Up Close it Feels Dangerous: Anxiety in the Face of Risk

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Abstract

We model an anxious agent as one who is more risk averse for imminent than for distant risk. Such preferences can lead to dynamic inconsistencies with respect to risk trade-offs. We derive implications for financial markets such as a term structure of risk premia, as well as overtrading and price anomalies around announcement dates, which are found empirically. We show that strategies to cope with anxiety can explain costly delegation of investment decisions. Finally, we model how an anxiety-prone agent may endogenously become overconfident and take excessive risks.
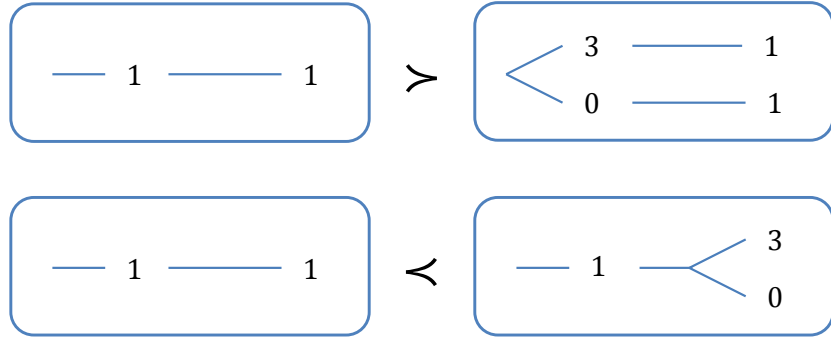
Figure 1: Preference of an anxious agent

1 Introduction

Economists have extensively investigated dynamically inconsistent preferences. The literature has, however, focused on inconsistency of *time* preferences, while neglecting implications for risk preferences. We study a particular case of dynamically inconsistent *risk* preferences. Using these preferences, we are able to address pricing anomalies concerning instantaneous risk-return tradeoffs, which hyperbolic discounting cannot address even in a dynamic model.[1]

We define an anxiety-prone decision maker as more risk averse for imminent than for distant risk. As the resolution of uncertainty draws close, such an agent wants to pull back from gambles he previously decided to take, although there is no new information, and despite his beliefs not having changed for any other reason. This basic preference is illustrated in Figure 1 which displays the choices between intertemporal consumption streams consisting of sure payoffs of 1 and a coin toss with payoffs $\{0, 3\}$. When the coin toss comes in the first period and is therefore imminent, the agent prefers the deterministic consumption stream but when the coin toss comes in the second period, the agent prefers the uncertain consumption stream.

Such behavior is the result of dynamically inconsistent preferences with respect to risk trade-offs. This is markedly different from an agent having time-changing risk preferences. For an agent who simply values risks differently at different points

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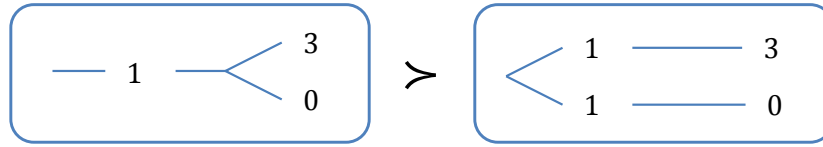
[1]See Luttmer and Mariotti (2003).

Figure 2: Preference for late resolution

in time, there is no intrapersonal disagreement about risk preferences (and the price of risky assets, for that matter). It is also distinct from a preference for the timing of the resolution of uncertainty, as an anxiety prone decision maker violates the axiom in Kreps and Porteus (1978) that assumes temporal consistency. For comparison, Figure 2 displays a preference for late resolution using the consumption streams analogous to Figure 1.

If an anxiety-prone agent trades in a financial market, he will require a higher risk premium for uncertainty resolved in the near future than for uncertainty resolved in the distant future. If there are sufficiently many anxious agents in the population, this implies a down-ward sloping term structure for risk premia. In fact, recent empirical work by van Binsbergen, Brandt, and Koijen (2011) finds just that, with claims to short-term dividends having almost twice the risk adjusted return of claims on long-term dividends.

In addition, anxiety causes an agent to trade excessively around dates of resolution of uncertainty such as earnings announcements. More specifically, he will sell risky securities just before information about these securities' payoffs is revealed, and buy back his position after the resolution of the risks. Such trading causes a predictable price dip before announcement dates, and price increases in the period the risk gets resolved. The empirical literature has found such an anomaly, and discussed it as the 'earnings announcement premium' (Bernard and Thomas, 1989). Lamont and Frazzini (2007) confirm that the selling pressure before the announcement as well as the buy pressure after the event stems from small investors, with large and presumably sophisticated investors taking the other side of the trades. Our theory predicts both of these features.

We also predict investor returns associated with such behavior. Overtrading due to anxiety is costly for two reasons. First, trading costs eat up returns even

if trading per se does not lead to losses. Odean (1999) famously documents this. Second, anxious investors sell before announcements when prices tend low, and buy back at higher prices after the resolution of uncertainty, thus losing with each round of trading in expectation, even absent trading costs. The sum of transaction costs and systematic trading losses may explain why retail investors shun equity exposure at prices neoclassical theory would predict. This gives rise to the equity premium puzzle. Our theory thus views (i) overtrading (ii) price anomalies around announcements and (iii) the equity risk premium as stemming from a single behavioral distortion – anxiety.

It is natural to expect sophisticated agents to come up with strategies to cope with anxiety. Such strategies involve the delegation of investment decisions, which is otherwise puzzling in light of sub-par performance of money managers (Gruber, 1996). Paying an agent to carry out future decisions according to present preferences is a simple but effective way to solve the dynamic inconsistency with respect to risks. Our theory also suggest a demand for particular fee schedules featured in investment funds and brokerage accounts. For example, an anxiety prone decision maker will prefer to have to pay for – or better yet be denied – immediate information about fund performance, because such information may prompt his future self to trade out of a position deemed reasonable presently. This is particularly true for information about increased risks, as we will explain in the section on overconfidence. The timing of investment decisions will be affected as well. Agents will invest in recent winners and pull out funds from recent losers, as Sirri and Tufano (1998) observe. No learning about fund managers' ability is required to explain this pattern.

As another strategy to cope with anxiety, we present a model of endogenous overconfidence. The desire to confine future behavior to present preferences gives rise to a demand for overconfidence. If exposed to a risky environment, the agent finds it beneficial to have overconfident beliefs in the future, as overconfidence helps counterbalance the anxiety he expects his future self to exhibit. Underestimating the risks, his future self will be more likely to take gambles that are favorable according to the manipulating self's preferences, but not according to the anxious self's preferences. We show that the agent can deceive himself to gener-

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ate such biased beliefs in an intrapersonal strategic communication game between his present and future self, despite the future self being a rational Bayesian updater and being aware of being deceived by its previous self. A comparative statics analysis confirms the intuition that agents more prone to anxiety are more likely to be overconfident, and that they tend to be overconfident to a greater degree. We thus provide a first micro-foundation of a systematic bias of beliefs that has helped explain many puzzles in financial economics that neoclassical theory has left open, such as seemingly excessive amounts of trade.

Moreover, as a result of overconfidence, an anxiety-prone agent may appear to take excessive risks. In our model, overconfidence arises only in high-risk environments. Therefore, we suggest that excessive risk-taking should feature most prominently in inherently risky domains such as securities trading. We conjecture that features of intra-organizational communication patterns can be explained with our theory. Occupational choices and associated cognitive dissonance are other areas we see fit. Ben-David, Graham, and Harvey (2010) confirm that financial top executives are systematically overconfident (realized market returns are within their 80% confidence intervals only 33% of the time). Ben-David, Graham, and Harvey (2007) show that this overconfidence translates into riskier corporate policy.

The rest of this paper is organized as follows. In Section 1.1 we relate our work to previous research on anxiety, both in psychology and economics. We present experimental evidence to support our *assumptions*, as well as a short overview on the literature on overconfidence, a *prediction* of our model. Section 2 presents our formal setup. Section 3 investigates how an anxiety-prone agent behaves in a stylized financial market. We also discuss implied institutional effects in that section. Section 4 presents our model of endogenous overconfidence. We conclude and lay out ideas for future research in Section 5.

1.1   Related Literature

Anxiety

People become 'anxious' as they approach risky situations. To measure 'anxiety' (in a popular sense of the word), psychologists have investigated physiological, emotional, and cognitive responses to anxiety provoking situations. All of them involve being exposed to risks, and immediacy of the risk is found to be a leading determinant for physiological and behavioral reactions to the risk. To illustrate, Roth, Breivik, Jørgensen, and Hofmann (1996) continues a whole series of psychological studies on anxiety of parachutists as the moment of the jump approaches, as well as during the fall (Fenz and Epstein, 1967; Fenz and Jones, 1972). Self-reported anxiety, heart rate and other measures peak right before the jump in novices.[2] Experienced jumpers learn to inhibit or control their fear, which helps them to perform better in their risky endeavor. Paterson and Neufeld (1987) also find imminence to be a major determinant of the appraisal of a threat in the laboratory. Objectively observable physiological responses besides heart beat and self-reported anxiety include sweating (Monat and Lazarus, 1991).

Lo and Repin (2002) measure the same physical responses of day traders to anxiety provoking situations. In a follow-up paper, Lo, Repin, and Steenbarger (2005) confirm that traders with stronger emotional response generate lower returns. We will argue in this paper that the response to anxiety in the face of risk includes changes of risk preferences, which cause trading losses. Indeed, Loewenstein, Weber, and Hsee (2001) list changes of risk preferences as emotional reactions to the immediacy of risk, despite cognitive evaluations of the risks remaining unchanged.

Economists have used the term anxiety before only in very specific circumstances. Maybe most notably, Epstein and Kopylov (2007) have a model of 'cold feet', in which a decision maker becomes more *pessimistic* as risks approach. Besides the prediction that people may pull back from risks previously decided to

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[2]Fear of flying seems a more commonly experienced situation. Accident statistics rarely change significantly between the time of ticket purchase and the actual flight. Yet, many passengers get more anxious as take-off is imminent. Introspection suggests that the run-up to an academic talk or other forms of public speaking, or performing music, trigger similar feelings.

take, their axiomatization has little in common with our approach.

Experimental Evidence

There is a significant body of experimental evidence documenting agents who are more risk averse if the resolution of uncertainty is temporally close than when it is distant. We want to highlight three studies which are particularly close to the phenomenon we address in this paper.[3]

Jones and Johnson (1973) have subjects participate in a simulated medical trial for a new drug where they have to decide on a dose of the drug to be administered. The subjects are told that the probability of experiencing unpleasant side-effects is increasing in the dose administered, as is the monetary compensation. More risk averse subjects should then choose lower doses than less risk averse subjects. In line with the predictions of our theory of anxiety, the study finds that subjects choose higher doses if they are to be administered the next day than when they are to be administered immediately.

In a second, more recent study by Onculer (2000), subjects are asked to state their certainty equivalent for a lottery to be resolved immediately, as well as for the same lottery to be resolved in the future. A lower certainty equivalent corresponds to higher risk aversion. The study finds that subjects state significantly lower certainty equivalents for the immediate lottery than for the future lottery.

The third study is by Noussair and Wu (2006). The study presents subjects with a list of choices between two binary lotteries as in Holt and Laury (2002). The first lottery always has prizes ($10.00, $8.00) while the second lottery always has prizes ($19.25, $0.50). Going down the list, only the respective probabilities of the two prizes change, varying from $(0.1, 0.9)$ to $(0.9, 0.1)$. As probability mass shifts from the second prize to the first prize, the second lottery becomes increasingly attractive compared to the first lottery. Subjects are asked to pick one of two lotteries for each of the probability distributions. The probability distribution at which a subject switches from the "safe" lottery to the "risky" lottery is a proxy

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[3]For other classic studies see Shelley (1994), Keren and Roelofsma (1995), and Sagristano, Trope, and Liberman (2002). Very recent work documenting the effect is in Baucells and Heukamp (2010), Coble and Lusk (2010), and Abdellaoui, Diecidue, and Onculer (2011).

for the subject's risk aversion. One of the chosen lotteries is actually played out, either on the same day or three months later. The study finds that 38.5% of subjects are more risk averse for the present than for the future.[4] Note that this study finds a within-subject effect!

In sum, people react differently to risks as a function of the time to resolution of the uncertainty *without believing the situation to get more risky.*

Overconfidence and its Relation to Forgetting

The previous subsection provided evidence to support the *assumption* of our model – higher risk aversion if the resolution of uncertainty is more imminent. In this section, we review psychological evidence of one of the model's *predictions*, namely that anxiety-prone agents exhibit overconfidence.[5]

Beginning with Adams and Adams (1961), countless studies in cognitive psychology on the calibration of subjective probabilities have reported that people overestimate the precision of their knowledge (Kahneman and Tversky, 1973; Alpert and Raiffa, 1982). Subjects often answer general knowledge questions incorrectly, yet with high reported confidence or even certainty. Indeed, they are so confident that they are willing to bet on their answers' correctness (Fischhoff, Slovic, and Lichtenstein, 1977). The effect abates, but does not disappear, when subjects are informed about other subjects' overconfidence in the task at hand. Psychologist as subjects are no exception (Oskamp, 1965). More particularly, overconfidence is greatest for difficult tasks, for forecasts with low predictability, and for undertakings lacking fast and clear feedback (Fischhoff, Slovic, and Lichtenstein, 1977; Hoffrage, 2004). Financial markets are a prime example of such an environment.

As for the mechanism how overconfidence is generated, in his essay "On the

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[4]7.7% are more risk averse for the future than the present and the risk aversion of the remaining subjects does not change.

[5]We emphasize the distinction between overconfidence, which refers to holding beliefs with excessively high precision, and over-optimism, which refers to overestimating the mean of a distribution. Neither is implied by the other, as Hvide (2002) clearly illustrates. Over-optimism is also documented in the psychology literature, albeit less prominently than overconfidence (see Langer, 1975; Weinstein, 1980; Moore and Healy, 2008). Applications of overoptimism to economics, such as Van den Steen (2004), are almost exclusively outside of the finance domain.

psychological mechanism of forgetting," Freud (1901) suggests that anxiety triggering information is prevented from entering memory and gets suppressed (see also Guenther, 1988). An implication is that forgetting probabilities in anxiety triggering environments should be higher than in subjectively safe situations. Zeller (1950) shows that more anxious people are more forgetful as a result of repression. Holmes (1995) gives a review of other experiments validating the memory manipulation implications of anxiety. Deliberate memory manipulation is also implied in Pearlin and Radabaugh (1976), who find that people "who experienced increased anxiety [...], showed stronger tendencies to endorse drinking as a way of controlling distress" (see also Morris and Reilly, 1987).

While overconfidence is a prediction of our model, existing models use overconfidence as an ingredient for finance applications. Agents in those models usually overestimate the precision of signals. Quite naturally, it leads to overreaction to the news associated with the overweighted signal (Daniel, Hirshleifer, and Subrahmanyam, 1998). Other uses of overconfidence are in explaining possibly excessive trade volume (Scheinkman and Xiong, 2003), and pricing of consumer products (Grubb, 2009). We are not aware of prior work that is concerned with overconfidence as a commitment device to take risks.

2 Model

Denote a possibly random intertemporal payoff stream from period t to period T by $X_t^T = (x_t, x_{t+1}, \ldots, x_T)$. Our anxiety-prone agent evaluates the consumption stream X_t^T according to the utility function

$$U_t(X_t) = E_t\left[v(x_t) + \delta u(x_{t+1}) + \cdots + \delta^{T-t}u(x_T)\right],$$

where v and u are von Neumann-Morgenstern utility indices, $\delta \leq 1$ is a discount factor and E_t is the expectations operator conditional on the information available at the beginning of period t.[6]

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[6]Assuming time separable utility inevitably implies marginal rates of inter-temporal substitution. Several recent writings find this a desirable trait, and explore the joint effects of non-exponential discounting and implied non-constant risk aversion. See, for example Fuden-

The only difference between our agent and a standard agent is that uncertainty in the current period is evaluated according to the utility function v while uncertainty in all future periods is evaluated according to the utility function u. To capture the effect of anxiety affecting imminent uncertainty, we assume that v is more risk averse than u.[7] The key effect of this assumption is that it introduces a time inconsistency in the agent's preferences which implies that he may choose differently from a given set of alternatives depending on the period of choice. The following example illustrates this point.

Example Let $v(x) = \sqrt{x}$ and $u(x) = x$ and let $\delta = 1$. Then the decision maker is risk averse with respect to current uncertainty and risk neutral with respect to future uncertainty. Now consider the following two lotteries:

$$\tilde{x} = \begin{cases} 4 & \text{with prob. } \alpha \\ 0 & \text{with prob. } 1 - \alpha \end{cases} \quad \text{and} \quad \tilde{y} = 1$$

Then v prefers the risky $\tilde{x}$ to the safe $\tilde{y}$ if $\alpha > \frac{1}{2}$ while u prefers $\tilde{x}$ to $\tilde{y}$ if $\alpha > \frac{1}{4}$ and there is disagreement between the two utility functions for all $\alpha \in \left(\frac{1}{4}, \frac{1}{2}\right)$. In particular, suppose that $\alpha = \frac{1}{3}$ and that the lotteries are resolved and paid out in period t. Then the agent will choose the safe option $\tilde{y}$ in period t but would prefer to commit to the risky option $\tilde{x}$ in all prior periods $t' < t$. He is willing to pay up to $\frac{1}{3}$ to commit to the risky option before period t and is willing to pay up to $\frac{5}{9}$ to avoid the risky option in period t.

3 Finance Applications

3.1 Term Structure of Risk Premia

Recent empirical work by van Binsbergen, Brandt, and Koijen (2011) finds a downward-sloping term structure of risk premia in the stock market. Based on

berg and Levine (2010), and Halevy (2008). The inter-temporal effect is, however, not the focus of our paper.

[7]Our notion of "more risk averse than" is the standard one going back to Pratt (1964).

	ST claim	S&P 500
Mean	1.16%	0.56%
Std. dev.	7.80%	4.69%
Sharpe ratio	0.1124	0.0586

Table 1: Monthly returns of short-term dividend strip and of the S&P 500 itself. Adapted from Table 1 in van Binsbergen, Brandt, and Koijen (2011).

the S&P 500, the paper prices a claim on the dividends in the near future in contrast to the value of the S&P 500 itself which is a claim on *all* future dividends.[8] The striking result is that the returns from holding the claim to only the short-term dividends is much higher than the return to holding the claim to all future dividends as displayed in Table 1 adapted from Table 1 in van Binsbergen, Brandt, and Koijen (2011). Not only is the return on the short-term claim higher – 14.8% vs. 6.9% annualized – but the Sharpe ratios show that also the risk adjusted excess return is almost twice as high for the short-term claim. These results strongly suggest that the risk premium for uncertainty resolved in the near future is significantly higher than the risk premium for uncertainty resolved in the distant future. We now show how our model of anxiety can easily account for this effect.

We consider a standard asset pricing setup in discrete time with two periods $t = 0, 1$. There are two assets, asset 0 pays a random dividend d_0 at the end of period 0 while asset 1 pays a random dividend d_1 at the end of period 1. Each asset is in net supply of 1 and the dividends d_t are i.i.d. At the beginning of period $t = 0$, the agent has to form a portfolio $(\phi_0, \phi_1, \xi_0, \xi_1)$ of the two assets as well as borrowing/lending for $t = 0, 1$, given some initial wealth w to solve the following

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[8]Since these dividend strips are not actually traded, the prices are derived from the prices of options on the S&P 500 using only a no-arbitrage condition (put call parity).

problem

$$\max_{\{\phi_0,\phi_1,\xi_0,\xi_1\}} E\left[v\left(c_0\right) + \delta u\left(c_1\right)\right]$$

$$\text{s.t.} \quad c_t = d_t\phi_t + \xi_t \text{ for } t = 0, 1$$

$$p_0\phi_0 + \xi_0 + p_1\phi_1 + \frac{\xi_1}{1+r} \leq w$$

For simplicity we assume that the risk-free rate $r = 0$ and that the agent's discount factor $\delta = 1$. Then the first-order conditions for an interior solution are

$$E\left[v'\left(c_0\right)\left(d_0 - p_0\right)\right] = 0$$

$$\text{and} \quad E\left[u'\left(c_1\right)\left(d_1 - p_1\right)\right] = 0.$$

For an anxiety-prone representative agent we have $c_0 = d_0$ and $c_1 = d_1$ which gives us the following result on risk premia. (All proofs are relegated to the appendix.)

Proposition 1 *If v is more risk averse than u, the return on the short-term claim is higher than the return on the long-term claim:*

$$\frac{E\left[d_0\right]}{p_0} > \frac{E\left[d_1\right]}{p_1}$$

This result shows that the anxiety model can directly account for the downward-sloping term structure of risk premia documented in van Binsbergen, Brandt, and Koijen (2011), in contrast to the leading asset pricing models currently in use.[9]

3.2 Announcement Effects

We now turn to the effects anxiety has in the context of announcements. We continue to use the standard setup of the previous section with two periods $t = 0, 1$. However, we now consider only a single asset with net supply of 1 and a

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[9]van Binsbergen, Brandt, and Koijen (2011) show that the term structure of risk premia is *upward-sloping* in both the habit formation model of Campbell and Cochrane (1999) as well as the long-run risk model of Bansal and Yaron (2004) which uses the recursive preferences of Epstein and Zin (1989).

random payoff d which is realized at the end of period 1. No uncertainty is resolved between period 0 and period 1. The uncertainty about the asset's payoff is meant to represent a scheduled earnings announcement which provides information about the stock's dividend. It can also be interpreted more generally as the resolution of payoff-relevant information for holders of the stock – the key element is that the timing of the resolution is fixed and known in advance.

The price of the stock in period t is denoted by p_t and borrowing and lending is possible at a risk-free rate of zero. At the beginning of each period t, the agent has to form a portfolio (ϕ_t, ξ_t) of stock holdings and borrowing/lending, given beginning-of-period wealth w_t.

We solve backwards. In period 1, the uncertainty of the stock's payoff is imminent so the anxious agent chooses a portfolio (ϕ_1, ξ_1) to solve

$$\max_{(\phi_1, \xi_1)} E\left[v\left(c_1\right)\right]$$
$$\text{s.t.} \quad c_1 = \phi_1 d + \xi_1$$
$$\phi_1 p_1 + \xi_1 \leq w_1$$

The first-order condition for an interior solution is

$$E\left[v'\left(\phi_1 d + w_1 - \phi_1 p_1\right)\left(d - p_1\right)\right] = 0. \tag{1}$$

If the agent already makes the portfolio decision in period 0, the non-anxious preferences u apply, and the first-order condition is

$$E\left[u'\left(\phi_0 d + w_0 - \phi_0 p_0\right)\left(d - p_0\right)\right] = 0. \tag{2}$$

Overtrading

Consider our anxiety-prone agent in an asset market dominated by standard agents with dynamically consistent risk aversion. Since there is no additional information revealed between period 0 and period 1, there is no reason for the price to change between the periods and we have $p_1 = p_0 =: p$. In addition, assume that the agent's wealth does not change so we have $w_1 = w_0 =: w$. Then, the first

order conditions (1) and (2) simplify to

$$E\left[v'\left(\phi_1\left(d-p\right)+w\right)\left(d-p\right)\right]=0$$
$$\text{and } E\left[u'\left(\phi_0\left(d-p\right)+w\right)\left(d-p\right)\right]=0.$$

This gives us the following result adapted from Wang and Werner (1994).

Proposition 2 *If v is more risk averse than u, we have $\phi_0 > \phi_1$.*

This result shows that our agent wants to hold more of the risky asset in period 0, with some distance to the risk, than in period 1, when the resolution of uncertainty is imminent. The implications of this result depend on the degree of sophistication of the agent. A sophisticated agent anticipates in period 0 that he will want to change his portfolio in period 1. If the agent has no way of preventing his future self from rebalancing, he may already choose the anticipated portfolio ϕ_1 in period 0 to avoid trading costs.

The more interesting case is that of a naive agent. In period 0, he will choose a portfolio ϕ_0 but once the resolution of uncertainty is imminent in period 1, he sells some of the risky asset to attain the portfolio $\phi_1 < \phi_0$. When we view the asset market as a sequence of periods with and without news about the asset, the agent overtrades, selling some of the stock before announcements and buying it back afterwards. Lamont and Frazzini (2007) find evidence that selling pressure before announcements indeed stems from small and supposedly unsophisticated traders, as does the buy pressure after announcements. Large and supposedly sophisticated traders take the other side of these trades.

Notably, in the presence of transaction costs, an anxious investor will earn lower returns than a buy-and-hold investor due to overtrading, as in Odean (1999). We examine other factors affecting individual investors' returns in the following sections.

Price Dip

To derive pricing implications, we now model an economy with an anxiety-prone representative agent. This implies that he has to hold the entire net supply of the

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stock, $\phi_t = 1$, consumes the entire payoff, $x_1 = d$, and cannot borrow or lend, $\xi_t = 0$. Substituting these values into the first order conditions (1) and (2), they simplify to

$$E\left[v'\left(d\right)\left(d - p_1\right)\right] = 0 \tag{3}$$

$$E\left[u'\left(d\right)\left(d - p_0\right)\right] = 0 \tag{4}$$

and we have the following result.

Proposition 3 *If v is more risk averse than u, we have $p_0 > p_1$.*

This result shows that the price at which the agent is willing to hold the stock is lower when the resolution of uncertainty is imminent than when it is still distant. If the agent is naive about his anxiety, he will be happy to hold the stock at a price of p_0 in period 0, irrationally expecting the price not to change in period 1. Once the earnings announcement is imminent, the agent becomes anxious and the price drops to p_1. Note that the price jumps after the announcement (albeit not as much) also in a model with a standard risk averse agent. However, the price dip before the announcement is uniquely produced by anxiety.

Rewriting the expectations in conditions (3) and (4) allows us to write the prices explicitly:

$$p_0 = E\left[d\right] + \frac{Cov\left(u'(d), d\right)}{E\left[u'(d)\right]} \quad \text{and} \quad p_1 = E\left[d\right] + \frac{Cov\left(v'(d), d\right)}{E\left[v'(d)\right]}$$

The second term in the two price equations is the risk premium. It discounts expected dividends more strongly at $t = 1$ than at $t = 0$, as shown in Proposition 3. In particular, the covariances are negative and the expectations positive, as both u' and v' are positive but decreasing. As one should expect, increasing but risk averse utility functions imply a price discount of the risky asset, relative to expected value. More risk aversion makes for heavier discounting, and vice versa. In the case of risk neutrality, $u'(d) = c$, the covariance term is zero as $u''(d) = 0$. Then, the asset trades at expected dividends.[10]

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[10]The same pricing equations result if the representative agent maximizes $u(x_0) + v(x_1)$ in period $t = 0$ and consumes out of wealth.

In a market populated by both anxious and standard agents, there will be a price drop before any scheduled announcement but not as large as in a market with only anxious agents. Accompanying the price drop we should expect to see anxious agents selling part of their stocks to standard agents. Right after the announcement, prices should on average appreciate as anxiety-prone agents buy back their positions.

Our theory thus combines predictions about both asset price movements *and* trade volume around announcement dates, which is a crucial feature of announcement anomalies, as Lamont and Frazzini (2007) explain. These authors also confirm that institutional investors lean against the individual investors' trades. A strategy of buying before announcement dates and selling thereafter yields excess returns of 7% to 18%, which they call the announcement premium. While their paper focuses on explaining the price and volume patterns with the 'attention grabbing hypothesis' (see also Lee, 1992; Hou, Peng, and Xiong, 2009; Barber and Odean, 2008), their empirical results provide equal support for our theory. Our theory shifts the focus to the other side of the same medal that Lamont and Frazzini (2007) examine: we ask why prices tend relatively *lower before* the announcement, which is depicted by Bernard and Thomas (1989). We call this the 'pre-earnings announcement dip'. We thereby offer a possible "common underlying cause for both volume and the premium" that Lamont and Frazzini (2007) have called for, as an alternative to the 'attention-grabbing hypothesis'.

Realized Returns

The stylized model above is not yet suited to be calibrated with data. However, the analysis in Bernard and Thomas (1989) suggests a pre-earnings announcement dip on the order of -0.5% (smaller for large firms than for small-caps). With four scheduled earnings announcements per year, a naive agent as depicted above stands to lose about 2% per year by overtrading in the face of scheduled quarterly earnings announcements alone. This loss comes on top of the transaction costs of overtrading. This squares nicely with the empirical result by Lo, Repin, and Steenbarger (2005), who confirm that more anxious agents generate lower returns. Our model predicts a similar price effect for scheduled news events relevant to the

equity market as a whole, such as the publication of unemployment figures.

A naive anxiety-prone investor's actual equity returns, i.e. the returns he enjoys from investing in equity after accounting for the losses imposed by anxious behavior, are lower than buy-and-hold returns derived from market data may suggest. This helps explain the equity premium puzzle. The Equity Premium Puzzle (EPP) states that equity returns are too high relative to bond returns than can be explained by reasonable levels of risk aversion and discount rates. If risk aversion were as high as implied by the difference between equity and bond returns, bond returns would have to be much higher than they actually are. The latter part of the problem is known as the "risk-free rate puzzle." Hence, models attempting to explain the EPP with agents, who are, effectively, very risk averse, can only explain the difference in returns between bonds and equity, but fail to explain the ensuing risk-free rate puzzle. For example, models assuming ambiguity aversion typically run into that problem. In contrast, anxiety explains part of the EPP without running into the risk-free rate puzzle by showing that effective equity returns to an anxiety-prone investor are not as high as they appear in the data, while bond returns are unaffected by anxiety. Dynamic inconsistency with respect to risks only distorts the price of the locally risky equity, but not the price of locally risk-free bonds.

Our predictions stem from the analysis of a naive anxiety-prone agent. As we will discuss in the next section, a sophisticated anxiety-prone agent may find ways to behave in a dynamically consistent way and thus suffer to a lesser extent from the costs of overtrading. Yet, the disutility implied by the use of a commitment device needs to be subtracted from the utility from equity returns of such an agent. For example, the following section shows how overconfidence can let an anxiety-prone decision maker make more dynamically consistent decisions. But then, the disutility from overconfidence, stemming from 'excessive risk-taking', needs to be subtracted from the now higher utility from holding equity without overtrading. Consequently, even a sophisticated anxiety-prone agent will find equity a worthwhile investment only at returns that are higher than the ones a standard consumption-based asset pricing model yields.

Note that most firms' equity prices may also be depressed, since institutional

counterparties may find it more profitable to use their capital to exploit the behavioral distortions of retail investors trading in stocks that have immanent earnings announcements, instead of pushing up equity prices across the board. Moreover, anxiety-prone agents' counterparties may anticipate the selling pressure by anxious agents before earnings announcements. If (they know that) they can not absorb the sales at the same price level, they will demand higher premia already ahead of the announcement date.

In sum, our theory of anxiety in the face of risk thus links the equity premium, price reactions to earnings announcements, and overtrading, and square nicely with the results of Lo, Repin, and Steenbarger (2005) on the relation of anxiety and trading performance.

3.3 Institutional Effects

An agent who plans according to preferences u, but is afraid his future self will disagree with these plans (because of having preferences v), may try to find ways to commit his future actions to his presently chosen plan of action. While Schelling (1984) and others have discussed the ethical aspects such a possibility brings about, the present discussion is only concerned with *that*, and how, the agent can restrict his future self's behavior – simply by virtue of having a first-mover advantage. Indeed, dynamic inconsistency with respect to risks gives a strong economic rationale for doing so. As sketched out above, an anxiety-prone agent faces losses that are not compensated by higher consumption at any time (as is the case for a hyperbolic discounter).

Delegation

Hiring an agent to carry out risk-taking decisions in the *future* according to the *current* self's preferences is one way to prevent future selves' preferences from conflicting with the current self's plans. In an investment setting, it may be the case that the anxious self is too risk averse to invest in equity, although the agent realizes this has long-run benefits. In this situation it makes sense for the agent to delegate investment decisions to a portfolio manager. The manager can still react

to news about particular assets, but has to stick to a predetermined split of asset classes.

As is the case for commitment devices for hyperbolic discounters, it is clear that having them is desirable, but it is less clear when an agent would start using them. The delegation of investment decisions provides a nice exemption to that rule. An agent prone to anxiety differs from a standard agent only in his evaluation of immediate risks. Thus, we expect to see greater inflows to money managers when immediate risks seem to be low, relative to the associated returns, even if such a temporary calm does not carry information about future performance. This may help to reinterpret respective evidence from the mutual fund industry. As falling prices increase risk estimates, low returns should be associated with low inflows to money managers. Indeed, Sirri and Tufano (1998) find that high returns trigger fund inflows, and vice versa.

Of course, effort costs of managing one's portfolio may also lead to delegation of investment management. However, effort costs can not justify hiring an agent that underperforms the index on average, as buying index funds is virtually costless and free of effort. Yet, the mutual funds industry is huge, and actual fund managers still tend to underperform the market Gruber (1996). While buying the index is free of effort, it is not free of anxiety. Self 0 may thus correctly anticipate that the anxious self 1 will underperform the market even more than a random portfolio manager by failing to invest in equity at all. Self 0 will therefore be willing to pay an investment manager, even if he expects him to underperform the market. The obvious solution would be to hire an agent to simply buy the index, but that may be infeasible in a model of career concerns.

Fees

A redemption fee is another feature of investment funds that sophisticated anxiety-prone decision-makers will demand. This may be one explanation why management and other fees are being competed away in the mutual funds industry, while lock-in fees continue to feature prominently. Variations of punishments for pulling out of risks an investor previously decided to take include fees for changing the equity/bonds ratio of one's investment in mutual funds, as well as fees imposed if

the total exposure to a certain asset class falls below a threshold.

Timing of Orders

The widespread practice of retail investors to submit overnight limit orders can be viewed as another costly way of coping with anxiety. Submitting overnight limit orders deprives the investor from the possibility to react to news in the time between submission of the order and execution, and furthermore represents a positive externality to other market participants: it represents an option to buy/sell at the quoted price. See Harris (2003) for a discussion. Writing such an option to trade, as well as foregoing the option to react to overnight news, would never be optimal for a standard agent. However, it helps overcome commitment problems imposed by anxiety. Instead of waiting to see his future self pull out from the decision to invest in the stock, the current self preempts the decision before going to bed, when the uncertainty is not yet imminent.

Demand for Delayed Resolution and Costs of Information

Self 1's risk preferences about future gambles are identical to self 0's preferences about the same gambles if there is no immediate resolution of uncertainty at $t = 1$. This implies a disutility for resolution of uncertainty, i.e. a disutility for information, in period $t = 1$. Self 0 will therefore be willing to pay for delaying the resolution of uncertainty from $t = 1$ to a later date in order to harmonize self 1's behavior with self 0's preferences. To be sure, this is not driven by a preference for the timing of the resolution of uncertainty, which *requires* temporal consistency Kreps and Porteus (1978). Hedge funds impose pull-out restrictions and publish performance reports at low frequencies, although the information is available continuously and creating a report is a largely automatable task. Note that the cost of having to provide liquidity does not explain such clauses. Imposing costs on deposits with short maturities will compensate the fund for the cost of liquidity provision, but putting a temporal distance between the investor's decision to pull out and the payout of the funds does neither protect the fund from withdrawals nor compensate for the implied costs. Concealing present risks,

however, prevents anxious investors from pulling out.

4 Overconfidence

If commitment devices are not available, an anxiety-prone agent has an incentive to distort his future self's beliefs. In particular, the present self would like to convince his future self that risks are lower than they actually are. This would lead the future self to take riskier decisions which are more in line with the current self's preferences. However, if the future self has access to additional information, the distorted beliefs may lead to decisions that are excessively risky, even from the current self's point of view. In this section we analyze such a situation similar to the model of Bénabou and Tirole (2002).[11]

For the sake of simplicity, we again restrict ourselves to two time periods, $t = 0, 1$, and set the discount factor to $\delta = 1$. In period 1 the agent has to choose between a risky or a safe alternative. The risky alternative is given by a lottery with random payoff x. The lottery is characterized by its distribution function G_θ where $\theta \in \{H, L\}$ denotes a state of the world that determines how risky the lottery is. We assume that G_H is a mean-preserving spread of G_L so the risky alternative is unambiguously riskier in state H than in state L. The prior probability of the high-risk state H is given by π. The safe alternative, on the other hand, is given by a constant payoff a.

The anxious agent in period 1 wants to take the risky alternative whenever

$$E_\theta[v(x)] > v(a) \,,$$

where E_θ denotes the expectation with respect to G_θ. Denoting the certainty equivalent of G_θ given the utility function v by c_v^θ, this condition can be rewritten as

$$c_v^\theta > a.$$

The agent wants to take the risky alternative, whenever its certainty equivalent

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[11]For earlier work stuying belief manipulation in a setting with β-δ time inconsistency see Carrillo and Mariotti (2000).

c_v^θ is greater than the safe alternative a.

The agent in period 0, when the risk is not imminent, wants to take the risky alternative whenever

$$E_\theta[u(x)] > u(a) \Leftrightarrow c_u^\theta > a.$$

Since v is more risk averse, we have $c_u^\theta > c_v^\theta$ for both $\theta \in \{H, L\}$ so the agent in period 0 (self 0) and the agent in period 1 (self 1) will disagree about the course of action if $a \in [c_v^\theta, c_u^\theta]$.

To make this problem interesting, we assume that the payoff of the safe alternative a is not known to the agent until period 1. Self 0 only knows the prior distribution F on $[\underline{a}, \overline{a}]$ but self 1 observes the realized value of a. The state of the world θ, on the other hand, is revealed to the agent at the beginning of period 0 in form of a perfectly informative "red flag" warning signal s if the state is high-risk

$$s = \begin{cases} R & \text{if } \theta = H \\ \emptyset & \text{if } \theta = L \end{cases}$$

If he receives a red flag, self 0 can choose the probability $\lambda \in [0,1]$ with which he will remember the signal, i.e.,

$$\lambda = \Pr[\hat{s} = R | s = R],$$

where $\hat{s}$ is self 1's recollection of the signal. We assume that self 1 is fully aware of his prior incentive to forget warning signals, so if he expects a memory probability λ^e and doesn't remember seeing a red flag he uses a Bayesian posterior

$$\pi(\lambda^e) = \frac{\pi(1 - \lambda^e)}{\pi(1 - \lambda^e) + 1 - \pi}.$$

Given this setup, self 0 and self 1 are playing a kind of Stackelberg game. First self 0 chooses the memory probability λ taking into account self 1's behavior and then self 1 decides between the risky and the safe alternative taking into account self 0's behavior. We are interested in the perfect Bayesian equilibria of this intrapersonal game.

First, we derive self 1's best response in $t = 1$, taking as given an expected

memory probability λ^e. If self 1 remembers seeing a red flag, $\hat{s} = R$, he knows that the state of the world is high-risk and chooses the risky alternative if $c_v^H > a$. If self 1 doesn't remember seeing a red flag, $\hat{s} = \emptyset$, he uses the Bayesian posterior $\pi(\lambda^e)$ and chooses the risky alternative if $c_v(\lambda^e) > a$ where $c_v(\lambda^e)$ is the certainty equivalent of the risky alternative given λ^e defined by

$$E[v(x)\,|\pi(\lambda^e)] = v(c_v(\lambda^e))\,.$$

Second, we derive self 0's best response in $t = 0$, taking as given self 1's behavior for an expected λ^e. If self 0 receives a warning signal and chooses a memory probability λ, his expected utility is

$$\lambda\left[\int_{\underline{a}}^{c_v^H} E_H[u(x)]\,dF(a) + \int_{c_v^H}^{\overline{a}} u(a)\,dF(a)\right]$$
$$+ (1-\lambda)\left[\int_{\underline{a}}^{c_v(\lambda^e)} E_H[u(x)]\,dF(a) + \int_{c_v(\lambda^e)}^{\overline{a}} u(a)\,dF(a)\right].$$

With probability λ the agent remembers the warning signal in period 1 and uses the certainty equivalent c_v^H as the threshold, choosing the risky alternative for payoffs of the safe alternative below the threshold and choosing the safe alternative for payoffs above the threshold. With probability $1 - \lambda$ the agent forgets the warning signal and uses the certainty equivalent $c_v(\lambda^e)$ as the threshold.

We denote the derivative of self 0's expected utility with respect to λ by

$$D(\lambda^e|v) := \int_{c_v^H}^{c_v(\lambda^e)} \big(u(a) - E_H[u(x)]\big)dF(a)\,.$$

This expression has a very natural interpretation. The warning signal changes self 1's decision only for values of $a \in \left[c_v^H, c_v(\lambda^e)\right]$. In this interval, self 1 chooses the risky alternative whenever he remembers seeing a red flag and the safe alternative otherwise. The effect on self 0's expected utility of remembering the warning signal more often is exactly the difference in utility from the safe action compared to the risky action for the values of a where the decision is affected.

There are three possibilities for perfect Bayesian equilibria in this setting:

- Honesty Equilibrium: If $D(1|v) \geq 0$, there is an equilibrium with $\lambda^* = 1$. In this equilibrium the agent never ignores red flags and doesn't influence his future self's beliefs.

- Overconfidence Equilibrium: If $D(0|v) \leq 0$, there is an equilibrium with $\lambda^* = 0$. In this equilibrium the agent always ignores red flags and makes his future self maximally overconfident.

- Mixed Equilibrium: If $D(\bar{\lambda}|v) = 0$ for some $\bar{\lambda} \in (0,1)$, there is an equilibrium with $\lambda^* = \bar{\lambda}$. In this equilibrium the agent plays a mixed strategy, ignoring the red flag with probability $1 - \bar{\lambda}$, and makes his future self partially overconfident.

Proposition 4 *One of the extreme equilibria always exists, either the honesty equilibrium or the overconfidence equilibrium or both. If both extreme equilibria exist, a mixed equilibrium also exists.*

The existence of each kind of equilibrium depends on the degree of anxiety of the agent, i.e., how big the difference in risk aversion is for risks that are imminent compared to risks that are distant. In particular, we can say that an agent i is more prone to anxiety than an agent j, if u_i and u_j are equally risk averse but v_i is more risk averse than v_j. This enables us to state the following result.

Proposition 5 *For an agent that is more prone to anxiety, (i) the honesty equilibrium is less likely to exist, (ii) the overconfidence equilibrium is more likely to exist, and (iii) if the mixed equilibrium exists, then it is associated with more overconfidence.*

Somewhat counterintuitively, people who are most prone to anxiety in the face of risk are the same ones that are most likely to exhibit overconfidence. Note further that a risky environment is necessary for overconfidence to arise, and to show effects in decision making. Financial markets are a prime example of such an environment. Ben-David, Graham, and Harvey (2010) confirm that financial top executives are systematically overconfident: realized market returns

are within their 80% confidence intervals only 33% of the time. A manifestation of overconfidence that is important in finance, and possibly important to understand individual agents' behavior during the recent financial crisis, is excessive risk-taking.

Excessive Risk-Taking

Equilibria with partial or maximal overconfidence can display excessive risk taking. In these equilibria it can be the case that the future self ends up taking risks which even the less risk averse current self would have avoided. To an observer who is unaware of the agent's intrapersonal conflict, the agent seems to take risks that are greater than can be explained with 'reasonable' preferences, i.e. u. This can happen if the true state of riskiness is high and the agent forgets the warning signal. In this case, whenever the payoff of the safe alternative is below the cutoff $c_v(\lambda^*)$ self 1 uses but above the cutoff c_u^H self 0 would like him to use, i.e. $a \in \left(c_u^H, c_v(\lambda^*) \right)$, the agent takes risks in period 1 that that self 0 considers excessive. Analytically, this can arise since the condition for an equilibrium with overconfidence, $D(\lambda^*|v) \geq 0$, does *not* necessarily imply $E_H[u(x)] > u(a)$ for all $a < c_v(\lambda^*)$, where self 1 chooses the risky alternative. Such a situation arises in all equilibria λ^* with $c_u^H < c_v(\lambda^*)$, i.e. the equilibrium cutoff used by self 1 is greater than the cutoff self 0 would use. To an outside observer who knows that the state is H, the anxious agent using the cutoff $c_v(\lambda^*)$ appears as if he were *less* risk averse than the non-anxious preference u.

Proposition 6 *In an equilibrium with $\lambda^* < 1$ and $c_u^H < c_v(\lambda^*)$, the agent will be observed to take excessive risks, i.e. he will appear less risk averse than u.*

Ben-David, Graham, and Harvey (2007) confirm empirically that overconfidence, observed in Ben-David, Graham, and Harvey (2010), translates into riskier corporate policy.

5 Conclusion and Plans for Future Research

In this paper, we define an anxiety-prone decision maker as an agent, whose risk aversion is higher the closer in time the resolution of uncertainty is. We discuss experimental evidence that is predicted by our model and show in examples and in a financial market model how this leads to dynamically inconsistent behavior. Linking such behavior to established puzzles about price and volume around earnings announcements, we suggest a clean, and arguably more credible way to think about these patterns than existing theories propose. Evidence from the trading floor also confirms our prediction that more anxiety-prone traders perform worse. We explain how sophistication about dynamic inconsistency and the associated costs will trigger institutional responses such as delegation of investment decisions, and the distinct design of brokerage and investment fund fees. We further suggest a connection to optimal patterns of information provision in financial markets. Finally, we show why it may be beneficial to a sophisticated anxiety-prone agent to hold overconfident beliefs, and how this can be accomplished.

Combining the above model of endogenous overconfidence with problems in financial economics seems a fruitful field of future research. We conjecture four possible areas of applications.

First, there should be an equilibrium level of overconfidence in financial markets. The costs of overtrading due to anxiety around news announcements can be mitigated by overconfidence. On the other hand, overconfidence may cause overtrading independent of news announcements according to Scheinkman and Xiong (2003). Such trading, while not directly causing expected losses, still bears transaction costs. But in addition, an overconfident agent also suffers from excessive risk taking, implying a disutility for the planning-self at $t = 0$. Trading off these costs should yield an optimal amount of overconfidence according to self 0's preferences. The equilibrium level of overconfidence should be increasing in transactions costs and bid-ask spreads, and thus be more pronounced in more illiquid securities. It should be negatively related to the earnings announcement premium, i.e. the predictable price fluctuations between announcement periods and periods without earnings announcements, and positively to the frequency of

scheduled announcements.

Second, recent influential works by Akerlof and Shiller (2010) and Reinhart and Rogoff (2009) have strongly suggested that time-changing confidence needs to be part of realistic models of market dynamics and the business cycle. Empirically, confidence is high when leverage is high and maturities are short, and vice versa. This is consistent with our notion that overconfidence arises when risks are high, and (not shown in the above model) under-confidence may arise when risks are low. As overconfident traders have a greater demand for risk than rational types do, overconfidence sustains excessive risk levels. Conversely, under-confidence helps sustain price levels below fundamentals in the crisis. Both outcomes may be possible under the same parameters in a model with multiple equilibria. Extending this static argument to a dynamic model will be more challenging.

Third, the above model of self-delusion is not necessarily to be taken literally, but can be seen as a metaphor for the choice of information systems and communication structures in organizations. Given a preference for a biased posterior, an anxiety-prone leader will implement information and communication systems that have him misinformed about risks. The scarcity of critical upward feedback, which is often said to be mandated by the head of the organization ('killing the messenger'), may be explained in this way. The more anxiety-prone the leader, the less upward feedback will be provided.[12] In the investment domain, the 'Ostrich Effect' may serve as an example. Karlsson, Loewenstein, and Seppi (2009) find that investors look up their portfolio performance less often after receiving a signal about increased risks.[13]

Fourth, occupational choices and associated cognitive dissonance may be a fruitful domain for applications of the overconfidence model. Nothing in the model prevents that the agent, rather than nature, choose the riskiness of the environ-

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[12]Management publications view the lack of upward feedback as the source of countless corporate disasters and a widespread phenomenon. There are also examples in history, where leaders that were certainly not known for pronounced propensity to anxiety, demanded critique by any means. Queen Elizabeth I is said to have rebuked a jester "for being insufficiently severe with her."

[13]The original finding is that investors tend to not look up their portfolio's performance after market-wide declines, about which they are likely to become informed via generic news reports. Note that (i) price drops may be caused by increases in risk levels, but also (ii) falling prices increase volatility estimates. Thus, in any case, falling prices are a signal for increased risk.

ment (and the thus implied perfectly informative signal). Parallel to the mechanism in the present model, the agent may choose to forget the information the he based his prior decision upon, i.e. that he chose a risky job over a safe one, and thus render himself overconfident (Akerlof and Dickens, 1982). This will be beneficial if the agent's job involves risk-taking. Professions such as securities trading should then be particularly likely to feature overconfident agents.

Appendix

Proof of Proposition 1. Since v is more risk averse than u we have

$$-\frac{v''(x)}{v'(x)} > -\frac{u''(x)}{u'(x)}$$

$$\Rightarrow -\frac{d}{dx}\log v'(x) > -\frac{d}{dx}\log u'(x)$$

Integrating both sides yields

$$\frac{v'(d)}{v'(p)} < \frac{u'(d)}{u'(p)}$$

for $d > p$ and the reverse inequality for $d < p$. For general p, d we then have

$$\left(\frac{u'(d)}{u'(p)} - \frac{v'(d)}{v'(p)}\right)(d - p) > 0$$

Taking expectations we get

$$\frac{E\left[u'(d)(d-p)\right]}{u'(p)} > \frac{E\left[v'(d)(d-p)\right]}{v'(p)} \tag{5}$$

Substituting in p_0 the RHS is zero and we get

$$E\left[u'(d)(d - p_0)\right] > 0,$$

which implies that $p_0 < p_1$ and therefore

$$\frac{E[d]}{p_0} > \frac{E[d]}{p_1}.$$

$\square$

Proof of Proposition 2. See Wang and Werner (1994). $\square$

Proof of Proposition 3. The proof is analogous to that of Proposition 1. Substituting p_1 in equation (5) the RHS is zero and we get

$$E\left[u'(d)(d - p_1)\right] > 0,$$

which implies that $p_0 > p_1$. $\quad\square$

Proof of Proposition 4. The belief $\pi(\lambda^e)$ is continuous and decreasing in λ^e. Therefore the certainty equivalent $c_v(\lambda^e)$ is continuous and increasing in λ^e. Finally, this implies that $D(\lambda^e|v)$ is continuous and increasing in λ^e. We then have either $D(1|v) \geq 0$ or $D(0|v) \leq 0$ or both so one of the extreme equilibria $\lambda^* \in \{0, 1\}$ always exists. For the case where $D(1|v) \geq 0$ and $D(0|v) \leq 0$, there exists a $\bar{\lambda} \in (0, 1)$ such that $D(\bar{\lambda}|v) = 0$ so the mixed equilibrium $\lambda^* = \bar{\lambda}$ also exists. $\quad\square$

Lemma 7 *Consider two von Neumann-Morgenstern utility functions v_1 and v_2. If v_2 is more risk averse than v_1, then $D(\lambda^e|v_2) < D(\lambda^e|v_1)$ for all λ^e.*

Proof. If v_2 is more risk averse than v_1, then $c_{v_2}^H < c_{v_1}^H$ and $c_{v_2}(\lambda^e) < c_{v_1}(\lambda^e)$ for all λ^e. This implies that for all λ^e:

$$
\begin{aligned}
D(\lambda^e|v_2) &= -\int_{c_{v_2}^H}^{c_{v_2}(\lambda^e)} \big(u(a) - E_H[u(x)]\big)dF(a) \\
&< -\int_{c_{v_1}^H}^{c_{v_1}(\lambda^e)} \big(u(a) - E_H[u(x)]\big)dF(a) \\
&= D(\lambda^e|v_1)
\end{aligned}
$$

$\quad\square$

Lemma 8 *Consider two von Neumann-Morgenstern utility functions v_1 and v_2. If v_2 is more risk averse than v_1 and if there are $\bar{\lambda}_1$ and $\bar{\lambda}_2$ such that $D(\bar{\lambda}_1|v_1) = 0$ and $D(\bar{\lambda}_2|v_2) = 0$, then $\bar{\lambda}_1 < \bar{\lambda}_2$.*

Proof. If v_2 is more risk averse than v_1, then $c_{v_2}^H < c_{v_1}^H$ so the integral in $D(\bar{\lambda}_2|v_2)$ has a smaller lower bound. Since $\big(u(a) - E_H[u(x)]\big)$ is a strictly increasing function of a, for $D(\bar{\lambda}_1|v_1) = D(\bar{\lambda}_2|v_2) = 0$ it is necessary that $c_{v_2}(\bar{\lambda}_2) > c_{v1}(\bar{\lambda}_1)$, i.e. that the integral in $D(\bar{\lambda}_2|v_2)$ must have a greater upper bound. Since $c_{v_2}(\lambda) < c_{v_1}(\lambda)$ for a given λ, and $c_v(\lambda)$ is increasing in λ for v_1 and v_2, this implies $\bar{\lambda}_2 > \bar{\lambda}_1$. $\quad\square$

Proof of Proposition 5. From Lemma 7 we know that $D(1|v_2) < D(1|v_1)$ for v_2 more risk averse than v_1. Therefore an honesty equilibrium exists for v_1 if it exists

for v_2. Again using Lemma 7 we know that $D\left(0|v_2\right) < D\left(0|v_1\right)$ for v_2 more risk averse than v_1. Therefore an overconfidence equilibrium exists for v_2 if it exists for v_1. Finally, if a mixed equilibrium exists for v_1 and v_2, characterized by $\bar{\lambda}_1$ and $\bar{\lambda}_2$ respectively, then by Lemma 8 we have $\bar{\lambda}_1 < \bar{\lambda}_2$. $\qquad\square$

Proof of Proposition 6. Follows directly from the derivation in the main text. $\square$

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