

BORDEAUX ECONOMICS WORKING PAPERS
CAHIERS D'ECONOMIE DE BORDEAUX

When choosing is painful: anticipated regret and psychological opportunity cost

Emmanuelle Gabillon

GREThA-UMR CNRS 5113, Université de Bordeaux

emmanuelle.gabillon@u-bordeaux.fr

Abstract

This paper is a contribution to regret theory, which we generalize in two ways. Since the intensity of regret depends on the information the decision-maker has about the results of the foregone strategies (feedback), we build a model of choice which accommodates any feedback structure. We also show that the reference point, which characterizes the regret utility function introduced by Quiggin (1994), does not always represent an anticipated feeling of regret. It can also correspond to another negative feeling related to the act of choosing, which we call psychological opportunity cost (POC), borne at the very moment of choosing. We find behavioral deviations from the predictions of the classical Expected Utility Theory. We obtain correlation loving, greater reluctance to take on risk, and information avoidance at decision time. Our model also offers a theoretical framework for experimental studies about inaction inertia.

Keywords: choice, correlation loving, inaction inertia, information, regret, risk aversion.

JEL: D80 . D81 . D91

To cite this paper: Emmanuelle GABILLON (2020), When choosing is painful: anticipated regret and psychological opportunity cost, Bordeaux Economics Working Papers, BxWP2020-04.

<https://ideas.repec.org/p/grt/bdxewp/2020-04.html>

1 Introduction

Zeelenberg and Pieters (2007) observe that “all other negative emotions can be experienced without choice, but regret cannot”. The feeling of regret is based on a comparison between the chosen action payoff and what the decision-maker (DM) could have obtained by making another choice. Although regret is felt after the choice has been made, it can be anticipated at the time of the decision making. Regret theory studies the effects of the anticipation of regret on decision making.

The essential foundations of regret theory were laid down in the seminal works of Bell (1982, 1983) and Loomes and Sugden (1982, 1987). The preference foundations for Loomes and Sugden (1987) have been provided by Fishburn (1989), Sugden (1993) and Quiggin (1994). More recently, Diecidue and Somasundaram (2017a) propose the first axiomatic foundation for Loomes and Sugden (1982), who separate the utility and regret functions. The representation of Diecidue and Somasundaram (2017a), with continuous utility and regret functions, is also consistent with the existing quantitative measurement method of regret theory of Bleichrodt *et al.* (2010). A state-of-the art overview of regret theory has also been carried out by Bleichrodt and Wakker (2015).

Apart from a few exceptions that we address below, regret theory considers only those situations in which the results of the foregone options are perfectly observable. In this paper, we refer to this assumption as a perfectly informative feedback structure (FS). Foregone option payoffs, however, are not always perfectly resolved. A firm manager observes the revenues generated from his past corporate investment decisions, but not those from unimplemented alternative investment opportunities. A hiring manager who has selected a person for a particular position, has no feedback on what would have been the performance and level of involvement of unretained candidates. Such challenging life decisions as career choices, marriage, or the choice before surgery between two different surgeons, offer other examples in which the DM receives poor feedback about the eventual consequences if a different option had been adopted. Bell (1983) is the first to stress the relevance, in regret theory, of information about foregone outcomes¹ (see also Humphrey 2004). In the case of a choice between two independent lotteries, Bell (1983) studies under which condition a DM would

¹Although their paper does not focus on information, the idea of imperfect information is also to be found in the dynamic model of Krähmer and Stone (2008), in which the DM does not perfectly observe the results of past foregone alternatives.

prefer having the foregone lottery resolved or unresolved. This approach consists in a comparison between two extreme FS: a perfectly informative FS, in which the foregone lottery payoff is perfectly observable, and the opposite situation, in which a DM does not obtain any feedback about the foregone alternative. We refer to the latter situation as a non-informative FS. In the present paper, we pursue the study of regret and information. Unlike Bell (1983), who considers two extreme FS, we develop a model which is the first to generalize regret theory to make it applicable to any FS. In order to do so, we proceed in two steps.

First, we consider a DM who has to choose between different lottery-like options, subsequently designated as ‘actions’, and who anticipates receiving, once her choice has been made, certain information about the payoffs of the foregone actions. That information can have any level of precision and can be of any nature, such as a signal or a message on the foregone action outcomes. At the feedback stage, after the choice has been made, the DM learns the result of the chosen action and receives the information about the foregone actions.

Second, given the information at the feedback stage, the DM revises her beliefs about the foregone actions. Regret results then from the comparison between the chosen action’s outcome and the DM’s opinion about the outcomes of the foregone actions.

Somasundaram and Diecidue (2017b) also consider the possibility of no feedback in regret theory. They compare risk taking under a perfectly informative FS and a non-informative FS, in a theoretical and experimental analysis. Somasundaram and Diecidue consider that feedback enhances anticipated regret and thus assume that the DM is more regret-averse under perfect feedback than under no feedback. In their approach, however, the different states of nature in which regret is anticipated are the same whether under perfect feedback or under no feedback. Unlike Somasundaram and Diecidue (2017b), we consider that the DM’s regret aversion is independent of the FS, and show how both the intensity of the feeling of regret, as well as the different states of nature in which the DM experiences regret, depend on the FS. In our model, the DM’s anticipated regret is endogenous, depending on the information she anticipates having on the foregone options.

In order to obtain preferences which accommodate any type of FS, we propose a generalization of Quiggin’s utility function. Quiggin (1994) introduces the regret-utility function $u(x, r)$, where

the reference point r , representing the impact of anticipated regret on utility, is defined as the best possible outcome that could have been attained : $r = \max \{x, y_1, \dots, y_N\}$. This reference point definition is based on the assumption that the foregone options payoffs y_1, \dots, y_N are perfectly observable at the feedback stage. We propose a generalization of the reference point definition, which encompasses all situations in which the foregone option payoffs are not fully observable. Preferences properties are also investigated. In a pairwise choice model, Loomes and Sugden (1987) show that, in regret theory, under perfect feedback, the preservation of ‘statewise stochastic dominance’ is a natural property. In this paper, statewise stochastic dominance is preserved under a perfectly informative FS, but we explain why this property cannot be generalized to imperfect feedback, except in pairwise choices.

Our generalization of Quiggin’s utility function enables us to establish that the reference point does not systematically represent an anticipated feeling of regret. Instead, it can represent another type of negative feeling, one which we refer to as a psychological opportunity cost (POC).

In order to introduce in which circumstances a POC can be borne, let us consider a DM who can choose between two options, A and B. The DM particularly appreciates option A, but that option is risky and could have a bad outcome, leading to a strong feeling of regret. As option B is less attractive, she would choose option A without hesitation if she were not regret-averse. Option A would represent her rational choice but, since she is regret-averse, she could prefer to choose option B, in order to protect herself from potential regret. When she finally chooses B, we show that the reference point in the DM’s utility function does not represent an anticipated feeling of regret: it represents, instead, a POC, borne at the very moment of choosing. Choosing option B is painful because the DM is fully aware that she is, in so doing, depriving herself of choosing the option that she fundamentally prefers. We will see that the arbitrage between POC (option B) and anticipated regret (option A) can only occur when the FS is not perfectly informative, a situation in which the concept of POC takes on its full meaning. The two phenomena, POC and regret, although different, share common features: they both represent negative feelings related to the act of choosing. They both occur when an unchosen alternative is (POC), or finally turns out to be

(regret) more attractive². POC and anticipated regret also represent two alternative interpretations of the reference point in the utility function $u(x, r)$.

In this paper, we also study the behavior of a regret-averse DM. Our main assumption is regret aversion (the utility function $u(x, r)$ decreases with r). We do not make assumptions about the second-order derivatives of the utility function. Our results are therefore compatible with a large set of utility functions, and are independent of risk preferences.

First, we investigate the impact of regret aversion on risk taking. When a DM has the choice between a riskless option and a risky option, we show that a regret-averse DM, whatever her risk preferences, is more likely to choose the riskless option than a classical expected utility maximizer. This result is obtained when the FS is non-informative. Under no feedback, the riskless option insures the DM against experiencing regret. The attractiveness of a riskless choice is thus stronger for a regret-averse DM than for a classical expected utility maximizer. Consequently, a DM can choose the riskless option while she would have adopted the risky option if she had not been regret-averse. In other words, a regret-averse DM is willing to bear a POC in order to avoid the risk of regret associated to the risky choice. We show that the maximum POC that a DM accepts to tolerate corresponds to the regret premium of Bell (1983). On the empirical side, our results are in line with the findings of Zeelenberg (1999), who observes that regret aversion increases people's propensity to choose the sure option, when the foregone lottery is not resolved.

We also show that, under certain specifications of the choice set, a regret-averse DM is a correlation-lover, regardless of the FS: an increase in concordance between the risky alternatives in the choice set, as defined by Tchen (1980) and Epstein and Tanny (1980), increases the DM's well-being.

Lastly, we study the desirability of information at the time the choice is made. When the FS is not perfectly informative, we show that additional information, at the decision time, can be detrimental to a regret-averse DM's well-being. Additional information can be a source of additional anticipated regret and, despite the fact that the DM is better informed, her expected utility can be negatively affected. Anticipated regret has already been identified as a cause of information

²In that respect, regret is also a psychological opportunity cost, which is felt after the choice, since the previously-made choice prevents the DM benefiting from an alternative, which turns out to be better.

avoidance in Bell (1983). Bell’s result applies to information about the outcomes of the foregone options, information which arrives after the choice (feedback). In our paper, we show that regret aversion is also a cause of information avoidance, when information arrives at the decision stage, before the choice is made.

The paper is organized as follows. Section 2 presents empirical studies in psychology, for which the concept of POC could prove particularly useful. In Section 3, we introduce both the concept of FS and the DM’s preferences. Section 4 gives the formal definition of a POC. Section 5 is devoted to the behavioral implications of regret aversion.

2 Related literature in psychology

We present here a summary of works in psychology which, we believe, could usefully benefit from our concept of psychological opportunity cost.

Our model can be useful in gaining additional insight into the choices observed in the experimental study of Tykocinski and Pittman (1998) about inaction inertia. Inaction inertia is observed when the fact of foregoing a first attractive opportunity increases the likelihood of not seizing a second attractive, albeit lesser, opportunity. In Tykocinski and Pittman (1998), a DM fails, for one reason or other, to take the opportunity to rent a very nice apartment located at only two minutes walking distance from her workplace. She then has the opportunity of renting another very nice apartment, but one that is at twelve minutes walking distance. Inaction inertia consists in foregoing that second opportunity, even though it is attractive. Tykocinski and Pittman explain inaction inertia by anticipated regret. They show that people decline the second opportunity because they try “to prevent or to put an end to the unpleasant psychological experience of regret”. Seizing the second opportunity would activate counterfactual thinking, the unpleasant comparison between obtainable outcomes and the superior outcomes that could have been obtained from the initial and foregone opportunity. In another experimental study, Van de Ven and Zeelenberg (2011) show that regret aversion is one of the causes of people’s well-documented reluctance to trade lottery tickets. People do not like to exchange one lottery ticket for another, even if they obtain a bonus for doing

so. This reluctance represents a deviation from rational decision making, as the rational choice consists in trading the lottery tickets. Van de Ven and Zeelenberg’s experiment shows that people are willing to forego the opportunity to get a bonus in order to prevent future regret. Similarly, in our model, a DM can voluntarily turn away from the rational choice (option A) in order to avoid experiencing regret. The DM passes up on a valuable opportunity in favor of a less valuable action (option B), in the same way that people adopt inaction in Tykocinski and Pittman’s experiment, or refuse to trade lottery tickets in Van de Ven and Zeelenberg’s experiment. Our model, however, also sheds additional light on these experiments by suggesting that missing out on the opportunity to rent the second apartment, or foregoing a bonus, has a negative impact on people’s well-being. The POC measures the extent to which the utility of the suboptimal choice (inaction or keeping the initial lottery ticket) is negatively affected by avoiding a better opportunity. To the best of our knowledge, the POC has not yet been identified in experimental studies, which focus exclusively on the possible causes of apparently irrational choices. While regret could be a possible explanation of suboptimal decision-making, the POC, on the contrary, weakens the tendency to make a suboptimal choice. It decreases the utility that a DM would derive from adopting such a choice. It does not create behavioral bias but reduces behavioral bias. This could be one reason why this feeling has not yet been identified. Our model suggests that people make an arbitrage between the best opportunity, whose utility is lowered by anticipated regret, and the inferior opportunity, whose utility is lowered by a POC. People’s decisions result from an arbitrage between these two feelings.

Our POC also resembles the concept of “postchoice discomfort” introduced by Carmon *et al.* (2003). In their experimental study, the authors show that, when people choose one option, they can experience a feeling of discomfort because the foregone options are no longer feasible. In that case, “choosing feels like losing”; losing the “prefactual ownership of the foregone options”. The POC closely resembles the feeling of postchoice discomfort studied by Carmon *et al.*. There is, however, one significant difference: postchoice discomfort occurs when people have to choose between two equally attractive alternatives. In our model, the DM experiences a POC when she deliberately foregoes a more valuable alternative.

3 Basic framework

We consider a two-date model. We call *decision stage* the time of the choice, and *feedback stage* the time of complete or partial uncertainty resolution. At the decision stage, one action is chosen out of a set of alternatives. At the feedback stage, the result of the chosen action is observed, and certain feedback about the results of the foregone alternatives is received.

The choice set $\Phi = \{Y_1, \dots, Y_{N+1}\}$ contains $N + 1$ actions, with a typical action Y_n , a positive random variable which takes its values y_n in the compact support $W_{Y_n} \subset \mathbb{R}^+$. The assumption of positive action payoffs is made for the sake of simplicity, although it could easily be removed by assuming that the DM is endowed with initial wealth. In what follows, we use uppercase to refer to a random variable, and lowercase to refer to a realization of a random variable. Throughout the rest of the paper, either $\{Y_1, \dots, Y_{N+1}\}$ or $\{X, Y_1, \dots, Y_N\}$ are used to refer to the choice set Φ , depending on whether we need or not to distinguish the chosen action X from the other alternatives.

3.1 Feedback structure

One important feature of our model consists in introducing the possibility for the DM to receive, after her choice, feedback about the results of the foregone alternatives. We assume that a DM observes not only the result x of the chosen action X , but also receives information I_X about the realized payoffs of the foregone alternatives Y_1, \dots, Y_N . We denote by $F_X = (X, I_X)$ the action X feedback. Action X feedback contains all the information sources available at the feedback stage when action X has been chosen. F_X also represents the uncertainty a DM is faced with when she chooses action X . A realization $f_x = (x, i_x)$ of F_X corresponds to the realization of a particular state of nature at the feedback stage. We also assume that, at the feedback stage, given the observation of $f_x = (x, i_x)$, a DM revises her beliefs about the foregone actions. After the information has been processed, a foregone action Y_n is thus characterized by a posterior probability distribution. Whenever possible, the probability distribution revision is made using Bayes' rule. The comparison of the $N + 1$ alternatives, made by the DM at the feedback stage, is developed in Section 3.2.

Although information I_X can be of any type³, we develop here, for the sake of clarity, an example in which action payoffs are continuous random variables, and information I_X has the following structure:

$$I_X = (1 - \lambda_X) Y_X + \lambda_X \Lambda_X, \quad (1)$$

where λ_X is a real parameter, $Y_X = \begin{pmatrix} Y_1 \\ \vdots \\ Y_N \end{pmatrix}$ is a random vector which contains the N random

payoffs of the foregone actions (all actions except X), $\Lambda_X = \begin{pmatrix} \varepsilon_1^X \\ \vdots \\ \varepsilon_N^X \end{pmatrix}$ is a vector of N zero-mean continuous random variables, with $\forall Y_n \in \Phi \setminus \{X\}, \forall y_n \in W_{Y_n}, E(\varepsilon_n^X | y_n) = 0$.

In this setting, I_X is a noisy multi-dimensional signal of Y_X and i_x denotes a realization of the multi-dimensional signal⁴ I_X .

In an alternative setting, information I_X could, for example, rule out some elements of the support W_{Y_n} in which a foregone action Y_n takes its values. The DM learns, at the feedback stage, that the foregone action Y_n has taken its value in a sub-set of W_{Y_n} .

In general, information about the foregone alternatives at the feedback stage depends on the particular action X which has been chosen. The informational content of $F_X = (X, I_X)$ depends on the degree of stochastic dependence between X and the foregone actions, and also on the precision of information I_X .

We are now able to define the FS, which characterizes the choice set $\Phi = \{Y_1, \dots, Y_{N+1}\}$.

Definition 1. *The FS F_Φ represents the set of all the action feedbacks:*

$$F_\Phi = \{F_{Y_1}, \dots, F_{Y_{N+1}}\} = \{(Y_1, I_{Y_1}), \dots, (Y_{N+1}, I_{Y_{N+1}})\}.$$

³That information, however, is assumed to be anticipable. In other words, information must be consistent with the prior probability distributions of Y_1, \dots, Y_N . It can not correspond to an unanticipated event (for example, “ Y_n takes a value outside W_{Y_n} ”).

⁴A similar idea can be found in the paper of Krämer and Stone (2008), which extends regret to a dynamic context, considering a DM who observes not only the realization of the chosen strategy outcome, but also the realization of a signal about the past foregone strategies.

By choosing a particular action X , a DM selects not only a random payoff X but also a particular feedback F_X . The real choice set, which is relevant for decision making, is not Φ but F_Φ . We give, in what follows, the definitions of perfectly informative, non-informative, as well as imperfectly informative FS.

Definition 2. $F_\Phi = \{F_{Y_1}, \dots, F_{Y_{N+1}}\}$ is perfectly informative when $\forall Y_n \in \Phi$, I_{Y_n} gives perfect information about the values taken by $Y_1, \dots, Y_{n-1}, Y_{n+1}, \dots, Y_{N+1}$. If we use the specification of Equation 1, the FS is perfectly informative when $\forall Y_n \in \Phi$, $\lambda_{Y_n} = 0$.

$F_\Phi = \{F_{Y_1}, \dots, F_{Y_{N+1}}\}$ is non-informative when $\forall Y_n \in \Phi$, I_{Y_n} gives no information about the values taken by $Y_1, \dots, Y_{n-1}, Y_{n+1}, \dots, Y_{N+1}$. If we use the specification of Equation 1, the FS is non-informative when $\forall Y_n \in \Phi$, $\lambda_{Y_n} = 1$.

$F_\Phi = \{F_{Y_1}, \dots, F_{Y_{N+1}}\}$ is imperfectly informative in all other situations.

Under a non-informative FS, a DM, whatever her choice, observes only the outcome of her choice without obtaining any additional information about the other alternatives. In the present paper, however, we do not rule out (unless otherwise specified) the possibility of stochastic dependence between the alternatives in the choice set. Consequently, even under a non-informative FS, the observation of the chosen action payoff can be a source of information about the foregone alternatives.

3.2 Preferences

Following Quiggin (1994), we adopt a regret utility function (r-utility) which depends on the payoff of the chosen action X and on a reference point. Quiggin's expected r-utility can be written as follows:

$$E[u(X, R)], \quad (2)$$

with $R = \max\{X, Y_1, \dots, Y_N\}$.

Variable R represents the impact of anticipated regret on the DM's utility. In the event $R > X$, a foregone action performs better than the chosen action, and regret is anticipated. The definition of the reference point in Quiggin (1994) implies that R cannot be lower than X , excluding the

feeling of rejoicing when a DM learns that the chosen action turns out to be the best action⁵. Following Quiggin (1994), we do not consider rejoicing in this paper. Experimental studies show that, for most people, anticipated regret, and not anticipated rejoicing, has the greater impact on choices (Zeelenberg *et al.* 1996; Mellers *et al.* 1999; Mellers 2000). Psychology studies also find that people’s counterfactual thinking is more oriented toward what could have been better, rather than toward what could have been worse (Gilovich 1983; Roese 1997; Epstein and Roese 2008).

The definition of the reference point in Quiggin (1994) also assumes that the results of the foregone alternatives Y_1, \dots, Y_N are anticipated as being perfectly observable. In what follows, we generalize Quiggin’s reference point to any FS. In order to do that, we first generalize the concept of choiceless utility (c-utility), introduced by Loomes and Sugden (1982) and Bell (1982) in their additive regret utility function⁶.

Definition 3. *The c-utility function is defined as $v(x) = u(x, x)$ and measures the satisfaction generated by the consumption of payoff x , independently of any choice-related feeling.*

In Definition 3, the c-utility function represents preferences in which sensitivity to emotions has been removed ($r = x$) and corresponds to the DM’s preferences if she were not regret averse. In what follows, we refer to the c-utility function as the fundamental, or rational, preferences of a DM. The c-utility $v(x)$ also represents the utility of x when the payoff x is evaluated in a no-choice context. In this paper we assume that, at the feedback stage, the c-utility function is used to compare the outcomes of the $N + 1$ alternatives. A choiceless evaluation criterion is appropriate because, at that stage, the DM is no longer in a choice context.

We introduce the assumptions about the r-utility function $u(x, r)$ which are required for our results. 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 $\frac{\partial v(x)}{\partial x}$.

A0. The r-utility $u(x, r)$ is differentiable on \mathbb{R}^{+2} .

A1. $v'(x) = u_1(x, x) + u_2(x, x) > 0$.

⁵Rejoicing can occur when the reference point satisfies the definition $r = \text{Max}\{Y_1, \dots, Y_N\}$.

⁶The additive regret utility function of Loomes and Sugden (1982) and Bell (1982) is $u(x, y) = v(x) + f(v(x) - v(y))$, where y represents the payoff of the foregone action, $v(\cdot)$ and $f(\cdot)$ are, respectively, the choiceless utility function and the regret-rejoice function.

A2. $u_1(x, r) > 0$.

A3. $u_2(x, r) < 0$.

Assumptions A1 and A2 state that the DM, whether regret-averse (A2) or not (A1), prefers to consume more rather than less.

We show in this paper that, when $r > x$, that does not necessarily imply that regret is felt. A reference point greater than the chosen action payoff can also mean that a POC is supported. A formal definition of a POC is given in Section 4. At this stage, a POC should be interpreted as a choice-related feeling that decreases utility. Assumption A3 states that the r-utility decreases with the reference point. Given payoff x , the reference point increases when the intensity of the negative emotion (regret or POC) increases, so that utility decreases. Assumption A3 characterizes regret and POC aversion.

Assumptions A0 to A3 are rather general assumptions. In particular, we do not make assumptions about second-order derivatives of the utility function $u(x, r)$. Our results are therefore compatible with any type of risk preferences and can be obtained with a wide range of utility functions, including the additively separable utility function $u(x, r) = g(x) + h(r)$. In regret theory (under perfect feedback), separability yields exactly the same predictions as the expected utility theory. We show, in this paper, that when the assumption of perfectly informative FS is removed, the reference point is choice-dependent, which entails violations of expected utility theory, even under separability.

The following multiplicative r-utility functions $u(x, r) = -e^{-\gamma x + kr}$, $u(x, r) = x^\gamma r^{-k}$ and $u(x, r) = -x^{-\gamma} r^k$ satisfy assumptions A0 to A3 when $\gamma > k > 0$, as does the linear and additively separable utility function $u(x, r) = x - kr$ with $0 < k < 1$.

At the feedback stage, each foregone action Y_n is characterized by a posterior probability distribution after the information (a realization f_x of F_X) has been processed. The posterior probability distribution represents the DM's knowledge about Y_n at the feedback stage. The DM evaluates the $N + 1$ alternatives with the c-utility function. We compute the posterior certainty equivalent of

action Y_n with the c-utility function:

$$v \left(CE_{Y_n}^{v, f_x} \right) = E \left[v(Y_n) | f_x \right], \quad (3)$$

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

The posterior certainty equivalent of the chosen action is equal to the realization of the payoff itself.

$$CE_X^{v, f_x} = x. \quad (4)$$

We can now give the definition of a reference point which accommodates any FS.

Definition 4. *The reference point R^{F_x} is the highest posterior certainty equivalent:*

$$R^{F_x} = \text{Max} \left\{ X, CE_{Y_1}^{v, F_x}, \dots, CE_{Y_N}^{v, F_x} \right\}.$$

The notation R^{F_x} indicates, in superscript, the variables that a DM observes at the feedback stage. Under assumption A1, the reference point is the certainty equivalent of the alternative *which maximizes the expected c-utility, given available information at the feedback stage*. Definition 4 generalizes, in several directions, the approach of Bell (1983), which considers the additive r-utility function $v(x) + f(v(x) - E[v(y)])$, in which regret-rejoicing is determined by the difference between the value of chosen action's outcome $v(x)$ and the expected value, under no feedback, of the unique foregone action $E[v(y)]$. From Definition 4, we obtain the generalization of preferences to any FS:

$$E[u(X, R^{F_x})] = E \left[u \left(X, \text{Max} \left\{ X, CE_{Y_1}^{v, F_x}, \dots, CE_{Y_N}^{v, F_x} \right\} \right) \right], \quad (5)$$

which gives, under a perfectly informative FS, $E[u(X, R^{F_x})] = E[u(X, \text{Max}\{X, Y_1, \dots, Y_N\})]$. Under a perfectly informative FS, our reference point definition fully coincides with that of Quiggin (1994) (see Equation 2). In that particular case, the reference point is independent of the choice which has been made whereas, in general, the reference point does depend on the chosen alternative.

Preferences, represented by Equation 5, display the following properties.

Proposition 1. *Under a perfectly informative FS, preferences preserve statewise stochastic dominance. Under an imperfectly informative or a non-informative FS, preferences do not preserve statewise stochastic dominance, except in a pairwise choice.*

When actions are stochastically independent, first-order stochastic dominance is preserved under a perfectly informative FS and under a non-informative FS.

Preferences satisfy the irrelevance of statewise dominated alternatives.

Proof. See Appendix A

Regret theory is a model of choice that does not necessarily attribute a unique value to different actions with the same payoff probability distribution. For that reason, Loomes and Sugden (1987) show that regret theory has no reason to preserve first-order stochastic dominance (FSD). In a pairwise choice model, the authors show, however, that under natural conditions, regret theory, established under perfect feedback, does preserve statewise stochastic dominance (SD): action Y_i is preferred to action Y_j whenever action Y_i systematically yields a better outcome than action Y_j . In this paper, we generalize the result of Loomes and Sugden (1987) to any FS. When the choice set contains two actions, we show that SD is preserved whatever the FS. With a general choice set, we show that SD is preserved under a perfectly informative FS, but also that this result cannot be generalized to the other FS. When the FS is not perfectly informative, each action is not only characterized by its random payoff but also by the information the choice of this action conveys about the other actions. Consequently, when there are more than two actions in the choice set, the statewise dominated action can involve less anticipated regret than the statewise dominant action. We give, in Appendix A, an example in which SD is not satisfied. We do not consider this result as a weakness of our model. On the contrary, it illustrates just how important feedback is in regret theory, and how the assumption of perfect feedback, under which the preservation of SD is clearly desirable, represents a particular case.

Loomes and Sugden (1987) show that, under perfect feedback, FSD is preserved in the particular case in which the choice is made between two stochastically independent actions. Similarly, our

model preserves FSD when actions are independent, under a perfectly informative FS but also under a non-informative FS. Under a non-informative FS, when actions are stochastically independent, the choice of a particular action does not convey any information about the foregone action payoffs. Only payoff probability distributions matter, and FSD is preserved.

Quiggin (1994) proposes preferences (see Equation 2), which satisfy, under perfect feedback, the irrelevance of statewise dominated alternatives (ISDA). The preference between preexisting action A and action B is not modified when a statewise dominated action is introduced in the choice set. In our model, the generalization of preferences to any FS maintains the ISDA property. Preferences cannot be manipulated by the introduction of a statewise dominated action. Note, however, that while a statewise dominated action is unattractive under the assumption of a perfectly informative FS, SD is not preserved when the FS is not perfectly informative. A DM can decide to choose the statewise dominated action when that particular choice provides a better protection against anticipated regret (see Appendix A). In so doing, the DM is not the victim of a ‘money pump’, since she does not end up in a situation which is no better than her starting point.

4 Psychological opportunity cost

The event $R^{F_x} > X$ means that, at the feedback stage, a foregone action is preferred to the chosen action. Given information F_X , the DM learns, at the feedback stage, that another action would have been a better choice. According to regret theory, in such event, regret is felt, and the reference point in the r-utility $u(X, R^{F_x})$ represents an anticipated feeling of regret. In this paper, however, we identify a particular configuration in which the event $R^{F_x} > X$ is associated to another negative feeling, which cannot be identified as a feeling of regret. We refer to this feeling as a psychological opportunity cost (POC). The following definition is useful to introduce our concept of POC.

Definition 5. *Action Y_n (which can be the chosen action X itself) is, after the choice, the ex-post preferred action when $r^{f_x} = CE_{Y_n}^{v, f_x}$.*

Definition 5 states that action Y_n is the *ex-post* preferred action in a particular state of nature f_x ,

when it maximizes the expected c-utility function, given the information available at the feedback stage f_x .

Definition 6. *Choosing action X involves a POC when, at the decision stage, the DM anticipates that another action Y_n will be the ex-post preferred action in every state of nature at the feedback stage: $R^{Fx} = CE_{Y_n}^{v, Fx} \geq X$, with a strict inequality $R^{Fx} > X$ holding on a set of non-zero probability.*

Whatever the state of nature f_x , the reference point r^{fx} is equal to the certainty equivalent of action Y_n , $CE_{Y_n}^{v, fx}$. Action Y_n is anticipated to always maximize the DM's expected c-utility at the feedback stage. A POC is felt when the DM chooses action X while knowing that she will fundamentally prefer another action Y_n , whatever the future state of nature. The reference point represents the pain of knowing, from the outset, that another action Y_n will systematically be preferred to the chosen action X . The reference point cannot represent an anticipated feeling of regret, since it would be inconsistent to choose action X while being sure to regret not having chosen Y_n instead of X (we develop this point in Example 1).

In contrast, regret occurs when the DM learns, in a particular state of nature, that another action has performed better than the chosen action. Regret is felt when the DM learns, at the feedback stage and only at that stage, that she prefers another particular action to the chosen action. The main difference between anticipated regret and POC can be stated as follows: regret is anticipated when the *ex-post* preferred action cannot be identified with certainty at the decision stage. It will be known only at the feedback stage. A POC is borne at the decision stage, when the *ex-post* preferred action is both known with certainty at the decision stage, and is different from the chosen action. In order to better understand the difference between POC and anticipated regret, we consider a simple example taken under a non-informative FS. Throughout all the examples given in this paper, even though we do not advocate this particular utility function for regret modeling, we have chosen to use a linear and additively separable utility function to make clear that our results are not explained by second-order effects.

Example 1. We consider a non-informative FS, and a choice set containing a sure payoff of \$100, and a lottery L where \$150 can be won with probability 0.7, or nothing with probability 0.3. The r -utility function is $u(x, r) = x - \frac{r}{2}$ and the c -utility function is $v(x) = u(x, x) = \frac{x}{2}$.

The c -utility of lottery L is $0.7 \times \frac{150}{2} = 52.5$ and $CE_L^v = 105$.

The c -utility of \$100 is $\frac{100}{2} = 50$.

If the DM were not regret-averse, she would choose lottery L . The DM, in this example, fundamentally prefers the lottery.

Now, the expected r -utility of lottery L is $0.7 \times \left(150 - \frac{\text{Max}\{150, 100\}}{2}\right) + 0.3 \times \underbrace{\left(0 - \frac{\text{Max}\{0, 100\}}{2}\right)}_{\text{Regret state}} = 37.5$.

In the state of nature in which the lottery payoff is 0, the DM learns that she had not made the right choice and regrets not having chosen the \$100.

The r -utility of \$100 is $100 - \frac{\text{Max}\{100, 105\}}{2} = 47.5$.

The comparison of r -utilities indicates that the regret-averse DM chooses the \$100. The rational choice would consist in selecting the lottery, but the DM renounces selecting that lottery to protect herself from potential regret.

The choice of the \$100 involves, however, a negative feeling since the r -utility of \$100 is lower than the c -utility of \$100. In this paper, we claim that the reference point in the r -utility of \$100 cannot represent an anticipated feeling of regret. Under a non-informative FS, when the DM chooses the \$100, she receives no information after the choice: she already knows the result of her choice and does not observe the result of the lottery. There is thus no reason to feel regret at the feedback stage. Moreover, if that were the case, it would mean that the DM, who chooses the \$100, is certain to feel regret after her choice since, at the decision stage, she already knows that she fundamentally prefers the lottery ($CE_L^v > 100$). Why, in that case, would the DM choose the \$100 instead of the lottery, if she is sure to regret not having chosen the lottery? As the regret-interpretation of the reference point introduces an inconsistency in the DM's behavior, the reference point needs, therefore, to be interpreted differently. Right from the decision stage, the ex-post preferred action (the lottery) is known with certainty. The reference point $CE_L^v = 105$, in the r -utility of \$100, represents a negative

feeling experienced at the decision stage. Choosing the \$100 generates a POC, because it implies missing out on the opportunity to play in the lottery, which represents the option that the DM would have adopted if she had not been regret-averse. The r -utility of lottery L is lower than the c -utility of lottery L because of anticipated regret, whereas the r -utility of \$100 is lower than the c -utility of \$100 because of a POC. This example illustrates a POC when a DM chooses between a sure thing and a random lottery. Another example, in which the DM chooses between two risky actions, is given in online Appendix B.

It should be noted that the POC could easily be estimated in an experimental study. First, people's preferences would need to be estimated in order to compute, for each participant, the Arrow-Pratt certainty equivalent for the lottery. The second step would consist in confronting people with the choice between the \$100 and lottery L and selecting people, if any, who have chosen the \$100 even though they have a certainty equivalent for the lottery that is greater than 100. For those people, the POC could be measured by the difference $CE_L^v - 100$.

When there is a POC of choosing X , the expected r -utility of X is written as follows:

$$E[u(X, R^{Fx})] = E\left[u\left(X, CE_{Y_n}^{v, Fx}\right)\right]. \quad (6)$$

When action X is adopted, the DM knows, from the outset, that whatever the realization of the future state of nature, her *ex-post* preferred action is not X , but action Y_n . What could be unknown at the decision stage, however, is the exact extent to which action Y_n will be preferred. Additional information on this point can arrive at the feedback stage, when the DM learns in which state of nature f_x she is. That is why we do not exclude the fact that the reference point also incorporates an anticipated feeling of regret in states in which the reception of good news about Y_n is anticipated (feedback), and/or in states in which the reception of bad news about action X 's payoff is anticipated. In that situation, the DM does not feel regret because she learns that she prefers another action Y_n to the chosen action (something she already knows) but because she learns that her choice is worse than expected, and that it would finally have been better to choose Y_n .

When there is a POC, the reference point can be decomposed as follows:

$$\forall f_x, r^{f_x} = CE_{Y_n}^{v,f_x} = x + \underbrace{CE_{Y_n}^v - CE_X^v}_{\text{POC}} + \underbrace{CE_X^v - x}_{\text{News about } X} + \underbrace{CE_{Y_n}^{v,f_x} - CE_{Y_n}^v}_{\text{News about } Y_n}. \quad (7)$$

In this decomposition, the POC is measured by the difference between the certainty equivalent of the rational choice and the certainty equivalent of the chosen action: $CE_{Y_n}^v - CE_X^v > 0$. The computation of $CE_{Y_n}^v - CE_X^v$ is based on information available at the decision stage. It should be noted, however, that the condition $CE_{Y_n}^v - CE_X^v > 0$ is not sufficient to have a POC. When there is a POC, a DM not only knows that $CE_{Y_n}^v - CE_X^v > 0$ but also knows that $CE_{Y_n}^{v,f_x} - x \geq 0$ in each state of nature f_x .

News about X and Y arrives after the choice, at the feedback stage. If there is good news ($CE_X^v - x + CE_{Y_n}^{v,f_x} - CE_{Y_n}^v < 0$), we can interpret this case as one in which the DM learns that the situation is not as bad as in its evaluation at the decision stage (POC alleviation). If there is bad news ($CE_X^v - x + CE_{Y_n}^{v,f_x} - CE_{Y_n}^v > 0$), we can interpret this case as one in which the DM learns that the situation is worse than in its evaluation at the decision stage (regret).

We do not pretend that the above decomposition perfectly separates regret from POC, but this decomposition shows that a POC might coexist with anticipated regret in some states of nature.

5 Behavioral implications of regret aversion

In what follows, we continue to use the expression ‘regret aversion’, while it would be more relevant to talk about regret and POC aversion. In this section, we analyze some specific behaviors, related to regret aversion, which are not consistent with the predictions of the classical expected utility model.

5.1 Arbitrage between POC and anticipated regret

The following proposition generalizes the result obtained in Example 1.

Proposition 2. *When the choice of action X involves a POC (of not choosing action Y_n instead*

of X) and represents, however, the DM's optimal choice then

1. the event $R^{F_{Y_n}} > Y_n$ occurs with non-zero probability.
2. action X would not be an optimal choice in the c -utility model.

Proof. See Appendix C.

When $R^{F_{Y_n}} > Y_n$, the reference point, in the expected r -utility of Y_n , reflects anticipated regret. In other words, action X can be preferred only if choosing Y_n exposes to having a feeling of regret. The situation analyzed in Proposition 2 can occur under any FS, except under the perfectly informative one. Under a perfectly informative FS, there is a POC of choosing X when action Y_n offers the greatest payoff in all states of nature⁷. In that case, action Y_n is also the best choice, and a DM never finds it optimal to bear a POC. This could be one reason why the concept of POC has eluded identification in regret literature, focused for the most part on perfect feedback.

The second point in Proposition 2 states that action X does not represent a rational choice since, in the c -utility model, it would not be optimal to choose action X . The choice of an action involving a POC is motivated by emotional determinants, and represents a behavioral deviation from the traditional expected utility model.

Our model offers a theoretical framework for the experimental study of Tykocinski and Pittman (1998) (see Section 2 for a presentation their experimental study), in which people tend to choose inaction to avoid having to feel regret. In this paper, we show that the knowledge of missing out on a better opportunity negatively affects the utility obtained from inaction. Our model suggests that, in Tykocinski and Pittman's experiment, people bear a negative feeling when choosing inaction, because they know that they are not making the rational choice. Without the POC, we could expect the inaction bias to be observed more frequently.

5.2 Regret aversion and attitude toward risk

Let us consider a choice set containing two risky actions $\Phi = \{Y_1, Y_2\}$. In what follows, we assume that Y_j ($j = 1, 2$) is a binary random variable, taking the value \underline{y} with probability p_j , and the value

⁷Under perfect feedback, there is a POC of choosing X instead of Y_n when $R^{F^X} = \text{Max}\{X, Y_1, \dots, Y_N\} = Y_n$.

\bar{y} with probability $1 - p_j$. Without loss of generality, we assume that $0 < \underline{y} < \bar{y}$ and $p_1 \geq p_2$. We also assume that the joint distribution of Y_1 and Y_2 is parametrized by a correlation coefficient ρ (Denuit *et al.* 2010):

$$\begin{aligned} \Pr(Y_1 = \underline{y}, Y_2 = \underline{y}) &= p_1 p_2 + \rho, \\ \Pr(Y_1 = \bar{y}, Y_2 = \underline{y}) &= (1 - p_1) p_2 - \rho, \\ \Pr(Y_1 = \underline{y}, Y_2 = \bar{y}) &= p_1 (1 - p_2) - \rho, \\ \Pr(Y_1 = \bar{y}, Y_2 = \bar{y}) &= (1 - p_1) (1 - p_2) + \rho, \end{aligned} \tag{8}$$

with $\text{Max}\{-p_1 p_2, -(1 - p_1)(1 - p_2)\} \leq \rho \leq (1 - p_1) p_2$ to ensure probability values between 0 and 1.

When $\rho = 0$, the DM is faced with an independent choice set. When ρ is positive, the DM is faced with a positive dependent choice set, and when ρ is negative, the DM is faced with a negative dependent choice set. An increase in ρ corresponds to a correlation increasing transformation of the joint distribution of Y_1 and Y_2 , as defined by Epstein and Tanny (1980). This transformation, which shifts weight towards realizations where both variables are small or large, leaves the marginal distributions of Y_1 and Y_2 unchanged. A correlation increasing transformation corresponds to an increase in concordance between Y_1 and Y_2 , as defined by Tchen (1980) and Epstein and Tanny (1980).

In what follows, we define as a correlation lover a DM who likes a correlation increasing transformation of the choice set $\Phi = \{Y_1, Y_2\}$. More precisely, the DM is a correlation lover when her expected r-utility increases with ρ , whether she chooses Y_1 or Y_2 .

The FS $F_\Phi = \{F_{Y_1}, F_{Y_2}\}$ is defined as follows: information I_j ($j = 1, 2$) in $F_{Y_j} = (Y_j, I_j)$ is a signal on action Y_k ($k = 2, 1$). If we focus on action F_{Y_1} (we make similar assumptions about F_{Y_2}), the probability distribution of I_1 is:

$$\begin{aligned}\Pr(I_1 = \underline{i} | Y_1 = \underline{y}, Y_2 = \underline{y}) &= \underline{q}_1 \quad \text{and} \quad \Pr(I_1 = \bar{i} | Y_1 = \underline{y}, Y_2 = \underline{y}) = 1 - \underline{q}_1, \\ \Pr(I_1 = \underline{i} | Y_1 = \underline{y}, Y_2 = \bar{y}) &= \underline{p}_1 \quad \text{and} \quad \Pr(I_1 = \bar{i} | Y_1 = \underline{y}, Y_2 = \bar{y}) = 1 - \underline{p}_1.\end{aligned}\tag{9}$$

Information I_1 is a signal on Y_2 . The above probability distribution is given when $Y_1 = \underline{y}$. When $Y_1 = \bar{y}$, a DM, who has chosen Y_1 , does not feel any regret and information on Y_2 is useless. Without loss of generality, we assume $\bar{i} > \underline{i}$ and $\underline{q}_1 \geq \underline{p}_1$. The signal I_1 is perfectly informative when $\underline{q}_1 = 1$ and $\underline{p}_1 = 0$ (perfect feedback), is not informative when $\underline{q}_1 = \underline{p}_1$ (no feedback) and is partially informative in the other cases (imperfect feedback).

The expected r-utility of Y_j is:

$$E \left[u \left(Y_j, R^{F_{Y_j}} \right) \right] = p_j E_{I_j} \left[u \left(\underline{y}, CE_{Y_k}^{v, \underline{y}, I_j} \right) \middle| Y_j = \underline{y} \right] + (1 - p_j) u(\bar{y}, \bar{y}), \tag{10}$$

where $(j, k) \in \{(1, 2), (2, 1)\}$. The expectation operator $E_{I_j} [\cdot | Y_j = \underline{y}]$ represents the conditional expectation with respect to I_j , given that $Y_j = \underline{y}$. The notation $CE_{Y_k}^{v, \underline{y}, I_j}$ refers to the certainty equivalent of Y_k , given the observation of $Y_j = \underline{y}$ and the signal I_j .

When $Y_j = \underline{y}$, regret occurs as soon as $CE_{Y_k}^{v, \underline{y}, I_j} > \underline{y}$, and the r-utility in this regret state is $u(\underline{y}, CE_{Y_k}^{v, \underline{y}, I_j})$.

We obtain the following proposition:

Proposition 3. *When the choice set contains actions Y_1 and Y_2 , whose joint distribution is defined by Equation 8, a DM is a correlation lover.*

Proof. See Appendix D.

Appendix D shows that the DM's expected r-utility, $E \left[u \left(Y_j, R^{F_{Y_j}} \right) \right]$, $j = 1, 2$, increases with ρ (see Equation 10). In the regret state where $Y_j = \underline{y}$, reference point $CE_{Y_k}^{v, \underline{y}, I_j}$ depends on the level of correlation between Y_1 and Y_2 . Compared to the case of independence ($\rho = 0$), a positive correlation decreases $CE_{Y_k}^{v, \underline{y}, I_j}$ and thus decreases regret intensity, whereas a negative correlation increases regret intensity. This result is valid whatever the FS, and is obtained without any assumption about risk

preferences. Gollier (2018) also considers correlation loving in regret theory, but the author focuses on the correlation between a particular lottery and the state-dependent best alternative (a notional lottery which corresponds to the reference point under perfect feedback). A marginal increase in concordance between a lottery and the reference point increases the DM's expected utility, when the utility function is supermodular. In our approach, we consider, instead, the concordance between the two actions in the choice set. A DM is said to be a correlation lover when she likes a correlation increasing transformation of the choice set, which corresponds to an increase in concordance between Y_1 and Y_2 . It is worth noting that, under Specification 8, we obtain correlation loving under any FS, without assuming supermodularity. The assumption of regret aversion (A3) is sufficient.

In what follows, we consider a non-informative FS. *Action X no longer represents the chosen alternative but a riskless action which generates a sure payoff.* According to the traditional expected utility model (c-utility model), a DM who has the choice between a riskless action X and a risky action Y , chooses the riskless action when $v(X) \geq E[v(Y)]$, which is equivalent to having $X \geq CE_Y^v$. On the contrary, she chooses the risky action Y when $v(X) < E[v(Y)]$ or, equivalently, when $X < CE_Y^v$.

We show, in this section, that regret aversion increases a DM's tendency to choose the riskless action when the FS is non-informative. In other words, a DM not only chooses action X when $X \geq CE_Y^v$, but can also be found choosing X when $X < CE_Y^v$. This result is independent of the DM's risk preferences, since we do not make assumptions related to this point.

In what follows, we give the definition of the regret certainty equivalent of a risky action Y , which we henceforth refer to as CE_Y^u (with u in superscript).

Definition 7. *The regret certainty equivalent CE_Y^u of a risky action Y corresponds to the sure payoff which makes the DM indifferent between CE_Y^u and Y , under a non-informative FS.*

Under a non-informative FS, the regret certainty equivalent CE_Y^u is the X -solution of⁸:

$$u(X, \text{Max}(X, CE_Y^v)) = E[u(Y, \text{Max}(Y, X))]. \quad (11)$$

⁸Given that payoff X is certain and that the FS is non-informative, we have $CE_Y^{v,FX} = CE_Y^v$.

The regret certainty equivalent CE_Y^u meets the cancellation price definition of Bell (1983), except that we consider a model which excludes rejoicing. We obtain the following proposition:

Proposition 4. CE_Y^u exists and is unique.

$\underline{y} < CE_Y^u < CE_Y^v$, where \underline{y} denotes the minimum value that Y can take on its support W_Y .

Proof. See Appendix E.

The meaning of Proposition 4 is easy to grasp. When the DM chooses between a sure action X and a risky action Y under a non-informative FS, the choice of the sure action protects her from anticipated regret. When the sure action is chosen, nothing happens after the choice. The DM does not learn the result of the foregone risky lottery and knows, from the decision stage, the payoff of the sure action. There is no arrival of information after the choice and, thus, no reason to feel regret. Consequently, under a non-informative FS, a riskless action is more attractive when the DM is regret-averse than when she is not (c-utility model). The regret certainty equivalent of a risky action is thus lower than its Arrow-Pratt certainty equivalent. Our finding is consistent with the experimental study of Zeelenberg (1999). When people choose between a sure thing and a risky gamble, Zeelenberg (1999) shows that regret-averse people have a greater tendency to choose the sure option when there is no feedback, because, under no feedback, the sure option protects from anticipated regret.

When a regret-averse DM chooses between a risky action and a sure action, she can choose the riskless action X even if that choice involves a POC. This occurs when the payoff of the sure action X verifies $CE_Y^u < X < CE_Y^v$. The difference $CE_Y^v - CE_Y^u$ indicates to what extent the DM is ready to bear a POC in order to avoid anticipated regret. The difference $CE_Y^v - CE_Y^u$ corresponds to the regret premium of Bell (1983). In the present paper, we compute the regret premium with a general regret utility function, encompassing the particular additive regret utility function of Bell (1983). We also establish a connection between our concept of POC and the concept of regret premium.

Corollary 1. *The regret premium $CE_Y^v - CE_Y^u$ corresponds to the maximum POC that a DM is ready to bear to avoid anticipated regret.*

When rejoicing is not taken into account, the regret premium is always positive and is independent of risk preferences.

Bell (1983), who considers rejoicing, shows that the sign of the regret premium depends on the shape of the regret-rejoice function in his additive regret utility function. In contrast, Corollary 1 states that the regret premium is always positive, when rejoicing is not taken into account. Since, empirically, regret aversion has a greater impact than rejoice seeking, we can expect to observe positive regret premiums. Our result is compatible with a wide range of utility functions, including the additive regret utility function of Bell (1983). In particular, we do not assume risk aversion. Under no feedback, a DM, whether she is risk-averse, risk-neutral or risk-loving, has a greater tendency to choose the sure option than a traditional expected utility maximizer. The sign of the regret premium is not determined by risk preferences. More generally, disentangling the effects of regret aversion and risk aversion on decision-making remains an important empirical and theoretical issue.

Somasundaram and Diecidue (2017b) have led an empirical investigation in which, in particular, they study the sign of the regret premium. They propose a very nice decomposition of a DM's risk premium under perfect feedback, which is the sum of the Arrow-Pratt risk premium, of the regret premium and of the resolution premium (difference between the risk premium under feedback and no feedback). In order to compute each component of the risk premium, they use the pairwise choice model of Bell (1982) and Loomes and Sugden (1982). Somasundaram and Diecidue consider two opposing FS: perfect feedback and no feedback. In their approach, the DM's regret aversion is assumed to change with the FS, while the probability of experiencing regret is assumed to be independent of the FS. That is why, in Somasundaram and Diecidue (2017b), the sure action does not fully protect against anticipated regret when the FS is not informative. For that reason, and also because rejoicing is taken into account, Somasundaram and Diecidue find that the regret premium can be negative (depending on probabilities). In our model, when the DM chooses the sure thing and does not observe the result of the foregone risky action (no feedback), the probability of experiencing regret, which is determined endogenously, is equal to zero. In the introduction to his paper, Zeelenberg (1999) says "Take, for example, the often-used choice between a gamble and

a sure thing. If you opt for the sure thing you normally do not learn whether the gamble would have been better. If you opt for the gamble you will always learn the outcome of the gamble and the outcome of the sure thing, thus you will always know whether the sure thing would have been better. Thus the sure thing protects you from regret, whereas the gamble carries some risk of regret. If you in this case anticipate regret you will opt for the sure thing, revealing risk-aversion.” This assertion explains why, in our paper, the regret premium is always positive.

5.3 Regret aversion and information avoidance

In this section, we study the desirability of I , information which arrives at the decision stage, and which can be used by a DM to make her choice. While information value is always positive in the expected utility model, we show that information can be harmful when a DM is regret-averse. We consider a choice set $\{X, Y_1, \dots, Y_N\}$, where X represents a DM’s optimal choice, when information I is not available. If X_I denotes the DM’s optimal choice given information I , we compare the DM’s expected r-utility without information $E[u(X, R^{F_X})]$ with the DM’s expected r-utility when the arrival of information is anticipated $E[u(X_I, R^{I, F_{X_I}})]$. Information avoidance occurs when $E[u(X_I, R^{I, F_{X_I}})] < E[u(X, R^{F_X})]$.

We distinguish two channels through which information operates:

1. First, a DM revises her beliefs in accordance with Bayes’ rule: probability distributions are modified. We call this channel the *probability effect*.
2. Secondly, information can modify the regret that the DM anticipates feeling when she chooses a strategy. We call this channel the *regret effect*. For example, a good signal on action Y can decrease the expected r-utility of action X , because choosing X can expose to feeling more regret than before (the regret of not having chosen Y).

The harmfulness of information might seem somewhat surprising, because we assume that information is processed in an optimal way. The DM effectively uses information I . In order to illustrate this point and understand its underlying mechanisms, we give, in what follows, an example in which information I is harmful.

Example 2. We consider a non-informative FS and a choice set $\Phi = \{Y_1, Y_2\}$ containing two stochastically independent risky actions. Action Y_1 takes value 1 with probability 0.4 and value 2 with probability 0.6. Action Y_2 takes values 0, 1 and 2.5 with equal probabilities. In this example, information I is about Y_2 . We consider a signal on action Y_2 which takes value i_1 when $y_2 = 0$, and i_2 otherwise. The observation of i_1 indicates bad news about Y_2 , while the observation of i_2 indicates rather good news. The DM receives the signal at the decision stage, using it to determine her best choice. The r -utility function is $u(x, r) = x - \frac{r}{2}$ and the c -utility function is $u(x, x) = \frac{x}{2}$.

Table 1: Information avoidance

Y	$E[v(Y)]$	CE_Y^v	$E[u(Y, R^{F_Y})]$	CE_Y^{v, i_1}	CE_Y^{v, i_2}
Y_1	0.8	1.6	0.767	1.6	1.6
Y_2	0.583	1.167	0.216	0	1.75

with $Y \in \{Y_1, Y_2\}$, $E[v(Y)]$ the expected c -utility of Y , CE_Y^v the Arrow-Pratt certainty equivalent of Y , $E[u(Y, R^{F_Y})]$ the expected r -utility of Y , CE_Y^{v, i_1} the Arrow-Pratt certainty equivalent of Y given information i_1 and CE_Y^{v, i_2} the Arrow-Pratt certainty equivalent of Y given information i_2 .

Column 4 in Table 1 indicates that action Y_1 is the optimal strategy without information. The r -utility is equal to 0.767. The signal modifies the certainty equivalent of Y_2 , while keeping unaffected action Y_1 certainty equivalent (see columns 3, 5 and 6 of Table 1).

Table 2: Information avoidance

Y	$E[u(Y, R^{i_1, F_Y}) i_1]$	$E[u(Y, R^{i_2, F_Y}) i_2]$	$E[u(X_I, R^{I, F_{X_I}})]$
Y_1	<u>0.8</u>	0.65	0.75
Y_2	-0.8	<u>0.725</u>	

with $Y \in \{Y_1, Y_2\}$, $E[u(Y, R^{i_1, F_Y}) | i_1]$ the expected r -utility of Y given information i_1 , $E[u(Y, R^{i_2, F_Y}) | i_2]$ the expected r -utility of Y given information i_2 , $E[u(X_I, R^{I, F_{X_I}})]$ the expected r -utility before the signal I , where X_I represents the optimal choice given information I .

In Table 2, we see that $X_{i_1} = Y_1$ and $X_{i_2} = Y_2$ (see columns 2 and 3).

Given i_1 , Y_1 remains optimal. Since $Y_2 = 0$, the DM does not feel any regret and her expected r -utility is higher than before, that is to say $0.8 > 0.767$ (see column 4 in Table 1 and column 2 in

Table 2). This is one consequence of the regret effect of the signal. Even if the signal is about action Y_2 , it affects the expected r -utility obtained from action Y_1 . The comparison between column 4 in Table 1 and column 3 in Table 2 indicates that the expected r -utility from choosing Y_1 has decreased with information i_2 ($0.65 < 0.767$). Choosing Y_1 exposes to more regret than before, because action Y_2 certainty equivalent is greater $CE_{Y_2}^{v,Y_1,i_2} = 1.75 > 1.167$ (see columns 3 and 6 in Table 1). This is another consequence of the regret effect of the signal. Column 3 in Table 2 also indicates that Y_2 becomes the optimal choice. However, given i_2 , the r -utility from choosing Y_2 is equal to 0.725, which is lower than 0.767 (the expected r -utility obtained from Y_1 without the signal). This means that, if the expected r -utility obtained from Y_1 had not decreased, action Y_2 , despite the positive signal i_2 , would not have become optimal. In the r -utility model, the probability effect of the signal i_2 is not sufficient, in itself, to make Y_2 optimal (in contrast with what happens in the c -utility model, see column 6 of Table 1). The strength of regret effect, which decreases the expected r -utility of Y_1 , explains why the DM switches from action Y_1 to action Y_2 . The weakness of the probability effect also explains why this switching results in a decrease of the overall utility from 0.767 to 0.75. The details of the computation are given in Appendix F.

When information directly enters the DM's utility, this can create an incentive to avoid information (Golman *et al.* 2017). In our model, information does not modify only probabilities, but also enters the DM's utility function via the reference point. In the example taken above, we consider a non-informative FS. It would be easy to show that, under a perfectly informative FS, information avoidance does not occur, as in the expected utility model. Under a perfectly informative FS, the expression of the reference point, $R = \text{Max}\{X, Y_1, \dots, Y_N\}$, does not depend on information I . By contrast, when the FS is not perfectly informative, the reference point formula, $R^{I, F_X} = \text{Max}\{X, CE_{Y_1}^{v,I, F_X}, \dots, CE_{Y_N}^{v,I, F_X}\}$, incorporates information I .

6 Conclusion

Regret theory has essentially been developed under perfect feedback, when the outcomes of the foregone actions are perfectly resolved. The more general version developed here accommodates

any type of feedback context, thereby allowing a better understanding of the reference point in the utility function of a regret-averse DM. We show that the reference point does not exclusively represent an anticipated feeling of regret, but embodies a more general emotional mechanism: the fact that choosing has an impact on utility via a mental process which makes the idea of choice painful. Our model highlights the interweaving between this emotional mechanism and information, leading us to conclude that perfect feedback represents a special case, and that a full understanding of decision making in regret theory needs to take into account imperfect feedback.

Appendix A

Under a perfectly informative FS, the expected r-utility of an action Y_j is given by $E[u(Y_j, R)]$, where $R = \max\{Y_1, \dots, Y_{N+1}\}$. Action Y_j statewise dominates action Y_i when $Y_j \geq Y_i$ (with strict inequality holding on a set of non-zero probability). Under assumption A2, we have $E[u(Y_j, R)] > E[u(Y_i, R)]$, which means that Y_j is strictly preferred over Y_i . Preferences are consistent with SD under perfect feedback. We consider now an imperfect or a non-informative FS and the choice set $\Phi = \{X, Y\}$, where X statewise dominates Y . Under assumption A1, we have $X \geq CE_Y^{v, F_X}$ and thus:

$$E[u(X, R^{F_X})] = E\left[u\left(X, \max\{X, CE_Y^{v, F_X}\}\right)\right] = E[u(X, X)] = E[v(X)]. \quad (\text{A.1})$$

We also have $CE_X^{v, F_Y} \geq Y$ and thus:

$$E[u(Y, R^{F_Y})] = E\left[u\left(Y, \max\{Y, CE_X^{v, F_Y}\}\right)\right] = E\left[u\left(Y, CE_X^{v, F_Y}\right)\right] \leq E[v(Y)]. \quad (\text{A.2})$$

X statewise dominates Y implies, under assumption A1, that $E[v(Y)] < E[v(X)]$ and, given equations A.1 and A.2, we obtain $E[u(Y, R^{F_Y})] < E[u(X, R^{F_X})]$. SD is always preserved when the choice set contains two actions. Now, let us give an example in which SD is not preserved. The r-utility function is $u(x, r) = x - \frac{r}{2}$ and the c-utility function is $v(x) = u(x, x) = \frac{x}{2}$. The choice set contains three actions $\Phi = \{Y_1, Y_2, Y_3\}$ characterized by the following payoffs:

Probability	Y_1	Y_2	Y_3
$\frac{1}{4}$	0	15	10
$\frac{1}{4}$	28	10	10
$\frac{1}{4}$	10	5	5
$\frac{1}{4}$	0	5	5

In this example, action Y_2 statewise dominates action Y_3 . We assume that $F_\Phi = \{F_{Y_1}, F_{Y_2}, F_{Y_3}\}$ is a non-informative FS. We first compute the expected r-utility of Y_1 . When Y_1 is chosen and when $y_1 = 0$, the DM does not know the exact payoff of Y_2 (according to the posterior probability distribution, it can be 15 or 5 with equal probabilities) and the exact payoff of Y_3 (according to the posterior probability distribution, it can be 10 or 5 with equal probabilities). The DM compares $y_1 = 0$ with $CE_{Y_2}^{v, y_1=0} = 10$ and with $CE_{Y_3}^{v, y_1=0} = 7.5$.

$$E[u(Y_1, R^{F_{Y_1}})] = \frac{1}{2} \left(0 - \frac{\text{Max}(0, 10, 7.5)}{2} \right) + \frac{1}{4} \left(28 - \frac{\text{Max}(28, 10, 10)}{2} \right) + \frac{1}{4} \left(10 - \frac{\text{Max}(10, 5, 5)}{2} \right) = 2.25. \quad (\text{A.3})$$

Similarly, we compute the expected r-utilities of Y_2 and Y_3 .

$$E[u(Y_2, R^{F_{Y_2}})] = \frac{1}{4} \left(15 - \frac{\text{Max}(15, 0, 10)}{2} \right) + \frac{1}{4} \left(10 - \frac{\text{Max}(10, 28, 10)}{2} \right) + \frac{1}{2} \left(5 - \frac{\text{Max}(5, 5, 5)}{2} \right) = 2.125. \quad (\text{A.4})$$

$$E[u(Y_3, R^{F_{Y_3}})] = \frac{1}{2} \left(10 - \frac{\text{Max}(10, 14, 12.5)}{2} \right) + \frac{1}{2} \left(5 - \frac{\text{Max}(5, 5, 5)}{2} \right) = 2.75. \quad (\text{A.5})$$

Although action Y_2 statewise dominates action Y_3 , action Y_3 is preferred over action Y_2 . Choosing Y_3 gives less information on the payoff of the foregone action Y_1 than choosing Y_2 . Anticipated regret is less salient with action Y_3 . Despite the non-informative FS, action feedbacks are different, namely F_{Y_3} (which consists in exclusively observing Y_3) is less informative than F_{Y_2} (which consists in exclusively observing Y_2). In this example, the difference between action feedbacks prevails over statewise dominance. We can strengthen this informational effect by accentuating the difference between action Y_2 and action Y_3 feedbacks. For example, we can assume that, when the DM

chooses action Y_2 , she receives a perfect signal about the foregone action payoffs, whereas, when Y_3 is chosen, she receives no feedback. Under this imperfect FS, the expected r-utility of Y_3 is not modified, and it could be easily verified that the expected r-utility of Y_2 is equal to 1.5, which is even lower than before.

We consider now a choice set containing $N+1$ stochastically independent actions $\phi = \{Y, Y_1, \dots, Y_N\}$, where Y represents any action in the choice set and Y_1, \dots, Y_N represent the foregone actions when Y is chosen. We also consider a non-informative FS. Under these two assumptions, the choice of a particular action does not give any information on the foregone action payoffs. As a result, the certainty equivalents are independent of the outcome of the choice which has been made. The expected r-utility of any action Y is

$$E[u(Y, R^{F_Y})] = E[u(Y, \text{Max}\{Y, CE_{Y_1}^v, \dots, CE_{Y_N}^v\})] = E[U(Y)], \quad (\text{A.6})$$

where $U(y) = u(y, \text{Max}\{y, CE_{Y_1}^v, \dots, CE_{Y_N}^v\})$ is a strictly increasing function of y under assumptions A1 and A2.

Consequently, if Y_j first-order stochastically dominates Y_i , we have $E[U(Y_j)] > E[U(Y_i)]$. Under a non-informative FS, first-order stochastic dominance is preserved when actions are stochastically independent.

We still consider here a choice set containing $N + 1$ stochastically independent actions but we consider now a perfectly informative FS. The expected r-utility of any action Y is

$$E[u(Y, R^{F_Y})] = E[u(Y, \text{Max}\{Y, Y_1, \dots, Y_N\})]. \quad (\text{A.7})$$

Function $u(y, \text{Max}\{y, y_1, \dots, y_N\})$ is strictly increasing with y under assumptions A1 and A2. Thus $U(y) = E_{Y_1, \dots, Y_N}[u(y, \text{Max}\{y, Y_1, \dots, Y_N\})]$, where the operator $E_{Y_1, \dots, Y_N}[\cdot]$ represents the expectation with respect to Y_1, \dots, Y_N , is also a strictly increasing function of y . Consequently, if Y_j first-order stochastically dominates Y_i , we have $E[U(Y_j)] > E[U(Y_i)]$. Under a perfectly informative FS, first-order stochastic dominance is preserved when actions are stochastically independent.

In order to show that preferences satisfy the ISDA property whatever the FS, we consider the choice set $\Phi = \{Y, Y_1, \dots, Y_N\}$, where Y represents any action in the choice set and where Y_1, \dots, Y_N represent the foregone actions when Y is chosen. The introduction of a new action in the choice set modifies $E[u(Y, R^{F_Y})]$ if it modifies the reference point $R^{F_Y} = \text{Max}\{Y, CE_{Y_1}^{v, F_Y}, \dots, CE_{Y_N}^{v, F_Y}\}$. If we introduce an action Z , which is statewise dominated by Y ($Y \geq Z$, with a strict inequality over a set of non-zero probability) then, under assumption A1, we have $Y \geq CE_Z^{v, F_Y}$. If we introduce an action Z , which is statewise dominated by a foregone action Y_j ($Y_j \geq Z$, with a strict inequality over a set of non-zero probability) then, under assumption A1, we have $CE_{Y_j}^{v, F_Y} \geq CE_Z^{v, F_Y}$. In both cases, we obtain $R^{F_Y} = \text{Max}\{Y, CE_{Y_1}^{v, F_Y}, \dots, CE_{Y_N}^{v, F_Y}, CE_Z^{v, F_Y}\} = \text{Max}\{Y, CE_{Y_1}^{v, F_Y}, \dots, CE_{Y_N}^{v, F_Y}\}$. The expected r-utility of any action Y is the same, whether action Z is present or not in the choice set. The preference ordering between existing actions in the choice set is not modified when action Z is introduced. As previously seen, however, in this Appendix, a DM can choose action Z despite the fact that Z is statewise dominated. In the above example, action Y_1 is preferred over Y_2 but if Y_3 , which is statewise dominated by Y_2 , is introduced in the choice set, the DM modifies her choice in favor of Y_3 .

Appendix B

We consider a non-informative FS, and a choice set containing two stochastically independent risky actions $\Phi = \{X, Y\}$. Under these assumptions, the choice of one action does not give any information on the foregone action payoff. As a result, the certainty equivalents of X and Y are independent of the outcome of the choice which has been made. We have $CE_X^{v, F_Y} = CE_X^v$ and $CE_Y^{v, F_X} = CE_Y^v$. Action X takes value 2.5 with probability 0.1, and value 3 with probability 0.9. Action Y takes value 0 with probability 0.2, and value 4 with probability 0.8. The r-utility function is $u(x, r) = x - \frac{r}{2}$ and the c-utility function is $v(x) = u(x, x) = \frac{x}{2}$. First, we compute the expected c-utilities of X and Y :

$$E[v(X)] = 0.1 \frac{2.5}{2} + 0.9 \frac{3}{2} = 1.475. \quad (\text{B.1})$$

$$E[v(Y)] = 0.2 \frac{0}{2} + 0.8 \frac{4}{2} = 1.6. \quad (\text{B.2})$$

From this, we can easily compute $CE_X^v = 2.95$ and $CE_Y^v = 3.2$. As $CE_Y^v > CE_X^v$, action Y would be optimal in the c-utility model. The expected r-utilities are:

$$E[u(X, R^{F_X})] = 0.1 \left(2.5 - \frac{\text{Max}\{2.5, 3.2\}}{2} \right) + 0.9 \left(3 - \frac{\text{Max}\{3, 3.2\}}{2} \right) = 1.35. \quad (\text{B.3})$$

As, in each state of nature, action X payoff is lower than CE_Y^v , there is a POC of choosing X . Choosing X is painful because, when X is chosen, action Y is the *ex-post* preferred action in all future states of nature.

$$E[u(Y, R^{F_Y})] = 0.2 \left(0 - \frac{\text{Max}\{0, 2.95\}}{2} \right) + 0.8 \left(4 - \frac{\text{Max}\{4, 2.95\}}{2} \right) = 1.305. \quad (\text{B.4})$$

When Y is chosen and when $y = 0$, the decision maker (DM) learns that she has not made the right choice and feels regret ($y = 0 < CE_X^v$). In this example, the DM fears the regret associated with event $y = 0$. Action X represents the optimal choice, despite the associated psychological opportunity cost. As in Example 1, we observe a preference reversal between the c-utility model and the r-utility model.

Appendix C

According to Definition 6, there is a POC of choosing X when another action Y_n is the *ex-post* preferred action in all states:

$$R^{F_X} = CE_{Y_n}^{v, F_X} \geq X \text{ with strict inequality holding on a set of non-zero probability.} \quad (\text{C.1})$$

$$\Leftrightarrow E[v(Y_n) | F_X] \geq v(X) \text{ with strict inequality holding on a set of non-zero probability.} \quad (\text{C.2})$$

$$\Rightarrow E[v(X)] < E[v(Y_n)]. \quad (\text{C.3})$$

In the c-utility model, choosing X is not optimal (whereas it could be easily be shown that Y_n is an optimal choice). If choosing action X involves a POC, then Equation C.3 is satisfied and, under A3, we also have $E[u(X, R^{F_X})] = E[u(X, CE_{Y_n}^{v, F_X})] < E[v(X)]$. We thus obtain:

$$E[u(X, R^{F_X})] < E[v(Y_n)]. \quad (\text{C.4})$$

And, under A3, we also have:

$$E[u(Y_n, R^{F_{Y_n}})] \leq E[v(Y_n)]. \quad (\text{C.5})$$

with equality when $R^{F_{Y_n}} = Y_n$.

Given equations C.4 and C.5, $E[u(X, R^{F_X})] \geq E[u(Y_n, R^{F_{Y_n}})]$ is possible only when C.5 is written with a strict inequality, when event $R^{F_{Y_n}} > Y_n$ occurs with non-zero probability. This condition means that choosing action Y_n exposes a DM to the possibility of facing regret. It is easy to verify that action Y_n , which is always the *ex-post* preferred action when action X is chosen, cannot itself involve a POC.

Appendix D

We focus on action Y_1 . The same reasoning applies to Y_2 . Equation 10 can be written as follows:

$$E[u(Y_1, R^{F_{Y_1}})] = p_1 \Pr(I_1 = \underline{i} | Y_1 = \underline{y}) u(\underline{y}, CE_{Y_2}^{v, \underline{y}, \underline{i}}) + p_1 \Pr(I_1 = \bar{i} | Y_1 = \underline{y}) u(\underline{y}, CE_{Y_2}^{v, \underline{y}, \bar{i}}) + (1 - p_1) u(\bar{y}, \bar{y}). \quad (\text{D.1})$$

$$\begin{aligned}
E[u(Y_1, R^{F_{Y_1}})] &= p_1 \left[\left(p_2 + \frac{\rho}{p_1} \right) q_1 + \left(1 - p_2 - \frac{\rho}{p_1} \right) \underline{p}_1 \right] u(\underline{y}, CE_{Y_2}^{v, \underline{y}, \underline{i}}) \\
&\quad + p_1 \left[\left(\left(p_2 + \frac{\rho}{p_1} \right) (1 - q_1) + \left(1 - p_2 - \frac{\rho}{p_1} \right) (1 - \underline{p}_1) \right) \right] u(\underline{y}, CE_{Y_2}^{v, \underline{y}, \bar{i}}) \\
&\quad + (1 - p_1) u(\bar{y}, \bar{y}). \tag{D.2}
\end{aligned}$$

with

$$v(CE_{Y_2}^{v, \underline{y}, \underline{i}}) = \Pr(Y_2 = \underline{y} | Y_1 = \underline{y}, I_1 = \underline{i}) v(\underline{y}) + \Pr(Y_2 = \bar{y} | Y_1 = \underline{y}, I_1 = \underline{i}) v(\bar{y}). \tag{D.3}$$

and

$$v(CE_{Y_2}^{v, \underline{y}, \bar{i}}) = \Pr(Y_2 = \underline{y} | Y_1 = \underline{y}, I_1 = \bar{i}) v(\underline{y}) + \Pr(Y_2 = \bar{y} | Y_1 = \underline{y}, I_1 = \bar{i}) v(\bar{y}). \tag{D.4}$$

Equations C.3 and C.4 give:

$$v(CE_{Y_2}^{v, \underline{y}, \underline{i}}) = \left[\frac{\left(p_2 + \frac{\rho}{p_1} \right) q_1}{\left(p_2 + \frac{\rho}{p_1} \right) q_1 + \left(1 - p_2 - \frac{\rho}{p_1} \right) \underline{p}_1} \right] v(\underline{y}) + \left[1 - \frac{\left(p_2 + \frac{\rho}{p_1} \right) q_1}{\left(p_2 + \frac{\rho}{p_1} \right) q_1 + \left(1 - p_2 - \frac{\rho}{p_1} \right) \underline{p}_1} \right] v(\bar{y}). \tag{D.5}$$

and

$$\begin{aligned}
v(CE_{Y_2}^{v, \underline{y}, \bar{i}}) &= \left[\frac{\left(p_2 + \frac{\rho}{p_1} \right) (1 - q_1)}{\left(p_2 + \frac{\rho}{p_1} \right) (1 - q_1) + \left(1 - p_2 - \frac{\rho}{p_1} \right) (1 - \underline{p}_1)} \right] v(\underline{y}) \\
&\quad + \left[1 - \frac{\left(p_2 + \frac{\rho}{p_1} \right) (1 - q_1)}{\left(p_2 + \frac{\rho}{p_1} \right) (1 - q_1) + \left(1 - p_2 - \frac{\rho}{p_1} \right) (1 - \underline{p}_1)} \right] v(\bar{y}). \tag{D.6}
\end{aligned}$$

Easy computations give:

$$\frac{\partial v(CE_{Y_2}^{v, \underline{y}, \underline{i}})}{\partial CE_{Y_2}^{v, \underline{y}, \underline{i}}} \frac{\partial CE_{Y_2}^{v, \underline{y}, \underline{i}}}{\partial \rho} = - \frac{q_1 \underline{p}_1}{p_1 \left[(q_1 - \underline{p}_1) \left(p_2 + \frac{\rho}{p_1} \right) + \underline{p}_1 \right]^2} [v(\bar{y}) - v(\underline{y})] \leq 0 \implies \frac{\partial CE_{Y_2}^{v, \underline{y}, \underline{i}}}{\partial \rho} \leq 0. \tag{D.7}$$

$$\frac{\partial v \left(CE_{Y_2}^{v, \underline{y}, \bar{i}} \right)}{\partial CE_{Y_2}^{v, \underline{y}, \bar{i}}} \frac{\partial CE_{Y_2}^{v, \underline{y}, \bar{i}}}{\partial \rho} = - \frac{(1 - \underline{q}_1) (1 - \underline{p}_1)}{p_1 \left[(\underline{p}_1 - \underline{q}_1) \left(p_2 + \frac{\rho}{p_1} \right) + 1 - \underline{p}_1 \right]^2} [v(\bar{y}) - v(\underline{y})] \leq 0 \implies \frac{\partial CE_{Y_2}^{v, \underline{y}, \bar{i}}}{\partial \rho} \leq 0. \quad (\text{D.8})$$

And

$$\begin{aligned} \frac{\partial E[u(Y_1, R^{F_{Y_1}})]}{\partial \rho} &= (\underline{q}_1 - \underline{p}_1) \left[u(\underline{y}, CE_{Y_2}^{v, \underline{y}, \bar{i}}) - u(\underline{y}, CE_{Y_2}^{v, \underline{y}, i}) \right] \\ &\quad + p_1 \left[\left(p_2 + \frac{\rho}{p_1} \right) \underline{q}_1 + \left(1 - p_2 - \frac{\rho}{p_1} \right) \underline{p}_1 \right] u_2(\underline{y}, CE_{Y_2}^{v, \underline{y}, i}) \frac{\partial CE_{Y_2}^{v, \underline{y}, i}}{\partial \rho} \\ &\quad + p_1 \left[\left(p_2 + \frac{\rho}{p_1} \right) (1 - \underline{q}_1) + \left(1 - p_2 - \frac{\rho}{p_1} \right) (1 - \underline{p}_1) \right] u_2(\underline{y}, CE_{Y_2}^{v, \underline{y}, \bar{i}}) \frac{\partial CE_{Y_2}^{v, \underline{y}, \bar{i}}}{\partial \rho}. \quad (\text{D.9}) \end{aligned}$$

Since $CE_{Y_2}^{v, \underline{y}, \bar{i}} \geq CE_{Y_2}^{v, \underline{y}, i}$, the first term in Equation D.9 is positive under A3. Given equations D.7 and D.8, the second and third term in Equation D.9 are positive under A3. We thus have $\frac{\partial E[u(Y_1, R^{Y_1})]}{\partial \rho} \geq 0$.

Appendix E

When $X = \underline{y}$, Equation 11 is not satisfied. Under A1 and A3, the comparison between the left-hand side and the right-hand side of Equation 11 gives:

$$u(\underline{y}, CE_Y^v) < E[u(Y, Y)]. \quad (\text{E.1})$$

When $X = CE_Y^v$, Equation 11 is not satisfied. Under A3, we have:

$$u(CE_Y^v, CE_Y^v) > E[u(Y, \text{Max}\{CE_Y^v, Y\})]. \quad (\text{E.2})$$

We demonstrate the following lemma:

Lemma 1. *Function $u(x, \text{Max}\{x, CE_Y^v\})$ strictly increases with x , and function $E[u(y, \text{Max}\{x, y\})]$*

strictly decreases with x .

Proof. When $x \leq CE_Y^v$, $u(x, \text{Max}\{x, CE_Y^v\}) = u(x, CE_Y^v)$, which strictly increases with x under A2. When $x > CE_Y^v$, $u(x, \text{Max}\{x, CE_Y^v\}) = u(x, x) = v(x)$ which strictly increases with x under A1. Function $u(x, \text{Max}\{x, CE_Y^v\})$ thus strictly increases with x .

When $x < y$, $u(y, \text{Max}\{x, y\}) = u(y, y)$, which is independent of x . When $x \geq y$, $u(y, \text{Max}\{x, y\}) = u(y, x)$ which strictly decreases with x under A3. Function $E[u(y, \text{Max}\{x, y\})]$ thus strictly decreases with x , provided that $x \geq \underline{y}$. \square

Given equations E.1 and E.2 and Lemma 1, and under assumption A0, the X -solution of Equation 11 exists, is unique and belongs to $]\underline{y}, CE_Y^v[$.

Appendix F

Under the assumptions of Example 2, the choice of one action does not give any information on the foregone action payoff. As a result, the certainty equivalents of Y_1 and Y_2 are independent of the outcome of the choice which has been made. We have $CE_{Y_1}^{v, F_{Y_2}} = CE_{Y_1}^v$ and $CE_{Y_2}^{v, F_{Y_1}} = CE_{Y_2}^v$. First, we compute the expected c-utilities and the certainty equivalents of Y_1 and Y_2 :

$$E[v(Y_1)] = 0.4 \frac{1}{2} + 0.6 \frac{2}{2} = 0.8 \text{ and } CE_{Y_1}^v = 1.6. \quad (\text{F.1})$$

$$E[v(Y_2)] = \frac{1}{3} \frac{0}{2} + \frac{1}{3} \frac{1}{2} + \frac{1}{3} \frac{2.5}{2} \simeq 0.583 \text{ and } CE_{Y_2}^v \simeq 1.167. \quad (\text{F.2})$$

The expected r-utilities when there is no signal are

$$E[u(Y_1, R^{F_{Y_1}})] = 0.4 \left(1 - \frac{\text{Max}\{1, 1.167\}}{2}\right) + 0.6 \left(2 - \frac{\text{Max}\{2, 1.167\}}{2}\right) \simeq 0.767. \quad (\text{F.3})$$

$$E[u(Y_2, R^{F_{Y_2}})] = \frac{1}{3} \left(0 - \frac{Max\{0, 1.6\}}{2} \right) + \frac{1}{3} \left(1 - \frac{Max\{1, 1.6\}}{2} \right) + \frac{1}{3} \left(2.5 - \frac{Max\{2.5, 1.6\}}{2} \right) \simeq 0.217. \quad (F.4)$$

Action Y_1 represents the optimal choice and the DM's expected r-utility is 0.767.

When information i_1 is received, the expected r-utilities become

$$E[u(Y_1, R^{i_1, F_{Y_1}}) | i_1] = 0.4 \left(1 - \frac{Max\{1, 0\}}{2} \right) + 0.6 \left(2 - \frac{Max\{2, 0\}}{2} \right) = 0.8. \quad (F.5)$$

$$E[u(Y_2, R^{i_1, F_{Y_2}}) | i_1] = 0 - \frac{Max\{0, 1.6\}}{2} = -0.8. \quad (F.6)$$

We thus have $X_{i_1} = Y_1$.

When information i_2 is received, Y_2 can take values 1 and 2.5 with equal probabilities. Let us first compute the expected c-utility of Y_2 and its certainty equivalent given i_2 .

$$E[v(Y_2) | i_2] = \frac{1}{2} \frac{1}{2} + \frac{1}{2} \frac{2.5}{2} = 0.875 \text{ and } CE_{Y_2}^{v, i_2} = 1.75. \quad (F.7)$$

Then, the expected r-utilities are:

$$E[u(Y_1, R^{i_2, F_{Y_1}}) | i_2] = 0.4 \left(1 - \frac{Max\{1, 1.75\}}{2} \right) + 0.6 \left(2 - \frac{Max\{2, 1.75\}}{2} \right) = 0.65. \quad (F.8)$$

$$E[u(Y_2, R^{i_2, F_{Y_2}}) | i_2] = \frac{1}{2} \left(1 - \frac{Max\{1, 1.6\}}{2} \right) + \frac{1}{2} \left(2.5 - \frac{Max\{2.5, 1.6\}}{2} \right) = 0.725. \quad (F.9)$$

We thus have $X_{i_2} = Y_2$. Information i_2 increases utility obtained from strategy Y_2 , and decreases utility obtained from strategy Y_1 .

Before receiving the information, the expected r-utility is:

$$E[u(X_I, R^{F_{X_I}})] = \frac{1}{3} \times 0.8 + \frac{2}{3} \times 0.725 = 0.75 < 0.767. \quad (F.10)$$

The expected r -utility when information I is expected to be received, is lower than the expected r -utility when no information is expected. This is tantamount to saying that information is harmful.

References

- Bell, D. E., 1982. Regret in decision making under uncertainty. *Operations Research* 30(5), 961-981.
- Bell, D. E., 1983. Risk premiums for decision regret. *Management Science* 29(10), 1156-1166.
- Bleichrodt, H., Cillo, A., Diecidue, E., 2010. A quantitative measurement of regret theory. *Management Science* 56(1), 161-175.
- Bleichrodt, H., Wakker, P.P., 2015. Regret theory: a bold alternative to the alternatives. *The Economic Journal* 125(March), 493-532.
- Carmon, Z., Wertenbroch, M., Zeelenberg, M., 2003. Option attachment: when deliberating makes choosing feel like losing. *Journal of Consumer Research* 30(1), 15-29.
- Denuit, M., Eeckhoudt, L., Rey, B., 2010. Some consequences of correlation aversion in decision science. *Management Science* 53(1), 117-124.
- Diecidue, E., Somasundaram, J., 2017a. Regret theory: A new foundation. *Journal of Economic Theory* 172, 88-119.
- Epstein, L. G., Tanny, S.M., 1980. Increasing generalized correlation: A definition and some economic consequences. *Canadian Journal of Economics* 13, 16-34.
- Epstude, K., Roese, N. J., 2008. The functional theory of counterfactual thinking. *Personality and Social Psychology Review* 12(2), 168-192.
- Fishburn, P. C., 1989. Non-transitive measurable utility for decision under uncertainty. *Journal of Mathematical Economics* 18(2), 187-207.
- Gilovich, T., 1983. Biased evaluation and persistence in gambling. *Journal of Personality and Social Psychology* 44(6), 1110-1126.

- Gollier, C., 2018. Aversion to risk of regret and preference for positively skewed risks. *Economic Theory*, <https://doi.org/10.1007/s00199-018-1154-4>.
- Golman, R., Hagmann, D., Loewenstein, G., 2017. Information Avoidance. *Journal of Economic Literature* 55(1), 96-135.
- Humphrey, S., 2004. Feedback-conditional regret theory and testing regret-aversion in risky choice. *Journal of Economic Psychology* 25(6), 839-857.
- Krähmer, D., Stone, R., 2008. Regret in dynamic decision problems. Working paper.
- Loomes, G., Sugden, R., 1982. Regret theory: an alternative theory of rational choices under uncertainty. *The Economic Journal* 92(368), 805-824.
- Loomes, G., Sugden, R., 1987. Some implications of a more general form of regret. *Journal of Economic Theory* 41(2), 270-287.
- Mellers, B. A., 2000. Choice and the relative pleasure of consequences. *Psychological Bulletin* 126(6), 910-924.
- Mellers, B. A., Schwartz, A., Ritov, I., 1999. Emotion-based choice. *Journal of Experimental Psychology: General* 128(3), 332-345.
- Quiggin, J., 1994. Regret theory with general choice sets. *Journal of Risk and Uncertainty* 8(2), 153-165.
- Roese, N.J., 1997. Counterfactual thinking. *Psychological Bulletin* 121(1), 133-148.
- Somasundaram, J., Diecidue, E., 2017b. Regret theory and risk attitudes. *Journal of Risk and Uncertainty* 55(2-3), 147-175.
- Strack, P., Viefers, P., 2014. Too proud to stop: regret in dynamic decisions. <http://dx.doi.org/10.2139/ssrn.2465840>.
- Sugden, R., 1993. An axiomatic foundation for regret theory. *Journal of Economic Theory* 60(1), 159-180.

- Tchen, A., 1980. Inequalities for distributions with given marginals. *Annals of Probability* 8, 814–827.
- Tykocinski, O. E., Pittman, T. S., 1998. The consequences of doing nothing: inaction inertia as avoidance of anticipated counterfactual regret. *Journal of personality and social psychology* 75(3), 607-616.
- Van de Ven, N., Zeelenberg, M., 2011. Regret aversion and the reluctance to exchange lottery tickets. *Journal of Economic Psychology* 32(1), 194-200.
- Zeelenberg, M., 1999. Anticipated regret, expected feedback and behavioral decision making. *Journal of Behavioral Decision Making* 12, 93-106.
- Zeelenberg, M., Beattie, J., van der Pligt, J., de Vries, N.K., 1996. Consequences of regret aversion: Effects of expected feedback on risky decision making. *Organizational Behavior and Human Decision Processes* 65, 148-158.
- Zeelenberg, M., Pieters, R., 2007. A theory of regret regulation 1.0. *Journal of Consumer Psychology* 17(1), 3-18.

GREThA UMR CNRS 5113

Université de Bordeaux
Avenue Léon Duguit
33608 Pessac – France
Tel : +33 (0)5.56.84.25.75

<http://gretha.u-bordeaux.fr/>

LAREFI

Université de Bordeaux
Avenue Léon Duguit
33608 Pessac – France
Tel : +33 (0)5.56.84.25.37

<http://larefi.u-bordeaux.fr/>

Last issues - Derniers numéros

- 2020-03 **Emergence et viabilité d'une filière de production dans l'imagerie médicale : les syndicats face à la politique industrielle française**
by Samuel KLEBANER
- 2020-02 **Understanding the Dynamics of Value Chains with Irreversible Investments**
by Lionel COSNARD
- 2020-01 **Coming from afar and picking a man's job: Women immigrant inventors in the United States**
by Edoardo FERRUCCI & Francesco LISSONI & Ernest MIGUELEZ
- 2019-17 **Public R&D and green knowledge diffusion: Evidence from patent citation data**
by Gianluca ORSATTI
- 2019-16 **Tied in: the Global Network of Local Innovation**
by Ernest MIGUELEZ & Julio RAFFO & Christian CHACUA & Massimiliano CODA-ZABETTA & Deyun YIN & Francesco LISSONI, Gianluca TARASCONI
- 2019-15 **The impact of the abolishment of the professor's privilege on European university-owned patents**
by Catalina MARTINEZ & Valerio STERZI
- 2019-14 **Between territorial and virtual proximities. The digitization process of the French ecosystem of complementary local currencies**
by Yannick LUNG & Léo MALHERBE & Matthieu MONTALBAN
- 2019-13 **MUST-B: a multi-agent LUTI model for systemic simulation of urban policies**
by Nathalie GAUSSIER & Seghir ZERGUINI
- 2019-12 **Industry 4.0, towards a de-globalization of value chains? Expected effects of advanced industrial robotics and additive manufacturing on the coordination system**
by Vincent FRIGANT

Ion LAPTEACRU and Ernest MIGUELEZ are the scientific coordinators of the Bordeaux Economics Working Papers. The layout and distribution are provided by Cyril MESMER and Julie VISSAGUET.