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# SUBJECTIVE AMBIGUITY AND MORAL HAZARD IN A PRINCIPAL-AGENT MODEL

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## Abstract

It is suggested that individual behavior under ambiguity, or knightian uncertainty, may represent an alternative explanation for contractual incompleteness with respect to the traditional approach in terms of transactions costs. This paper aims at showing that the introduction of ambiguity in the economic analysis of contracts may be very fruitful. In particular, we analyze how ambiguity affects the optimal compensation scheme in a principal-agent framework, where the principal cannot observe the agent's effort and, contrary to standard assumptions, is ambiguity-averse. Also, our model makes it possible to generalize the Mukerji (1998) approach to contractual incompleteness. In fact, it shows that incomplete contracts are costly and that, before reaching the conclusion that ambiguity leads to contractual incompleteness, their costs should be compared with those of complete contracts, other things being equal.

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**Keywords**: ambiguity, agency, E-capacity, contractual incompleteness

# SUBJECTIVE AMBIGUITY AND MORAL HAZARD IN A PRINCIPAL-AGENT MODEL

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## 1. Introduction

Contracts are often incomplete, i.e. many obligations by the parties are left unspecified ex ante and cumbersome ex post renegotiation is allowed.

Several authors have argued that this is due to uncertainty and to the extremely high cost involved in the unambiguous description of a whole set of contingent actions (Hart-Moore 1999). Several criticisms have been leveled against this approach, arguing in particular that it lacks rigorous analytical foundations (Maskin-Tirole, 1999)

These criticisms prompted different types of reaction. The transaction cost approach has been defended and strengthened by its staunchest advocates while alternative explanations have been set out. Among the latter, Bernheim and Whinston (1998) argued that it might be optimal to leave unspecified even aspects of the transactions that could be easily described and verified, owing to complementarities with other unverifiable aspects. Therefore, it is not a problem of transaction costs but of complementarity.

A different perspective has been suggested by Mukerji (1998). His approach is based upon the role that might be played by ambiguity, which in this case is understood not as lack of clarity in writing the contract but as an

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individual's attitude in the presence of knightian uncertainty (ambiguity henceforth). Mukerji argues that ambiguity – in particular, ambiguity aversion – may explain why people refrain from writing a well specified contract, perhaps considering optimal a 'null contract' – the 'quintessentially incomplete contract', as Hart and Moore call it - which relies on ex post renegotiation, when uncertainty will have been dissolved.

The introduction of ambiguity into the economic analysis of contracts is a felicitous idea, as it may shed new light on several questions that have so far been analyzed on the basis of a transaction cost approach, though not too convincingly at times.

The aim of this paper is twofold. The first is to present a model of the principal-agent type where, contrary to common assumptions, the Principal is confronted not only with risk but also with ambiguity. In particular, it will be shown that the optimal compensation scheme offered by the Principal to the Agent will be quite different from that in the standard model.

The second purpose is to argue that ambiguity may not be a sufficient condition for contract incompleteness. In fact, what is needed is a careful comparison of the costs implied in both complete and incomplete contracts. Ambiguity necessarily creates costs, and may enhance the attractiveness of ex post renegotiation under 'null contract', as Mukerij argued. However, sometimes ex post renegotiation may entail such high costs as to make it desirable to have as complete a contract as possible from the start. In this case a contract of the type we propose should be chosen. Very high costs of ex post renegotiation in a Principal-Agent context arise, for instance, when the agent selects a course of action that is catastrophic for the principal. In another paper we showed how the model can apply to such a catastrophic event as the Mad Cow Disease (Basili-Franzini, 2003).

This paper is organized as follows. In Section 2 we introduce ambiguity and ambiguity aversion. In Section 3 we present and solve a Principal-Agent model with unobservable effort and an ambiguity-averse Principal. Concluding remarks are in Section 4.

## 2. Ambiguity and ambiguity aversion

Decision theory under uncertainty describes how an individual does and/or should choose between a set of alternatives, when the consequences of each action are tied to events about which the individual is uncertain, i.e. she does not know what will occur. The individual acts on the basis of a well-defined utility function, which represents her preferences and involves an evaluation of their consequences as well as their likelihood. The individual maximizes her expected utility by weighting consequences with a unique additive probability measure on the set of states of the world: objective (von Neumann-Morgenstern 1944), subjective (Savage 1954) and objective-subjective (Anscombe-Aumann 1963), so as to induce the linearity of the functional preference. Given first order stochastic dominance[1], linearity of probabilities is a direct consequence of two very similar axioms, the Independence Axiom in the von Neumann and Morgenstern theory, and the Sure-thing Principle in the Savage theory.

[1] Given two acts $X$ and $Y$ with cumulative distribution functions $F_X$ and $F_Y$, $X$ first order stochastically dominates $Y$ if $F_X(t) \leq F_Y(t)$ for all $t \in R$. If an individual feels $X$ at least as favorable as $Y$, the cumulative distribution of the preferred prospect never exceeds that of the inferior prospect.

Experimental evidence has revealed systematic violations of the Independence Axiom and the Sure-thing Principle that are inconsistent with the hypothesis of expected utility maximization. The best known of these violations is the Ellsberg Paradox (1961).

Consider the following version of the Ellsberg experimental thought. Given an urn containing ninety balls, of which thirty are red, and the remaining sixty are either blue or white, agents are allowed to extract one ball only. Let $f_j$ = [$\alpha$ if r, $\beta$ if b, $\chi$ if w] be a bet (or act), such that the outcome is $\alpha$ if a red ball (r) is drawn, $\beta$ if it is blue (b) and $\chi$ if it is white (w). There are four possible bets (j=1,2,3,4), that is $f_1$ = [100 if r, 0 if b, 0 if w]; $f_2$ = [0 if r, 100 if b, 0 if w]; $f_3$ = [100 if r, 0 if b, 100 if w]; $f_4$ = [0 if r, 100 if b, 100 if w]. Agents are asked to choose between two pairs of lotteries, i.e. $f_1$ and $f_2$, then $f_3$ and $f_4$. Most agents (more than 70%) exhibit the following strict preference $f_1 \succ f_2$ and $f_4 \succ f_3$. This observed behavior leads to a contradiction (the Sure-thing Principle does not hold), since: $f_1 \succ f_2$ implies $p_r > p_b$, while $f_4 \succ f_3$ implies $p_b + p_w > p_r + p_w$ or $p_r < p_b$, where $p_i$, i=b, r, w denotes the probability of the event of a ball of color *i*.

These preferences contradict the expected utility theory and every other theory of rational behavior under uncertainty that assumes a unique additive probability measure over the states of the world. Hence, “it is impossible, on the basis of such choices, to infer even qualitative probabilities for the events in question…to find probability numbers in terms of which these choices could be described - even roughly or approximately – as maximizing the mathematical expectation of utility” (Ellsberg 1961, p 655). The Ellsberg Paradox and recent experimental evidence (Camerer 1999) suggest that most people would rather make unambiguous choices than ambiguous ones. Inducing evidence that individual choices are not affected by "the relative desirability of the possible payoffs and the relative likelihood of the events affecting them, but …the nature of one's information concerning the relative likelihood of events. What is at issue might be called the ambiguity of this information, a quality depending on the amount, type, reliability and unanimity of information, and giving rise to one's degree of confidence in an estimate of relative likelihood" (Ellsberg 1961, p. 657).

Schmeidler (1989) and Gilboa (1987), in the Anscombe and Aumann and Savage approach, respectively, axiomatize a generalization of expected utility, which provides a derivation of utility and non-necessarily-additive probability or capacity[2] by the Choquet integral[3] (Choquet 1954). The individual expresses ambiguity aversion or pessimism if her non-additive measure is convex[4]. Indeed, she assigns greater probabilities to unfavorable than to favorable states. Ambiguity may be represented by a set of possible priors (additive probabilities) instead of a unique prior on the underlying

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[2] Let $\Omega=\{w_1,...,w_n\}$ be a non-empty finite set of states of the world and let $\Sigma=2^\Omega$ be the set of all events. A function $\mu:\Sigma\rightarrow R_+$ is a non-necessarily-additive probability measure or a capacity if $\mu(\emptyset)=0$, $\mu(\Omega)=1$and $\forall$ $\sigma_1,\sigma_2\in\Sigma$ such that $\sigma_1\supset\sigma_2$, $\mu(\sigma_1)\geq\mu(\sigma_2)$. A capacity is convex if $\forall\sigma_1,\sigma_2\in\Sigma$, $\mu(\sigma_1\cup\sigma_2)+\mu(\sigma_1\cap\sigma_2)\geq\mu(\sigma_1)+\mu(\sigma_2)$ and $\mu$ is super-additive if $\mu(\sigma_1\cup\sigma_2)\geq\mu(\sigma_1)+\mu(\sigma_2)$ for $\sigma_1\cap\sigma\sigma_2=\emptyset$.

[3] The Choquet integral of a real-valued function $f:\Omega\rightarrow R$ with respect to $\mu$ is $\int fd\mu=\int_0^\infty\mu(\{w|\,f(w)\geq t\})dt+\int_{-\infty}^0[\mu(\{w|\,f(w)\geq t\})-1]dt$

[4] The convexity of the capacity is a sufficient condition for pessimism and encompasses the conservative statement that an individual acts "as though the worst were somewhat more likely than his best estimates of likelihood would indicate he distorted his best estimates of likelihood, in the direction of increased emphasis on the less favorable outcomes and to a degree depending on his best estimate" (Ellsberg 1961, p. 667).

state space and her preferences are compatible with the maximin expected utility decision rule.[5]

In this paper we consider *E-capacities* (Ellsberg capacities), which are a "parameterized version of a capacity based on an additive probability distribution that makes it possible to include known probabilities for a partition of unambiguous events" (Eichberger-Kelsey 1999, p. 133). E-capacities were introduced by Ellsberg (1961) and were axiomatized by Eichberger and Kelsey (1999) to accommodate the observed Ellsberg Paradox with the decision theory. E-capacities are a representation of the beliefs of an individual that considers both her probability assessments for events and the reliability (*degree of confidence*) of her probability assessments. The principal has incomplete information, parameterized in her degree of confidence, about the relationship between her utility and the agent's effort. The principal evaluates her expected utility, subject to the agent's effort, by combining her expected utility with respect to the most reliable probability distribution and her worst possible expected utility, each weighted by her degree of confidence.

Let $\Omega=\{w_1,...,w_n\}$ be a non-empty finite set of states of the world and let $\Sigma=2^{\Omega}$ be the set of all events. Let $g$ be an act, such that $g:\Omega\to C$, and let $C$ be the set of finite consequences. Let $\{E_1,\ldots,E_n\}$ be a partition of $\Omega$ with probabilities $p(E_i)$, such that $\sum_{i=1}^{n} p(E_i)=1$, that is a partition of

[5] The maximin expected utility postulates that an agent with multiple priors looks at the least value of expected utility for any act and chooses the act for which the minimum value is greatest. Ellsberg (1961); Arrow-Hurwicz (1972); Gilboa-Schmeidler (1989); Chateauneuf (1991).

*unambiguous events*. Given an additive probability distribution $\pi$ on $\Omega$, let $\Pi(p)$ be the set of *information consistent* additive probabilities, such that $\Pi(p) := \{\pi \in \Delta(\Omega) \left| \sum_{\omega \in E_i} \pi(\omega) = p(E_i)\right\}$ with $i=1,2,\ldots,n$ and for all $A \in \Omega$ let $\beta_i(A): \Omega \to \{0,1\}$, such that $\beta_i(A) \to \{1$ if $E_i \subseteq A$; 0 otherwise$\}$ be the function characterizing events including at least one unambiguous event (Eichberger-Kelsey 1999, p. 118).

Due to ambiguity aversion, the principal has to consider all the sets of conditional probability distributions compatible with her incomplete information on the basis of her degree of confidence $\rho \in [0,1]$. Consequently, the *E-capacity* $\upsilon(\pi,\rho)$ is $\upsilon(A|\pi,\rho) = \sum_{i=1}^{n} [\rho\pi(A \cap E_i) + (1-\rho)p(E_i)\beta_i(A)$ $\forall A \in \Omega$. The Choquet integral of $\upsilon(\pi,\rho)$ "is a weighted average of the expected utility with regard to an additive probability distribution and the worst expected outcome obtained in the unambiguous events [and] this Choquet integral is identical to a representation of preferences over actions suggested in Ellsberg" (Eichberger-Kelsey 1999, p. 133).

## 3. A Principal-Agent model with unobservable effort under ambiguity aversion

Consider the owner (principal) of a firm whose profit depends on the actions taken by the manager (agent) she will hire (contingent events).[6] The principal's utility depends on the profit and the latter depends, at least partially, on the manager's actions. The principal cannot observe the actions taken by the agent (*hidden action*). Since the principal submits to the manager a contract that designs his compensation, the compensation scheme should give the agent the incentive to act with fairness. For simplicity's sake, only two qualities of the manager's labor are assumed, *low* and *high effort*. Thus, effort expresses the one-dimensional measure of the manager's labor quality. Nonetheless, the manager's labor quality is neither observable by the principal nor can it be perfectly inferred from profits. Hence it is assumed that the principal utility is stochastically related to the agent's effort by a conditional density function.

The principal is ambiguity-averse (pessimist), with respect to the relationship between quality of effort and profit, and she has more than one additive conditional density function on contingent events. The principal feels more confident of obtaining a high profit if the manager selects the high effort, but she is unable to attach a unique probability to all the events induced by the agent's actions like in the Ellsberg Paradox. Given ambiguity aversion, the principal has a conditional density function on contingent events that she considers as her best estimate and a set of additive conditional density functions that her "information - perceived as scanty, unreliable, ambiguous – does not permit [*her*] confidently to rule out" (Ellsberg 1961, p. 661).

The principal maximizes her utility, which is the utility of the profit less the agent's wage. More specifically, she is an *E-capacity* maximizer with a degree of confidence $\rho \in [0,1]$. If the information partition does not contain only single element sets and the degree of confidence $\rho$ equals 1, there will be ambiguity about events, but the principal will feel her probability assessment is correct. If the degree of confidence $\rho$ equals 0, the principal will attach a set of probability distributions over events, none of which will be considered fully reliable (*complete ambiguity*).

Let $u(\phi)=\phi$ be the principal utility (*risk neutrality*), with $\phi \in [\phi°, \phi*]$ the low and high profit, respectively. Let $e$ be the agent's effort level, such that $e$ could be $e°$ (low effort) or $e*$ (high effort). Since the effort is not observable, the relationship between profits and the agent's effort level is described by conditional density functions $f(\phi|e)$, with $f(\phi|e) \geq 0$ for all $e$ and $\phi \in [\phi°, \phi*]$, all of which are information consistent. The cumulative distribution function $F(\phi|e*) \leq F(\phi|e°)$ is assumed for all $\phi \in [\phi°, \phi*]$, with strict inequality for some $\phi$. This implies that the principal's expected profit is larger when $e*$ holds.[7]

The agent is a risk-averse utility maximizer with a separable utility function $u(s,e) = v(s) - \gamma(e)$, where $v(s)$ is the utility of monetary wage $s$ and $\gamma(e)$ represents the monetary equivalent of effort disutility, such that

[6] Our model has several features in common with the one developed in Mas-Colell-Whinston-Green (1995).

[7] $F(\phi|e*) \leq F(\phi|e°)$ implies first order stochastic dominance.

$\gamma(e^*) > \gamma(e^\circ)$. The agent's utility increases with s and decreases with *e*, both at decreasing rates; moreover $u(s,e^\circ) > u(s,e^*)$ for all *s*.

There is a conflict between the target of the principal and the purpose of the agent. Given unobservable effort and ambiguity aversion, the principal's optimal contract solves the following problem:

$$Max_{s(\phi)}\{\rho\int_{\phi^\circ}^{\phi^*}(\phi - s(\phi))\, f(\phi|e)d\phi + (1-\rho)\min_{s(\phi),\, f(\phi|e)}\int_{\phi^\circ}^{\phi^*}(\phi - s(\phi))\, f(\phi|e)d\phi\} \qquad [1]$$

such that

$$(i)\int_{\phi^\circ}^{\phi^*} v(s(\phi))\, f(\phi|e)d\phi - \gamma(e) \geq \bar{u}$$

$$(ii) Max_{\bar{e}}\int_{\phi^\circ}^{\phi^*} v(s(\phi))\, f(\phi|\bar{e})d\phi - \gamma(\bar{e})$$

Condition (*i*) is a *participation constraint*, which shows that the agent expected utility is at least equal to his reservation utility level $\bar{u}$; on the other hand, condition (*ii*) is an *incentive constraint*, which assures the agent's optimal effort level *e*, under the compensation scheme *s*($\phi$).

Since the contract specifies effort level *e*, choosing $\phi$ to maximize [1], it is assumed that the principal has to minimize the expected value of the agent's wage, that is

$$Max_{s(\phi)}\{\rho\int_{\phi^\circ}^{\phi^*} - s(\phi)\, f(\phi|e)d\phi + (1-\rho)\min_{s(\phi),\, f(\phi|e)}\int_{\phi^\circ}^{\phi^*} - s(\phi)\, f(\phi|e)d\phi\} \qquad [2]$$

or

$$Min_{s(\phi)}\{\rho\int_{\phi^\circ}^{\phi^*} s(\phi)\, f(\phi|e)d\phi + (1-\rho)\max_{s(\phi),\, f(\phi|e)}\int_{\phi^\circ}^{\phi^*} s(\phi)\, f(\phi|e)d\phi\} \qquad [3]$$

such that

$$(i)\int_{\phi^\circ}^{\phi^*} v(s(\phi))\, f(\phi|e)d\phi - \gamma(e) \geq \bar{u}$$

$$(ii) Max_{\bar{e}}\int_{\phi^\circ}^{\phi^*} v(s(\phi))\, f(\phi|\bar{e})d\phi - \gamma(\bar{e})$$

Let us consider the case in which the principal's purpose is to induce effort level *e**. Constraint (*ii*) can be written as:

$$(iii)\int_{\phi^\circ}^{\phi^*} v(s(\phi))\, f(\phi|e^*)d\phi - \gamma(e^*) \geq \int_{\phi^\circ}^{\phi^*} v(s(\phi))\, f(\phi|e^\circ)d\phi - \gamma(e^\circ) \qquad [4]$$

Consider the problem [2] and assume that the co-state variables are strictly positive[8], $s(\phi)$ must satisfy the first order condition

$$\rho\{-1)\, f(\phi|e^*) + (1-\rho)(-1)\, f^\wedge(\phi|e^*) + \lambda v'(s(\phi))\, f(\phi|e^*) +$$
$$+ \mu v'(s(\phi))[\, f(\phi|e^*) - f(\phi|e^\circ)] = 0$$

Where $f^\wedge(\phi|e^*)$ is the minimum conditional density function with respect to e* in the information consistent set.[9] Dividing by $f(\phi|e)v'(s(\phi))$, the first order condition becomes

$$\rho(-\frac{1}{v'(s(\phi))}) + (1-\rho)(-\frac{1}{v'(s(\phi))}\frac{f^\wedge(\phi|e^*)}{f(\phi|e^*)}) + \lambda + \mu[1 - \frac{f(\phi|e^\circ)}{f(\phi|e^*)}] = 0 \qquad [5]$$

or

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[8] Co-state variables equal to zero are either impossible or induce the violation of the constraints.

[9] If the information consistent set only includes singleton, there is no ambiguity and the degree of confidence does not matter.

$$\frac{1}{v'(s(\phi))}[\rho+(1-\rho)\frac{f\wedge(\phi|e^*)}{f(\phi|e^*)}]=\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}] \quad [6]$$

To evaluate how the wage varies with $\rho$, consider the derivative of [6] with respect to $\rho$

$$\frac{1}{v'(s(\phi))}[1-\frac{f\wedge(\phi|e^*)}{f(\phi|e^*)}]=\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}] \quad [7]$$

It turns out that $\frac{1}{v'(s(\phi))}[1-\frac{f\wedge(\phi|e^*)}{f(\phi|e^*)}]\leq(\geq)0$, that is the wage might decrease or increase when $\rho$ increases.

If $\rho$=1, the principal faces ambiguity but she is certain about the correctness of her probability assessment. It appears as a special case of E-capacity in which there is only a unique conditional probability function and

$$\frac{1}{v'(s(\phi))}=\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}] \quad [8]$$

The compensation scheme pays more than in the case of observable effort[10] for outcomes that are statistically more likely to occur under $e^*$ than under $e^\circ$ and less for outcomes that are statistically more likely under $e^\circ$ than under $e^*$, respectively $[\frac{f(\phi|e^\circ)}{f(\phi|e^*)}]<1$ and $[\frac{f(\phi|e^\circ)}{f(\phi|e^*)}]>1$.

[10] When the effort is observable the optimal compensation scheme is $\frac{1}{v'(s(\phi))}=\lambda$, the payment is a constant and the manager would receive exactly his reservation utility level, that is $v(s(\bar{\phi}))-\gamma(e)=\bar{u}$.

If $\rho$=0, the principal faces a condition of *complete ambiguity* and

$$\frac{1}{v'(s(\phi))}\frac{f\wedge(\phi|e^*)}{f(\phi|e^*)}=\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}] \quad \text{or}$$

$$\frac{1}{v'(s(\phi))}=\frac{f(\phi|e^*)}{f\wedge(\phi|e^*)}\{\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}]\} \quad [9]$$

When the principal is ambiguity-averse, the optimal wage is lower (respectively higher) than the compensation paid when the principal ignores ambiguity if $f\wedge(\phi|e^*)>f(\phi|e^*)$ (respectively $f\wedge(\phi|e^*)<f(\phi|e^*)$). Roughly speaking, under ambiguity aversion the principal will pay less for 'bad outcomes', which are more likely given $f\wedge(\phi|e^*)$ than given $f(\phi|e^*)$. Instead, she will pay more for 'good outcomes', which are more likely given $f(\phi|e^*)$ than given $f\wedge(\phi|e^*)$.

Consider the case of $\rho=\frac{1}{2}$, or *partial ambiguity*. In this case:

$$\frac{1}{v'(s(\phi))}=\frac{1}{2}\{\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}]\}+\frac{1}{2}\frac{f(\phi|e^*)}{f\wedge(\phi|e^*)}\{\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}]\}$$
$$=\frac{f\wedge(\phi|e^*)+f(\phi|e^*)}{2f\wedge(\phi|e^*)}\{\lambda+\mu[1-\frac{f(\phi|e^\circ)}{f(\phi|e^*)}]\} \quad [10]$$

Other things being equal, an ambiguity-averse principal will pay a lower wage in the face of bad events, which are more likely when $f\wedge(\phi|e^*)>f(\phi|e^*)$. On the other hand, the principal will pay a higher wage for favorable events, which are more likely when $f\wedge(\phi|e^*)<f(\phi|e^*)$.

Moreover when $\rho = \frac{1}{2}$, the optimal wage the principal offers the agent will be higher for bad events and lower for favorable events than under complete ambiguity.

Finally, consider the case in which the principal wants to implement effort level *e*°. The principal will offer an optimal wage $s(\phi) = v^{-1}[\bar{u} - \gamma(e°)]$. Since the manager's wage is unaffected by the level of effort, he will always choose *e*°, that is the effort level with lowest disutility, and will always receive $\bar{u}$. The principal will offer a fixed wage $s° = v^{-1}[\bar{u} - \gamma(e°)]$, when she either disregards or considers ambiguity.

Our results show that the optimal wage could depend on the principal's ambiguity aversion. In order to grasp the meaning of this result one should bear in mind that, on the basis of our assumptions, the higher effort *e** is optimal also when the principal ignores ambiguity or has a less pessimistic attitude. Therefore, the change in the wage function does not have the goal of inducing effort *e**, whereas the lower effort *e*° would be chosen with less pessimistic probabilities or disregarding ambiguity.

Due to ambiguity, it may very well happen that the more pessimistic probabilities alter the expected utilities attached by the principal to different $\phi$. This in turn implies that, in order to maximize her utility, the principal will associate higher or lower wages to the various observed results, according to the criterion specified above. Obviously, the chosen wage function must be included among those, which fulfill the incentive and utility constraints on the part of the agent. This effect of ambiguity can be labeled "*the welfare effect*" on the wage. Alongside this, another effect can be singled out. We shall call it the "*higher effort inducing*" effect. It takes place when ambiguity makes it worthwhile implementing the higher effort, whereas without ambiguity the lower effort would maximize profit.

## 4. Concluding remarks

Ambiguity is a very common condition in economic decision-making under uncertainty. In this paper we have shown how the traditional results of Principal-Agent theory are to be modified when an ambiguity attitude is considered. Under our assumptions, the principal, though not the agent, faces ambiguity as to the relation between her utility and the agent's chosen effort and, moreover, she is ambiguity-averse, i.e. her estimates are biased toward pessimism.

Under this assumption, the compensation scheme becomes rather complex mainly because the confidence of the principal in the probability distributions consistent with her informative set is an additional determinant of the optimal wage paid to the agent in any conditional state of the world.

A contract which implements this type of compensation scheme may be very costly to write and is not free from the risk of misinterpretation and difficult verifiability. This means that an ambiguity attitude may lead to lack of clarity in the interpretation of contractual agreements. The latter type of ambiguity is often considered a cause of high transaction costs, which make it better to revert to incomplete contract. Our model clarifies that, at least in this respect, transaction costs may not be an explanation of incomplete contracts entirely separate from uncertainty. Therefore, some apparently alternative explanations of incomplete contracts, which we referred to in the introduction, are not really alternative.

More important, however, is the point that, despite its costs, a complete contract may still be preferable to a ‘null contract’ and ex post renegotiation. That is true if under an incomplete contract the agent may select as his best an action that leads with a positive probability to a catastrophic event in terms of the principal’s utility function. Several extremely important social situations share this feature: the case of genetically modified organisms or of global warming. Under these conditions the complete contract could be a better alternative despite its costs.[11] In this field, as in many others, a careful comparison of the institutional alternatives should be carried out, in order to dodge all the perils of the ‘Nirvana fallacy’ which Demsetz (1969) drew our attention to a long time ago.

Making ambiguity an important feature of the transactions to be analyzed and institutionally compared is an important step forward.

[11] Basili-Franzini (2003) apply the model to a peculiar type of catastrophic event, the so-called Mad Cow Disease.

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