Derivatives Trading: Physicists Favor Less Complex and Risky Theory

The investment options known as derivatives have been in the news for over 20 years. Trading in derivatives has been credited with making huge profits—and accused of playing havoc with the well-being of financial, industrial and other institutions, such as Baring's Bank and Orange County, California. The last few years have been marked by an increasing emphasis on the negative aspects of derivatives, a growing belief that they are a loose cannon that endangers the very structure of the contemporary economic world and even charges that somehow mathematicians and physicists are to blame (see PHYSICS TODAY, May 1995, page 55).

Too little attention has been given to the fact that derivatives trading is based on a mathematical theory that is too complex for most MBAs to master and that it is flawed in its hypothetical underpinnings. The theory—the first complete mathematical theory of derivatives and other options—was published by Fischer Black and Myron S. Scholes in the *Journal of Political Economy* in 1973, the same year that an organized market for negotiable options opened in Chicago. Owing to its mathematical elegance, and especially because of the urgent need for a well-defined framework created by the Chicago market, the Black–Scholes theory was very rapidly and widely accepted both by academics and traders, a rare occurrence in the history of science.

Using this theory effectively, however, requires the application of the elegant, sophisticated and efficient mathematical tools of stochastic calculus. The subtlety of the mathematics is accessible only to a mathematical elite, notwithstanding the fact that the theory is taught in graduate economics and business courses. We believe that 95 percent of MBA students may not have the background to understand it deeply and therefore be able to criticize it and appreciate its limits, which is an essential step for those whose job is to estimate and limit the financial risks associated with derivatives.

The validity of a scientific theory is gauged as much by the validity of its underlying hypotheses as it is by the logic of the deductive path leading from the hypotheses to the results. Unfortunately, one of Black and Scholes's hypotheses, that of an uncorrelated log-normal distribution of continuously varying prices, is quite unrealistic. It depicts a world in which uncertainty can be tamed, risks can be mastered, crashes never happen and a drop of 5 percent in market price in 24 hours should occur only once every thousand years.

There is an even more serious problem with the Black–Scholes theory. The peculiar structure of the restrictive set of hypotheses underlying it, although mathematically convenient, leads to a counterintuitive result: Notwithstanding the uncertainty associated with the random fluctuations of stock market prices, the issuer, or seller, of the option can follow a strategy that completely cancels all his risks—a condition that represents the utopia of all insurers. Even without mastering the gory mathematical details, traders are impressed, even anesthetized, by this message, enough to throw away all caution.

The usual perception among traders is that the risks involved in derivatives trading must be small in practice because the risks can be made to vanish in theory. In fact, no banker using the Black–Scholes equation can know exactly the exposure of his establishment to such risks. This is because the Black–Scholes theory is silent on the crucial question of risk in that the underlying hypotheses and mathematical framework lead to a solution without any risk. One cannot measure something that is not supposed to exist.

In the same vein, because all the financial software packages that have been developed for traders are based on the Black–Scholes theory or its variants, they cannot provide an estimate of the risk of a given position.

We claim that what is lacking in the Black–Scholes theory is the physicist's approach, which can be characterized as involving an interplay between data and theory. In particular,

continued on page 128

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LETTERS *(continued from page 15)*

if one uses the tools of statistical physics, which have been applied to a gamut of subfields ranging from magnetism to earthquakes, one can formulate a theory of options that is clearer and uses a simpler mathematical formalism that allows for large deviations and crashes in particular.

We have attempted such an approach.[1] We think it could lead to a better understanding of the nature of the problems by both players in the market and managers of financial institutions. One critical aspect of our approach is that it calculates the risks associated with derivatives. As the record over the past 20 years shows, actual risks can be significant.

It is also evident that the lack of regulation has played a key role in the present turmoil surrounding derivatives. We believe that effective regulation will appear spontaneously when reliable quantitative estimates of the degree of risk of each market position can be developed. On this issue, we rely on the optimistic concept that the availability of useful information will lead to a natural limitation on exposure to risk. Recent work on complex systems has shown that feedback provided by the learning process is sufficient to create self-organized and self-regulated dynamical functioning, at least in biological systems (as discussed in PHYSICS TODAY, March 1991, page 9 and July 1991, page 9).

Much work remains to be done, both theoretically and practically, to bring about the efficient use of such risk estimators in the field of derivatives, as well as their application to other financial products.[2] Meanwhile, it is important to recognize that the financial world continues somehow to avoid the systematic use of risk assessments, even though they have long been applied to various industrial and natural hazards, such as the siting of nuclear plants and the occurrence of earthquakes.

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Celestial Rays Raise Hopes of Finding Their Sources

Ultrahigh-energy cosmic rays, above 10^{19} electron volts, have been reported coming from the supergalactic plane (PHYSICS TODAY, December 1995, page 9). This result may be even more important than it first seems because it is supported by recent gamma-ray and x-ray observations. The gamma-ray observations up to about 1000 MeV from EGRET show extensions of this high-energy radiation down through the spine of the Virgo cluster of galaxies, and through the southern extension of that cluster and beyond.[1] The ROSAT x-ray observations show > 0.4-keV x rays coming from the Virgo cluster along this line.[2] They also show higher-energy (>1.0 keV) x rays extending farther south along the supergalactic equator for a total of over 11 degrees.[3]

The investigators who have made the cosmic-ray observations suggest that the rays are powered by active extragalactic objects situated in the Local Supercluster. This seems to be the only reasonable site for their origin and agrees with the suggestions that have been made for a similar origin for the observed gamma rays and x rays.

The possibility for making further important progress, of course, lies in the identification of the specific objects that are generating this huge energy and the elucidation of the basic physical mechanisms responsible.

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Lowest Notes on Violin Require Skill and Guts

The report (September 1995, page 20) of anomalously low frequency sound from the violin deals with what should really be called a rediscovery of a technique that has long been used by great violinists.

Despite the credibility of independent discoveries by Frederick Halgedahl and Mari Kimura, the credit for achieving low, nonharmonic tonalization through increased bow pressure has already been assigned to Niccolò Paganini. According to my source, virtuoso violinist Ruggiero Ricci, Paganini made use of this "secret" method to enhance his bow control—a practice later emulated by generations of virtuosos. Yet Paganini historian Joseph Gold believes that the actual discovery goes back to the great 18th-century violin master Giuseppe Tartini.

Although it is hard to discover anything new about the violin, the interpretations of Roger Hanson *et al.* and their mathematical underpinning by Knut Guettler are convincing and meritorious. They break welcome new ground in a field that tends to ignore how violins are actually played.

The forced subfundamental emissions are occasionally used to produce cellolike tones below the fundamental of the G string. But their musical significance lies primarily in their ubiquitous presence in sounds produced on the violin's other three strings under the dynamics of forte and fortissimo. The low musical third is an essential transient in each attack of the bow, and is especially audible in the staccato mode.

The technique of forced bowing required to produce low emissions is artistically acceptable only if old-fashioned gut-based strings are used. Metal and synthetic strings have frictional characteristics and stiffness that result in too much noise.

One amusing aspect of the recent interpretations is that they could have occurred 30 years ago if the members of the acoustics societies had been more inclined to generate sound from the violin as it is supposed to be done, by using the bow rather than mechanical transducers. Now, though, perhaps more acoustics scholars will rededicate themselves to the study of the real violin sound and will then be able to narrow the gap that exists between what they know and what performers feel.

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Cartoon Assessment

The cartoon reproduced on page 85 of the January issue is in exceedingly poor taste. Regardless of what view one takes in the current debate about the effects of electro-