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A FEW COMMENTS ON ACADEMIC FINANCE

By Dick Joss

Over the past two years I have written four articles for Risks and Rewards and have given presentations based on these articles at conferences sponsored by the Society of Actuaries. The articles, which deal with purely mathematical issues, have been critical of some models in modern academic finance. The four articles are:

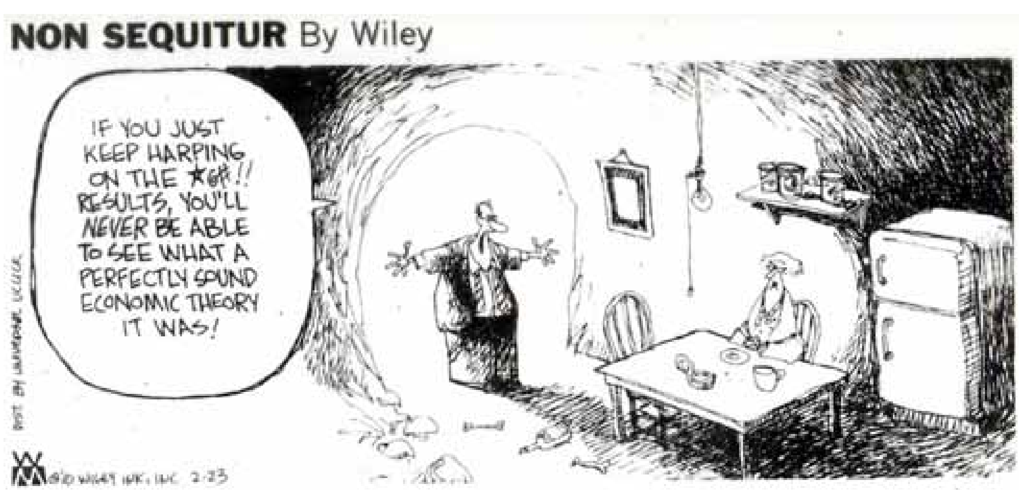
1. Those Pesky Arithmetic Means. R&R – February 2011;
2. Arbitrage and Stock Option Pricing: A Fresh Look at the Binomial Model. R&R – August 2011;
3. Those Pesky Arithmetic Means (Part 2). R&R – February 2012; and
4. A Fresh Look at Lognormal Forecasting. R&R – February 2012.

I am not the only person raising concerns. Articles in such general business publications as *Fortune, Forbes, Business Week,* and *The Economist* have all raised questions about the reliability of the mathematical models that are currently being used. Dr. Craig Barrett, who at the time was the CEO of Intel, wrote an April 23, 2003, op-ed for *The Wall Street Journal* stating that he was uncomfortable signing off on Intel's annual report because of concerns about the Black-Scholes stock option pricing model. In the same vein Warren Buffet went to great lengths in the 2008 Berkshire Hathaway annual report to demonstrate that the Black-Scholes formula could not possibly be right.

Even some academics have raised red flags. Dr. David S. Bates in his paper, "Jumps and Stochastic Volatility: Exchange Rate Processes Implicit in the Deutsche Mark Options," included the following sentence near the end of the paper: "The ultimate research agenda may therefore be to identify those omitted 'fundamentals' that are showing up as parameter shifts in current option pricing models." The problems highlighted in the four *R&R* articles would be just such omitted "fundamentals."

The collapses of Long-Term Capital Management, Bear Stearns, and Lehman Brothers Holdings all add to the level of concern. Even more recently, the $2 billion loss reported by JP Morgan Chase on its derivative investments has generated a new call for more regulation. But if the root cause of the problems are omitted fundamentals, then new regulation is unlikely to provide any relief.

Finally, even the comic strips have gotten in to the act. Below is a *Non-Sequitur* panel which highlights a very valid concern with respect to the academic finance mathematical models.



In short, maybe the "perfectly sound" economic theory contains a few holes.

These issues are all extremely important to actuaries. Like most professional advisors, actuaries are subject to the potential for malpractice litigation. Actuaries do not have the luxury of relying upon theories that may have mathematical problems. As actuaries, we need to study any concerns (such as those presented in the four R&R articles) and make sure that advice provided to our clients or employers is based on a solid mathematical foundation.

MATHIEU BOUDREAULT RESPONSE

In response to the above mentioned articles, Mathieu Boudreault, assistant Professor at UQAM, agreed to write two articles concerning the complex issues in the mathematics of financial engineering and their impact on actuarial science. The first of these articles appears in this issue of R&R, and the second is scheduled to be published next February.

First and foremost, I want to thank Dr. Boudreault for writing a most interesting article. He uses clear illustrations and well written explanations to highlight the current approaches to financial engineering. I encourage all actuaries to take the time to read and thoroughly understand the article. I agree completely with Dr. Boudreault that actuaries need to become more familiar with these complex issues.

My concerns with modern academic finance are not so much theoretical as they are practical. In some cases, the theory may make complete sense, but the application of the theory in practice may be difficult or even impossible. Perhaps, it is these very real practical difficulties that are creating the concern expressed by the general business community.

In addition, many of the key conclusions of academic finance are based on the assumption that observed historical investment returns may be treated as independent and identically distributed (i.i.d.) data. However, Dr. Boudreault and many other leading members of the academic finance community have now conceded that this assumption is not true. And while many leading academics have focused their attention on an investment return assumption that features jumps and stochastic volatility, perhaps even greater scrutiny of how historical investment returns are analyzed is warranted.

AN INTERESTING ILLUSTRATION

As noted above, the Black-Scholes stock option pricing model is perhaps the academic finance model that is creating the greatest concern in the general business community. It is easy to see where the concern comes from by looking at a simple illustration. Although the illustration will involve a longer-duration option, which is relevant for the expensing of employee stock options, the basic issues are just as critical for the pricing of shorter-term listed options. As for the longer-duration option illustration, consider the case of a stock that is currently selling for $100 a share, the strike price is also $100, the risk-free rate is 2 percent, the option term is 10 years, and the volatility is a high (but not uncommon) 120 percent. Using these inputs, the Black-Scholes formula says that the put option price should be $77 and the call option price should be $95.

To many people, these prices are just too high to even be considered as possible prices for the respective option contracts. Let's look at the put option price first. At the $77 price, the purchaser of the option needs to hope that the share price of the stock decreases 77 percent just to get his or her money back, and the absolute best that the purchaser of the option could do is hope that the company goes completely out of business and the share price drops to zero. In this case, the investor will earn an average return of 2.6 percent per year over the 10-year period. All other possibilities generate lower returns, and many possibilities result in

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the investor losing his or her entire $77 investment. Given that the investor has a choice of where to invest his or her $77, the possibility of spending it to purchase this put option contract makes no economic sense. If the investor's outlook for the stock was this poor, rather than purchasing the put option as "insurance" against the potential that the share price will drop, the investor should just sell the stock, and invest the $100 proceeds elsewhere.

As for the call option, the investor has the choice of using his or her $95 to buy the call option or buy .95 share of the stock. When these two choices are compared, the purchase of the stock always turns out to be the better investment, unless the stock averages an annual rate of return in excess of 35 percent per year over the entire 10-year period. Again, as in the case of the put option contract, it seems hard to imagine that an investor would willingly choose to invest in this particular call option contract. The possibility of investing in the underlying security makes so much more financial sense.

While many people in the general public think that these prices seem wrong, even actuaries engaged in investment hedging have also expressed concern. At the Chicago Board Options Exchange Risk Management Conference held March 11 – 13, 2012, several insurance company actuaries mentioned to me the "high cost of volatility reduction." In other words, while it is possible to use stock options to reduce portfolio volatility, the price paid for such a strategy in terms of reduced investment return seems high. Clearly, if the options were bought or sold at a different price, the cost of volatility reduction could be reduced.

The complaint of these insurance company actuaries seemed to be supported with an unusual The New York Times article on March 14, 2012, the day after the Risk Management Conference was over. In the article Greg Smith suggested that some investment banks may be putting the bank's profitability ahead of the needs of its clients. He noted that in some inner circle communications, bank employees may even refer to their clients as "muppets" for their willingness to engage in transactions that have very little potential to generate a reasonable return for their investment. In short, there seems to be some real sense that stock options are not priced correctly from both the buyer and seller perspectives.

WHERE A PROBLEM OCCURS

The source of the above noted seemingly high prices for both the put and call options can be traced back to the exact mechanics of how the assumed lognormal distribution of possible returns on the underlying security is used to price option contracts. Following along with the above illustrations the Black-Scholes model assumes that over the next 10 years there is the possibility that due purely to random chance all of the historically observed very low returns could occur together. This puts significant upward pressure on the calculated Black-Scholes put option price. The Black-Scholes model also assumes that over the next 10 years there is the possibility that due purely to random chance all of the historically observed high returns could occur together. This puts significant upward pressure on the calculated Black-Scholes call option price. Both of these assumptions about possible future return scenarios fail to take into account that in actual markets the high and low returns often cancel each other out.

This topic was discussed in R&R article 4) mentioned above, where it was suggested that observed investment return data was better described using conditional probabilities than independent probabilities. When this one change is made, the $77 put option price gets lowered to $31 and the $95 call option price gets lowered to $49. To many people, these lower prices stand a much better chance of attracting willing buyers than do their original Black-Scholes counter parts.

Furthermore, there is no alteration in the basic Black-Scholes theory to make this change. This is merely a theoretical change in how observed historical investment return

"... HISTORICAL INVESTMENT RETURN DATA IS NOT INDEPENDENT AND IDENTICALLY DISTRIBUTED."

data is to be factored into the calculation process. In short, this difference is due solely to an "assumption" about the nature of the historical data. Clearly this one assumption has a very large impact. And given that leading academics no longer assume that historical data is i.i.d., review of this critical assumption takes on greater importance.

In addition, based on the risk-neutral and arbitrage-free theories of option pricing, if the $49 option price was not correct and the true call option price needed to be $95, then according to the law of one price and the Black-Scholes theory there should be a significant arbitrage opportunity generated if the option were actually on the market at the lower call option price of $49. But the theory that yields such an arbitrage opportunity assumes very specific growth patterns for possible returns on the underlying security. These very specific random chance growth patterns are currently a key part of the basic Black-Scholes theoretical development.

But the change in assumption about the nature of historical data also yields new and different specific growth patterns for the underlying stock. The law of one price and the Black-Scholes theory coupled with these new assumed growth patterns would support the $49 call option price. In short, once the assumption change is made, the arbitrage possibility would appear to occur for prices other than $49, not prices other than $95. Hence, the traditional Black-Scholes theory will not help at all to try and resolve the difference between the $49 call option price and the $95 call option price.

It is also important to note that neither of these theoretical approaches which entail very specific possible stock growth patterns reflects the fact that in real markets there is no chance that either of these stock growth patterns will actually play out. Hence, in real markets as generated by the buy/sell decisions of actual investors the supposed arbitrage opportunity simply does not exist. There is no way to take either of the $95 call option price or the $49 call option price and create a hedging strategy that guarantees a return to the investor no matter what happens to the underlying stock. It is always possible that the actual stock growth pattern will produce a loss from any specific hedging strategy.

This one change is not only significant for stock option pricing, but plays a role in the funding of defined benefit pension plans and the advice provided to 401(k) participants as well. A change to reflect the conditional nature of historically observed investment return data would be significant. I would hope that the issue could be discussed and debated within the academic and practitioner communities and be fully resolved.

It is now widely acknowledged in the academic finance community that historical investment return data is not i.i.d. Given the importance of these issues to actuaries, I trust that the involvement of the actuarial academic community will lead to a more full and complete discussion of these two questions: Are historical investment return data conditional data? And what consequences does this paradigm shift have for actuaries?

FINAL SUMMARY

Clearly, actuaries have a huge social responsibility. We help ensure the solvency of insurance companies and the adequacy of employee benefit plans. We need to be extra cautious of all our techniques and methods to be sure that our clients or employers receive advice that is in keeping with this social responsibility.

John Stuart Mill's classic book On Liberty was first published in 1859. In the book, Mill discusses a variety of philosophical issues on human interaction, and the development of a rational society. Of particular interest, at least to mathematicians, is the following quotation:

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"The peculiarity of the evidence of mathematical truths is that all the argument is on one side. There are no objections, and no answers to objections. But on every subject on which difference of opinion is possible, the truth depends on a balance to be struck between two sets of conflicting reasons."

Whether or not observed historical investment returns are independent or conditional data is purely a mathematical question. Actuaries need to be sure that their work is as complete and accurate as possible. Before using historical investment returns in any meaningful way, they should verify whether or not this data is conditional in nature. To get the answer wrong could lead to financial insecurity in insurance companies or inadequate funding in benefit plans.

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