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The safety first expected utility model: Experimental evidence and economic implications

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Abstract

Roy's [Roy, A., 1952. Safety first and the holding of assets. Econometrica 20 (3), 431–449] safety first criterion advocates the minimization of the probability of outcomes below a certain "disaster" level. This paper examines safety first theoretically and experimentally. We find that safety first plays a crucial role in decision-making, inducing choices that cannot be explained by, and even contradict, risk-aversion, Prospect Theory, and loss-aversion in general. Yet, safety first alone cannot explain individual choice. Therefore, we propose an expected utility – safety first (EU–SF) model where decisions are made based on a weighted average of the safety first criterion and standard expected utility maximization. We experimentally estimate these relative weights, and discuss their economic implications.

Introduction

Roy (1952) was the first to suggest the idea of "Safety First". According to this criterion individuals consider outcomes below a certain value as a "disaster". What constitutes a "disaster" depends on the individual. For example, some people may consider the disaster level as the minimal wealth level required for physical existence. Others may consider a loss that will force them to sell their home and move to a neighborhood with a lower socio-economic class as a disaster (see Friedman and Savage, 1948). From the point of view of a CEO, a third consecutive year of falling short of analysts' expectations, implying probable termination, may be classified as a disaster. For some investors being "in the red", i.e. having a negative rate of return, may be considered as a disaster, etc. Roy argues that when making decisions about uncertain prospects, individuals' first consideration is to minimize the probability of reaching disaster, hence the name "Safety First" (SF). Moreover, Roy advocates that the SF criterion is more relevant to people than expected utility maximization. This idea of target-rate-based behavior can also be found in various areas of risk management as early as

Roy's (1952) work. For example Heady (1952), noted the sensibility of this type of objective in the land allocation problem, writing:

*He (the farm manager) also may attempt to combine enterprises in a manner to minimize the probability that income will drop below levels required to meet family living expenses, farm costs, and principal payments. Or, he may simply attempt to minimize the probability that his business will become bankrupt in any specified period (*Heady, 1952*, p. 482).*

Conforming to Roy's idea, Fishburn (1997) also asserts that decision makers frequently associate risk with a failure to attend some target return (see also Dantzig, 1956, Hanssmann, 1968).

Formally, the SF criterion can be described as follows: consider two alternative prospects, F and G, and denote the "disaster" level by d. Then, F is preferred to G if and only if: $\mathbf{Pr}_F(x < d) < \mathbf{Pr}_G(x < d)$, where $\Pr_F(x<d)$ is the probability of obtaining an outcome $x<d$ under prospect F (i.e. the above inequality means that at point d the cumulative probability of F is smaller than that of G). Roy discusses a situation where the exact return distributions are not necessarily known. He therefore employs Chebyshev's inequality to obtain an upper bound on $\Pr_F(x<d)$. In our framework (and in our experiments) the distribution of returns is known precisely. Therefore we employ the actual shortfall probabilities instead of upper bound estimates for these probabilities. (Note that for the special case of Normal return distributions the Chebyshev upper bounds and the actual shortfall probabilities yield the same *ranking* of prospects. In addition, as Haley and Whiteman (2008) show, various upper bound estimates may yield interesting insights into the relation between the one-period and multi-period setups, as discussed below).

Several studies have extended Roy's original SF criterion and have investigated the economic implications of SF behavior. For example Pyle and Turnovsky (1970), analyze the relationship between SF and standard mean-variance optimization. Levy and Sarnat (1972) show that if the disaster level is equal to current wealth times $(1+r)$, where r stands for the interest rate, and no lending is allowed, the optimal portfolio for a SF investor is the CAPM tangency portfolio (see also Goetzmann and Broadie, 1992). Arzac and Bawa, 1977, Bawa, 1978 generalize the SF criterion, and relate the generalized criterion they develop to the stochastic dominance criteria. Milevsky (1999) explores the effect of the investment horizon on the asset allocation choice of SF investors.

Recent studies extend the idea of SF to a multi-period setting. Stutzer (2003) develops a new investment decision framework related to SF: the investor maximizes the probability that the growth rate of the invested wealth will exceed some pre-determined target growth rate. By choosing a portfolio with expected growth rate higher than the target growth rate, one can ensure that the probability of not exceeding the target rate decays to zero asymptotically as T approaches infinity. However, as many portfolios can achieve this goal, Stutzer suggests choosing the portfolio which makes the decay in this probability as fast as possible. The suggested criterion is called the "decay rate maximization" criterion. One possible interpretation of this rule is that the probability of a disaster (i.e. not achieving the target rate) at the end of any given investment period is minimized, when the investors faces an investment horizon not known in advance (see also Stutzer, 2000). Stutzer (2003) shows that under some conditions the novel decay rate maximization criterion is equivalent to the maximization of a power utility function with an endogenously determined risk-aversion parameter.[1] Haley and Whiteman (2008) show that Stutzer's framework is equivalent to a one-period SF setting where the Chernoff upper bound on the shortfall probability is employed instead of the actual probability.

While quite a few studies investigate the idea of SF and its implications, all in all, SF has had only limited impact on financial economics. This may be due to the fact that the basic SF rule of minimizing $\Pr(x<d)$ may

lead to paradoxical behavior which is considered unacceptable by most economists. For example, suppose that $d=0$ and that prospect F yields \$0.01 with certainty. Prospect G yields −\$0.01 with a probability of 1% and \$1,000,000 with a probability of 99%. SF implies preference for F, even though it is quite clear that most people will prefer G (and a similar paradoxical example can be constructed for any other value of d). Thus, the one-period SF rule may, in general, ignore many important aspects of the distribution.[2] Expressed alternatively, if the SF rule is stated in the expected utility framework it implies an unacceptable utility function (see Fig. 1a and the discussion below). Despite of this drawback, the idea of SF, or at least some variation of this criterion, is intuitively very appealing.[3]

In this study we first develop a one-period decision rule that incorporates both the notion of SF of Roy and the notion of expected utility, where not only $\Pr(x<d)$ is taken into account (e.g., in the above example, the \$10,00,000 outcome would also matter). In this framework $\Pr(x<d)$ plays a special role, but it is not the only statistic taken into account. The model developed in this paper suggests that decisions are made based on a weighted average of standard expected utility (or expected value) maximization with a continuous utility function, and SF. We call this model the EU-SF model. Our general analyses is relevant to all possible non-decreasing utility functions. Having this theoretical decision rule we then experimentally test the role that SF plays in decision-making under risk. To the best of our knowledge, this is the first direct experimental investigation of SF. We find strong evidence that SF plays an important role in the decision-making process. Moreover, the experimental results we find cannot be explained by the standard expected utility framework with risk aversion or by Prospect Theory. While it may seem that SF and loss aversion have similar implications, we show that this is not the case, and that the experimental results cannot be explained by any degree of loss aversion.

While our findings suggest that SF plays a key role in decision-making, the experimental evidence supports the hypothesis that SF should be considered in combination with the standard decision-making models. Our experimental setup allows us to test the EU-SF model and to estimate the respective weights assigned to the EU and SF factors (in this part we make various alternative assumptions about the shape of the utility function, e.g. linear, CARA, CRRA. Fortunately, the estimates are not very sensitive to these alternative assumptions). We show that the experimental evidence is consistent with the EU-SF model, and we estimate the weights assigned to EU and SF as 0.9 and 0.1, respectively.

Based on this finding, we investigate the implications of the EU-SF model to equilibrium and to asset pricing. We show that, in contrast to Roy's original formulation, the EU-SF model is perfectly consistent with an equilibrium with risky assets as well as a risk-free asset. Moreover, under Normal return distributions, the EU-SF model is consistent with the Separation Theorem and the CAPM. We show that the experimentally estimated weight of 0.1 assigned to SF implies a reduction of about 30% in the asset allocation to equity. Furthermore, it induces an increase of approximately 2% in the equity premium relative to the case where the SF factor is not taken into account.

The paper is organized as follows: in Section 2 we briefly review SF and the standard decision-making criteria examined. This section also presents the EU-SF model. Section 3 provides the experiments and the results. Section 4 analyzes the implications for asset pricing, and Section 5 concludes.

Section snippets

Decision-making criteria

In this section we provide a brief review of the main decision-making criteria that are tested experimentally. We begin with the expected utility framework and stochastic dominance criteria. Next, we describe Prospect Theory and CPT, and we give the formal definition of the SF criterion. Then, we discuss the proposed EU-SF model, which combines the EU and SF frameworks.…

The experiments and results

The subjects participating in the experiments are business-school students (undergraduate, MBA and Ph.D. students) from several universities (UCLA, University of Washington, Hebrew University, Manhattan College), and practitioners, who are either mutual fund managers or financial analysts. As similar results were obtained across the various subject groups, for brevity sake we report here only the aggregate results (the results by subject group are available upon request). The experiments were…

Safety first, asset allocation, and asset pricing

This section investigates the key implications of the EU-SF model to asset allocation, equilibrium pricing, and to Rabin's (2000) calibration results. The experimentally estimated value of α=0.1 may not seem very high, and this may seem to suggest little effect on optimal asset allocation and pricing – after all, with α=0 the EU-SF model reduces to the standard EU framework. How large are the effects of α=0.1?…

Conclusions

Risk-aversion is a basic ingredient in most economic models. A competing paradigm is Prospect Theory, with preferences implying risk-aversion for gains and risk-seeking for losses. In this paper we suggest an alternative preference which attaches weight to the probability of disaster, capturing Roy's idea of Safety First (SF). We experimentally show that safety first is an important factor in the decision-making process. In experiments where some of the outcomes are negative and the two…

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> …Our findings also carry insights for asset pricing: Both myopic loss aversion (Benartzi and Thaler, 1995) and loss probability aversion have been related to the reluctance of private investors to take financial risks and may therefore contribute to the high level of the equity premium (Mehra and Prescott, 1985). Levy and Levy (2009) estimate that two percentage points of the equity premium can be attributed to a "safety first principle", which resembles loss probability aversion. However, loss probability aversion only works against stock investments for positive interest rates.…

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> …Loss aversion more generally is not capable of capturing our findings. In this way our results support – in a market setting – findings of Levy and Levy (2009) who test such preferences experimentally but also show the theoretical implications for investments and asset pricing. They show, for example, that preferences found in our study on the market and individual level can explain about one third of the equity premium puzzle.…

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