On the Quantification of the Financial Market -- Rocket Science: Boom or Bust ?

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It is perhaps difficult to dispute the widely held notion that modern financial investment theory began with a seminal article entitled "Portfolio Selection" by Harry Markowitz. The article established the mean-variance framework for stock returns and was published in the March 1952 issue of the Journal of Finance. Markowitz demonstrated that an important criterion to portfolio selection is not to merely focus on maximizing expected return. The more appropriate approach is to consider the equilibrium relationship between the portfolio's variance and its expected return.

The portfolio variance is a function of the co-movement between any two individual securities in the portfolio. The portfolio's risk, and therefore the expected return imposed on it, is highly dependent on the correlation between all possible pair-wise combinations of securities in the portfolio. In this framework, the variance of the portfolio, which measures the relative dispersion in the returns of each individual security in the portfolio, can therefore be interpreted as the risk embedded in the portfolio. This insight allows one to systematically allocate the weightings of the constituent securities given an exogenously imposed level of expected return.

Through this mean-variance framework, one is therefore able to judiciously determine the constituents in the portfolio while being able to target an expected return and, at the same time, be able to minimize the risk of investing in the portfolio. Of course, nowadays we summarily brush aside this brilliant insight as the principle of diversification -- don't put all your eggs in one basket. In retrospect, not only is it *common sense*, it is also a highly effective means of managing risk. Perhaps, this is the most important breakthrough in risk management. It is also perhaps the first time when the financial markets experienced a resurgence of mathematics since Louis Bachelier's doctoral dissertation at the Sorbonne in 1900 exploring the analytical valuation for options.

The mathematics of portfolio optimization is easy. In its simplest form, it can be stated very compactly as a quadratic programming problem. The minimum-variance portfolio with expected return μ is the solution $w(\mu)$ to

$$\begin{aligned} &\min \quad \frac{1}{2} w^t \Sigma w \\ &\text{subject to} \quad I^t w = 1 \\ &\text{and} \quad z^t w = \mu . \end{aligned}$$

The solution to the quadratic program above can be easily determined with the help of a spreadsheet.

In 1973, two decades after Markowitz's breakthrough, the venerable Black-Scholes formula, with an extension to dividend yield δ by Merton, viz.,

$$C = S e^{-\delta(T-t)} N[d] - K e^{-r(T-t)} N[d - \sigma\sqrt{(T-t)}]$$

$$\text{where} \qquad d = [\ln(S/K) + r - \delta + \sigma^2 (T-t)/2] / \sigma\sqrt{(T-t)}$$

became a standard valuation model for options. It still is for many products. Not only is the model simple and easy to understand, it is also compact and flexible enough to function on hand-held calculators and spreadsheets.

The Black-Scholes model has indeed become the beginning and also the end of the mystique surrounding the valuation of generalized contingent claims -- vanilla options being one of them. All issues relating to modern contingent claims can be traced to the same general equilibrium framework established by Black and Scholes, and independently by Merton. Whether one prices a vanilla put option on a dividend-paying stock, a short-dated FLEX option on the 30-year Treasury bond, or a European swaption on 3-month LIBOR, the Black-Scholes-Merton formula is inevitably linked to both the genesis of the contract design and the culmination of a hedged position booked in the back office. And in the intricacies of path-dependent contingent claims, e.g., a barrier option on the Nikkei 225 Index, average strike on Brent crude oil, range floaters with digital payouts indexed to COFI and embedded in a note, a ratchet or ladder or cliquet or shout option on the DM/US rate, the assumptions inherent in the Black-Scholes model are always invoked one way or the other.

It is now 1997 -- some four decades after Markowitz's article and 20 years after the brilliant Black, Scholes, and Merton formulation. What has become of us in the financial industry? What will become of us in the next 10 years? Portfolio optimization has become as trivial as high school matrix algebra and as easily implementable in spreadsheets. Everybody knows about implied volatility and the Black-Scholes formula. People even frown on the implied volatility smile as they know very well that their ability to trade away from the at-the-money range hinges on their intuition of that elusive smile. As elusive as it sometimes seems, the implied smile is no longer as mysterious as Mona Lisa's. It too could be very simply captured in a spreadsheet -- just as Mona Lisa's smile on a canvas.

Exotic options are no longer that exotic. Non-standard derivatives, we now call them. And as far as interest rate derivatives are concerned, we have evolved to an arbitrage-free and equilibrium framework -- all implementable on lattices and trees, bushy or otherwise, which can be pruned, trimmed, or allowed to explode, as long as the valuation could be performed in a reasonable time. And with more powerful machines, computing time is no longer a constraint in the scheme of things. There are now more than a dozen supercomputers in active use in the financial industry today.

The mystique is gone -- thanks largely in part to the massive influx of PhDs from the hard sciences. We will not remain poor academics -- not anymore. The allure of money was simply too tempting to resist. The challenge of doing basic research in a trading environment quite similar to what we were used to doing in our past academic lives was a very exciting prospect. One by one we descended from our academic ivory towers. And still more are arriving. The death knell of defense projects and the end of the Cold War rings agreeably upon the ears of Wall Street. But to what effect?

We -- and the rest of the horde -- all think the same way. All tend to make similar assumptions. All of us strive to derive something out of another thing and sometimes, out of nothing. And all compete to whet the appetite of the same limited number of clients whose nerves are tough enough to play the derivatives game. It is now rocket science brought to a higher level. More and more willing space cadets like myself line up on the launch pad. Five, four, three, two, one, ignition starts ... and another new derivative product is launched into the Street -- this time, a 25-year mission on board the USS American Swaption starship, fully equipped with munitions -- amortizable notionals contingent on dual indexes, resettable strikes, and payoffs quantizable in different numeraire. We therefore trek further and deeper into LIBOR-CMT space. We extend ourselves longer and farther out on the yield curve. We stretch wider and gravitate more freely into highly leveraged payoffs ... and it is all not too difficult. Our mission: to seek out new factor models and to explore strange new derivatives. To boldly go where no one has gone before. But at whose expense?

As the financial markets continue to become more quantified, the level of mathematics becomes less and less accessible to more and more people. In fact, the mathematics encapsulating many of the more innovative interest rate derivative products are now completely incomprehensible to the majority, if not all, of senior management. How many people can understand the assumptions and diffusion processes of the short rate r underlying many interest rate derivatives, with mean-reverting stochastic volatility σ, such as these,

$$
\begin{aligned}
dr &= \alpha(\theta(t) - r)dt + \sigma r^{\beta} dZ \\
d\sigma &= \gamma(\sigma_o - \sigma)dt + \phi\sigma dW \\
dZdW &= \rho dt \ ?
\end{aligned}
$$

The answer is quite clear: very few.

The industry too is loaded with charlatans who have learned how to holler the right buzz words -- diffusion process, jump diffusions, stochastic partial differential equations, equivalent martingale measure, so they say, and a whole slew of other stuff invoked in the name of Norbert Weiner and K. Ito, our esteemed colleagues in physics and mathematics. But what do they mean? In fact, the Black-Scholes partial differential equation is not even stochastic in nature! It is purely deterministic -- believe it or not!

With ever increasing impetus toward integrated firm-wide risk management, the once boring credit related portfolio is now actually being transformed into a plethora of lively frenzied credit derivatives. Although credit derivatives do not really create new forms of risk, by twisting and contorting old risks, we have naively blind-sighted ourselves into more complacent acceptance of old risks disguised as less sanguine risks, thereby obsfucating the original intrinsic and unmitigated risks. It seems that some of the most basic lessons from fundamental risk management are still waiting to be learned.

The crux of the problem lies not in simply being able to model new products very quickly nor to know the right buzz words, but perhaps more importantly to understand what the embedded risks are and how to manage them. Today, it is so easy to price any complicated structures. The mathematics and physics are all there. The space cadets are all eagerly lined up on the launch pads. But all to often, we fail to take one more step further. That all too important, but often neglected, one step further decides who remains or exits from the derivatives game.

The market is now saturated with ideas but, in my opinion, not much effort has been spent to understand these new creations. We have become insouciant in our frenzy to launch new products, and we run the risk of being consumed by our own creations -- drowning in the tempest of the tidal waves they generate. Not much unified infrastructure, as far as systems and hardware are concerned, have been envisioned to manage these risks. In many cases, complex structures are not properly housed in properly designed systems, and so they continue to sit -- in our spreadsheets. My estimate of the average life is 2.5 years for a senior trader on the trading desk, however, most of our newer innovations in the interest rate sector have much longer durations or weighted average lives and will therefore continue to be with us for many more years to come. In many cases, they will continue to sit -- on our simple spreadsheets -- long after the traders who put on the positions have all departed. And long after the space cadets on the launch pads have moved on elsewhere.

The derivatives game can only be won by those who fully understand the embedded risks and have learned to manage them. It should be a game only for those who see value beyond the immediate, beyond the year-end bonus. The management of risk has therefore suddenly become more important. It is now time to reflect back on the common sense philosophy espoused in the work of Markowitz some 40 years ago. It is now time to trace back to the dawn of the quantification of the financial markets. The game has changed; the structures, more complex; and the competition, definitely more intense. But the lessons to be learned are still there. It is time to exercise more common sense and to behave more responsibly. All too often our vision, or lack of it, is clouded by too much mathematical abstractions, and we could not see beyond the obvious, beyond common sense. All too often our perceptions are numbed by the cacophonous roar and intense heat at the frenzied launch pads. The simplicity of Maxwell's equations in electromagnetism, the compact elegance of Einstein's field equations of general relativity, and the clarity of the Black-Scholes-Merton formulation -- all are lessons in simplicity that we can all learn from. This should be our vision for the next 10 years -- responsible and prudent risk management, firmly grounded on simple and unfatigable common sense principles.

The quantification of the financial markets is here -- it has been here for a long time. We cannot wish it away. And there is no turning back. The current momentum sustained in the markets will continue to propel all of us forward, deeper and further into new and uncharted financial hyperspace. And as we gather around the launch pads once again, only one question remains -- boom or bust?