in retirement portfolios and how frequently they manage those portfolios. Only those individuals who participated in defined contribution retirement plans would answer those two questions. Because 78.5% of the professors in our sample participated in defined contribution plans, we found our comparison group to be valid. We have thoroughly investigated the behavior of finance faculty with respect to their defined contribution plans and have published our findings in another research paper.[1]

We agree with Mr. Merseburg that we should compare individuals with similar pay rates, and we did control for income in our cross-sectional analysis. Finally, he mentions that our control group should include only civil servants with "tenure-like protections." This control was pointed out by an *FAJ* referee during the review process and was addressed prior to acceptance. As we indicated in Note 15, our results are unaffected and remain robust after controlling for the effect of tenure.

Mr. Merseburg is correct in suggesting that if we used a subsample of the population that is more similar to finance professors, we would be more likely to find less of a disparity in their investment behavior. However, the focus of our study was to see how (dis)similar finance professors are to the general public after controlling for demographic factors. In fact, factors such as those suggested by Mr. Merseburg are precisely the reason why we argued that it may be an "oversimplification" to assume/recommend that all investors hold equities. As we indicated in our conclusion, we are not surprised that finance professors hold more stocks than the general public. What we believe is more revealing from our study is the counterintuitive finding that a large number of finance professors do not participate in the stock market.

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Notes

1. A.M. Hibbert, E.R. Lawrence, and A.J. Prakash, "The Role of Financial Education in the Management of Retirement Savings," *Journal of Behavioral Finance*, vol. 13, no. 4 (2012):299–307.

"Do Financial Markets Reward Buying or Selling Insurance and Lottery Tickets?": A Comment

In answering the question posed by his recent article (September/October 2012), Antti Ilmanen concluded—seemingly backed by a great deal of "empirical" examination and citing a large number of studies—that investors should not merely be uninsured but should also consider selling such insurance. Selling volatility on the left tail "adds value in the long term." He also included carry trades because they imply tail-selling risk insurance.

Perhaps Ilmanen cited too many papers and arguments for comfort. Just as in a complicated detective novel in which the character with the most alibis often turns out to be the murderer, the enumeration of "backup" arguments fails to mask a central methodological error: a combination of (1) cherry picking and (2) missing nonlinear effects and asymmetries in errors (deviations from the model result in considerably more harm when one is wrong than when one is right). Merely adding these nonlinear responses to tail events does more than reverse the result. Further, because Ilmanen included a review of all supporting arguments against the purchase of small-probability events, refuting his article allows the refutation of the prevailing arguments that posit the overpricing of small odds in finance. So, it turns out that there is not a single study that convincingly demonstrates the overpricing of small probabilities in finance or economics (outside of artificial setups).

There are two elephants in the room in the form of exclusion of central (i.e., nonlinear) evidence:

- *First elephant.* Ilmanen excluded the stock market crash of 1987 from his analysis. But because of the convexity of option payoffs, the return from such crashes is convex to distance from moneyness. So, to use a very extreme (but illustrative) case, an option located 20 standard deviations from the money would return 230,000 times its daily premium erosion in the event of a 20-standard-deviation move (i.e., standard deviations from the implied volatility

at which the option was purchased). Hence, one would need more than 2,000 years of data showing an absence of 1987-style crashes—generously assuming that the environment is stable—to pronounce the sale of these options "safe." Even those options that are closer to the money (and commonly traded) deliver a large enough payoff to forbid us from making claims based on a few decades' worth of data; for instance, an option 12 standard deviations away from the money returns 5,000 times the daily erosion.

Another misunderstanding concerns the path dependence of these payoffs, which compounds the payoff asymmetry. When the implied volatility quadruples, a 15-standard-deviation out-of-the-money option becomes a 3.75-standard-deviation option and its value is multiplied by 3,300. Implied volatility (as represented by various volatility indices, such as the Chicago Board Options Exchange Volatility Index, or VIX) quadrupled at least six times over the past quarter century. **Table 1** shows the convexity of options to changes in implied volatility. These changes in implied volatility induce a second layer of optionality that is missing from Ilmanen's analysis—with opportunities for the option owner and a squeeze for the seller. (In a well-publicized debacle, the speculator Victor Niederhoffer went bust because of explosive changes in implied volatility in his option portfolio, not because of market movement; moreover, the options that bankrupted his fund ended up expiring worthless weeks later. The same thing happened with Long-Term Capital Management in 1998.)

- *Second elephant.* Ilmanen discussed "carry trades" but ignored the disastrous effect of bank loans (small-probability selling) in the 2008 debacle (as well as bank loans during the 1982 and 1991 credit problems); he even cited a 2004 paper of mine that includes bank loans as a domain of tail selling.[1] The losses of 2008, estimated by the International Monetary Fund to be more than $5 trillion (before the government transfers and bailouts), would offset every single gain from tail selling in the history of economics.

Excluding the crash of 1987 and bank loans would be like claiming that the 20th century was extremely peaceful by excluding World Wars I and II. These two fallacies alone would be devastating for the entire idea. But let us examine additional errors related to a misunderstanding of nonlinearities.

- *Convexity bias.* Ilmanen made the severe error of ignoring the effect of Jensen's inequality on the nonlinearity of the difference between the VIX and delivered volatility. The VIX, by design, delivers a payoff that is closer to the variance swap. Let's say that the VIX is "bought" at 10% for two successive periods—that is, the component options are purchased at a combination of volatilities that corresponds to a VIX at that level. Because of nonlinearity, one would benefit from an episode of 4% volatility followed by an episode of 15%, for an average of 9.5%; Ilmanen seemed to treat this 0.5 percentage point gap as a loss.
- *Misuse of the VIX.* Using the VIX to gauge small probabilities is inappropriate. The VIX is not quite representative of the "tails"; its value is dominated by at-the-money options, and the fact that at-the-money options can be expensive has no bearing on the argument because we are concerned with the tails. When betting on fat-tailedness, I used to sell at-the-money options because we can safely say—in agreement with Ilmanen—that, owing to their linearity, they are patently expensive, and such a statement is robust to the first elephant.
- *Ludic fallacy.* Real life has little to do with lottery tickets where the probabilities and maximum payoff are generally known. Ilmanen noted the phenomenon called "long-shot bias" while citing papers on bounded payoffs (with a defined upper limit) and binary payoffs in unrelated domains (what I call the "ludic fallacy"). These packages, discussed in several papers[3] cited in the Ilmanen article, are not sensitive to fat tails (there are no true exposures to explosive tail payoffs); I have written a brief note on the problem.[4] Ilmanen also conflated long volatility trading (a more or less convex strategy) with investment in high- or low-volatility stocks.

Table 1. The Effect of an Explosion of Implied Volatility on the Pricing of Options (Expressed in a Multiplier of the Original Premium)

	Volatility Doubles	Volatility Triples	Volatility Quadruples
ATM	2	3	4
5σ OTM	5	10	16
10σ OTM	27	79	143
15σ OTM	302	1,486	3,298
20σ OTM	7,686	72,741	208,429

Note: The at-the-money (ATM) option is linear to volatility, whereas the out-of-the-money (OTM) options are increasingly convex.[2]

Finally, linking all these errors is a misunderstanding of the effect of the severe nonlinearity of the payoff of out-of-the-money options on inference and decisions. We check people getting on airplanes without "evidence" that they are terrorists simply because the consequence of letting terrorists board planes would be monstrous; likewise, there are some inferential mistakes that people are unwilling to make. Ilmanen failed to understand that in the tails, the difference between absence of evidence and evidence of absence is compounded. Alas, such arguments—based on supernaive inference from the past, not on assessment of fragility—led banks to blow up in 2008: They had "empirical evidence" that their payoffs were "safe."

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Notes

1. N.N. Taleb, "Bleed or Blowup? Why Do We Prefer Asymmetric Payoffs?" *Journal of Behavioral Finance*, vol. 5, no. 1 (2004):2–7.
2. N.N. Taleb and R. Douady, "Mathematical Definition and Mapping of (Anti)Fragility," *Quantitative Finance* (forthcoming), shows how one can detect the probability of extreme loss from the convexity of the payoff to changes in standard deviation.
3. For example, Joseph Golec and Maurry Tamarkin, "Bettors Love Skewness, Not Risk, at the Horse Track," *Journal of Political Economy*, vol. 106, no. 1 (February 1998):205–225; Erik Snowberg and Justin Wolfers, "Explaining the Favorite–Long Shot Bias: Is It Risk-Love or Misperceptions?" *Journal of Political Economy*, vol. 118, no. 4 (August 2010):723–746.
4. N.N. Taleb, "A Short Note to Explain Why 'Prediction Markets' & Game Setups Have Little to Do with Real-World Exposures," in *Metaprobability, Convexity, & Heuristics* (technical companion for *Incerto, A Philosophical Essay on Uncertainty*), electronic book (2012): www.fooledbyrandomness.com.

"Do Financial Markets Reward Buying or Selling Insurance and Lottery Tickets?": Author Response

I would like to thank Nassim Taleb for reviewing my article. Taleb makes some interesting points, a few of which are incorrect, starting with his perception that I recommend selling insurance. I have made no such recommendation. On the basis of my survey, I concluded that (1) various forms of selling financial catastrophe insurance earn positive long-run returns but (2) they tend to suffer sharp losses in bad times. Taleb's main argument is that we do not have enough data to warrant the first conclusion (which goes against his prior beliefs), and surprisingly, he misses the opportunity to underline the second conclusion, which is the real benefit of the long-option strategies that he favors. Perhaps our conclusions differ because they rely on different types of analysis. Taleb has great confidence in his prior beliefs; he is highly certain about things that I consider, at best, plausible speculations supported by anecdotes rather than empirical analysis. In contrast, my survey drew deliberately balanced conclusions from a wide-ranging set of theories and empirical evidence.

I am a "two-handed economist" to a fault, trying to see both sides of any argument. This is also true when it comes to the title question posed by my article. The literature on this topic is one sided: Most researchers take it as a given that investors like positive skewness, insurance, and lotteries (and thus overpay for these features). Therefore, when I reviewed the literature, I was delighted to find Taleb taking the other side and controversially arguing that investors prefer negative skewness (which would make skewness and many options structurally underpriced and many long-volatility strategies outperform in the long run).[1]

Taleb's initial point—that I used too many arguments and too much evidence (like the guy with the most alibis in a detective novel)—is a strange one. This argument belongs in Taleb's own "graveyard of silent evidence." What investigator would not prefer to have more evidence—say, a witness as well as fingerprints? In real life, the obvious suspect tends to be guilty—even if this reality does not make for the most interesting detective novel. Of course, one should want to analyze both sides of the issue, and indeed, the goal of my article was to investigate both the costs and the benefits of taking tail risks.

The main theoretical arguments that Taleb disputes are twofold.

- In rational finance, investors require higher long-run returns from investments that perform poorly in bad times. This compensation should be especially high for such asymmetric payoffs as short-volatility and carry-seeking strategies and other forms of selling financial catastrophe insurance. Conversely, investors are willing to pay for downside protection and accept lower long-run returns for "safe haven" assets. In contrast, Taleb claims that investors