a^{\bar{k}})\hat{u}(w_x^*) - \hat{v}^{\bar{k}}\right) > 0$$

the actual incentive compatibility constraint fails. And so part 1 of the theorem follows.

If the agent is magnanimous, i.e., $\beta_x < \beta_{x+1}$ for $x = 1, \dots, n-1$, then $B^{\bar{k}} < B^j$ and $U(a^{\bar{k}}, \mathbf{w}^*) < U(a^j, \mathbf{w}^*)$. Furthermore, we can infer from Equation (39) that $U(a^j, \mathbf{w}^*) > U(a^k, \mathbf{w}^*)$, for every $k < j$. But notice that for $k > j$, $B^k > B^j$ and if

$$\frac{(B^k - B^j)}{B^j} > \frac{-\varepsilon_k^j}{\left(\sum_{x=1}^{n} p(x; a^k)\hat{u}(w_x^*) - \hat{v}^k\right)}$$

then $U(a^k, \mathbf{w}^*) > U(a^j, \mathbf{w}^*)$, which means the agent would prefer to undertake the *more costly* action k. Thus part 2 of the theorem follows.

To prove part 3 of the theorem, observe that the first-order conditions of the principal–agent problem to implement action j are

$$-\pi(x; a^j) + p(x; a^j)u'(w_x^*)\sum_{k=1}^{n}\lambda_k\left(1 - \frac{p(x; a^k)}{p(x; a^j)}\right) + \mu p(x; a^j)u'(w_x^*) = 0, \quad x \in \{j+1, \dots, n\} \tag{40}$$

where λ_k are the Lagrange multipliers corresponding to the incentive compatibility constraints, μ is the Lagrange multiplier corresponding to the participation constraint, and w_x^* denote the optimal values of w_x. Because the participation constraint is not binding, $\mu = 0$. Now from Bayesian updating we have for $x \in \{j+1, \dots, n\}$

$$\begin{aligned}\frac{p(x; a^k)}{p(x; a^j)} &= \frac{\beta_x \pi(x; a^k)}{\beta_x \pi(x; a^j)} = \frac{\beta_x}{\beta_x} \times \frac{\pi(x; a^0)}{\sum_{z=k+1}^{n}\pi(z; a^0)} \\ &\quad \times \frac{\sum_{z=j+1}^{n}\pi(z; a^0)}{\pi(x; a^0)} = \frac{\sum_{z=j+1}^{n}\pi(z; a^0)}{\sum_{z=k+1}^{n}\pi(z; a^0)}\end{aligned} \tag{41}$$

Hence, Equations (40) and (41) imply that, for all $x, y \in \{j+1, \ldots, n\}$,

$$\frac{\pi(x;a^j)}{\pi(y;a^j)} = \frac{p(x;a^j)u'\left(w_x^*\right)\sum_{k=1}^n \lambda_k\left(1-\frac{p(x;a^k)}{p(x;a^j)}\right)}{p(y;a^j)u'\left(w_y^*\right)\sum_{k=1}^n \lambda_k\left(1-\frac{p(y;a^k)}{p(y;a^j)}\right)} \tag{42}$$

$$= \frac{\beta_x\pi(x;a^j)u'\left(w_x^*\right)\sum_{k=1}^n \lambda_k\left(1-\frac{\sum_{z=j+1}^n \pi(z;a^0)}{\sum_{z=k+1}^n \pi(z;a^0)}\right)}{\beta_y\pi(y;a^j)u'\left(w_y^*\right)\sum_{k=1}^n \lambda_k\left(1-\frac{\sum_{z=j+1}^n \pi(z;a^0)}{\sum_{z=k+1}^n \pi(z;a^0)}\right)}$$

$$= \frac{\beta_x\pi(x;a^j)u'\left(w_x^*\right)}{\beta_y\pi(y;a^j)u'\left(w_y^*\right)}$$

Thus, the optimal contract requires $\beta_i u'(w_i^*) = \beta_{i+1}u'(w_{i+1}^*)$ for $i = j+1, \ldots, n-1$ and $w_i^* = 0$ for $i = 1, \ldots, j$. Because $u'(\cdot)$ is decreasing in w, this implies $[w_i^* - w_{i+1}^*]\,[\beta_i - \beta_{i+1}] > 0$ for $i = j+1, \ldots, n-1$, as required. ■

3. CONCLUDING REMARKS

The analysis in this article illustrates and underscores the possible pitfalls of employing subjective expected utility theory to the analysis of principal–agent problems. The source of difficulty is that the agent's preferences may admit alternative equivalent representations involving distinct subjective probabilities, effect-dependent utility functions, and (dis)utilities of actions. If one's only concern is with individual decisions and one is willing to assume effect-independent preferences, then nothing essential is lost by imposing the convention that the utility functions are effect independent and defining action-dependent subjective probabilities and (dis)utilities of actions consistent with this convention. In other words, if the only application of the theory is to individual decision making, then it is not necessary to separate utility and true probability, because only the product of the two matters. Our analysis shows that this is no longer the case if the model is to be applied to the richer context of the principal–agent theory. We analyzed a simple example but the reader will recognize that the issue pervades the entire principal–agent literature.

The qualitative conclusions and insights of our analysis transcend the specification of the model in Section 2. In particular, the assumption that contracts that require the agent to pay the principal if some effects obtain are not enforceable is not essential, and the analysis may be extended to moral-hazard problems that satisfy the usual full-support condition. Under the full-support assumption it may take a while (i.e., many observations) for the principal to conclude with some confidence, using statistical inference, that an agent is shirking. Thus, the model may be extended to the analysis of repeated contracting with learning. Such an extension might be used when applying agency theory to nonprofit and for-profit organizations. For instance, if agents employed by nonprofit organizations are magnanimous toward their employers whereas employees of for-profit firms are jealous of their employers then, under the contracts *perceived to be optimal by the employers* the former employees enjoy an "informational rent" whereas the latter employees tend to shirk.[4]

Our analysis also raises a general concern regarding the applicability of contract theory to problems involving moral hazard, especially when the principal and the agent relations have personal (as opposed to just pecuniary) dimensions. It makes clear that, generally speaking, the information asymmetry with which contract designers must grapple pertains not just to the agent's "hidden actions" but also to the agent's "hidden characteristics," namely, his preferences. Unless the principal knows the agent's actual preferences she cannot be certain that the contract she designs will yield the desired action. Because, as our analysis suggests, the information required is unlikely to be accessible to the principal, if contract theory is to have empirical applications it must inevitably be reformulated to incorporate both the "hidden actions" and "hidden characteristics" aspect of information asymmetry.

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