Regret theory and risk attitudes*

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Abstract

We examine risk attitudes under regret theory and derive analytical expressions for two components—the resolution and regret premiums—of the risk premium under regret theory. We posit that *regret*-averse decision makers are risk seeking (resp., risk averse) for low (resp., high) probabilities of gains and that feedback concerning the foregone option reinforces risk attitudes. We test these hypotheses experimentally and estimate empirically both the resolution premium and the regret premium. Our results confirm the predominance of regret aversion but not the risk attitudes predicted by regret theory; they also clarify how feedback affects attitudes toward both risk and regret.

Keywords Regret theory, Resolution premium, Regret premium

JEL Classification D81

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1 Introduction

In economics and management, the classic model of expected utility (von Neumann and Morgenstern 1947) is the benchmark for representing preferences under risk and uncertainty. Yet several models have been introduced since the 1970s to accommodate some of expected utility's descriptive failures (for reviews see Starmer 2000, Wakker 2010). *Regret theory* (Bell 1982, Loomes and Sugden 1982) is one of the most popular alternatives to expected utility (EU). Regret theory is based on the intuition that a decision maker (DM) — when choosing among risky objects (e.g., lotteries, gambles, and investments) — is concerned not only about the payoff he receives but also about the foregone payoff, i.e., had he chosen differently.[1] Regret theory has a simple structure: a utility function capturing attitudes toward outcomes and a function capturing the effect of regret. Despite this structural simplicity, regret theory can account for many of the empirical violations of EU (Loomes and Sugden 1982). The key to explaining these violations is the psychological intuition that most decision makers are by nature regret averse. Regret theory's intuitive content and explanatory power make it well suited to real-world applications. For example, Barberis et al. (2006), Gollier and Salanié (2006), Muermann and Volkman (2006), Michenaud and Solnik (2008), and Qin (2015) have applied the notion of regret to financial and insurance decisions. Perakis and Roels (2008) reinterpreted the newsvendor model in terms of regret, and Filiz-Ozbay and Ozbay (2007) and Engelbrecht-Wiggans and Katok (2008) proposed models in auction theory that rely on regret. Diecidue et al. (2012), Nasiry and Popescu (2012), and Viefers and Strack (2014) focused on dynamic applications of regret.

To deploy regret theory for decision analysis, the risk attitudes under that theory should be well understood. Under EU, risk attitudes are fully captured by "utility curvature" (Wakker 2010); in more complex models, such as prospect theory (Kahneman and Tversky 1979, Tversky and Kahneman 1992, Tversky and Wakker 1995), risk attitudes are captured by the interaction between utility and a probability weighting function that

[1] The role of regret in the psychology of decision making has been extensively investigated (Larrick 1993, Larrick and Boles 1995, Zeelenberg 1999, Connolly and Zeelenberg 2002, Connolly and Butler 2006).

yields a fourfold pattern of risk attitudes. Under regret theory, however, it is not clear how the interaction between utility and regret is related to risk attitudes. Bell (1983) formalized the risk premium under regret theory and showed that it consists of two distinct components: a resolution premium and a regret premium. However, Bell (1983) did not suggest an empirical method suitable for measuring these two components (Anand 1985).

In this paper, we provide an analytical expression for both the resolution premium and the regret premium. These expressions enable—for the first time—a precise characterization of risk attitudes under regret theory and thus rigorous predictions about the risk attitudes of a regret-averse decision maker. We predict that regret-averse DMs will be risk seeking for low probabilities of gains and risk averse for high probabilities; we also postulate that risk attitudes are reinforced by feedback about the foregone payoff. We introduce a method to measure the risk premium under regret theory. This method allows us then to compute both the resolution and regret premiums and thereby to understand the effect of feedback on regret attitudes. Finally, we design an experiment to estimate empirically the risk premium's components and to test our predictions about risk attitudes. The experiment serves also as a descriptive test of regret theory.

The data support regret aversion as a robust empirical phenomenon. However, we find no significant support for the risk attitude predictions of regret theory. We also discover that immediate feedback polarizes regret attitudes: It increases the regret aversion of regret-averse subjects but it reduces the regret aversion within the entire subject pool.

The paper is organized as follows. Section 2 introduces the notation and the definition of regret theory; in Section 3, we first derive analytically the two components of the risk premium under regret theory and then introduce a measurement that distinguishes the two components. Building on this new measurement, Section 4 derives formal predictions for the risk attitudes of a regret-averse decision maker; the experiment described in Section 5 tests those predictions. We discuss the experiment's results and conclude in Section 6.

2 Notation and basic concepts

Consider a state space S. Subsets of S are events E. The outcome set is $\mathbb{R}$, with real numbers designating amounts of money. Prospects are state-contingent outcomes mapping the state space S to $\mathbb{R}$. Prospects are denoted by lower case letters $(f, g, \ldots)$, and outcomes are usually denoted by Greek letters (α, β, γ, δ) or by Roman letters with subscripts (e.g., x_1). Consider a preference relation $\succeq$ over the set of prospects. Strict preference $\succ$, indifference (or equivalence) $\sim$, and reverse preferences $\preceq$ and $\prec$ are defined as usual. Let $\mathbb{R}^n$ denote the set of all prospects. A prospect f is denoted by $f = (E_1\,, f_1; \,\ldots; \,E_n\,, f_n)$, where $f_1, \ldots, f_n$ are outcomes under events $E_1, \ldots, E_n$. For a prospect f, we use $\alpha_{E_i} f$ to signify that the outcome of prospect f under event E_i is replaced by α. The prospect f is also denoted by $(p_1\,, f_1; \,\ldots; \,p_n\,, f_n)$, where $p_1, \ldots, p_n$ are the probabilities attached to events $E_1, \ldots, E_n$.

Regret theory considers the utility of the outcomes associated with the selected prospect and also the regret or "rejoice" associated with comparisons between the selected and the foregone prospect. Before defining regret theory formally, we examine some of its basic formulations and properties. Consider the two-outcome prospects $\alpha_E\beta$ and $\gamma_E\delta$. The general formulation of regret theory proposed by Loomes and Sugden (1987) postulates a real-valued function ψ such that

$$\alpha_E\beta \succeq \gamma_E\delta \iff p\psi(\alpha, \gamma) + (1-p)\psi(\beta, \delta) \geq 0. \tag{2.1}$$

The function $\psi(\alpha, \gamma)$ can be interpreted as assigning a real-valued index to the net advantage of choosing $\alpha_p\beta$ rather than $\gamma_p\delta$ if event E obtains with subjective probability p. The function ψ is unique up to scale—that is, it can be replaced by any other function $\psi' = a\psi$ without affecting preferences—and satisfies the following two restrictions.

1. The function ψ is *strictly increasing* (resp., *strictly decreasing*) in its first (resp., second) argument: for any outcome γ, if $\alpha > \beta$ then $\psi(\alpha, \gamma) > \psi(\beta, \gamma)$ and $\psi(\gamma, \alpha) < \psi(\gamma, \beta)$.

2. The function ψ is *skew symmetric*: for all α and β, $\psi(\alpha, \beta) = -\psi(\beta, \alpha)$.

Bell (1982) and Loomes and Sugden (1982) considered a restricted form of Eq. (2.1) in which

$$\psi(\alpha, \beta) = Q(u(\alpha) - u(\beta)), \tag{2.2}$$

where Q is the regret function and u is a von Neumann–Morgenstern utility function.[2] We use Eq. (2.2) to define regret theory formally as follows.

Definition 1. *Regret theory* holds if there exist both a continuous strictly increasing utility function $u\colon \mathbb{R} \to \mathbb{R}$ and a continuous strictly increasing skew-symmetric regret function $Q\colon \mathbb{R} \to \mathbb{R}$ such that

$$f \succeq g \iff \sum_{i=1}^{n} p_i \cdot Q(u(f_i) - u(g_i)) \geq 0; \tag{2.3}$$

here $f = (E_1, f_1; \ldots; E_n, f_n)$ and $g = (E_1, g_1; \ldots; E_n, g_n)$ are prospects and p_i is the subjective probability of event E_i. The skew-symmetry of Q implies $Q(\alpha) = -Q(-\alpha)$ for any outcome α.

Expected utility is the special case of Eq. (2.3) in which Q is the identity function. The convexity (resp., concavity) of the Q-function indicates regret aversion (resp., regret seeking). Regret aversion is responsible for the distinctive predictions of regret theory (see Loomes and Sugden 1982, Bleichrodt and Wakker 2015). Bleichrodt et al. (2010) presented the first quantitative (non parametric) measurement of Eq. (2.3), i.e., allowed to measure utility u and regret function Q at the individual level.

Definition 1 illustrates the behavior of a DM that compares the outcomes of the chosen prospect with those of the foregone prospect, state by state. Therefore, if the DM receives feedback about the chosen and foregone prospect (post choice), then the possibility of regret — receiving a lower outcome compared to the foregone prospect — becomes more salient to the DM. We conjecture that this makes the DM to engage more

[2] Loomes and Sugden (1982) refer to u as a "choiceless utility function".

intensely in such state by state outcome comparisons before choosing. The intuition is supported by the psychological research: Larrick and Boles (1995), Zeelenberg et al. (1996), Zeelenberg and Beattie (1997), and Zeelenberg (1999) have shown that systematic effects of anticipated regret are observed in conditions — like immediate feedback — where the possibility of regret is made highly salient to the DM. Therefore feedback seems to enhance anticipated regret. However, regret theory — as in Definition 1 — does not incorporate feedback. To provide a thorough analysis of risk attitudes under regret theory, it is therefore required to include feedback into Eq. (2.3). For this purpose, we consider two variants of Eq. (2.3): the first variant uses a regret function Q_N to capture "pure" anticipated regret with **No feedback**, while the second variant uses a regret function Q_F to capture anticipated regret when **Feedback** is available. Therefore, by comparing the regret functions under feedback (Q_F) and no feedback (Q_N), we can understand the effect of feedback on anticipated regret and choices. Larrick and Boles (1995) and Zeelenberg (1999)) have shown that resolving the foregone option and providing immediate feedback increases regret aversion. As the DM becomes more regret averse, the Q function becomes more convex. We therefore expect Q_F to be more convex than Q_N. We validate this assumption later in our experiment.

3 Risk premium under regret: Derivation

The *risk premium* of a prospect is the monetary difference between its expected value (EV) and the sure amount (the certainty equivalent CE) that makes the DM indifferent to that prospect. The risk premium (RP) under regret theory, is the difference between the EV and the CE of the prospect under regret theory. To provide a complete characterization of risk premium under regret theory, we focus on the regret theory variant under feedback. In this case, the risk premium is $RP = EV - CE_{RT_F}$, where CE_{RT_F} is the certainty equivalent under regret theory with feedback. Given the certainty equivalent under regret theory with no feedback (CE_{RT_N}) and certainty equivalent under expected utility (CE_{EU}), the risk premium under regret theory with feedback (RP) can be rewritten as follows:

$$RP = (CE_{RT_N} - CE_{RT_F}) + (CE_{EU} - CE_{RT_N}) + (EV - CE_{EU}). \tag{3.1}$$

The first component $(CE_{RT_N} - CE_{RT_F})$ is the *resolution premium.* This entails that the DM is not indifferent to "resolving" the foregone option: the premium is the amount a DM pays to avoid the resolution of the foregone option. The convexity of Q_F compared to Q_N determines the resolution premium. The second component $(CE_{EU} - CE_{RT_N})$ is the *regret premium,* i.e., is the extra amount that a DM pays to avoid regret as compared to an EU maximizer. The convexity of Q_N and the concavity of u determine the regret premium. The third component $(EV - CE_{EU})$ is the risk premium under expected utility. The concavity of utility function u determines the risk premium under EU.

To provide intuition for Eq. (3.1), consider a DM facing choices 1 and 2 in Table 1. Assume the four events E_1, E_2, E_3, and E_4 are equally likely; as a consequence f and g, f' and g' have the same expected value. Suppose the DM prefers prospect f to g and receives nothing after the uncertainty is resolved (e.g., event E_4 turns up). The DM will regret the decision: not only he received \$0, but he also lost the opportunity to earn a sure amount of \$15,000. The premium a DM is willing to pay in order to avoid regret is the *regret premium*.

Suppose the DM prefers prospect f' to g' and then—after resolution of the uncertainty—receives nothing. The DM might (or might not) like to hear about the outcomes of prospect g'. The amount of money a DM will pay to avoid (hearing about) resolution of the foregone prospect is the *resolution premium*.[3]

[3] If instead the DM does want to hear about (resp., is indifferent to) the foregone prospect's payoffs, then the resolution premium is negative (resp., zero).

Choice 1	E_1	E_2	E_3	E_4
f	\$ 20k	\$ 20k	\$ 20k	0
g	\$ 15k	\$ 15k	\$ 15k	\$ 15k
Choice 2	E_1	E_2	E_3	E_4
f'	\$ 40k	0	0	0
g'	\$ 20k	\$20k	0	0

Table 1: Choice between prospects

In the rest of this section we derive analytical expressions for the risk premium components under regret theory as in Eq. (2.1).

Resolution premium

Consider prospects of the form $x = (p\,, x_k;\ 1-p\,, x_0)$; here $p \in (0,1)$ and $x_k \geq x_0 \geq 0$. The resolution premium (ResP) of a prospect x is the difference between CE_{RT_N} and CE_{RT_F}; it is derived in Appendix A and is given by

$$\mathrm{ResP}(x) = CE_{RT_N} - CE_{RT_F} = u^{-1}\left(u(x_k) \left(\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_N^{-1}\left(\frac{p}{1-p}\right)} \right) \right) - u^{-1}\left(u(x_k) \left(\frac{Q_F^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_F^{-1}\left(\frac{p}{1-p}\right)} \right) \right). \tag{3.2}$$

Replacing Q_F and Q_N in Eq. (3.2) with the power function specifications $Q_F(\alpha) = \alpha^{\theta_1}$ and $Q_N(\alpha) = \alpha^{\theta_2}$, we obtain

$$\mathrm{ResP}(x) = CE_{RT_N} - CE_{RT_F} = u^{-1}\left(u(x_k) \left(\frac{\left(\frac{p}{1-p}\right)^{1/\theta_2}}{1 + \left(\frac{p}{1-p}\right)^{1/\theta 2}} \right) \right) - u^{-1}\left(u(x_k) \left(\frac{\left(\frac{p}{1-p}\right)^{1/\theta_1}}{1 + \left(\frac{p}{1-p}\right)^{1/\theta_1}} \right) \right).$$

Here θ captures the convexity of Q function, and thereby regret aversion.

Regret premium

The regret premium (RegP) for prospect x is the difference between the certainty equivalent under EU (CE_{EU}) and the CE under regret with no feedback (CE_N), where the latter is derived in Appendix A. Hence, we can write the regret premium (RegP) of prospect x as

$$\text{RegP}(x) = u^{-1}\left(u(x_k) \cdot p\right) - u^{-1}\left(u(x_k)\left(\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_N^{-1}\left(\frac{p}{1-p}\right)}\right)\right). \tag{3.3}$$

Replacing Q_N in Eq. (3.3) with the power function specification $Q_N(\alpha) = \alpha^{\theta_2}$, we obtain

$$\text{RegP}(x) = u^{-1}\left(u(x_k) \cdot p\right) - u^{-1}\left(u(x_k)\left(\frac{\left(\frac{p}{1-p}\right)^{1/\theta_2}}{1 + \left(\frac{p}{1-p}\right)^{1/\theta_2}}\right)\right).$$

Risk premium under expected utility

The risk premium under expected utility (RP_{EU}) for the prospect x is the difference between the expected value (EV) of the prospect and the certainty equivalent under expected utility (CE_{EU}):

$$RP_{EU}(x) = p \cdot x_k + (1-p)x_0 - u^{-1}(p \cdot u(x_k)). \tag{3.4}$$

Note that, for any two-outcome prospect $x = (p\,, x_k;\, 1-p\,, x_0)$, the term $u(x_0)$ can be scaled to 0 and the risk premium under expected utility can be computed using Eq. (3.4).

4 Risk attitudes under regret

According to the results presented in Section 3, the risk premium of prospect x under regret is the sum of resolution premium, regret premium, and risk premium under expected utility ($\mathrm{ResP}(x) + \mathrm{RegP}(x) + RP_{EU}(x)$). Larrick and Boles (1995) and Zeelenberg et al. (1996) provided experimental evidence that a regret-averse decision maker could be both risk averse and risk seeking without any further characterization. Given that we have derived expressions for the components of risk premium under regret, in this section we present a result that characterizes the risk attitude of a regret-averse DM—that is, a decision maker described by a convex Q-function. Under regret theory, a DM's risk attitude is reflected mainly by the regret function Q while the utility function u captures attitude toward money. To extract the pure effect of regret on risk attitude, in the following analysis we shall assume that u is linear (thereby RP_{EU} is assumed to be zero). Previous literature (Fox et al. 1996, Lopes and Oden 1999) has documented a linear utility function when the amounts of money involved are moderate. The assumption of linear utility under regret theory was also validated empirically by the estimates of Bleichrodt et al. (2010), and Baillon et al. (2015). Under linear utility, the expressions for resolution premium (ResP) and regret premium (RegP) in Eq. (3.2) and Eq. (3.3) can be simplified as follows (scaling $u(x_0) = 0$ yields $u(x_k) = x_k - x_0$):

$$\mathrm{ResP}(x) = (x_k - x_0) \cdot \left(\left(\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_N^{-1}\left(\frac{p}{1-p}\right)} \right) - \left(\frac{Q_F^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_F^{-1}\left(\frac{p}{1-p}\right)} \right) \right), \tag{4.1}$$

$$\mathrm{RegP}(x) = (x_k - x_0) \cdot \left(p - \left(\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_N^{-1}\left(\frac{p}{1-p}\right)} \right) \right). \tag{4.2}$$

Consider a prospect of the form $x = (p\,, x_k;\, 1-p\,, x_0)$, where $x_k \geq x_0 \geq 0$. The following proposition uses Eq. (4.1) and Eq. (4.2) to characterize the risk attitudes of a regret-averse decision maker.

Proposition 1. *Suppose regret theory holds with a linear utility function u and a regret function Q_F. Then a regret-averse DM is risk seeking for probabilities $p \in (0, 1/2)$, is risk averse for probabilities $p \in (1/2, 1)$, and is risk neutral for probability $p = 1/2$.*

Proof. The proof (see Appendix B) relies on analyzing the resolution and regret premiums for all possible values of probability p (i.e., $p = 1/2$, $p \in (0, 1/2)$, and $p \in (1/2, 1)$). We prove the proposition by showing that both the resolution premium and the regret premium are negative for probabilities $p \in (0, 1/2)$ yet are positive for probabilities $p \in (1/2, 1)$. □

Under no feedback—the case of a regret-averse DM with regret function Q_N and *no* feedback about resolution of the foregone option—the resolution premium (ResP) is zero and hence the risk premium coincides with the regret premium (RegP). It follows from Proposition 1 that the regret premium is negative for probability $p \in (0, 1/2)$ and positive for probability $p \in (1/2, 1)$. So even in the absence of feedback, a regret-averse DM is risk seeking for $p < 1/2$ and risk averse for $p > 1/2$. These risk attitudes are reinforced (because of the resolution premium) when there is feedback, as described in Proposition 1.[4]

If the utility function u is not linear, then the regret-averse DM is still risk seeking for low probabilities of gains and risk averse for high probabilities; however, the risk neutrality cutoff point is no longer $p = 1/2$. In particular, if u is concave (resp., convex) then the DM is risk seeking for probabilities $(0, m)$, $m < 1/2$ (resp., $m > 1/2$).

Resolution and regret premiums: An example

To illustrate the intuition behind Proposition 1, we calculate resolution and regret premiums for a specific example. Following the empirical estimates of Bleichrodt et al. (2010), we assume that $u(\alpha) = \alpha^{0.96}$ for the utility function and that $Q_N(\alpha) = \alpha^{1.73}$. Because Q_F is expected to be more convex than Q_N, we assume $Q_F(\alpha) = \alpha^{3.26}$ — a value in the top decile of the estimates from Bleichrodt et al. (2010). Assuming $u(0) = 0$, we com-

[4]In our set-up, note that the resolution premium is computed independently from the regret premium. So our set-up allows a regret averse DM to be resolution seeking.

pute the resolution and regret premiums of the prospect $(p_j\,, 100;\; 1-p_j\,, 0)$ for different probabilities p_j.

Probability	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Resolution premium	–11.68	–8.53	–5.56	–2.75	0	2.77	5.65	8.75	12.16
Regret premium	–11.5	–19.32	–13.52	–6.94	0	7.01	13.83	20.04	24.49
CE_{EU}	9.09	18.70	28.53	38.50	48.58	58.74	68.97	79.26	89.61
CE_{RT_N}	20.58	39.32	42.87	45.83	48.58	51.33	54.31	57.91	63.14
CE_{RT_F}	32.27	46.56	47.62	48.19	48.58	48.95	49.48	50.47	52.95
Total risk premium	–23.18	–27.85	–19.09	–9.69	0	9.78	19.48	28.79	36.66

Table 2: Resolution premium and regret premium for a specific example

Table 2 reports the resolution and regret premiums computed using (respectively) Eq. (3.2) and Eq. (3.3). The certainty equivalent of regret theory under no feedback (CE_{RT_N}) is computed by adding the regret premium to the CE under EU (CE_{EU}); we obtain the CE of regret theory under feedback (CE_{RT_F}) by adding the resolution premium to the CE_{RT_N}. The risk premium, resolution premium, and regret premium are negative for low probabilities and are positive for high probabilities of gains. This relation indicates that a regret-averse DM is risk seeking for low probabilities of gains and risk averse for high probabilities (under no feedback) and that this attitude is reinforced in the presence of feedback owing to the resolution premium. The intuition for this result is as follows. If a DM is choosing between a prospect and its expected value, then for low probabilities—say, a choice between $(0.05\,, 100;\; 0.95\,, 0)$ and 5 for sure—the DM prefers the prospect because the anticipated regret of *not* choosing the prospect and losing out on larger amount (here, of 100) is greater. Yet for high probabilities—say, a choice between $(0.95\,, 100;\; 0.05\,, 0)$ and 95 for sure —the DM prefers the EV because the anticipated regret of choosing the prospect, receiving nothing, and losing out on the sure amount (here, of 95) is greater. Figure 1 plots the CE under conditions F and N as well as the expected value.

Our example illustrates Proposition 1 and predicts an inverse-S curve for the certainty equivalents of the prospects under consideration. Because of the resolution premium, this curve is less linear when there is feedback. Given this example and Proposition 1, we make two summary predictions as follows. (i) When evaluating prospect $x = (p\,, x_k;\; 1-p\,, x_0)$,

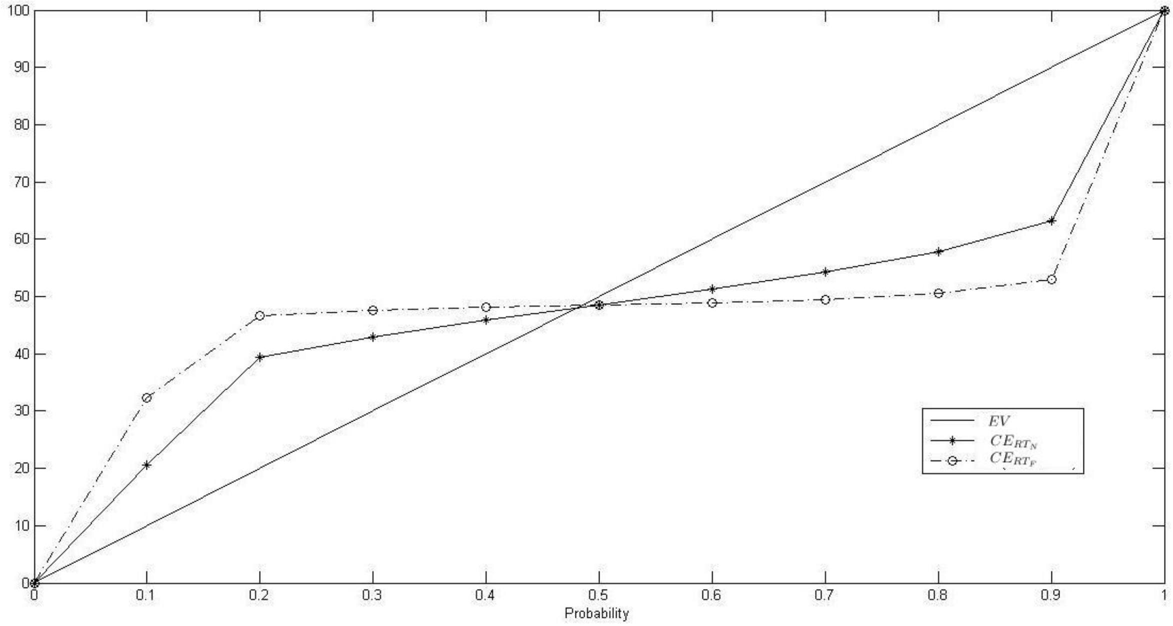

Figure 1: Expected value, Regret theory CEs under No feedback (CE_{RT_N}) and Feedback (CE_{RT_F})

a regret-averse decision maker is risk seeking for low probabilities of gains ($p < 1/2$) and risk averse for high probabilities ($p > 1/2$); (ii) the risk attitude of a regret-averse DM is reinforced in the presence of feedback owing to the resolution premium.

We tested these predictions in an experimental study. The next section is devoted to reporting the results of that study.

5 The experiment

Our experiment consisted of choices between prospects and was divided into two sections. Section I involved 24 questions devised for identifying regret-averse decision makers. The questions amounted to choices between two (three-outcome) prospects whose outcomes were determined by rolling a 6-sided die. Of these two prospects, one is clearly preferable to—and so should be chosen by—a regret-averse DM. In section II of the experiment, another 26 questions were used to assess the risk attitudes of the regret-averse DMs identified in section I. These latter questions were also choices between two prospects, but at this stage the outcomes were determined by rolling a 20-sided die. Much as in section I, we expect that a particular one of the two prospects would be chosen by (and only by) a risk-averse decision maker. Each section of the experiment featured two conditions: with **Feedback (condition F)** and with **No feedback (condition N)**. The experimental subjects were randomly assigned (in equal numbers) to one of these two conditions, both of which employed the exact same questions. In condition F, these subjects received immediate feedback about their payoff after each choice by rolling a 6- or 20-sided die (depending on the experiment's section). Immediately after the subject chose one of the prospects, a computer-simulated die was rolled and the subject was informed of the outcome. In condition N, subjects received no feedback after their choices.

We tested our predictions in terms of the following two hypotheses.

- H1: *Regret-averse subjects are risk seeking for low probabilities* ($p < 1/2$) *and risk averse for high probabilities* ($p > 1/2$) *in conditions F and N both.*

- H2: *The risk attitudes of regret-averse subjects are reinforced more under condition F than under condition N.*

The outcomes of prospects used in the experiment were small (€0–€99) and therefore within the domain of a decision maker's linear evaluation. This presumption allowed us to test both H1 and H2 for $p < 1/2$ and for $p > 1/2$.

5.1 Methodology

5.1.1 Subjects and stimuli

The computer-based experiment was conducted at the INSEAD–Sorbonne lab in Paris. The 107 subjects (71 female), of mean age 23, were university students in Paris. The stimuli used in each of the sections are shown in Appendix C. The section I stimuli (Figure 3) correspond to the monetary outcomes received under both prospects—outcomes that are determined by rolling a 6-sided die. In section II of the experiment, the stimuli (Figure 4) again correspond to the monetary outcomes received under both prospects, but now those outcomes are determined by rolling a 20-sided die. The subjects were asked to express their preferences when comparing two prospects. Figure 5 depicts a (condition F) feedback value as indicated by the feedback device (6-sided die).

5.1.2 Incentives

Each subject participating in the study was paid a flat fee of €8. To supplement that amount we instituted a randomized incentive procedure: subjects were informed that they might be able to play one of their randomly selected choices for real and win a cash amount of as much as €99. At the end of the experiment, 8 of the 107 subjects were randomly selected to play one of their choices for real. The selected subjects were asked to draw a question number from a box that consisted of all the questions used in the experiment. If the subject was in the Feedback condition, then she was paid the outcome originally given as immediate feedback for that particular question; if the subject was in the No feedback condition, then she rolled a 6- or 20-sided die. Thus the extra payouts were based on the subjects' original choices and a roll of the die. The average extra amount earned by these eight randomly selected subjects was €25.

5.1.3 Procedures

Subjects were randomly assigned to one of the two experimental conditions and were informed that the experiment would take about 45 minutes to complete. The subjects were then given detailed instructions regarding the stimuli and the experiment, and they were also briefed about the incentive system. The instructions in both conditions were identical except that, in condition F, the subjects were told that they would know their payoff immediately after each choice. Both conditions used the same questions; the only difference between them was the presence of feedback.[5] The order of questions was randomized once, after which the same order was presented to all subjects.

The questions in section I consisted of a choice between two prospects (see Table 16 in

[5]The full list of questions is given in Appendix D (the instructions are available at goo.gl/jKOT3R and goo.gl/3ftKzu).

Appendix D). In each such pair, the "RA" prospect is the one that should be chosen by a regret-averse decision maker. Subjects were allowed to choose one of the two prospects or to express indifference; they were also informed that, if they expressed indifference between two prospects, then the computer would select one of them (with equal probability) on their behalf. In section I, the subjects' responses to 16 of the 24 questions were used to identify regret-averse individuals. Of those 16 questions, 8 were choices between what we set up to be a regret-averse (RA) and a regret-seeking (RS) prospect of the same EV; the remaining 8 were choices between a RA and a RS prospect of different expected values. Six additional questions were used to estimate the Q-function parametrically; the section I questions also included one to assess dominance and one to check for consistency. After answering the 24 questions in section I of the experiment, all subjects proceeded to section II.

In section II of the experiment, subjects were required to choose between a less risky and a more risky prospect having the same expected value (see Table 17 in Appendix D). The presentation of less risky and more risky prospects was counterbalanced across questions. Monetary outcomes in section II ranged from €0 to €50. Subjects were allowed to choose one of the prospects or to express indifference. The subjects' responses to 26 questions in section II were used to identify risk attitudes. After answering the questions in sections I and II, subjects were asked to provide personal and demographic information.

5.1.4 Validity of measurement

To ensure valid responses, we included dominance and consistency checks. These checks are detailed in what follows.

Dominance checks

There were two dominance checks, one in each section of the experiment. The dominance checks were a choice between two prospects, one of which stochastically dominates the other. This check was included as question 11 in section I and as question 14 in section II.

Consistency checks

These checks were included in the experiment to ensure consistent responses. One of the questions in each section was repeated (i.e., asked twice); thus, questions 8 and 17 (in section I) were identical and questions 3 and 16 (in section II) were identical.

5.1.5 Analyses

We first present data for the classification of subjects according to regret attitudes, after which to test hypotheses H1 and H2, we analyze the risk attitudes of regret-averse subjects. Differences between proportions were tested via binomial and multinomial methods, and the significance of differences was tested parametrically.

Analysis for section I

We classified subjects based on their regret attitudes. Removing the dominance and consistency checks left 22 questions, of which 16 allowed us to classify subjects according to their regret attitudes. For each of those 16 questions, a subject could choose the RA or the RS prospect or could express indifference. A subject who expressed indifference for the majority of questions was classified as regret neutral; one who chose the RA (resp., RS) prospect for the majority of questions was classified as regret averse (resp., regret seeking). All subjects with no majority choice were classified as "mixed". As mentioned previously, in half of the 16 questions the RA prospect's EV was lower than that of the RS prospect. The reason for including such questions is to control for the curvature of utility function at individual level.[6]

The remaining six questions in section I allowed us to estimate parametrically the regret function Q under conditions F and N at the aggregate level and test if Q_F is

[6]A subject with a concave or convex utility function might prefer the RA prospect despite not being regret averse. For instance, consider a choice between prospects $a = (E_1, 20;\ E_2, 70;\ E_3, 30)$ and $b = (E_1, 45;\ E_2, 25;\ E_3, 50)$ when all three events are equally likely. Prospect a is a RA prospect because if Q is convex and u is linear then $Q(45) > Q(25) + Q(20)$, in which case $a \succeq b$. If instead u is convex and Q is linear, we still have still $a \succeq b$. Similar cases occur also when u is concave and Q is linear. To avoid classifying such subjects as regret averse, we included eight questions in which the RA prospect's EV was *lower* than that of the RS prospect.

convex than Q_N (the assumption that underlie our hypotheses). We assume a linear utility function and a power function specification for the regret function: $Q(\alpha) = \alpha^\theta$ if $\alpha \geq 0$ and $Q(\alpha) = -|\alpha|^\theta$ if $\alpha < 0$. The six questions were chosen such that it covered the range of θ values $[0.8, 2.4]$ observed in Bleichrodt et al. (2010) and Baillon et al. (2015). The aggregate θ estimated under conditions F and N allowed to compute the resolution and regret premiums via (respectively) Eq. (4.1) and (4.2).

Analysis for section II

Following the classification derived in section I, we restricted our focus to regret-averse subjects. So in the results and analysis for section II of the experiment, the term "subjects" refers to regret-averse subjects. After removal of the dominance and consistency checks there remained 23 questions, of which 16 were a choice between a risky prospect and a sure outcome. These 16 questions allowed us to classify subjects based on their risk attitudes. Just as with regret attitudes in Section I, a subject who expressed indifference for the majority of questions was classified as risk neutral; one who chose the safe (resp., risky) prospect for majority of questions was classified as risk averse (resp., risk seeking). As before, subjects with no majority choice were classified as "mixed". Because the 16 questions asked subjects to choose between a risky prospect and a sure outcome, the certainty effect (Kahneman and Tversky 1979, Cohen and Jaffray 1988) could affect their choices. To control for this effect, the remaining 7 questions in section II were a choice between two risky prospects: a "low probability of a large outcome" prospect and a "high probability of a small outcome" prospect of the same expected value. These 7 questions allowed us to test H1 while controlling for the certainty effect. For each question, a subject could choose one of the risky prospects or express indifference. Note that the prospects we included in Section II, had probability of positive outcomes in the range $(0 - 0.3]$ or $[0.7, 1)$. We did not include the intermediate range of probabilities to control for utility curvature (see discussion after Proposition 1 for details).

We divide the rest of our analysis of section II into three levels: subject, question, and aggregate. Hypotheses H1 and H2 were tested at all three levels. For the first two levels, we classified (respectively) subjects' choices and the questions themselves as being either "consistent with H1", "inconsistent with H1", or "unclassified." In aggregate level, we consider all choices made by all subjects and check their consistency with H1. [7]

5.2 Results

Of the 54 subjects in condition F, three violated the dominance check; in condition N there was no dominance violation. We performed the analysis both with and without those subjects and, since no significant differences were found, we include all the subjects in the following analysis.

5.2.1 Section I

Table 3 shows, for each condition, the number (and percentage) of subjects classified in terms of their regret attitudes.

	Condition F	Condition N
Regret averse	36 (67%)	49 (92%)
Regret seeking	14 (26%)	3 (6%)
Regret neutral	3 (6%)	—
Mixed	1 (2%)	1 (2%)

Table 3: Classification of experimental subjects based on regret attitudes

In both conditions, the majority of the subjects were regret averse: 67% in condition F and 92% in condition N. The proportion of regret-averse subjects was greater than the proportion of mixed subjects ($p < 0.001$) and regret-seeking subjects ($p < 0.001$) in both conditions, which indicates that—as one would expect—regret aversion is the dominant phenomenon. We also measured the proportion of regret-averse choices made by subjects: 67.5% in condition F and 82.8% in condition N. The difference is significant ($p < 0.001$), so section I of the experiment offers solid evidence that feedback reduces regret aversion.

[7] If more than 50% of choices are consistent with H1, we classify the subject and question as "consistent with H1." In case of indifference, we choose one of the options with equal probability.

Estimation of regret and resolution premium: The role of feedback

Six questions in section I allowed for estimating the regret function Q under conditions F and N. In Table 4 we list the aggregate-level choices of subjects under both conditions for the six questions, where MRA denotes the more regret-averse prospect (on the left) and LRA the less regret-averse prospect (on the right). For each question, the exponent θ that renders a decision maker indifferent between the MRA and LRA prospects is reported in the second column. The percentage of subjects choosing MRA and LRA under each condition is reported in the last four columns of the table.

Questions (MRA vs. LRA)	Indifference θ	Condition F		Condition N	
		% MRA	% LRA	% MRA	% LRA
$(22, 96, 43)$ vs. $(67, 1, 78)$	0.8	78	17	96	4
$(99, 23, 35)$ vs. $(9, 73, 75)$	1	56	37	67	25
$(27, 32, 83)$ vs. $(69, 78, 8)$	1.3	**56**	**39**	75	25
$(89, 32, 18)$ vs. $(9, 71, 73)$	1.6	**37**	**52**	**48**	**40**
$(25, 93, 22)$ vs. $(69, 18, 73)$	1.95	33	50	**27**	**58**
$(35, 32, 73)$ vs. $(79, 75, 15)$	2.41	13	78	25	73

Table 4: Estimating θ at the aggregate level—**all experimental subjects**
Notes: MRA = more regret-averse prospect; LRA = less regret-averse prospect. Boldface values indicate the switching point.

Table 4 shows that, at the aggregate level, the majority choice shifts from MRA to LRA for a value of θ between 1.3 and 1.6 under feedback and between 1.6 and 1.95 under no feedback. We use this information to derive an aggregate θ value of 1.45 (i.e., the midpoint between 1.3 and 1.6) under condition F; under condition N, we derive $\theta = 1.78$ (midpoint between 1.6 and 1.95). Hence the corresponding Q-functions under condition F and condition N are $Q_F(\alpha) = \alpha^{1.45}$ and $Q_N(\alpha) = \alpha^{1.78}$, respectively. We observe that the Q-function under feedback (Q_F) is *less* convex than the Q-function under no feedback (Q_N); overall, then, immediate feedback *reduces* subjects' level of regret aversion. The estimated Q-function under condition N, $Q_N(\alpha) = \alpha^{1.78}$, is consistent with Bleichrodt et al. (2010).

Next we shall estimate the Q-function of regret-averse subjects only. Table 5 lists the proportion of these subjects choosing MRA and LRA under conditions F and N. We observe that the majority choice shifts from MRA to LRA for θ between 1.95 and 2.41 under feedback and between 1.6 and 1.95 under no feedback. Given this majority choice, we derive the Q-functions under conditions F and N as $Q_F(\alpha) = \alpha^{2.16}$ and $Q_N(\alpha) = \alpha^{1.78}$, respectively. For these regret-averse subjects we observe that the Q-function under feedback (Q_F) is *more* convex than the Q-function under no feedback (Q_N); hence immediate feedback *increases* the regret aversion of subjects who are already regret averse.

Questions (MRA vs. LRA)	Indifference θ	Condition F		Condition N	
		% MRA	% LRA	% MRA	% LRA
$(22, 96, 43)$ vs. $(67, 1, 78)$	0.8	89	8	98	2
$(99, 23, 35)$ vs. $(9, 73, 75)$	1	75	19	72	21
$(27, 32, 83)$ vs. $(69, 78, 8)$	1.3	69	25	77	23
$(89, 32, 18)$ vs. $(9, 71, 73)$	1.6	56	33	**56**	**33**
$(25, 93, 22)$ vs. $(69, 18, 73)$	1.95	**44**	**39**	**28**	**58**
$(35, 32, 73)$ vs. $(79, 75, 15)$	2.41	**19**	**72**	26	74

Table 5: Estimating θ at the aggregate level—**regret-averse subjects** only
Note: See Notes to Table 3.

From the results reported in Tables 3 and 4, we inferred that immediate feedback leads to less regret aversion (i.e., a less convex Q-function). For regret-averse subjects, however, the regret function is more convex under feedback than under no feedback (see Table 5). We also estimated Q-functions for regret-*seeking* subjects, which were the same in condition N as in condition F.[8] Thus feedback increases the number of regret-seeking subjects and thereby reduces the subject pool's overall regret aversion. At the same time, feedback increases the regret aversion of regret-averse subjects. In short, feedback polarizes regret attitudes: subjects who are regret averse or regret seeking become even more so when feedback is given.

In the analysis that follows, we once again focus solely on regret-averse subjects. Our previous estimates of the exponent θ for regret-averse subjects enables measurement of

[8]The estimated regret functions of regret-seeking subjects are identical under conditions F and N: $Q_F(\alpha) = Q_N(\alpha) = \alpha^{0.9}$. However, feedback increases the number of regret-seeking subjects. In particular, the number (14) of regret-seeking subjects in condition F is significantly larger than the number (3) of regret-seeking subjects in condition N. Feedback therefore decreases the entire subject pool's regret aversion. The extremely few regret-seeking subjects under condition N precludes any meaningful comparison with their counterparts under condition F.

the two components of risk premium under regret theory. As a concrete example, in Table 5 we report the resolution and regret premiums of the prospect $(p_j\,, 50;\, 1 - p_j\,, 0)$ computed for different probabilities p_j using Eqs. (4.1) and (4.2), respectively.

Probability	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Resolution premium	–2	–1.51	–0.99	–0.49	0	0.49	0.99	1.51	2
Regret premium	–6.27	–5.72	–4.15	–2.16	0	2.16	4.15	5.72	6.27
Expected value	5	10	15	20	25	30	35	40	45
CE (condition N)	11.27	15.72	19.16	22.16	25	27.83	30.84	34.27	37.83
CE (condition F)	13.27	17.23	20.15	22.65	25	27.34	29.85	32.76	35.83
Total risk premium	–8.27	–7.23	–4.16	–2.65	0	2.65	4.16	7.23	8.27

Table 6: Resolution premium and regret premium under conditions F and N

In Figure 2 we plot the estimated certainty equivalent under condition F and condition N. H1 states that—under both conditions—a decision maker is risk seeking for low probabilities of gains ($p < 0.5$) and risk averse for high probabilities ($p > 0.5$). Since immediate feedback increases the regret aversion of a regret-averse DM (makes his Q-function more convex), it follows that the DM should be more risk seeking (resp., risk averse) for low (resp., high) probabilities in condition F than in condition N; this is hypothesis H2. Thus, our results from section I validate the assumptions about regret attitudes that underlie our hypotheses. We next discuss the validity of H1 and H2 in section II of the experiment.

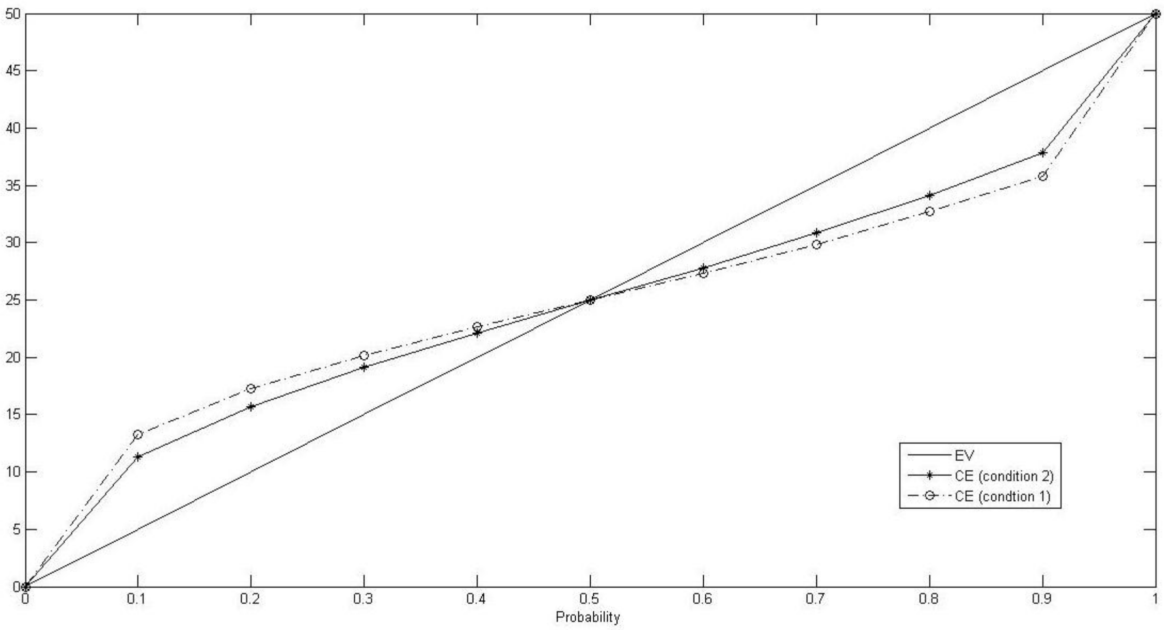

Figure 2: Certainty equivalent under conditions F and N for the estimated value of θ

5.2.2 Section II

We now present results concerning the risk attitudes of regret-averse subjects. There were 36 (67%) such subjects in condition F and 49 (92%) in condition N. The classification of regret averse subjects based on risk attitude is described in the Appendix F. Predominantly, regret averse subjects were risk averse in both the conditions. We now test the risk attitudes of regret averse subjects (hypotheses H1 and H2) at the subject level, the question level, and the aggregate level.

Subject-level results

We employed two sets of questions for the measurement of risk attitude. In questions from the first set we provided each subject the choice between a risky prospect and its expected value. For this first set of questions, Table 7 reports the number (and percentage) of subjects who are—with respect to H1—consistent, inconsistent, and unclassified. The proportion of subjects consistent with H1 was 56% in condition F and 63% in condition N, but that difference is not significant. We observe that, in both conditions, a higher percentage of subjects are consistent than inconsistent with H1. However, this difference is not significant either in condition F ($p = 0.24$) or in condition N ($p = 0.06$).

	Condition F	Condition N
Consistent with H1	20 (56%)	31 (63%)
Inconsistent with H1	13 (36%)	18 (37%)
Unclassified	3 (8%)	0 (0%)

Table 7: Classification of subjects based on consistency with H1—**first set** of questions

In questions from the second set we provided subjects with a choice between two risky prospects: a "low probability of a large outcome" prospect and a "high probability of a small outcome" prospect of the same expected value. According to H1, a regret-averse subject should prefer the "low probability of a large outcome" prospect. For this second set of questions, Table 8 reports the number of subjects who are consistent or inconsistent with H1 (or unclassified). The proportion of subjects whose choices were consistent with H1 was only 22% in condition F and 12.2% in condition N—significantly smaller, in both conditions, than those of the subjects who are *inconsistent* with H1. Clearly, then, participant responses to the second set of questions run counter to that hypothesis.

	Condition F	Condition N
Consistent with H1	8 (22%)	6 (12.2%)
Inconsistent with H1	27 (75%)	41 (83.6%)
Unclassified	1 (3%)	2 (4%)

Table 8: Classification of subjects based on consistency with H1—**second set** of questions

Question-level results

As just discussed, we used two sets of questions to measure risk attitudes. Table 9 lists the proportion of subjects choosing between a risky prospect and its expected value. For each of the 16 questions, Table 9 gives the choice predicted by H1, the majority choice, and the proportion of subjects choosing the prospect that is consistent with H1. Table 10 summarizes results concerning the number of questions for which the majority of subject responses is consistent with H1. For 10 out of 16 questions the majority choice was consistent with H1 in condition N; in condition F, the majority choice was consistent with H1 for 11 out of 16 questions. The other questions were all inconsistent with H1.

		Condition F		Condition N	
Question choices	Prediction of H1	Proportion choosing		Proportion choosing	
		Prospect A	Prospect B	Prospect A	Prospect B
$(0.8, 40; 0)$ vs. 32	B	31%	**67%****	14%	**84%****
$(0.95, 50;0)$ vs. 47.5	B	42%	**56%**	27%	**69%****
$(0.05, 50;0)$ vs. 2.5	A	**53%**	42%	37%	57%
$(0.3, 40; 0)$ vs. 12	A	19%	78%**	6%	88%**
$(0.1, 40; 0)$ vs. 4	A	47%	53%	24%	67%**
$(0.7, 50; 0)$ vs. 35	B	36%	**58%**	14%	**84%****
$(0.15, 40; 0)$ vs. 6	A	22%	72%**	22%	68%**
$(0.75, 40; 0)$ vs. 30	B	14%	**81%****	8%	**92%****
$(0.2, 50; 0)$ vs. 10	A	19%	75%**	14%	78%**
$(0.85, 50; 0)$ vs. 42.5	B	28%	**72%****	16%	**82%****
$(0.9, 40; 0)$ vs. 36	B	36%	**64%***	14%	**84%****
$(0.25, 50; 0)$ vs. 12.5	A	19%	78%**	18%	78%**
$(0.9, 5; 0)$ vs. 4.5	B	13%	**87%****	11%	**86%****
$(0.05, 8; 0)$ vs. 0.4	A	**61%****	29%	**69%****	14%
$(0.1, 5; 0)$ vs. 0.5	A	**65%****	29%	**75%****	14%
$(0.95, 8; 0)$ vs. 7.6	B	26%	**74%****	14%	**81%****

Table 9: Percentage of subjects making choices that are consistent vs. inconsistent with H1—risky prospects vs. their expected values

Notes: Payoffs for responses to questions (i.e., subjects' choices) are denominated in euros (€). Boldface indicates that the majority of responses to that question were consistent with H1.

*significant at $\alpha = 10\%$, **significant at $\alpha = 5\%$, ***significant at $\alpha = 1\%$

	Condition F	Condition N
Consistent with H1	11	10
Inconsistent with H1	5	6
Unclassified	0	0

Table 10: Classification of questions based on majority choices with respect to H1

For each question, we tested whether the proportion of choices consistent with H1 is different from the proportion of choices inconsistent with H1; Table 11 presents the results. At the 95% confidence level, under condition F we found that 7 questions were consistent with H1, 4 were inconsistent with H1, and the other 5 questions were unclassified; under condition N, 10 (resp. 5) questions were consistent (resp. inconsistent) with H1 and the remaining question was unclassified. So overall, subject responses to the first set of questions support H1 under condition N and—even more strongly—under condition F.

	Condition F		Condition N	
	$\alpha = 0.05$	$\alpha = 0.1$	$\alpha = 0.05$	$\alpha = 0.1$
Consistent with H1	7	8	10	10
Inconsistent with H1	4	4	5	5
Unclassified	5	4	1	1

Table 11: Classification of questions based on consistency with H1 and significance of proportions

We also tested hypothesis H1 using the second set of questions, which asked subjects to choose between two risky prospects: a "low probability of a large outcome" prospect and a "high probability of a small outcome prospect" of the same expected value. To be consistent with H1, subjects should prefer the "low probability of a large outcome" prospect. Table 12 lists the prospects and the proportion of subjects choosing each. Except for one question in condition 1, we find no support for H1 in the responses to these questions.[9]

[9]If the certainty effect influenced our result, then the subjects would have been more consistent with respect to H1 for the *second* set of questions (since both prospects are risky). However, our evidence points in the opposite direction.

Question choices	H1 prediction	Condition F		Condition N	
		Proportion choosing		Proportion choosing	
		Prospect A	Prospect B	Prospect A	Prospect B
$(0.3, 40; 0)$ vs. $(0.8, 15; 0)$	A	17%	72%**	8%	80%**
$(0.1, 45; 0)$ vs. $(0.9, 5; 0)$	A	42%	56%	18%	73%**
$(0.1, 40; 0)$ vs. $(0.8, 5; 0)$	A	33%	58%	20%	63%**
$(0.05, 50; 0)$ vs. $(0.85, 3; 0)$	A	**50%**	42%	33%	55%
$(0.15, 50; 0)$ vs. $(0.75, 10; 0)$	A	22%	78%**	10%	80%**
$(0.2, 40; 0)$ vs. $(0.8, 10; 0)$	A	14%	78%**	10%	78%**
$(0.25, 40; 0)$ vs. $(0.8, 12.5; 0)$	A	22%	69%**	14%	73%**

Table 12: Percentage of subjects making choices that are consistent vs. inconsistent with H1—two risky prospects (less probable high payoff vs. more probable low payoff)
Note: See Notes to Table 9.

Much as with the subject-level results, we observe that majority choices for most of the questions are consistent with H1 when subjects are asked to choose between a risky prospect and its expected value. However, if subjects are asked to choose between two risky projects—one offering a less probable high payoff and the other a more probable low payoff—then participant choices are inconsistent with H1. We conclude that there is no evidence in favor of H1 at the question level of analysis.

Aggregate-level results

Table 13 shows that the majority of choices were consistent with H1—both in condition F (53.4%) and in condition N (56.5%). We found that in both conditions the subjects were risk averse for both low and high probabilities of gains. We conclude that, although more than 50% of the choices were consistent with H1, we do not find evidence of risk seeking for small probabilities.

Questions	Choices consistent with H1	Risk attitude
Condition F		
$p < 1/2$	104 out of 278 (37.4%***)	Risk aversion
$p > 1/2$	193 out of 278 (69.4%***)	Risk aversion
Total	297 out of 556 (53.4%*)	Consistent with H1
Condition N		
$p < 1/2$	112 out of 366 (30.6%***)	Risk aversion
$p > 1/2$	302 out of 366 (82.5%***)	Risk aversion
Total	414 out of 732 (56.5%***)	Consistent with H1

Table 13: Choices consistent with H1 at the aggregate level
*significant at $\alpha = 10\%$, ***significant at $\alpha = 1\%$

We also tested H1 by comparing the proportion of subjects choosing the "low probability of a large outcome" prospect over the "high probability of a small outcome" prospect. Table 14 reveals that the choices of most subjects were inconsistent with H1. Thus we find no evidence in favor of H1 at the aggregate level, either.

Conditions	Consistent with H1	Inconsistent with H1
Condition F	26%	66%***
Condition N	16%	71%***

Table 14: Aggregate-level choices between less probable high payoffs and more probable low payoffs
***significant at $\alpha = 1\%$

To validate H2, we compared the proportion of choices consistent with H1 in condition F versus condition N. Table 15 presents the results, which indicate that—in line with our prediction—regret-averse subjects are more risk seeking for *low* probabilities under feedback. Yet for high probabilities also we find that, contrary to our prediction, increased risk seeking under feedback. When all questions are considered, the evidence in favor of H2 is neither significant nor persuasive. The subjects become uniformly more risk seeking under Feedback than under No feedback.

	Proportion consistent with H1			
Choice	Condition F	Condition N	Difference	Effect of feedback
$p < 1/2$	37.4%	30.6%	6.8%*	Increased risk seeking
$p > 1/2$	69.4%	82.5%	−13.1%**	Reduced risk aversion
Total	53.4%	56.5%	−3.1%	Reduced consistency with H1

Table 15: Effect of feedback (resolution premium) at the aggregate level and across all choices—regret-averse subjects
*significant at $\alpha = 10\%$, **significant at $\alpha = 5\%$

The analysis of Section II focuses only on risk attitudes of regret averse subjects. However, to fully understand the effect of feedback on risk attitudes, we consider the entire sample that includes regret neutral and regret seeking subjects. Appendix E reports the full analysis. In sum, under condition N, given that regret averse subjects form 92% of the sample, the results described for regret averse subjects (in Table 15 and 16) and the entire subject pool are identical. Under condition F, as 33% of the subjects are regret seeking or neutral, the risk attitudes of "regret averse" subjects and the "entire sample" differ. The comparison of Table 15 with Table 20 shows that the "entire sample" and "regret averse" subjects are globally risk averse and feedback increases risk seeking for low and high probabilities. However, under feedback, the "entire sample" is more risk seeking for probabilities $p > 0.5$ than "regret averse" subjects. To further explore, we looked at the risk attitudes of subjects who are *non regret averse* (see Table 22 and 23 in Appendix E): Under condition F the non regret averse subjects are risk averse for low probabilities ($p < 0.5$) and risk seeking for high probabilities ($p > 0.5$). This behavior of non regret averse subjects is consistent with regret theory's prediction under concave Q.

We also conducted an extensive online pilot study (on the Socialsci platform). The 121 subjects (64 female, mean age = 31.6) were Americans representing all income levels. Results of the lab experiment reported in this paper replicated, by and large, those of the pilot. In both studies: (i) regret aversion was the dominant phenomenon under both conditions; (ii) there was support for H1 at the subject, question, and aggregate level for the first set of questions under both conditions; and (iii) feedback increased the risk-seeking attitudes of regret-averse subjects for both small and large probabilities. In the pilot we were able to check the robustness of results to payoff levels lower than those used in section II of this experiment. The detailed pilot results are available upon request.

6 Discussion and conclusions

The paper presents an analysis of risk attitudes under regret theory. We derive analytical expressions for the risk premium's two components under that theory: the resolution premium and the regret premium. We also empirically estimate those two components and characterize the risk attitude of a regret-averse decision maker. That characterization yields two predictions that we test in an experiment. We find that regret aversion is a robust phenomenon. The estimates for the parameter of the regret function Q were also in accordance with findings reported in Bleichrodt et al. (2010). Our consistent results across two experiments (lab study and online pilot) for a total of 228 subjects, lend credence to regret theory and to our experimental methodology.

We find mixed support for the risk attitudes predicted by regret theory. We observe that our results are consistent with H1 when the choice is between a prospect and a sure outcome. However, we do not find support for H1 when subjects must choose between two prospects of the same expected value (a "low probability of a large outcome" prospect and a "high probability of a small outcome" prospect). Because responses to the second set of questions could not be confounded by a certainty effect (since there was no sure outcome), we expected them to offer more support for H1. However, we found almost no support for H1 in the second set of questions under either condition: irrespective of feedback, subjects preferred (to a significant degree) a more probable low payoff over a less probable high payoff. The support for H1 in the first set of questions and the absence of that support in the second set is surprising, and it suggests that a different mechanism could be operating in responses to the two sets of questions. For example, subjects could have attended more to probabilities in the second than in the first set of questions; that emphasis could have triggered a comparison (regret versus rejoice) on the probability scale rather than on the outcome scale, resulting in choices that are inconsistent with H1.

The role of probability attention and probability transformation has been extensively studied in decision theory. Since regret theory captures comparisons only on the outcome scale and ignores comparisons on the probability scale, it may not always predict risk attitudes accurately. The above argument is also supported by the data: In Appendix G, we compare the predictions of regret theory with another popular alternative to expected utility that transforms probabilities i.e, prospect theory. We find that, for intermediate probabilities $p \in (0.1, 0.5]$, prospect theory with an inverse-S probability weighting fits the data better than regret theory. Therefore, further development and investigation is needed of models that can capture anticipated regret on both probability and outcome scales; one example is the perceived relative argument model, or PRAM (Loomes 2010).

The other explanation for the lack of support for regret theory's risk attitude predictions is that we used three-outcome prospects to identify regret averse DMs (section I), but two-outcome prospects to test their risk attitudes (section II). Theoretically this should not matter, but decreasing the number of outcomes changes the state space and could have made outcome comparisons difficult (Baillon et al. 2015 also face a similar issue). Additionally, in section II stimuli (for both set of questions), we were not able to make outcome comparisons distinct. For example to trigger outcome comparisons in the first set of questions, we were not able to split the single outcome of the safe prospect into two separate outcomes coinciding with the risky prospect's state space — as event splitting effect (Starmer and Sugden 1993) could affect the results.

Our experiment also provides new insights regarding the effect of feedback on regret and risk attitudes. It is assumed in most of the psychology literature (Josephs et al. 1992, Larrick 1993, Larrick and Boles 1995, Ritov and Baron 1995, Ritov 1996, Zeelenberg et al. 1996) that people are generally regret averse and that feedback about foregone options increases regret aversion. In contrast, our results indicate that a significant number of subjects were actually regret seeking when there is feedback about payoffs. We observe that, although immediate feedback *reduces* the regret aversion of entire subject pool, it increases the regret aversion of regret-averse subjects,[10] thus validating the assumptions

[10] When subjects whose responses in section II were inconsistent with regret theory are removed and

that underlie our hypothesis H2. Our results also emphasize that the effect of feedback on anticipated regret is less straightforward than its treatment in the psychology literature suggests. Because our study does not employ a within-subject design, we cannot ascertain precisely how feedback influences subjects exhibiting various degrees of regret aversion. Nonetheless, the results presented here provide the first evidence that feedback may affect subjects differently depending on their prior attitude towards regret. Future research should provide more insights on how prior regret attitude moderates the effect of feedback on regret attitudes.

We were also able to measure the effect of feedback for the first time in the literature: We empirically estimated the resolution premium and thereby quantified the psychological pain (and pleasure) of immediate feedback. In other words, we were able to estimate precisely how much more a decision maker would pay for a risky prospect when she expects to receive immediate feedback. This estimation has the potential to allow deployment of regret theory for applications in public policy, marketing, and investment. For example, the resolution premium accounts for why a regret-averse investor prefers betting on the underdog in a sport competition (i.e., feedback) to investing in a start-up venture of equal worth (delayed or no feedback).

The results reported in this paper also help us understand the effect of feedback on the risk attitudes of regret-averse DMs. Regret theory predicts that if feedback increases an individual's regret aversion then it should reinforce his risk attitude (H2). Although the regret aversion of regret-averse subjects did increase under feedback in our experiment, we do not find statistical support for H2. In our experiment (and also in the pilot study), regret-averse subjects are significantly more risk-seeking for both low and high probabilities of gains. However, interestingly we find that non regret averse subjects behave consistently with regret theory under feedback. Thus it seems that anticipated regret could be one of the many mechanisms that moderates the effect of feedback on risk attitudes. The literature on decision from experience (Barron and Erev 2003, Hertwig et al. 2004, Erev et al. 2015) provides additional evidence concerning the effect of feed-

the Q-function is then recomputed, we still find that feedback polarizes regret attitudes.

back on attitudes toward risk. In a recent paper, consistent with our results, Erev et al. (2015) find that feedback instigates regret minimizing choices, but increases risk seeking for gains. They suggest different mechanisms (like the change in shape of probability weighting function, reliance on a small sample) that could mediate the effect of feedback on risk attitudes. Future research should compare such alternatives with the mechanism (explored in this paper) of anticipated regret. Doing so would increase still further our knowledge about the role of immediate feedback in affecting risk attitudes.

By modeling the risk attitudes under regret theory and measuring resolution and regret premium empirically, we show that regret theory is a simple yet powerful framework to describe the pervasive emotion of regret and the risk attitudes associated. However our experimental results suggest that regret theory provides a partial account of risk attitudes as it captures the regret-rejoice trade-offs on the outcome scale only. As a consequence, decision analysts can effectively use regret theory to understand the effects of anticipated regret and feedback on the outcome scale. Decision theorists should target their efforts in developing new models to capture the regret-rejoice trade-offs also on the probability scale.

Appendices

Appendix A

Resolution premium – derivation

Consider prospects of the form $x = (p\,, x_k;\, 1-p : x_0)$ for $p \in (0,1)$ and such that $x_k \geq x_0 \geq 0$. We indicate the certainty equivalents of prospect x under conditions F and N by CE_{RT_F} and CE_{RT_N}, respectively; thus the resolution premium is the difference between CE_{RT_F} and CE_{RT_N}. Under condition F, we have $y_1 \sim (p\,, x_k;\, 1-p\,, x_0)$.

According to regret theory,

$$pQ_F(u(x_k) - u(CE_{RT_F})) + (1-p)Q_F(u(x_0) - u(CE_{RT_F})) = 0.$$

We scale the lowest outcome x_0 such that $u(x_0) = 0$; this yields

$$pQ_F(u(x_k) - u(CE_{RT_F})) + (1-p)Q_F(-u(CE_{RT_F})) = 0,$$

$$\frac{p}{1-p} = \frac{Q_F(u(CE_{RT_F}))}{Q_F(u(x_k) - u(CE_{RT_F}))}.$$

Assuming a power function specification for Q_F, we obtain

$$\frac{p}{1-p} = Q_F\left(\frac{u(CE_{RT_F})}{u(x_k) - u(CE_{RT_F})}\right).$$

Since $\frac{p}{1-p}$ is increasing, it follows that

$$Q_F^{-1}\left(\frac{p}{1-p}\right) = \frac{u(CE_{RT_F})}{u(x_k) - u(CE_{RT_F})},$$

$$u(CE_{RT_F}) = u(x_k)\frac{Q_F^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_F^{-1}\left(\frac{p}{1-p}\right)},$$

$$CE_{RT_F} = u^{-1}\left(u(x_k)\frac{Q_F^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_F^{-1}\left(\frac{p}{1-p}\right)}\right). \tag{6.1}$$

Similarly, the value of CE_{RT_N} is elicited as $CE_{RT_N} = u^{-1}\left(u(x_k)\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1+Q_N^{-1}\left(\frac{p}{1-p}\right)}\right)$. Hence the resolution premium of prospect x may be written as

$$\mathrm{ResP}(x) = CE_{RT_F} - CE_{RT_N} = u^{-1}\left(u(x_k)\left(\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_N^{-1}\left(\frac{p}{1-p}\right)}\right)\right) - u^{-1}\left(u(x_k)\left(\frac{Q_F^{-1}\left(\frac{p}{1-p}\right)}{1 + Q_F^{-1}\left(\frac{p}{1-p}\right)}\right)\right). \tag{6.2}$$

Appendix B

Proof of Proposition 1

We prove Proposition 1 by using Eqs. (4.1) and (4.2) to analyze the risk premium (ResP+RegP) for three possible cases.

Case 1: Probability $p = 1/2$. Substituting $p = 0.5$ in Eq. (4.1) and Eq. (4.2) yields $\mathrm{ResP}(x) = \mathrm{RegP}(x) = 0$ because $Q_F(1) = Q_{N^-}(1) = 1$. Hence the risk premium is equal to zero. Therefore, when utility u is linear, a regret-averse decision maker (convex Q) is risk neutral toward prospect x when the probability of positive outcome $p = 1/2$.

Case 2: Probability $p \in (0, 1/2)$.

(a) First we analyze the resolution premium (ResP). Since Q_N is less convex than Q_F, it follows that $Q_F^{-1}\left(\frac{p}{1-p}\right) > Q_N^{-1}\left(\frac{p}{1-p}\right)$. Then $\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1+Q_N^{-1}\left(\frac{p}{1-p}\right)} < \frac{Q_F^{-1}\left(\frac{p}{1-p}\right)}{1+Q_F^{-1}\left(\frac{p}{1-p}\right)}$ and so, by Eq. (4.1) and since $x_k \geq x_0$, we have $\mathrm{ResP}(x) < 0$.

(b) In order to analyze the regret premium (RegP), in Eq. (4.2) we put $p = 0.5 - l$; then for $l \in (0, 1/2)$ we obtain $\mathrm{RegP}(x) = x_k\left(0.5 - l - \left(\frac{Q_N^{-1}\left(\frac{0.5-l}{0.5+l}\right)}{1+Q_N^{-1}\left(\frac{0.5-l}{0.5+l}\right)}\right)\right)$. The fraction $\frac{Q_N^{-1}\left(\frac{0.5-l}{0.5+l}\right)}{1+Q_N^{-1}\left(\frac{0.5-l}{0.5+l}\right)}$ is increasing in the concavity of Q_N^{-1} (i.e., of $1/Q_2$) and in the convexity of Q_N; hence its lowest value occurs when Q_N is linear. Thus $\mathrm{RegP}(x) = 0$ for linear Q_N, so for convex Q_N we must have $\mathrm{RegP}(x) < 0$.

Since $\mathrm{ResP}(x) < 0$ and $\mathrm{RegP}(x) < 0$—as just established in (a) and (b), respectively—it follows that the risk premium is $\mathrm{ResP}(x) + \mathrm{RegP}(x) < 0$. Therefore, a regret-averse DM (convex Q) is risk seeking for probabilities $p \in (0, 1/2)$.

Case 3 : Probability $p \in (1/2, 1)$.

(a) For $p > 0.5$ we have $\dfrac{p}{1-p} > 0$; therefore, since Q_N is less convex than Q_F, we must have $Q_F^{-1}\left(\frac{p}{1-p}\right) < Q_N^{-1}\left(\frac{p}{1-p}\right)$. Hence $\frac{Q_N^{-1}\left(\frac{p}{1-p}\right)}{1+Q_N^{-1}\left(\frac{p}{1-p}\right)} > \frac{Q_F^{-1}\left(\frac{p}{1-p}\right)}{1+Q_F^{-1}\left(\frac{p}{1-p}\right)}$ and so, again by Eq. (4.1) and because $x_k \geq x_0$, in this case $\mathrm{ResP}(x) > 0$.

(b) To analyze RegP, in Eq. (4.2) we put $p = 0.5 + l$; then for $l \in (0, 1/2)$ we obtain $\mathrm{RegP(x)} = x_k\left(0.5 + l - \left(\frac{Q_N^{-1}\left(\frac{0.5+l}{0.5-l}\right)}{1+Q_N^{-1}\left(\frac{0.5+l}{0.5-l}\right)}\right)\right)$. The fraction $\frac{Q_N^{-1}\left(\frac{0.5+l}{0.5-l}\right)}{1+Q_N^{-1}\left(\frac{0.5+l}{0.5-l}\right)}$ decreases as the concavity of Q_N^{-1} increases and also as the convexity of Q_N increases. As before, then, it follows that this fraction's highest value occurs when Q_N is linear. For linear Q_N we have $\mathrm{RegP}(x)$=0 and so $\mathrm{RegP}(x) > 0$ for convex Q_N.

So given that (a) $\mathrm{ResP}(x) > 0$ and (b) $\mathrm{RegP}(x) > 0$, the risk premium must be $\mathrm{ResP}(x) + \mathrm{RegP}(x) > 0$. As a consequence, a regret-averse DM (convex Q) is risk averse for probabilities $p \in (1/2, 1)$.

Note that the above proof, based on regret and resolution premium assumes a power parametric specification for the Q function, that is $Q(\alpha) = \alpha^{\theta}$. However, a power parametric specification is not necessary for the Proposition 1 to hold. We show below that the Proposition 1 is much more general, and holds irrespective of parametric specification for the Q function. Consider the prospect $x = (p : x_k; (1-p) : x_0)$, the expected value of the prospect x is $px_k + (1-p)x_0$. To prove Proposition 1, first we analyze risk attitudes under no feedback.

The regret averse DM chooses prospect x over its expected value when,

$$pQ_N(u(x_k) - u(px_k + (1-p)x_0)) + (1-p)Q_N(u(x_0) - u(px_k + (1-p)x_0)) > 0. \quad (6.3)$$

Assuming u is linear, the expression becomes $pQ_N((1-p)(x_k - x_0)) - (1-p)Q_N(p(x_k - x_0))$. We now analyze the sign of the expression for different probabilities.

When $p = 0.5$, then $pQ_N((1-p)(x_k - x_0)) - (1-p)Q_N(p(x_k - x_0)) = 0$. Therefore prospect x is indifferent to the expected value of x (DM is risk neutral). When $p < 0.5$, as

Q_N is convex, we get $Q_N(p(1-p)(x_k-x_0)) < (1-p)Q_N(p(x_k-x_0)) < pQ_N((1-p)(x_k-x_0))$. Therefore, $pQ_N((1-p)(x_k-x_0)) - (1-p)Q_N(p(x_k-x_0)) > 0$, which implies that the prospect x is preferred to the expected value of x (DM is risk seeking). When $p > 0.5$, as Q_N is convex, we get $Q_N(p(1-p)(x_k-x_0)) < pQ_N((1-p)(x_k-x_0)) < (1-p)Q_N(p(x_k-x_0))$. Therefore, $pQ_N((1-p)(x_k-x_0)) - (1-p)Q_N(p(x_k-x_0)) < 0$, which implies that the expected value of prospect x is preferred to prospect x (DM is risk averse). Thus, we have shown that Proposition 1 holds under no feedback.

Now we analyze the choice of a regret averse DM under feedback. Under feedback, a regret averse DM chooses prospect x over its expected value when,

$$pQ_F((1-p)(x_k-x_0)) - (1-p)Q_F(p(x_k-x_0)) > 0.$$

Comparing the preference of a regret averse DM under Feedback and No feedback, we get

$$pQ_F((1-p)(x_k-x_0)) - (1-p)Q_F(p(x_k-x_0)) - (pQ_N((1-p)(x_k-x_0)) - (1-p)Q_N(p(x_k-x_0))).$$

Rewriting the above expression, we get

$$p(Q_F((1-p)(x_k-x_0)) - Q_N((1-p)(x_k-x_0))) - (1-p)(Q_F(p(x_k-x_0)) - Q_N(p(x_k-x_0))). \tag{6.4}$$

Now, when $p = 0.5$, the expression in Eq. (6.4) is equal to zero. Therefore, feedback makes no difference at $p = 0.5$. When $p < 0.5$, as Q_F is more convex than Q_N, we get $Q_F(p(1-p)(x_k-x_0)) - Q_N(p(1-p)(x_k-x_0)) < pQ_F((1-p)(x_k-x_0)) - Q_N((1-p)(x_k-x_0)) < (1-p)Q_F(p(x_k-x_0)) - Q_N(p(x_k-x_0))$. Therefore $p(Q_F((1-p)(x_k-x_0)) - Q_N((1-p)(x_k-x_0))) - (1-p)(Q_F(p(x_k-x_0)) - Q_N(p(x_k-x_0))) > 0$, which implies that under Feedback, the regret averse DM is more risk seeking than under No feedback. When $p > 0.5$, as Q_F is more convex than Q_N, we get $Q_F(p(1-p)(x_k-x_0)) - Q_N(p(1-p)(x_k-x_0)) < (1-p)Q_F(p(x_k-x_0)) - Q_N(p(x_k-x_0)) < pQ_F((1-p)(x_k-x_0)) - Q_N((1-p)(x_k-x_0))$. Therefore $p(Q_F((1-p)(x_k-x_0)) - Q_N((1-p)(x_k-x_0))) - (1-p)(Q_F(p(x_k-x_0)) - Q_N(p(x_k-x_0))) < 0$, which implies that under feedback, the regret averse DM is more risk averse than under

No feedback. Thus Proposition 1 is proved.

Appendix C

Example of experimental stimuli for sections I and II

Question 2: Choose between A and B (Note that the numbers 1,2,.....,6 in the figure below are obtained by rolling the six sided dice)

Choice	1	2	3	4	5	6
A	$ 30		$ 50		$ 5	
B	$ 10		$ 30		$ 45	

Which one do you choose? *

- Option A
- Option B
- Equally prefer option A and B

Figure 3: Screenshot of section I stimuli

Question 1: Choose between A and B (Note that the numbers 1,2,.....,20 in the figure below are obtained by rolling the twenty sided dice)

Choice	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	$ 20	$ 0																		
B	$ 1																			

Which do you choose? *

- Option A
- Option B
- Equally prefer option A and B

Figure 4: Screenshot of section II stimulii

The dice below was rolled and it showed "3", so you receive $80.You would have received $8 if you had chosen option B.

Figure 5: Screenshot of feedback

Appendix D

Questions used in sections I and II of the lab experiment

Three-outcome prospects (each outcome equally likely)	Choice of regret-averse DM (RA prospect)	Question design
$(35, 80, 40)$ vs. $(75, 8, 72)$	Option A	Same EV
$(30, 50, 5)$ vs. $(10, 30, 45)$	Option B	Same EV
$(64, 6, 60)$ vs. $(20, 90, 20)$	Option B	Same EV
$(15, 55, 65)$ vs. $(80, 25, 30)$	Option B	Same EV
$(58, 55, 40)$ vs. $(3, 80, 70)$	Option A	Same EV
$(9, 70, 75)$ vs. $(99, 30, 25)$	Option B	Same EV
$(30, 40, 50)$ vs. $(20, 30, 35)$	Dominance	
$(5, 50, 45)$ vs. $(55, 25, 20)$	Option B	Same EV
$(20, 25, 80)$ vs. $(55, 69, 1)$	Option A	Same EV
$(50, 6, 55)$ vs. $(20, 64, 25)$	Option B	Different EV
$(62, 40, 45)$ vs. $(3, 71, 75)$	Option A	Different EV
$(74, 81, 4)$ vs. $(30, 42, 86)$	Option B	Different EV
$(6, 76, 61)$ vs. $(60, 48, 33)$	Option B	Different EV
$(34, 75, 23)$ vs. $(69, 7, 58)$	Option A	Different EV
$(23, 18, 46)$ vs. $(43, 38, 8)$	Option A	Different EV
$(53, 29, 25)$ vs. $(4, 49, 55)$	Option A	Different EV
$(70, 50, 2)$ vs. $(30, 20, 71)$	Option B	Different EV
$(6, 76, 61)$ vs. $(60, 48, 33)$	Option B	Consistency check
(99,23,35) vs. $(9, 73, 75)$	Indiff. for $\theta = 1$	Measure Q function
$(22, 96, 43)$ vs. $(67, 1, 78)$	Indiff. for $\theta = 0.8$	Measure Q function
$(27, 32, 83)$ vs. $(69, 78, 8)$	Indiff. for $\theta = 1.3$	Measure Q function
$(89, 32, 18)$ vs. $(9, 71, 73)$	Indiff. for $\theta = 1.6$	Measure Q function
$(25, 93, 22)$ vs. $(69, 18, 73)$	Indiff. for $\theta = 1.95$	Measure Q function
$(79, 75, 15)$ vs. $(35, 32, 73)$	Indiff. for $\theta = 2.41$	Measure Q function

Table 16: Questions used in section I of the lab experiment
Notes: Payoffs for responses to questions are denominated in euros (€). EV = expected value.

Question choices	Prediction of H1
$(0.8, 40;0)$ vs. 32	B
$(0.95, 50;0)$ vs. 47.5	B
$(0.05, 50;0)$ vs. 2.5	A
$(0.3, 40; 0)$ vs. 12	A
$(0.1, 40; 0)$ vs. 4	A
$(0.7, 50; 0)$ vs. 35	B
$(0.15, 40; 0)$ vs. 6	A
$(0.75, 40; 0)$ vs. 30	B
$(0.2, 50; 0)$ vs. 10	A
$(0.85, 50; 0)$ vs. 42.5	B
$(0.9, 40; 0)$ vs. 36	B
$(0.25, 50; 0)$ vs. 12.5	A
$(0.9, 5; 0)$ vs. 4.5	B
$(0.05, 8; 0)$ vs. 0.4	A
$(0.1, 5; 0)$ vs. 0.5	A
$(0.95, 8; 0)$ vs. 7.6	B
$(0.3, 40; 0)$ vs. $(0.8, 15; 0)$	A
$(0.1, 45; 0)$ vs. $(0.9, 5; 0)$	A
$(0.1, 40; 0)$ vs. $(0.8, 5; 0)$	A
$(0.05, 50; 0)$ vs. $(0.85, 3; 0)$	A
$(0.15, 50; 0)$ vs. $(0.75, 10; 0)$	A
$(0.2, 40; 0)$ vs. $(0.8, 10; 0)$	A
$(0.25, 40; 0)$ vs. $(0.8, 12.5; 0)$	A

Table 17: Questions used in section II of the lab experiment to identify attitudes toward risk

Note: Payoffs for responses to questions are denominated in euros (€).

Appendix E

Analysis of risk attitudes for all subjects

Questions	Choices consistent with H1	Risk attitude
Condition F		
$p < 1/2$	153 out of 406 (37.7%***)	Risk aversion
$p > 1/2$	249 out of 406 (61.3%***)	Risk aversion
Total	402 out of 912 (44%*)	
Condition N		
$p < 1/2$	126 out of 398 (31.7%***)	Risk aversion
$p > 1/2$	328 out of 398 (82.4%***)	Risk aversion
Total	454 out of 796 (57%***)	

Table 18: Aggregate level choices of all subjects
*significant at $\alpha = 10\%$, **significant at $\alpha = 5\%$, ***significant at $\alpha = 1\%$

	Proportion consistent with H1			
Choice	Condition F	Condition N	Difference	Effect of feedback
$p < 1/2$	37.7%	31.7%	6%*	Increased risk seeking
$p > 1/2$	61.3%	82.4%	−21.1%**	Reduced risk aversion
Total	53.4%	56.5%	−15.1%	

Table 19: Effect of feedback (resolution premium) at the aggregate level and across all choices—all subjects
*significant at $\alpha = 10\%$, **significant at $\alpha = 5\%$, ***significant at $\alpha = 1\%$

Analysis of risk attitudes for non-regret averse subjects

Questions	Choices consistent with H1	Risk attitude
Condition F		
$p < 1/2$	49 out of 128 (38.3%)**	Risk aversion
$p > 1/2$	56 out of 128 (43.8%)	Risk seeking
Total	105 out of 256 (41%)**	
Condition N		
$p < 1/2$	14 out of 32 (43.8%)	Risk aversion
$p > 1/2$	26 out of 32 (81.2%)***	Risk aversion
Total	40 out of 64 (62.5%)**	

Table 20: Aggregate level choices of non regret averse subjects
*significant at $\alpha = 10\%$, **significant at $\alpha = 5\%$, ***significant at $\alpha = 1\%$

	Proportion consistent with H1			
Choice	Condition F	Condition N	Difference	Effect of feedback
$p < 1/2$	38.3%	43.8%	-5.5%	Reduced risk seeking
$p > 1/2$	41%	81.2%	-41.1%**	Reduced risk aversion
Total	53.4%	56.5%	-15.1%	

Table 21: Effect of feedback (resolution premium) at the aggregate level and across all choices— non regret averse subjects

*significant at $\alpha = 10\%$, **significant at $\alpha = 5\%$, ***significant at $\alpha = 1\%$

Appendix F

Classification of regret-averse subjects based on their risk attitudes

Table 22 reveals that the proportion of risk-averse subjects decreases when regret is made more prominent by feedback ($p < 0.05$). In both conditions, the proportion of risk-averse subjects was compared with the proportion of subjects exhibiting other risk attitudes; we found the proportion of risk-averse subjects to be greater than the proportion of risk-seeking ($p < 0.001$), risk-neutral ($p < 0.001$), and mixed subjects ($p < 0.001$). Risk aversion is the dominant finding in both conditions.

	Condition F	Condition N
Risk averse	25 (69%)	44 (89%)
Risk seeking	10 (27%)	4 (8%)
Risk neutral	—	—
Mixed	1 (4%)	1 (2%)

Table 22: Classification of regret-averse subjects based on risk attitudes

Appendix G

Comparing regret theory's prediction with prospect theory

The predictions made my regret theory in terms of H1 are close to those made by prospect theory (Kahneman and Tversky 1979, Tversky and Kahneman 1992). Under linear utility, prospect theory explains risk attitudes via the probability weighting function only. The most commonly observed shape of the probability weighting function is inverse-S, i.e., first concave (pointing to risk seeking), next convex (pointing to risk aversion) with a cutoff point at $\hat{p} \in [0,1]$. Gonzalez and Wu (1999) and Abdellaoui (2000) observed empirically that $\hat{p}$ is < 0.3.[11] Under regret theory (with linear utility – see Figure 2) the cutoff point between risk seeking and risk aversion is $p = 0.5$. When the probability p — to win the positive outcome — is in the interval $\hat{p} \leq p \leq 0.5$, then regret theory and prospect theory have different predictions. By analyzing choices in Table 10 for low $[0, 0.1]$ and intermediate probabilities $(0.1, 0.5]$, we can test the predictions of regret theory vis-a-vis prospect theory.

According to our data, when the probability of a positive outcome p is $p \leq 0.1$, the subjects are risk seeking for 3 out of 4 prospects under condition F and 2 out of 4 prospects under condition N. However, when probability p is $p > 0.1$, the subjects are risk averse under condition F and N for all prospects in Table 10. Therefore, in this interval, the evidence is consistent with prospect theory with an inverse-S weighting function and does not support regret theory.[12] To provide more intuition about the results we fit prospect theory to the data. We assume that the subjects have linear utility and probabilistically choose prospect with higher prospect theory value.[13]

[11] Abdellaoui et al. (2011) observed $\hat{p}$ to be < 0.15.

[12] Regret theory might still be able to explain the results with a concave utility. However, to accommodate the risk aversion observed, the utility function has to be extremely concave. For example, to explain risk aversion for prospect $(0.15, 40; 0)$ under condition N (for $Q_N(\alpha) = \alpha^{1.78}$) the power parameter θ of the utility function $u(\alpha) = \alpha^\theta$ at aggregate level should be less than 0.65.

[13] For a prospect $(p, \alpha; 0)$ the prospect theory value (v) under linear utility is given by $v = w(p)\alpha$. We then use a logit model to define the probabilistic choice of the subject: The subject chooses the option A over option B with probability $\frac{e^{v_A}}{e^{v_A} + e^{v_B}}$, where v_A and v_B are the prospect theory values of options A and B, respectively.

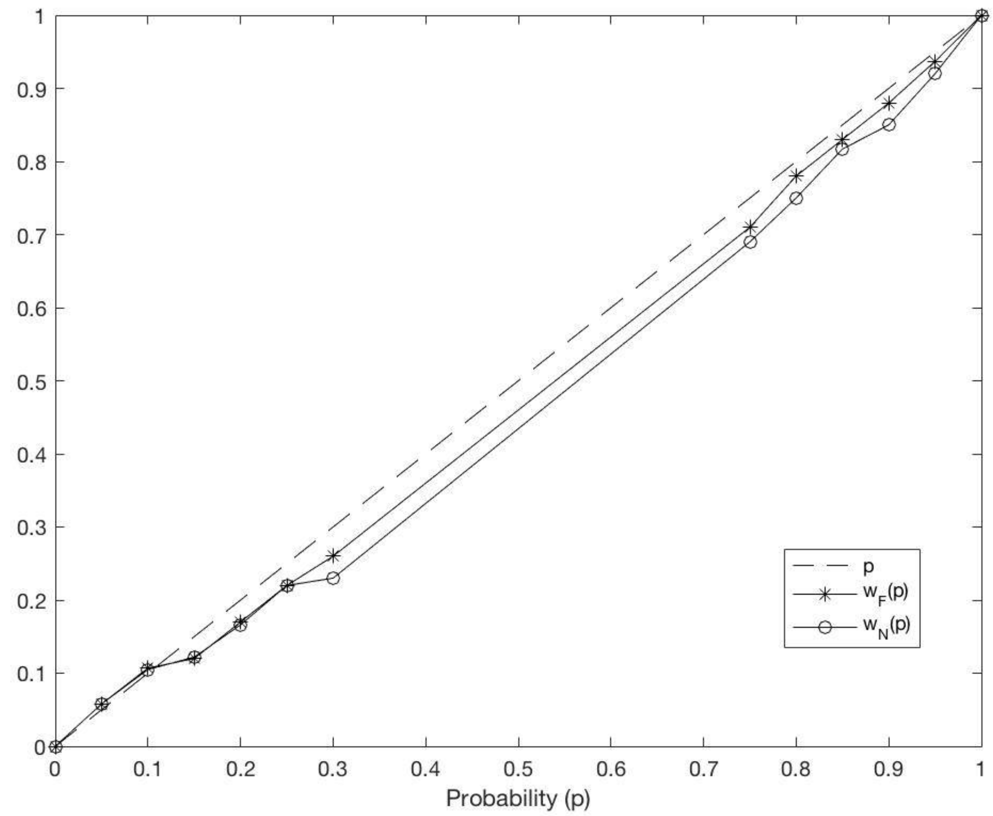

Figure 6: Prospect theory probability weighting function w_F (under Feedback) and w_N (under No feedback)

The probability weighting function under Feedback (w_F) and No feedback (w_N) is derived from the choices and is displayed in Figure 6. The two functions $w_F(p)$ and $w_N(p)$ lie above p for probabilities $p \leq 0.1$ and lie below p for probabilities $p > 0.1$. Therefore, the choices of the subjects are consistent with an inverse-S probability weighting function. The assumption of linear utility makes the weighting function less elevated than the ones observed in the literature (Gonzalez and Wu 1999, Abdellaoui 2000). Note also that for small probabilities $p \leq 0.15$, w_F and w_N overlap. However, for $p > 0.15$, w_N lies below w_F. This indicates that feedback makes the subject more risk seeking for intermediate and high probabilities.[14]

[14]Consistent with our results, van de Kuilen (2009) also found that immediate feedback makes the probability weighting linear and closer to the actual probabilities.

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