Regret, Feedback and Risk Behavior

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Abstract

Anticipated regret is primarily determined by the information (feedback) the decision-maker expects to receive about the outcomes of the options she did not choose. We examine how feedback influences a regret-averse decision-maker's well-being and risk-taking behavior. To achieve this, we use the statistical concept of sufficiency to categorize the different feedback structures based on their informational content. As regret aversion and feedback aversion are inextricably linked, we determine the conditions under which a regret-averse decision-maker is feedback-averse: the decision-maker is better off when feedback is less informative. Additionally, we demonstrate that in regret theory, risk-taking behavior is shaped by risk preferences, regret aversion, and feedback informativeness. In particular, when the DM is feedback-averse, the risk premium decreases as feedback becomes more informative. We offer a new theoretical perspective on the Allais paradox, suggesting that participants in Allais' experiment do not expect to receive information about the unchosen lottery outcomes. This particular informational context must be considered when analyzing the paradox with regret theory. Our approach also allows us to differentiate the roles of risk and regret aversion in the Allais paradox. We show that risk aversion and regret aversion are partially substitutable in the genesis of the choices that characterize the paradox.

Keywords: Regret theory, feedback, Risk-taking, Risk premium, Allais paradox.

JEL classification D80 . D81 . D91

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1 Introduction

A large part of regret theory is established under perfect information where the payoffs of the foregone alternatives are perfectly observable (Savage 1951; Luce and Raiffa 1956; Bell 1982; Loomes and Sugden 1982, 1987; Fishburn 1989; Sugden 1993; Quiggin 1994; Diecidue and Somasundaram 2015). Among the few exceptions, Bell (1983) considers the possibility of the unchosen option being unresolved when a decision maker (henceforth DM) has the choice between two lotteries. More recently, Gabillon (2020) proposed a general model that makes it possible to consider any level of information (feedback structure) on the foregone alternative payoffs. Gabillon (2020) shows that anticipated regret does depend on anticipated feedback. Bell (1983) was the first to understand that feedback is not neutral to a regret-averse DM. Considering an additive regret-utility function and a choice set containing two risky alternatives, the author obtains, under a series of assumptions, that a DM would prefer to have the foregone lottery unresolved rather than fully resolved. Curiously, this critical result has yet to be further developed and explored in the literature on regret theory. To our knowledge, the impact of feedback on a regret-averse DM's well-being has never been explored in depth in a theoretical model. Based on Gabillon (2020), we explicitly model feedback as signals on the foregone option outcomes, and we use the sufficiency statistical criteria to classify the feedback structures (FS) according to their informational contents: FS_A is more informative on the foregone option outcomes than FS_B if signals under FS_A are sufficient statistics for signals under FS_B. We also define feedback aversion as follows: FS_B is preferred to FS_A when FS_A is more informative than FS_B. A DM is feedback-averse if she prefers to avoid feedback on the outcomes of the foregone options. Convincing empirical evidence is in favor of feedback aversion. Feedback aversion is observed in Reb and Connolly (2009)'s experimental study: in repeated decision-making tasks, people tend to reject feedback on foregone options to avoid short-term regret, leading to reduced learning and poor long term performance. Zeelenberg *et al.* (1996) performed an experiment where they set up two risky lotteries to which participants were indifferent. Indifference, as regards the two lotteries, is established when there is no feedback on the foregone lottery. People exclusively obtain feedback on the lottery of their choice (which corresponds to a non-informative FS in our setting). One of the two lotteries is relatively risky, the other relatively safe. Zeelenberg *et al.* (1996) modify the feedback context and observe the behavioral consequences. When people know that the result of the relatively safe lottery will be systematically revealed, they are no longer indifferent, tending to prefer the relatively safe lottery. People try to protect themselves against having information about the relatively safe lottery if they choose the risky lottery. Zeelenberg *et al.* (1996) show that regret aversion induces risk-avoiding behavior (when people expect feedback on the safe lottery) or risk-seeking behavior (when people anticipate feedback on the risky lottery). We conclude from these observations that a complete definition of regret aversion should not be limited to sensitivity to anticipated regret but should also include feedback aversion. We determine the conditions under which a regret-averse DM is feedback-averse. For a feedback-averse DM, the non-informative FS represents the best situation, and the perfectly informative FS represents the worst situation. Information about the foregone alternative payoffs makes anticipated regret more salient and decreases the DM's well-being.

This paper also studies the impact of regret aversion and feedback on risk-taking behavior. In uncertainty economics, disentangling the effects of risk and regret aversion on risk-taking behavior remains empirically and theoretically underexplored. Engelbrecht-Wiggans and Katok (2009) address this issue in their sealed-bid first-price auction experiments. They investigate whether the tendency to bid higher than the risk-free Nash equilibrium can be attributed to risk aversion or regret aversion. Their findings provide strong support for the explanation based on regret and feedback. Filiz-Ozbay and Ozbay (2007) also argue that overbidding in first price auctions is derived from the anticipation of loser regret. To our knowledge, Somasundaram and Diecidue (2017) is the only paper examining risk attitudes under regret aversion. The authors consider two opposite situations: perfect feedback and no feedback. They do not, however, model feedback. They use the preferences of Bell (1982) and Loomes and Sugden (1982), assuming that feedback increases regret aversion. Indeed, the authors conjecture that feedback makes anticipated regret more salient. Empirically, the authors obtain strong support for regret aversion, but no confirmation of the risk attitudes predicted by their model. In this paper, our approach is different. We explicitly model feedback and we do not assume that feedback modifies regret aversion. We consider that preferences are independent of feedback, and we look at how risk behavior changes when feedback is modified. We show that, when the FS is non-informative, the risk premium under regret aversion is higher than the Arrow-Pratt risk premium. We refer to this result as a preference for certainty. Under a non-informative FS, a regretful DM will likely choose the sure thing more than a von Neumann-Morgenstern DM (henceforth vNM DM). The sure thing fully protects the DM against anticipated regret: after choosing the sure thing, the DM cannot observe the lottery's payoff and compare it to the sure thing. Consequently, the DM does not experience regret. Independently of risk preferences, this protection against anticipated regret strengthens the attractiveness of the sure thing (for empirical evidence, see Zeelenberg 1999) and increases the risk premium compared to the Arrow-Pratt risk premium. We go further by showing that, under feedback aversion, the risk premium decreases with the informativeness of the FS. The risk premium is thus maximal when the FS is non-informative and minimal when the FS is perfectly informative. The informational context influences risk-taking behavior. Under a non-informative FS, the choice of the sure thing fully protects the DM against anticipated regret. When, however, some information about the risky lottery is available after the choice, the sure thing no longer offers complete protection against regret and becomes less attractive. We even show that, under a perfectly informative FS, the preference for certainty can give way to a reverse phenomenon: the risk premium can be lower than the Arrow-Pratt risk premium, which reveals a preference for uncertainty. Risk preferences, regret aversion and feedback are all factors that determine risk-taking behavior. We also consider a feedback-averse DM indifferent between two risky options, Y_1 and Y_2. We show that providing additional information about the outcome of Y_2 if Y_1 is chosen causes the DM to be no longer indifferent, favoring now Y_2. Feedback aversion promotes risk-taking when Y_2 is the riskier option and encourages risk-avoidance when Y_2 is the safer choice. This finding is in complete agreement with the observations made by Zeelenberg *et al.* (1996) (see above in this introduction).

Lastly, we revisit the common consequence effect (CCE) version of the Allais paradox, focusing specifically on the preference for the safe option in the initial stage of the experiment. Despite the fact that the risky alternative nearly dominates the safe lottery in terms of first-order stochastic dominance, most individuals opt for the safe lottery. This preference suggests extreme levels of risk aversion under expected utility theory (EUT). Since EUT fails to adequately explain the choice of the safe option, we label this phenomenon the certainty bias puzzle. This puzzle is distinct from the certainty effect proposed by Kahneman and Tversky (1979) to account for preference reversal in the presence of a sure option. What we call the certainty bias puzzle is not related to the violation of the independence axiom; it stands independently of the second choice made in Allais' experiment. Regret theory has already tackled the problem of preference reversal within the CCE (Loomes and Sugden 1982; Bleichrodt and Walker 2015). These works are carried out under the implicit assumption of perfect feedback. However, it is not clear that participants in Allais' experiment expected to receive information about the outcomes of the lotteries they did not choose. Bell (1982) points out that the problem statement in Allais' experiment does not specify whether the unchosen gamble will be resolved. In this paper, we believe that when people are asked to select their preferred lottery without providing them any further details, they are unlikely to anticipate the resolution of the alternative they did not choose. The most natural (and even unconscious) attitude is not to anticipate the resolution of the unchosen alternative. Therefore, we propose a more realistic analysis of the Allais paradox based on the assumption of non-informative feedback. In our model, non-informative feedback, combined with regret aversion, proves to be the key factor in explaining the certainty bias puzzle. The preference for certainty, mentioned earlier in this introduction, explains the certainty bias puzzle. Under a non-informative FS, the safe option offers complete protection against feedback and, thus, against anticipated regret. We can predict the safe lottery's choice without assuming extreme levels of risk aversion, as in the EUT. Except for high-risk lovers, our model predicts the safe choice if people are sufficiently regret-averse. Besides, except for high risk-averse (who are expected to make choices consistent with the EUT) and high risk-lover DMs, our model can also predict the preference reversal which characterizes the Allais paradox. Furthermore, unlike previous explanations of the Allais paradox using regret theory, our model enables us to distinguish the individual effects of risk aversion and regret aversion on decision-making. We identify risk and regret aversion ranges that make preferences consistent with the CCE choice pattern. The paper is organized as follows: Section 2 presents the concept of FS and categorizes FSs based on their informativeness. Section 3 discusses preferences and introduces feedback aversion. Section 4 examines the risk-taking behavior of a regret-averse DM. Finally, Section 5 focuses on an analysis of the Allais paradox.

2 Feedback Structures

In this section, we briefly review the concept of FS introduced in Gabillon (2020) and we introduce the concept of sufficiency. Let $\Phi = \{Y_1, .., Y_{N+1}\}$ denote the set of $N+1$ risky alternatives. A risky alternative Y_n is a random variable taking its values on a set Ω, which contains a finite number of positive values. Without loss of generality, let X denote the chosen alternative and $Y_1, .., Y_N$ the foregone alternatives. In the rest of the paper, either $\{Y_1, .., Y_{N+1}\}$ or $\{X, Y_1, .., Y_N\}$ will refer to the choice set Φ depending on whether we need or not to distinguish the chosen alternative X from the other alternatives. To shorten our notations, let θ denote the realized payoffs $x, y_1, .., y_N$ and θ_{-X} the foregone realized payoffs $y_1, .., y_N$ when alternative X has been adopted. Let $p(\theta)$ denote the prior probability distribution of θ. We assume that, at the feedback stage (i.e., after the choice), a DM receives information about the alternative payoffs θ and revises her prior accordingly. When alternative X is adopted, the information obtained by the DM is a collection of probability spaces $\left\{\left(\mathcal{M}_X, \mathcal{F}_X, P_X^{\theta}\right)\right\}_{\theta \in \Omega^{N+1}}$, where $(\mathcal{M}_X, \mathcal{F}_X)$ is a measurable space representing the space of all possible signals endowed with a family of probability measures P_X^{θ}. A signal on state of nature θ is a random variable M_X taking its value m_X in $\mathcal{M}_X$. The probability distribution P_X^{θ} will, henceforth, be denoted by its generic term $p(m_X|\theta)$. Probability $p(m_X|\theta)$ represents the conditional probability of $M_X = m_X$ given the realized payoffs θ.

We also assume that a DM observes the payoff of the alternative she has selected: $\forall X \in \Phi$, signal M_X perfectly reveals the payoff x of the chosen option X.

Definition 1. *M_X is said to be non-informative if the probability distribution of M_X is the same for all θ_{-X}: $\forall x \in \Omega, \forall\ \theta_{-X} \in \Omega^N$, $p(m_X|x, \theta_{-X}) = p(m_X|x)$. One cannot learn about θ_{-X} by observing from M_X.*

M_X is said to be perfectly informative if for every pair $\left(\theta_{-X}^i, \theta_{-X}^j\right) \in \Omega^N \times \Omega^N$, the intersection of the support sets on which $p\left(m_X \left|\theta_{-X}^i, x\right.\right)$ and $p\left(m_X \left|\theta_{-X}^j, x\right.\right)$ are strictly positive is an empty

set. After observing M_X, θ_{-X} can be identified with certainty.

M_X is said to be imperfectly informative in all other situations.

Hereafter, we give the definition of a FS associated to a choice set Φ:

Definition 2. *The feedback structure FS_Φ, linked to the choice set $\Phi = \{Y_1, .., Y_{N+1}\}$, consists of the signals associated with each alternative in the choice set:*

$FS_\Phi = \left\{M_{Y_1}, ..., M_{Y_{N+1}}\right\}$

Definition 3. *FS_Φ is said to be non-informative if $\forall Y_n \in \Phi, M_{Y_n}$ is non-informative. A non-informative FS will be denoted by FS_Φ^{ni}.*

FS_Φ is said to be perfectly informative if $\forall Y_n \in \Phi, M_{Y_n}$ is perfectly informative. A perfectly informative FS will be denoted by FS_Φ^{pi}.

FS_Φ is said to be imperfectly informative in all other situations.

The statistical concept of sufficiency is used to compare information systems in the information economics literature (see for example Kihlstrom 1974). In what follows, we use the criteria of sufficiency to compare the informational content of two different signals M_X^a and M_X^b.

Definition 4. *M_X^a is sufficient for M_X^b relative to θ_{-X} if there exits a stochastic transformation $\pi\left(m_X^b \,|m_X^a\right)$ such that*

$\forall\theta \in \Omega^{N+1}, \forall m_X^b \in \mathcal{M}_X,\, p\left(m_X^b \,|\theta\right) = \sum\limits_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^b \,|m_X^a\right) p\left(m_X^a \,|\theta\right)$

with $\sum\limits_{m_X^b \in \mathcal{M}_X} \pi\left(m_X^b \,|m_X^a\right) = 1, \forall m_X^a \in \mathcal{M}_X$.

M_X^a is sufficient for M_X^b means that M_X^a is at least as good as M_X^b for learning about θ. Definition 4 can be reformulated as follows: M_X^a is sufficient for M_X^b if there exists a random quantity $\widehat{M}_X^b$ which is a "garbling" of M_X^a in the sense of Blackwell (1951):

1. $\widehat{M}_X^b$ is conditionally independent of θ given m_X^a: $\pi\left(m_X^b\,|m_X^a,\theta\right)=\pi\left(m_X^b\,|m_X^a\right)$.

2. The conditional probability of $\widehat{M}_X^b$ coincides with that of M_X^b: $\pi\left(m_X^b\,|\theta\right)=p\left(m_X^b\,|\theta\right)$.

We move from signal M_X^a to signal $\widehat{M}_X^b$ by adding noise. A DM who observes M_X^a can generate $\widehat{M}_X^b$ with the stochastic process $\pi_X\left(m_X^b\,|m_X^a\right)$, which is independent of θ_{-X}.

With the concept of sufficiency, we define a partial ordering on the set of all FSs:

Definition 5. *FS_Φ^a is sufficient for FS_Φ^b if, $\forall Y_n\in\Phi$, $M_{Y_n}^a$ is sufficient for $M_{Y_n}^b$.*

To go further, we introduce the following assumption:

A1. $\forall Y_n\in\Phi$, two potential signals $M_{Y_n}^a$ and $M_{Y_n}^b$ are conditionally independent given θ: $p\left(m_X^b\,|m_X^a,\theta\right)=p\left(m_X^b\,|\theta\right)$.

Assumption $A1$ rules out uninteresting situations that have no connection with reality in which, given θ, a signal $M_{Y_n}^a$ provides information about another signal $M_{Y_n}^b$ that would occur under another FS. $A1$ is verified when, for example, signals give information exclusively on θ.

We obtain the following Proposition:

Proposition 1. *FS_Φ^{pi} is sufficient for any FS. Under $A1$, any FS is sufficient for FS_Φ^{ni}.*

Proof. Proof See Appendix A. □

3 Preferences and feedback aversion

A DM's preferences are represented by the regret-utility function (r-utility) $u(x,r)$, where x represents the payoff of the chosen alternative X, and r a reference point. The reference point represents the impact of anticipated regret on the DM's utility. We will see in what follows that $r>x$ corresponds to a state of nature in which a foregone alternative performs better than the chosen alternative. In the event $r>x$, regret is anticipated. To define the reference point, we use the concept of choiceless utility (c-utility), which was first introduced by Loomes and Sugden (1982) and Bell (1982), and generalized in Gabillon (2020):

Definition 6. *The c-utility function, defined as* $v(x) = u(x, x)$*, measures the satisfaction generated by the consumption of payoff* x*.*

The c-utility function represents preferences in which sensitivity to regret has been removed ($r = x$) and corresponds to the DM's preferences if she were not regret-averse. Function $v(.)$ also represents a benchmark, which allows us to compare the results obtained under regret aversion with those in the EUT. We also assume that the $N + 1$ alternatives are evaluated with the c-utility function at the feedback stage.

Let $u_1(x, r)$ denote $\frac{\partial u(x,r)}{\partial x}$, $u_2(x, r)$ denote $\frac{\partial u(x,r)}{\partial r}$ and $v'(x)$ denote $\frac{\partial v(x)}{\partial x}$. We make the following assumptions about the r-utility function $u(x, r)$:

A2. The r-utility $u(x, r)$ is differentiable on $\mathbb{R}^{+2}$.

A3. $v'(x) = u_1(x, x) + u_2(x, x) > 0$.

A4. $u_1(x, r) > 0$.

A5. $u_2(x, r) < 0$.

Assumptions $A3$ and $A4$ state that the utility increases with payoff x. Assumption $A5$ characterizes regret aversion. Given payoff x, anticipated regret increases with the reference point, which decreases utility.

After observing the signal M_X at the feedback stage, the DM revises her prior probability $p(\theta)$ in a Bayesian way. After the information has been processed, beliefs are characterized by the posterior probability distribution $p(\theta | M_X)$. At the feedback stage, the DM evaluates the $N + 1$ alternatives with the posterior probability distribution and the c-utility function. We compute the posterior certainty equivalent of a foregone alternative Y_n with the marginal posterior probability distribution $p(y_n | M_X)$:

$$v\left(CE_{Y_n}^{v,M_X}\right) = E\left[v(Y_n) | M_X\right], \tag{1}$$

where the operator $E[.| M_X]$ represents the conditional expectation, given the signal M_X. The notation $CE_{Y_n}^{v,M_X}$ indicates, in superscript, that the certainty equivalent is computed with the c-utility function $v(.)$, given information M_X.

We can now define the reference point :

Definition 7. *The reference point R^{M_X} is the highest posterior certainty equivalent:*
$R^{M_X} = Max\left\{X, CE^{v,M_X}_{Max}\right\}$ *with* $CE^{v,M_X}_{Max} = Max\left\{CE^{v,M_X}_{Y_1}, ..., CE^{v,M_X}_{Y_N}\right\}$.

Under assumption $A3$, the reference point is the certainty equivalent of the alternative which maximizes the expected c-utility, given available information at the feedback stage. In the event $R^{M_X} > X$, the DM regrets her choice since a foregone alternative proves to be more attractive than the chosen alternative.

We obtain the preferences of a regretful DM :

$$E\left[u\left(X, R^{M_X}\right)\right] = E\left[u\left(X, Max\left\{X, CE^{v,M_X}_{Max}\right\}\right)\right]. \tag{2}$$

The properties of these preferences are analyzed in Gabillon (2020).

This paper introduces two additional assumptions about the r-utility function:

A6. $u_{22}\left(x, r\right) \leq 0$

A7. $v''\left(x\right) \leq 0$

When $A6$ is verified, a DM exhibits reference point risk aversion (RPRA). A reference point risk-averse DM has an increasing marginal disutility of regret. However, the RPRA property has another critical interpretation: the reference point R^{M_X} fluctuates with the feedback a DM receives about the payoffs of the foregone alternatives. Assumption $A6$ is thus the central assumption of feedback aversion. Assumption $A7$ is an assumption of risk aversion about the c-utility function. We show, in what follows, that $A6$ and $A7$ together imply feedback aversion. We note that inequalities in $A6$ and $A7$ are not strict: when $u_{22}\left(x, r\right) = 0$ and/or $v"\left(x\right) = 0$, the DM is feedback-averse.

We define feedback aversion as follows:

Definition 8. *If FS^a_Φ is sufficient for FS^b_Φ then a feedback-averse DM prefers FS^b_Φ to FS^a_Φ.*

A feedback-averse DM prefers to minimize her exposure to feedback about foregone alternatives.

We obtain the following proposition:

Proposition 2. *A DM who is reference-point-risk-averse (assumptions $A6$) and risk-averse (assumption $A7$) is feedback-averse.*

Proof. Proof See Appendix B. Proposition 2 is obtained under assumptions $A2$ to $A7$. □

Appendix B shows that, under assumptions $A6$ and $A7$, for any alternative $X \in \Phi$, the expected r-utility of X under FS_{Φ}^{b} is greater than or equal to its value under FS_{Φ}^{a} when FS_{Φ}^{a} is sufficient for FS_{Φ}^{b}. To get the intuition of Proposition 2, let us consider the following property obtained under $A7$ (see Equation B.19 in Appendix B):

$$\begin{aligned} &\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X, \\ &R^{m_X^b} \leq \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b \right.\right) R^{m_X^a}. \end{aligned} \tag{3}$$

For each signal value m_X^b, the reference point under FS_{Φ}^{b} is lower than the average value of reference points under FS_{Φ}^{a}. Under $A5$ ($u_2(x,r) < 0$) and $A6$ ($u_{22}(x,r) \leq 0$), easy computations give that the expected r-utility is higher under FS_{Φ}^{b} than under FS_{Φ}^{a}.

From propositions 1 and 2, we obtain the following corollary:

Corollary 1. *Among all FSs, FS_{Φ}^{pi} represents the worst FS for a feedback-averse DM. Under $A1$, among all FSs, FS_{Φ}^{ni} is the preferred FS.*

While Definition 8 and Proposition 2 consider the FSs that can be ordered with the sufficiency criteria, we stress the generality of Corollary 1. Among all FSs (without any restrictions), a feedback-averse DM prefers the non-informative FS. Similarly, among all FSs, the perfectly informative FS represents the least desirable one.

4 Feedback and risk behavior

Gabillon (2020) generalized the concept of regret certainty equivalent (RCE) under a non-informative FS, initially introduced by Bell (1983) under the name of cancellation price. In Bell (1983) and Gabillon (2020), the RCE is defined under the assumption of a non-informative FS. In what follows, we define the RCE for any FS and give the definition of the risk premium of a regret-averse DM.

Definition 9. *When a regret-averse DM chooses between a sure payoff Z and a risky alternative Y, the RCE of the risky alternative Y under FS_Φ, denoted by RCE_Y^{u,FS_Φ}, corresponds to the value of the sure payoff Z which makes the DM indifferent about choosing Z or Y under FS_Φ.*

$\Pi_Y^{u,FS_\Phi} = E(Y) - RCE_Y^{u,FS_\Phi}$ *denotes the risk premium under FS_Φ.*

RCE_Y^{u,FS_Φ} is the Z-solution of the following equation [1]:

$$E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right] = E\left[u\left(Y, Max\left(Y, Z\right)\right)\right], \tag{4}$$

where M_Z is the signal on the risky lottery Y when the sure payoff Z is adopted, and $v\left(CE_Y^{v,M_Z}\right) = E\left[v\left(Y\right)|\, M_Z\right]$ (see Equation 1).

Let CE_Y^v denote the Arrow-Pratt certainty equivalent of a risky alternative Y:

$$v\left(CE_Y^v\right) = E\left[v\left(Y\right)\right]. \tag{5}$$

Gabillon (2020) shows that, under a non-informative FS (M_Z conveys no information on Y), the RCE exists, is unique, and that $RCE_Y^{u,FS_\Phi^{ni}} < CE_Y^v$. Let $\Pi_Y^v = E(Y) - CE_Y^v$ denote the Arrow-Pratt risk premium. Based on Gabillon (2020), we can state the following corollary:

Corollary 2. *When the FS is non-informative, a regret-averse DM exhibits a preference for certainty regardless of her risk preferences: $\Pi_Y^{u,FS_\Phi^{ni}} > \Pi_Y^v$.*

[1]Gabillon (2020) shows that the reference point in the left-hand side of Equation (4) does not correspond to anticipated regret. Instead, it represents the psychological opportunity cost the DM is willing to support to avoid anticipated regret.

The risk premium is higher when anticipated regret is considered in decision-making than when it is not. Under a non-informative FS, the sure payoff offers protection against anticipated regret. A regret-averse DM is less likely to take risks than a vNM DM. Regret aversion under a non-informative FS increases the proportion of seemingly risk-averse people. Risk-neutral DMs exhibit a positive risk premium, and so do some risk lovers. It is worth noting that the preference for certainty does not resort to the assumptions of feedback aversion but only to regret aversion (assumption $A5$). The property of preference for certainty is obtained under a non-informative FS. In what follows, we demonstrate the existence of the RCE under any FS:

Proposition 3. *$\forall$ FS_Φ, RCE_Y^{u,FS_Φ} exists, is unique, and belongs to $]\underline{y},\overline{y}[$, where $\underline{y}$ and $\overline{y}$ respectively denote the minimum value and the maximum value that Y takes on its support Ω.*

Proof. Proof See Appendix C. Proposition 3 is obtained under assumptions $A1$ to $A5$. □

We also obtain the following proposition:

Proposition 4. *Under feedback aversion, if FS_Φ^a is sufficient for FS_Φ^b, we have $RCE_Y^{u,FS_\Phi^b} \leq RCE_Y^{u,FS_\Phi^a}$, or else $\Pi_Y^{u,FS_\Phi^a} \leq \Pi_Y^{u,FS_\Phi^b}$.*

Proof. Proof See Appendix C. Proposition 4 is obtained under assumptions $A2$ to $A7$. □

As the FS becomes informative, choosing the sure payoff offers less protection against feedback and anticipated regret. The sure payoff that a regretful DM would accept instead of the risky alternative Y increases with the informativeness of the FS, and the risk premium decreases.

From propositions 1 and 4, we obtain:

Corollary 3. *Under feedback aversion, $\forall FS_\Phi$, $\Pi_Y^{u,FS_\Phi^{pi}} \leq \Pi_Y^{u,FS_\Phi}$ and, under A1, $\Pi_Y^{u,FS_\Phi} \leq \Pi_Y^{u,FS_\Phi^{ni}}$.*

Proposition 4 states that, under feedback aversion, the risk premium decreases with the FS informativeness. It is under a perfectly informative FS that a feedback-averse DM is the most risk-taker and it is under a non-informative FS that she is the less.

In what follows, we introduce the risk premium's decomposition of Bell (1983):

$$\Pi_Y^{u,FS_\Phi} = E(Y) - CE_Y^v + CE_Y^v - RCE_Y^{u,FS_\Phi^{ni}}$$
$$- \left[RCE_Y^{u,FS_\Phi} - RCE_Y^{u,FS_\Phi^{ni}} \right]. \tag{6}$$

The first term is the Arrow-Pratt risk premium. The second term is the regret premium, and the last term is a generalization to any FS of the resolution premium introduced by Bell (1983). The regret premium is the difference between the Arrow-Pratt certainty equivalent and the regret certainty equivalent when the FS is non-informative. Compared to a vNM DM, the regret premium represents the extra amount a regret-averse DM will pay to avoid regret. At the utility level, Gabillon (2020) provides a psychological interpretation of the regret premium as the maximum psychological opportunity cost a DM will support to avoid anticipated regret. The resolution premium is the difference between the RCE under FS_Φ and the RCE under the non-informative FS. Bell (1983), who compare a situation of perfect feedback ($FS_\Phi = FS_\Phi^{pi}$) with a situation of no feedback, shows that the resolution premium is positive when the regret fonction is concave. The author considers an additive regret/rejoicing utility function. In this framework, the concavity of the regret function is a special case of our definition of feedback aversion. In this paper, we obtain that, whatever the FS, the resolution premium is positive when the DM is feedback-averse (see Proposition 4). For Somasundaram and Diecidue (2017), who also compare perfect feedback with no feedback, the resolution premium can be negative or positive depending on the prospect. The author's interpretation of the resolution premium stems from their hypothesis that feedback increases regret aversion (see Introduction).

Since the Arrow-Pratt risk premium and the regret premium are constant, the resolution premium is the portion of the risk premium that increases with the FS's informativeness (see Proposition 4). The following Proposition states that, under perfect feedback, the resolution premium can be so significant that the risk premium under regret aversion is lower than the Arrow-Pratt risk premium. Paradoxically, this happens for a risk-averse DM, who displays a preference for *un*certainty under perfect feedback.

Proposition 5. *When preferences are represented by the r-utility* $u(x,r) = x^{\alpha} - k(r-x)$ *(which satisfies A2 to A7) and when the FS is perfectly informative, the risk premium* $\Pi_Y^{u,FS_\Phi^{pi}}$ *satisfies* $0 \leq \Pi_Y^{u,FS_\Phi^{pi}} \leq \Pi_Y^v$ *when the DM is risk-averse* ($\alpha < 1$), $\Pi_Y^{u,FS_\Phi^{pi}} = \Pi_Y^v = 0$ *when the DM is risk neutral* ($\alpha = 1$) *and* $\Pi_Y^v \leq \Pi_Y^{u,FS_\Phi^{pi}} \leq 0$ *when the DM is risk-lover* ($\alpha > 1$)*.*

Proof. Proof See Appendix D. □

In Proposition 5 and the rest of the paper, risk preferences are defined with the c-utility function, representing the DM's preferences if she were not regret-averse. This approach allows us to disentangle the effect of risk aversion and regret aversion. We can see how anticipated regret affects risk behavior. All our model is based on the implicit comparison between the preferences of a regret-averse DM, represented by the r-utility function $u(x,r)$, and the corresponding vNM preferences, represented by the c-utility function $v(x) = u(x,x)$.

When $u(x,r) = x^{\alpha} - k(r-x)$, under perfect feedback, the risk premium of a risk-and-regret-averse DM is positive but lower than the Arrow-Pratt risk premium. The risk premium of a risk-neutral and regret-averse DM is equal to zero, and the risk premium of a risk-lover and regret-averse DM is negative but higher than the Arrow-Pratt risk premium. Risk behaviors are less differentiated when regret aversion is involved in decision-making than when it is not: a risk-averse DM is more risk-taker, and a risk-lover DM is less risk-taker. This result contrasts with what we obtain when the FS is non-informative. Under a non-informative FS, preference for certainty prevails regardless of risk preferences, systematically resulting in a risk premium above the Arrow-Pratt risk premium (see Corollary 2). Under perfect feedback, however, when $u(x,r) = x^{\alpha} - k(r-x)$, only risk-lover DMs exhibit a preference for certainty. For risk-averse DMs, Proposition 5 highlights a reverse phenomenon, which characterizes a preference for uncertainty (still compared to the EUT). Risk-taking behavior and feedback on the foregone options cannot be considered separately.

Let's consider now a choice set containing two risky alternatives $\Phi = \{Y_1, Y_2\}$ and a DM who is indifferent between Y_1 and Y_2 :

$$E\left[u\left(Y_1, Max\left(Y_1, CE_{Y_2}^{v,M_{Y_1}}\right)\right)\right]$$
$$= E\left[u\left(Y_2, Max\left(Y_2, CE_{Y_1}^{v,M_{Y_2}}\right)\right)\right], \quad (7)$$

with M_{Y_1} the signal about Y_2 when Y_1 is selected and M_{Y_2} the signal about Y_1 when Y_2 is selected.

From Proposition 2, we obtain the following corollary:

Corollary 4. *We consider a choice set $\Phi = \{Y_1, Y_2\}$ containing two risky alternatives to which a feedback-averse DM is indifferent. If the informativeness of signal M_{Y_1} increases (the new signal is sufficient for the previous signal about Y_2), the DM is no longer indifferent and prefers alternative Y_2.*

By proving Proposition 2 in Appendix *B*, we establish that if information about the forgone alternatives increases, the expected r-utility of the chosen alternative decreases. In our case, improving information about Y_2 when Y_1 is selected decreases the expected r-utility of Y_1, leading to a shift in preference, with the DM now favoring option Y_2. Feedback aversion favors risk-taking behavior when Y_2 is the riskier of the two alternatives and risk-avoiding behavior when Y_2 is the safest alternative. This result perfectly aligns with the observations of Zeelenberg *et al.* (1996) (see Introduction).

5 Preference for certainty and the Allais paradox

In what follows, we use our model to analyze the common consequence version of the Allais paradox. In Allais' experiment, people are asked the following two questions[2]:

Do you prefer situation A or situation B?

$$A \rightarrow \quad 1 \quad [1] \text{ and } B \rightarrow \begin{array}{lll} \nearrow & 5 & [0,1] \\ & 1 & [0,89] \\ \searrow & 0 & [0,01] \end{array}$$

[2]In Allais' experiment, payoffs are expressed in millions of francs.

Do you prefer situation C or situation D?

$$C \begin{array}{lll} \nearrow & 1 & [0,11] \\ \searrow & 0 & [0,89] \end{array} \text{ and } D \begin{array}{lll} \nearrow & 5 & [0,1] \\ \searrow & 0 & [0,9] \end{array}$$

The CCE is a behavioral regularity characterized by the A and D choice, which violates the EUT. An appeal to certainty (Kahneman and Tversky 1979, Wakker 2010, Schneider and Schonger 2019, Cerreia-Vioglio *et al.* 2015) or an aversion to zero (Incekara-Hafalir *et al.* 2021) have been proposed as possible explanations of why people choose A over B but prefers D over C. The first explanation considers that the CCE is an evidence of the certainty effect. The certainty effect can be defined as a tendency of people to favor a risk-free option in violation of Expected Utility. When choosing A while they prefers D to C, people overvalue certainty.

However, this paper considers the choice of situation A to be puzzling, regardless of the preference between C and D. To clarify this point, let us compare the following two situations:

$$A \rightarrow \quad 1 \quad [1] \text{ and } B' \begin{array}{lll} \nearrow & 5 & [0,1] \\ \searrow & 1 & [0,9] \end{array}$$

Situation B' first-order stochastically dominates situation A. Under the EUT, any DM with an increasing utility function prefers B'. One could expect that, by continuity, moving from B' to B will not significantly modify preferences between the two situations. Contrary to observation, one would expect that most people prefer situation B to situation A. In the EUT, the preference for situation A, observed in the Allais paradox, can only be explained by an extreme level of local risk aversion. If we consider the utility function $v\left(x\right) = x^{\alpha}$, situation A is preferred to situation B in the EUT when $\alpha < \frac{\ln(1{,}1)}{\ln(5)} \simeq 0{,}05921954 = 0{,}059^{+}$, which approximately corresponds to the 6% most risk-averse people in the experimental study of Holt and Laury 2002. We call the certainty bias puzzle the choice of the safe option in Allais' experiment.

Bleichrodt and Walker (2015) who confront the model of Loomes and Sugden (1982) with various paradoxes, analyze the CCE. A DM who has previously chosen A chooses situation D when she fears enough the state of nature in which C gives 0, and D gives 5. When the difference between 5 and 0 results in an intense regret (under a convexity assumption), Bleichrodt and Walker (2015) obtain the CCE. In Allais' experiment, however, people are not explicitly told that the result of the foregone situation will be disclosed. Since people are just told to choose the situation they prefer, it is reasonable to consider that they do not anticipate the resolution of the foregone situation. In our terminology, Allais' experiment is led under a non-informative FS. The "strong regret" arising from comparing the perceived payoff 0 and the lost payoff 5 has no reason to be anticipated. In our approach, a DM who chooses C anticipates comparing the result of C to her opinion about D, which corresponds, under a non-informative FS, to the Arrow-Pratt certainty equivalent of D, which will be denoted by CE_D^v in the following.

In what follows, we use the Arrow-Pratt certainty equivalent of situation B, CE_B^v, as a measure of risk preferences:

$$v\left(CE_B^v\right) = 0,1v\left(5\right) + 0,89v\left(1\right) + 0,01v\left(0\right). \tag{8}$$

Situation A is preferred to situation B in the EUT when $CE_B^v < 1$. Under risk aversion, CE_B^v is lower than the expected payoff of situation B, equal to $1,39$. In the following table, we summarize the different categories of risk preferences to which we will refer. The last line of the table gives the values of α when the c-utility function is $v\left(x\right) = x^{\alpha}$.

Table 1

$CE_B^v < 1$	$1 \leq CE_B^v < 1,39$	$CE_B^v = 1,39$	$CE_B^v > 1,39$
Highly risk-averse	Risk-averse	Risk-neutral	Risk-lover
$\alpha < 0,059^+$	$0,059^+ \leq \alpha < 1$	$\alpha = 1$	$\alpha > 1$

Let us first analyze the certainty bias puzzle. Under a non-informative FS, a DM chooses situation A if[3]:

$$
\begin{aligned}
& u\left(1, Max\left(1, CE_B^v\right)\right) \\
& > 0,1v\left(5\right) + 0,89v\left(1\right) + 0,01u\left(0,1\right). \qquad (9)
\end{aligned}
$$

To go further, let us introduce the additive r-utility function $u\left(x,r\right) = v\left(x\right) - kg\left(r-x\right)$ with $k > 0$, $v'\left(.\right) > 0$, $v\left(0\right) = 0$, $g'\left(.\right) > 0$ and $g\left(0\right) = 0$. Parameter k could be integrated into function $g\left(.\right)$, but we prefer to keep it outside as a measure of regret aversion. We summarize our findings in the following proposition:

Proposition 6. *Property 1: When $CE_B^v < 1$, a DM prefers situation A, whether or not she is regret-averse.*

Property 2: When $CE_B^v \geq 1$, a DM can prefer situation A only if she is regret-averse.

Property 3: When $CE_B^v \geq 1$ and $u\left(x,r\right) = v\left(x\right) - kg\left(r-x\right)$, a DM prefers situation A when $CE_B^v < 1+\delta < 2$ and when regret aversion k is sufficiently high: $k > k_{\min} = \frac{0,1v(5)-0,11v(1)}{0,01g(1)-g\left(CE_B^v-1\right)}$. If $g(.)$ is linear then $1+\delta = 1,01$. If $g(.)$ is strictly convex then $1+\delta > 1,01$. If $g\left(x\right) = x^{\beta}$ then $1+\delta = 1+0,01^{\frac{1}{\beta}}$.

Proof. Proof See Appendix E. □

A highly risk-averse DM ($CE_B^v < 1$) prefers situation A, whether or not she is regret-averse (property 1). Property 2 of Proposition 6 states that regret aversion is necessary to explain the certainty bias puzzle: the choice of situation A with a reasonable level of risk aversion ($CE_B^v \geq 1$) can only occur under regret aversion. Under a non-informative FS, situation A offers a protection against anticipated regret, creating a preference for certainty.

As the risk of feeling regret in situation B is very low (the probability is $0,01$), property 3 of Proposition 6 states that the protection against anticipated regret offered by situation A is not

[3] In the right-hand side of Equation (9), when $x = 0$ and $r = 1$, the reference point represents anticipated regret. On the left-hand side of Equation (9), the reference point does not represent anticipated regret, but a psychological opportunity cost (see Gabillon 2020). The DM supports a psychological cost because choosing situation A implies missing out situation B, which represents a "better" option (when $CE_B^v > 1$) that the DM would have adopted if she had not been regret-averse.

sufficiently attractive when risk aversion is too weak ($CE_B^v > 1+\delta$). When, on the contrary, risk aversion and regret aversion are sufficiently high ($CE_B^v < 1+\delta$ and $k > k_{\min}$), situation A is adopted. This choice happens all the more easily when the regret function is convex, corresponding to our assumption $A6$ of RPRA. Under a non-informative FS, the RPRA property should not be interpreted as feedback aversion but rather as a hypothesis of increasing marginal disutility of regret. When $g(x) = x^{\beta}$, we have $1+\delta \longrightarrow 2$ when $\beta \to +\infty$. The value of δ increases with the convexity of the regret function $g(.)$ but tends to a boundary. Proposition 6 states that regret theory with an additive r-utility function is unable to predict the preference for situation A when people are highly risk lovers ($CE_B^v \geq 2$). For all the other cases, however, any DM can prefer situation A if she is sufficiently regret-averse (k sufficiently high) and reference point-risk-averse (β sufficiently high).

Contrary to the EUT, our model explains the preference for situation A without assuming extreme levels of risk aversion. When $1 < CE_B^v < 1+\delta$, situation A is not the best option in the EUT (because $CE_B^v > 1$), whereas it is the right choice under regret aversion when $k > k_{\min}$. When the sensitivity to anticipated regret is sufficiently high ($k > k_{\min}$), we have $RCE_B^u < 1 < CE_B^v$: the regret-averse DM chooses situation A, whereas the vNM DM chooses situation B. The underlying property, which explains this result, is the preference for certainty under a non-informative FS ($RCE_B^u < CE_B^v$) presented in section 4. The informational context of Allais' experiment is the key to understanding people's extreme prudence when choosing situation A. When $u(x,r) = x^{\alpha} - k(r-x)^{\beta}$, the choice between situation A and situation B depends on three parameters: the risk aversion parameter α, the regret aversion parameter k, and the RPRA parameter β. Table 2 illustrates, for different values of α, the conditions that the regret parameters k and β must meet for the DM to prefer situation A to situation B:

Table 2

α	β	$k_{\min}$
$\alpha = 0,059^{+}$ ($CE_B^v = 1$)	$\beta_{\min} = 0^{+}$	$k_{\min} = 0^{+}$
$\alpha = 0,3$ ($CE_B^v \simeq 1,18$)	$\beta_{\min} \simeq 2,7234$	$k_{\min} \simeq +\infty$
	$\beta = 3$	$k_{\min} \simeq 13,94$
	$\beta = 5$	$k_{\min} \simeq 5,32$
	$\beta = 10$	$k_{\min} \simeq 5,21$
$\alpha = 0,5$ ($CE_B^v \simeq 1,24$)	$\beta_{\min} \simeq 3,23$	$k_{\min} \simeq +\infty$
	$\beta = 5$	$k_{\min} \simeq 12,35$
	$\beta = 10$	$k_{\min} \simeq 11,362$
$\alpha = 1$ ($CE_B^v = 1,39$)	$\beta_{\min} \simeq 4,891$	$k_{\min} \simeq +\infty$
	$\beta = 6$	$k_{\min} \simeq 60,174$
	$\beta = 10$	$k_{\min} \simeq 39,321$
$\alpha = 1,5$ ($CE_B^v \simeq 1,59$)	$\beta_{\min} \simeq 8,775$	$k_{\min} \simeq +\infty$
	$\beta = 10$	$k_{\min} \simeq 212,48$
	$\beta = 15$	$k_{\min} \simeq 104,80$

Table 2 reads: when $CE_B^v = 1$, situation A is strictly preferred as soon as k and β are strictly positive. When $CE_B^v = 1,18$, situation A is selected if β exceeds $2,7234$. But for $\beta = 2,7234$, k must be extremely high ($+\infty$). For $\beta = 3$, however, k must be greater than $13,94$. The rest of Table 2 reads the same way. Appendix E shows that $\beta_{\min}$ and $k_{\min}$ both increase with α: when risk aversion decreases, the attractiveness of situation B increases (CE_B^v increases with α). Regret parameters must increase in return to preserve the preference for situation A. This result shows that risk aversion and regret aversion can be substitutable when it comes to avoiding or taking risks. If we reduce risk aversion, we need to increase regret aversion in order to continue preferring situation A. Appendix E also shows that $k_{\min}$ decreases when β increases.

Let us now analyze the preference reversal paradox. All we have to do is to find the conditions under which situation D is preferred to situation C and confront these conditions with those under which A is preferred to B. Under a non-informative FS, a DM chooses situation D if:

$$\begin{aligned}&0,1u\left(5, Max(5, CE_C^v)\right)\\&+0,9u\left(0, Max\left(0, CE_C^v\right)\right)\\&>\\&0,11u\left(1, Max(1, CE_D^v)\right)\\&+0,89u\left(0, Max\left(0, CE_D^v\right)\right).\end{aligned} \tag{10}$$

We analyze Equation (10) in Appendix E. We summarize our results in the following table. Some results are general, and others are obtained with the r-utility function $u(x,r) = x^{\alpha} - k(r-x)^{\beta}$. Table 3 gives choices predicted by the EUT and regret theory (RT) for different levels of risk aversion. The main insights are given just after the table. We recall that the CCE is characterized by choices A and D.

Table 3: Is the CCE possible? Yes or No

	$CE_B^v < 1$	$1 \leq CE_B^v < 1^+$	$1^+ \leq CE_B^v < 2$	$CE_B^v \geq 2$
		Highly risk-averse	Risk-averse, risk-neutral and risk-lover	Highly risk-lover
EUT	AC	BD	BD	BD
RT	AC	choice A possible choice C	choice A possible choice D possible	choice B choice D possible
CCE possible?	No.	No.	Yes under RT.	No.

When risk aversion is very high ($CE_B^v < 1$), regret theory is unable to explain the choice of situation D in the Allais paradox. For a highly risk-averse DM, situation C is more attractive for two reasons:

a. Given her risk aversion, the DM values more C than D: when $CE_B^v < 1$, we have $CE_C^v > CE_D^v$.

b. Anticipated regret in situation D is more significant than in situation C. In situation D, the probability of experiencing regret is higher ($0,9 > 0,89$), and anticipated regret is stronger: in situation D, the DM feels regret when she compares 0 to CE_C^v whereas, in situation C, she feels regret when she compares 0 to $CE_D^v < CE_C^v$. In our model, anticipated regret depends on both regret aversion and risk aversion (which determines CE_C^v and CE_D^v).

When $1 \leq CE_B^v < 1^+$, this is a small intermediate case. Despite that CE_D^v is now greater than CE_C^v, situation C remains the optimal choice because the probability of experiencing regret in situation D is higher ($0,9 > 0,89$).

When $1^+ \leq CE_B^v < 2$, regret theory under a non-informative FS can explain both the preference for situation A (contrary to the EUT) and the choice of situation D. In situation D, although the probability of experiencing regret is higher ($0,9 > 0,89$), anticipated regret is weaker: the DM feels regret when she compares 0 to CE_C^v whereas, in situation C, she feels regret when she compares 0 to $CE_D^v > CE_C^v$.

When $CE_B^v \geq 2$ ($\alpha \geq 2,295$), the DM is such a risk lover that our model cannot predict the choice of the safe situation (situation A). Given that risk lovers with $\alpha > 1,95$ represent only 3% of participants in Holt and Laury (2002)'s experiment, we guess that probably almost nobody in the population displays $\alpha \geq 2,295$.

Our model is consistent with the Allais paradox since we predict that the A and D choice will be the most frequently observed if people are sufficiently regret-averse. According to our model, only high-risk-averse or high-risk-lover people will systematically exhibit a different pattern of choice.

6 Conclusion

One result of this paper shows that the risk-taking behavior of a regret-averse DM depends not only on risk aversion but also on regret aversion and feedback on foregone options. In particular, we show that while a regretful DM systematically exhibits a preference for certainty under a non-informative FS, she can display, on the contrary, a preference for uncertainty under a perfectly informative FS. Gabillon (2020) also shows that statewise stochastic dominance, a natural property of preferences, is satisfied under perfect feedback but cannot be generalized to any other FS. Given the particularity of its implications, the assumption of perfect feedback should be used with caution when drawing general conclusions about decision-making under regret aversion since risk-taking behavior and preference properties vary with the degree of resolution of the foregone options.

Appendix A

Let M_{Y_n} denote the signal associated to an alternative Y_n under any FS_{Φ}.

Signal M_{Y_n} is conditionally independent of θ given $M_{Y_n}^{pi}$: $p\left(m_{Y_n}\left|m_{Y_n}^{pi},\theta\right.\right) = p\left(m_{Y_n}\left|m_{Y_n}^{pi}\right.\right)$ since $m_{Y_n}^{pi}$ reveals θ. We thus have:

$$p\left(m_{Y_n}\left|\theta\right.\right) = \sum_{m_{Y_n}\in\mathcal{M}_{Y_n}} p\left(m_{Y_n}\left|m_{Y_n}^{pi}\right.\right) p\left(m_{Y_n}^{pi}\left|\theta\right.\right). \tag{A.1}$$

$M_{Y_n}^{pi}$ is sufficient for M_{Y_n}.

Let us now consider signals M_{Y_n} and $M_{Y_n}^{ni}$. We have:

$$\begin{aligned} p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right) &= \sum_{\theta\in\Omega^{N+1}} p\left(m_{Y_n}^{ni},\theta\left|m_{Y_n}\right.\right) \\ &= \sum_{\theta\in\Omega^{N+1}} p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right) p\left(\theta\left|m_{Y_n}\right.\right). \end{aligned} \tag{A.2}$$

Under $A1$, Equation (A.2) gives

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right)=\sum_{\theta\in\Omega^{N+1}}p\left(m_{Y_n}^{ni}\left|\theta\right.\right)p\left(\theta\left|m_{Y_n}\right.\right). \tag{A.3}$$

Given that $M_{Y_n}^{ni}$ is independent of θ, we obtain:

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right)=p\left(m_{Y_n}^{ni}\right)\sum_{\theta\in\Omega^{N+1}}p\left(\theta\left|m_{Y_n}\right.\right)=p\left(m_{Y_n}^{ni}\right). \tag{A.4}$$

In addition, we have:

$$\begin{aligned}p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)&=\frac{P\left(m_{Y_n}^{ni},m_{Y_n},\theta\right)}{p\left(m_{Y_n},\theta\right)}\\&=\frac{p\left(m_{Y_n}\left|m_{Y_n}^{ni},\theta\right.\right)p\left(m_{Y_n}^{ni}\left|\theta\right.\right)p\left(\theta\right)}{p\left(m_{Y_n}\left|\theta\right.\right)p\left(\theta\right)}.\end{aligned} \tag{A.5}$$

Under $A1$, Equation (A.5) give:

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)=\frac{p\left(m_{Y_n}\left|\theta\right.\right)p\left(m_{Y_n}^{ni}\right)}{p\left(m_{Y_n}\left|\theta\right.\right)}=p\left(m_{Y_n}^{ni}\right). \tag{A.6}$$

Equations (A.4) and (A.6) imply

$$p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)=p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right). \tag{A.7}$$

We also have:

$$p\left(m_{Y_n}^{ni}\left|\theta\right.\right)=\sum_{m_{Y_n}\in\mathcal{M}_{Y_n}}p\left(m_{Y_n}^{ni}\left|m_{Y_n},\theta\right.\right)p\left(m_{Y_n}\left|\theta\right.\right). \tag{A.8}$$

Equations (A.7) and (A.8) give

$$p\left(m_{Y_n}^{ni}\left|\theta\right.\right)=\sum_{m_{Y_n}\in\mathcal{M}_{Y_n}}p\left(m_{Y_n}^{ni}\left|m_{Y_n}\right.\right)p\left(m_{Y_n}\left|\theta\right.\right). \tag{A.9}$$

M_{Y_n} is sufficient for $M_{Y_n}^{ni}$.

Appendix B

FS^a_Φ is sufficient for FS^b_Φ (see definitions 4 and 5) implies that $\forall X \in \Phi, \forall \theta \in \Omega^{N+1}, \forall m^b_X \in \mathcal{M}_X$,

$$p\left(m^b_X \left|\theta\right.\right) p\left(\theta\right) = \sum_{m^a_X \in \mathcal{M}_X} \pi\left(m^b_X \left|m^a_X\right.\right) p\left(m^a_X \left|\theta\right.\right) p\left(\theta\right), \tag{B.1}$$

with $\sum\limits_{m^b_X \in \mathcal{M}_X} \pi_X\left(m^b_X \left|m^a_X\right.\right) = 1$.

Equation (B.1) can be rewritten as follows:

$$\begin{aligned} &\forall X \in \Phi, \forall \theta \in \Omega^{N+1}, \forall m^b_X \in \mathcal{M}_X, \\ &p\left(m^b_X, \theta\right) = \sum_{m^a_X \in \mathcal{M}_X} \pi\left(m^b_X \left|m^a_X\right.\right) p\left(m^a_X, \theta\right). \end{aligned} \tag{B.2}$$

By summing over θ, we obtain:

$$\begin{aligned} &\forall X \in \Phi, \forall m^b_X \in \mathcal{M}_X, \\ &p\left(m^b_X\right) = \sum_{m^a_X \in \mathcal{M}_X} \pi\left(m^b_X \left|m^a_X\right.\right) p\left(m^a_X\right). \end{aligned} \tag{B.3}$$

Besides, Equation (B.2) can also be written as follows:

$$\begin{aligned} &\forall X \in \Phi, \forall \theta \in \Omega^{N+1}, \forall m^b_X \in \mathcal{M}_X, \\ &p\left(\theta \left|m^b_X\right.\right) p\left(m^b_X\right) = \sum_{m^a_X \in \mathcal{M}_X} \pi\left(m^b_X \left|m^a_X\right.\right) p\left(\theta \left|m^a_X\right.\right) p\left(m^a_X\right). \end{aligned} \tag{B.4}$$

We obtain that $\forall X \in \Phi, \forall \theta \in \Omega^{N+1}, \forall m^b_X \in \mathcal{M}_X$,

$$p\left(\theta \left|m^b_X\right.\right) = \sum_{m^a_X \in \mathcal{M}_X} \frac{\pi\left(m^b_X \left|m^a_X\right.\right) p\left(m^a_X\right)}{p\left(m^b_X\right)} p\left(\theta \left|m^a_X\right.\right). \tag{B.5}$$

Since $\frac{\pi\left(m^b_X \left|m^a_X\right.\right) p\left(m^a_X\right)}{p\left(m^b_X\right)} = \pi\left(m^a_X \left|m^b_X\right.\right)$, Equation (B.5) becomes:

$$\forall X \in \Phi, \forall \theta \in \Omega^{N+1}, \forall m_X^b \in \mathcal{M}_X,$$
$$p\left(\theta \left| m_X^b \right.\right) = \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) p\left(\theta \left| m_X^a \right.\right). \tag{B.6}$$

Given that $\theta = \{x, y_1, ..., y_N\}$, it is easy to obtain from Equation (B.6) that $\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, \forall y_n \in \Omega, \forall m_X^b \in \mathcal{M}_X$,

$$p\left(y_n \left| m_X^b \right.\right) = \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) p\left(y_n \left| m_X^a \right.\right). \tag{B.7}$$

Besides (see Equation 1), we recall that

$$\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, v\left(CE_{Y_n}^{v, M_X^b}\right) = E\left[v\left(y_n\right) \middle| M_X^b\right]. \tag{B.8}$$

Or, equivalently:

$$\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, \forall m_X^b \in \mathcal{M}_X,$$
$$v\left(CE_{Y_n}^{v, m_X^b}\right) = \sum_{y_n \in \Omega_{Y_n}} p\left(y_n \left| m_X^b \right.\right) v\left(y_n\right). \tag{B.9}$$

From Equation (B.7) and Equation (B.9), we obtain that $\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, \forall m_X^b \in \mathcal{M}_X$,

$$v\left(CE_{Y_n}^{v, m_X^b}\right) = \sum_{y_n \in \Omega} v\left(y_n\right) \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) p\left(y_n \left| m_X^a \right.\right). \tag{B.10}$$

Or, equivalently,

$$\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, \forall m_X^b \in \mathcal{M}_X,$$
$$v\left(CE_{Y_n}^{v, m_X^b}\right) = \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b \right.\right) \sum_{y_n \in \Omega_{Y_n}} v\left(y_n\right) p\left(y_n \left| m_X^a \right.\right). \tag{B.11}$$

We obtain the following relationship between $CE_{Y_n}^{v, m_X^a}$ and $CE_{Y_n}^{v, m_X^b}$:

$$\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, \forall m_X^b \in \mathcal{M}_X,$$
$$v\left(CE_{Y_n}^{v,m_X^b}\right) = \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b\right.\right) v\left(CE_{Y_n}^{v,m_X^a}\right). \tag{B.12}$$

We thus have:

$$\forall X \in \Phi, \forall Y_n \in \Phi / \{X\}, \forall m_X^b \in \mathcal{M}_X,$$
$$v\left(CE_{Y_n}^{v,m_X^b}\right) \leq \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b\right.\right) v\left(CE_{Max}^{v,m_X^a}\right), \tag{B.13}$$

with $CE_{Max}^{v,m_X^a} = Max\left\{CE_{Y_1}^{v,m_X^a}, ..., CE_{Y_N}^{v,m_X^a}\right\}$.

And thus, we also have:

$$\forall X \in \Phi, \forall m_X^b \in \mathcal{M}_X, v\left(CE_{Max}^{v,m_X^b}\right)$$
$$\leq \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b\right.\right) v\left(CE_{Max}^{v,m_X^a}\right), \tag{B.14}$$

with $CE_{Max}^{v,m_X^b} = Max\left\{CE_{Y_1}^{v,m_X^b}, ..., CE_{Y_N}^{v,m_X^b}\right\}$.

Under assumption $A7$, Equation (B.14) implies:

$$\forall X \in \Phi, \forall m_X^b \in \mathcal{M}_X, v\left(CE_{Max}^{v,m_X^b}\right)$$
$$\leq v\left(\sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b\right.\right) CE_{Max}^{v,m_X^a}\right). \tag{B.15}$$

Which implies under $A3$:

$$\forall X \in \Phi, \forall m_X^b \in \mathcal{M}_X, CE_{Max}^{v,m_X^b}$$
$$\leq \sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b\right.\right) CE_{Max}^{v,m_X^a}. \tag{B.16}$$

Which implies

$$\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X, Max\left(x, CE_{Max}^{v,m_X^b}\right)$$
$$\leq Max\left(x, \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b\right.\right) CE_{Max}^{v,m_X^a}\right). \quad \text{(B.17)}$$

Moreover, since the Max function is convex, we have:

$$\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X, Max\left(x, CE_{Max}^{v,m_X^b}\right)$$
$$\leq \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b\right.\right) Max\left(x, CE_{Max}^{v,m_X^a}\right). \quad \text{(B.18)}$$

Given Definition 7, equations (B.18) can be rewritten as follows:

$$\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X, R^{m_X^b}$$
$$\leq \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b\right.\right) R^{m_X^a}. \quad \text{(B.19)}$$

For each signal value m_X^b, the reference point $R^{m_X^b}$ is lower than the average value of the reference point $R^{m_X^a}$.

Under $A5$, we obtain, that $\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X$,

$$u\left(x, \sum_{m_X^a \in M_X} \pi\left(m_X^a \left| m_X^b\right.\right) R^{m_X^a}\right) \leq u\left(x, R^{m_X^b}\right). \quad \text{(B.20)}$$

Which implies, under $A6$, that $\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X$,

$$\sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^a \left| m_X^b\right.\right) u\left(x, R^{m_X^a}\right) \leq u\left(x, R^{m_X^b}\right). \quad \text{(B.21)}$$

Since $\pi\left(m_X^a \left| m_X^b\right.\right) = \frac{\pi\left(m_X^b | m_X^a\right) p\left(m_X^a\right)}{p\left(m_X^b\right)}$, we obtain:

$\forall X \in \Phi, \forall x \in \Omega, \forall m_X^b \in \mathcal{M}_X$,

$$\sum_{m_X^a \in \mathcal{M}_X} \pi\left(m_X^b \left| m_X^a\right.\right) p\left(m_X^a\right) u\left(x, R^{m_a}\right)$$
$$\leq p\left(m_X^b\right) u\left(x, R^{m_X^b}\right). \quad \text{(B.22)}$$

Which implies that $\forall X \in \Phi, \forall x \in \Omega$,

$$\sum_{m_X^b \in M_X} \sum_{m_X^a \in M_X} \pi\left(m_X^b \left| m_X^a\right.\right) p\left(m_X^a\right) u\left(x, R^{m_X^a}\right)$$
$$\leq \sum_{m_X^b \in \mathcal{M}_X} p\left(m_X^b\right) u\left(x, R^{m_X^b}\right). \quad \text{(B.23)}$$

Or, equivalently, that $\forall X \in \Phi, \forall x \in \Omega$,

$$\sum_{m_X^a \in M_X} p\left(m_X^a\right) u\left(x, R^{m_X^a}\right) \leq \sum_{m_X^b \in M_X} p\left(m_X^b\right) u\left(x, R^{m_X^b}\right). \quad \text{(B.24)}$$

Taking the expectation with respect to x, we obtain:

$$\forall X \in \Phi,$$
$$E\left[u\left(X, Max\left(X, R^{M_X^a}\right)\right)\right] \leq E\left[u\left(X, Max\left(X, R^{M_X^b}\right)\right)\right]. \quad \text{(B.25)}$$

Appendix C

Proof of Proposition 3 :

First, let us show that, for any FS, the solution of Equation (4) exists and is unique.

If $Z = \underline{y}$ then the left-hand side (LHS) of Equation (4) is

$$E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right] = E\left[u\left(\underline{y}, CE_Y^{v,M_Z}\right)\right]. \quad \text{(C.1)}$$

The right-hand side (RHS) is

$$E\left[u\left(Y, Max\left(Y, Z\right)\right)\right] = E\left[u\left(Y, Y\right)\right] = E\left[v\left(y\right)\right]. \quad \text{(C.2)}$$

Equation (4) is not satisfied since, under $A4$ and $A5$, we have:

$$E\left[u\left(\underline{y}, CE_Y^{v,M_Z}\right)\right] \leq u\left(\underline{y}, \underline{y}\right) = v\left(\underline{y}\right) < E\left[v\left(y\right)\right]. \tag{C.3}$$

The RHS of Equation (4) is greater than the LHS.

If $Z = \overline{y}$ then the LHS of Equation (4) is

$$E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right] = u\left(\overline{y}, \overline{y}\right). \tag{C.4}$$

The RHS is

$$E\left[u\left(Y, Max\left(Y, Z\right)\right)\right] = E\left[u\left(Y, \overline{y}\right)\right]. \tag{C.5}$$

Equation (4) is not satisfied since, under $A4$, $u\left(\overline{y}, \overline{y}\right) > E\left[u\left(Y, \overline{y}\right)\right]$. The LHS of Equation (4) is now greater than the RHS.

Moreover, under $A3$ and $A4$, function $E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z}\right)\right)\right]$ increases with Z and under $A4$, function $E\left[u\left(Y, Max\left(Y, Z\right)\right)\right]$ decreases with Z. Under $A2$, the solution of Equation (4) exists, is unique, and belongs to $\left]\underline{y}, \overline{y}\right[$.

Proof of Proposition 4 :

The choice set is $\Omega = \{Z, Y\}$.

If Z_a and Z_b respectively denote the Z-solution of Equation (4) under FS^a and FS^b, let us show that $Z_b \leq Z_a$.

If FS_Φ^a is sufficient for FS_Φ^b, feedback aversion implies that (see Proposition 2):

$$\begin{aligned} &E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z^a}\right)\right)\right] \\ &\leq E\left[u\left(Z, Max\left(Z, CE_Y^{v,M_Z^b}\right)\right)\right]. \end{aligned} \tag{C.6}$$

The LHS of Equation (4) is greater under FS_{Φ}^{b} than under FS_{Φ}^{a}. The RHS of Equation (4), $E\left[u\left(Y, Max\left(Y,Z\right)\right)\right]$, is independent of the FS and decreases with Z under $A5$. We thus have $Z_b \leq Z_a$.

Appendix D

Under the assumptions of Proposition 5, $RCE_{Y}^{u,FS_{\Phi}^{i}}$ is the Z-solution of the following equation (see Equation 4):

$$
\begin{aligned}
&Z^{\alpha} - kE\left[Max\left(Y,Z\right) - Z\right] \\
&= E\left(Y^{\alpha}\right) - kE\left[Max\left(Y,Z\right) - Y\right]. \qquad \text{(D.1)}
\end{aligned}
$$

Equation (D.1) can be rewritten as follows:

$$
Z^{\alpha} + kZ = E\left(Y^{\alpha} + kY\right). \qquad \text{(D.2)}
$$

The Z-solution of Equation (D.2) is the Arrow-Pratt certainty equivalent of Y computed with the vNM utility function $\widehat{v}\left(Y\right) = Y^{\alpha} + kY$.

When $\alpha < 1$, the utility function $\widehat{v}\left(Y\right)$ displays less risk aversion than the c-utility function $v\left(Y\right) = Y^{\alpha}$ and $CE_{Y}^{v} < RCE_{Y}^{u,FS_{\Phi}^{pi}} < E\left(Y\right)$.

When $\alpha = 1$, the utility function $\widehat{v}\left(Y\right)$ displays risk neutrality as the c-utility function $v\left(Y\right) = Y^{\alpha}$ and $RCE_{Y}^{u,FS_{\Phi}^{pi}} = CE_{Y}^{v} = E\left(Y\right)$.

When $\alpha > 1$, the utility function $\widehat{v}\left(Y\right)$ displays less risk loving than the c-utility function $v\left(Y\right) = Y^{\alpha}$ and $CE_{Y}^{v} > RCE_{Y}^{u,FS_{\Phi}^{pi}} > E\left(Y\right)$.

Appendix E

Proof of Proposition 6:

Under a non-informative FS, we have $RCE_{B}^{u} < CE_{B}^{v}$ (see Corollary 2). When $CE_{B}^{v} < 1$ (risk aversion is high), we thus have $RCE_{B}^{u} < CE_{B}^{v} < 1$, which allows us to conclude that Equation (9) is satisfied.

In what follows, we pursue our analysis with $CE_B^v \geq 1$ (B is preferred to A in the EUT). Equation (9) is satisfied if

$$u\left(1, CE_B^v\right) > 0,1v\left(5\right) + 0,89v\left(1\right) + 0,01u\left(0,1\right). \tag{E.1}$$

Since $u\left(1, CE_B^v\right) \leq v\left(1\right) \leq v\left(CE_B^v\right)$, Inequality (E.1) can only be satisfied if $u\left(0,1\right) < v\left(0\right)$ (see Equation 8). When $CE_B^v \geq 1$, the DM must be sensitive to anticipated regret to exhibit a preference for situation A. Inequality (E.1) is satisfied when $RCE_B^u < 1 < CE_B^v$ which means that situation B is preferred in the EUT, while situation A is preferred under regret aversion. This result is possible due to the property of preference for certainty ($RCE_B^u < CE_B^v$) stated in Corollary 2.

When $u\left(x,r\right) = v\left(x\right) - kg\left(r-x\right)$ with $v\left(0\right) = 0$, RCE_B^u is the Z-solution of the following equation:

$$v\left(Z\right) - kg\left(CE_B^v - Z\right) = 0,1v\left(5\right) + 0,89v\left(1\right) - 0,01kg\left(Z\right). \tag{E.2}$$

Equation (E.2) is obtained with Equation (4) and $RCE_B^u < CE_B^v$.

Using Equation (8), we write Equation (E.2) as follows:

$$v\left(Z\right) + k\left[0,01g\left(Z\right) - g\left(CE_B^v - Z\right)\right] = v\left(CE_B^v\right). \tag{E.3}$$

Given that inequality (E.1) is satisfied when $RCE_B^u < 1$, Equation (E.3) implies:

$$v\left(1\right) + k\left[0,01g\left(1\right) - g\left(CE_B^v - 1\right)\right] > v\left(CE_B^v\right). \tag{E.4}$$

Equation (E.4) and $CE_B^v \geq 1$ imply:

$$0,01g\left(1\right) - g\left(CE_B^v - 1\right) > 0. \tag{E.5}$$

Given that $g'\left(.\right) > 0$, Equation (E.5) cannot be verified when $CE_B^v \geq 2$. When $CE_B^v \geq 2$, the

DM is such a risk-lover that regret theory cannot explain the preference for situation A observed in the Allais paradox.

Let us introduce $\delta < 1$, which verifies:

$$g(\delta) = 0,01 g(1). \tag{E.6}$$

The preference for situation A can only be explained when $CE_B^v < 1 + \delta$. When the regret function $g(.)$ is linear ($g(tx) = tg(x)$), we obtain $\delta = 0,01$. When the regret function is strictly convex ($g(tx) < tg(x)$ when $t < 1$), we have $\delta > 0,01$. When $g(x) = x^\beta$, we obtain $\delta = 0,01^{\frac{1}{\beta}}$. When $\beta \to +\infty$, we have $\delta \longrightarrow 1$ and situation A is preferred when $CE_B^v < 2$.

Secondly, Equation (E.4) is satisfied when k is high enough:

$$k > k_{\min} = \frac{v(CE_B^v) - v(1)}{0,01 g(1) - g(CE_B^v - 1)}. \tag{E.7}$$

Or else:

$$k > k_{\min} = \frac{0,1 v(5) - 0,11 v(1)}{0,01 g(1) - g(CE_B^v - 1)}. \tag{E.8}$$

Computations for Table 2:

When $u(x,r) = x^\alpha - k(r-x)^\beta$, Equation (E.5) can be written as follows:

$$0,01 - (CE_B^v - 1)^\beta > 0. \tag{E.9}$$

Which gives:

$$\beta > \beta_{\min} = \frac{0,01}{\ln(CE_B^v - 1)} \text{ when } CE_B^v < 2. \tag{E.10}$$

We also have:

$CE_B^v = (0,1 \times 5^\alpha + 0,89)^{\frac{1}{\alpha}}$ increases with α.

$k_{\min} = \frac{0{,}1v(5)-0{,}11v(1)}{0{,}01g(1)-g\left(CE_B^v-1\right)} = \frac{0{,}1\times 5^{\alpha}-0{,}11}{\left[0{,}01-\left(CE_B^v-1\right)^{\beta}\right]}$ increases with α, and decreases with β when $CE_B^v < 2$.

Choice between C and D:

Given that $0 < CE_C^v < 1$ and $CE_D^v > 0$, Equation (10) can be written as follows:

$$\begin{aligned} &0,1v\,(5) + 0,9u\,(0, CE_C^v) \\ &> 0,11u\,(1, Max(1, CE_D^v)) + 0,89u\,(0, CE_D^v)\,. \end{aligned} \tag{E.11}$$

We must consider two cases: the first case is $CE_D^v \leq 1$ which encompasses all the risk-averse DMs ($CE_D^v \leq 0,5$) and some risk lovers ($0,5 < CE_D^v \leq 1$). The second case is $CE_D^v > 1$.

1. When $CE_D^v \leq 1$, Equation (E.11) becomes:

$$0,1v\,(5) + 0,9u\,(0, CE_C^v) > 0,11v\,(1) + 0,89u\,(0, CE_D^v)\,. \tag{E.12}$$

   Which gives:

$$\begin{aligned} &\underbrace{[0,1v\,(5) - 0,11v\,(1)]}_{(I)} \\ &+ \underbrace{[0,9u\,(0, CE_C^v) - 0,89u\,(0, CE_D^v)]}_{(II)} > 0. \end{aligned} \tag{E.13}$$

   In what follows, we posit $v\,(0) = 0$ for the sake of simplicity. Expression (I) represents the difference between the expected utility of D and the expected utility of C in the EUT. Expression (II) represents the difference between anticipated regret in D and C. We consider three subcases:

   (a) When $CE_B^v < 1$ ($\alpha < 0,059^+$), we have $0,11v\,(1) > 0,1v\,(5)$ (see Equation 8), and thus $CE_C^v > CE_D^v$. Expression (I) and Expression (II) in Equation (E.13) are both negative, and Equation (E.13) cannot be satisfied. When $CE_B^v < 1$, the EUT $((I) < 0)$ and regret theory $((I) + (II) < 0)$ predict that situation C will be chosen instead of situation D.

(b) When $CE_B^v = 1$ ($\alpha = 0,059^+$), we have $0,11v\,(1) = 0,1v\,(5)$ (see Equation 8), and thus $CE_C^v = CE_D^v$. Expression (I) is equal to 0, and Expression (II) is negative. When $CE_B^v = 1$, the EUT predicts indifference between C and D. Regret theory predicts the choice of situation C because the probability of experiencing regret is lower in C than in D.

(c) When $CE_B^v > 1$ ($\alpha > 0,059^+$), we have $0,11v\,(1) < 0,1v\,(5)$ (see Equation 8), and thus $CE_C^v < CE_D^v$. Expression (I) in Equation (E.13) is positive. The EUT predicts choice D. By continuity with the previous case, the sign of Expression $(I) + (II)$ is negative when CE_B^v is just greater than 1.

If we consider, however, the r-utility function $u\,(x,r) = x^\alpha - k\,(r-x)^\beta$, Expression (I) and Expression (II) are both positive when $\alpha \geq 0,059633542 = 0,59^{++}$ ($\Leftrightarrow CE_B^v \geq 1,001230184 = 1^+$) and $\beta \geq 1$ (the regret function is linear or convex). See online appendix.

2. When $CE_D^v > 1$, Equation (E.11) can be written as follows:

$$\begin{aligned} &0,1v\,(5) + 0,9u\,(0, CE_C^v) \\ &> 0,11u\,(1, CE_D^v) + 0,89u\,(0, CE_D^v)\,. \end{aligned} \tag{E.14}$$

Or else:

$$\begin{aligned} &\underbrace{[0,1v\,(5) - 0,11u\,(1, CE_D^v)]}_{(I)} \\ &+ \underbrace{[0,9u\,(0, CE_C^v) - 0,89u\,(0, CE_D^v)]}_{(II)} > 0. \end{aligned} \tag{E.15}$$

When $CE_D^v > 1$, we also have $CE_B^v > 1$. When $\alpha \geq 0,59^{++}$ and $\beta \geq 1$, we know that Equation (E.13) is satisfied (see subcase c), which implies that Equation (E.15) is also satisfied.

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