DERIVATIVES IN A DYNAMIC ENVIRONMENT

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by

MYRON S. SCHOLES

Graduate School of Business, Stanford University, Stanford, CA, USA and Long-Term Capital Management, L.P., One East Weaver Street, Greenwich, CT 06831-5146, USA

1. INTRODUCTION*

The trading of financial derivatives on organized exchanges has exploded since the early 1970s. The trading of off-exchange financial derivatives on the so-called "Over-the-Counter" or "OTC" market has exploded since the mid-1980s. Academic and applied research on financial derivatives, which was initiated by the Black-Scholes and Merton option-pricing research in the late 1960s and early 1970s, also has exploded. As a result, three industries have blossomed: an exchange industry in derivatives, an OTC industry in synthetic products, and an academic industry in derivative research, populated by scientists in and out of academic institutions. The academic industry has seen a growth of research and course offerings in economics and business schools in the areas of options, futures, risk management, financial engineering, and by marrying institutional and derivative modeling, a richer approach to financial intermediation and innovation under uncertainty. In addition, business schools and economics departments have competition from new research and courses in mathematics departments and engineering schools in the mathematics of derivative pricing and alternative stochastic processes, and in law schools in understanding contracting under uncertainty.

The academic industry has produced myriad innovative research papers following the fundamental insights of Black and Scholes (1973) and Merton (1973). The Chicago Board of Trade and Chicago Mercantile Exchange initiated the exchange industry by developing financial options and futures contracts on securities; they have spawned the growth of many new derivative exchanges around the world. The first was the Chicago Board of Trade's sponsorship of the Chicago Board Options Exchange in 1973. Moreover, some exchanges such as the Options Market in Stockholm have transported the technology used to trade derivatives to other markets in Europe and Asia.

* I would like to thank Robert C. Merton for many years of fruitful and exciting discussions on these topics. In addition, I would like to thank my many colleagues at the University of Chicago, MIT, and Stanford University, for their ideas and stimulating discussions. Most important has been the support and involvement of Merton H. Miller in my career: I owe him a tremendous debt and cherish his friendship. I miss Fischer Black; I miss his friendship, his insights, and his good humor.

These exchanges succeed by producing the derivative contracts that add value for individuals and institutions around the world. The OTC industry, which has grown to prominence since the mid-1980s, first in the United States and now in every corner of the globe, is now larger in size than the exchange industry. Financial institutions in the OTC industry offer customized derivative products to meet the specific needs of each of their clients; the exchange industry offers standardized products to reach a richer cross-section of demand.

Each industry requires original research to understand the pricing and production costs of the products and financial services that they bring to their clients. Derivative research is quickly transferred to practice; moreover, practice stimulates both academic and applied research. Some of the best research is conducted outside of academic institutions and academics have found a home in each of the three industries. Graduates from mathematics, computer sciences, engineering and physics compete and cooperate with those trained in financial economics for research and structuring positions in both the exchange and OTC industry.

It is difficult to define financial derivatives in a dynamic environment. The purest among us might argue that any security is a derivative if its price dynamics depend on the dynamics of some other underlying asset or assets and time. This broad definition allows not only for what currently exists but also what new derivative instruments will be developed in the future with enhanced understanding and changing production costs. The popular press, however, tends to limit the definition to include financial options, futures and forward contracts either traded on an exchange or issued in the OTC industry. In the future they may come to be called financial products.

The will of Alfred Nobel states, in part, that the Nobel Prize shall be awarded for an "important discovery or invention." Fischer Black's and my discovery was how to price options and to provide a way to manage risk. Robert Merton developed an important alternative proof of the pricing technology and extended the approach in many directions including how to price options with dividends, how to price options when the interest rate is not constant, and how to apply a more general structure to price many other contingent contracts.

Black and Scholes have over the years been accused of inventing derivatives, at least those derivative products that have been claimed to have had bad economic consequences for their users. It is seldom remembered that these contracts have two sides: if a buyer loses, the ultimate seller might gain. Only if losses cause dead-weight costs is there a net loss to society. It is said that "every successful idea has a thousand fathers, and every failure is an orphan." Over the years we have been granted both distinctions. We did not, however, invent derivatives. Options existed in many financial contracts prior to the Black-Scholes and Merton pricing technologies. Options were noted to have been traded on the Amsterdam Stock Exchange in the late 17th century and traded on the Chicago Board of Trade into the early 1930s. As described in Cootner (1964), research in option pricing goes back as far as Bachelier's

Ph.D. thesis in 1900. Although they are not generally thought of as options, myriad securities and investment decisions have been made in the past and are being made currently that could be evaluated using the Black-Scholes technology. The technology was an invention that facilitated multiple inventions in each of the three industries. What I did not realize at the time of the invention was how the technology would evolve and how it would be used to produce new types of securities with imbedded options at lower cost than could be accomplished prior to the development of the technology. This enhanced the efficiency set of demanders and suppliers of capital, not only in the United States but also around the world.

With the Christmas season approaching at these Nobel award ceremonies in Stockholm, I will invoke the "Past," the "Present" and the "Future," as Charles Dickens did in "A Christmas Carol," to describe the evolution of derivatives in a dynamic environment. I do not mean to draw too fine a parallel, however. That is, I am not implying that through the eyes of Mr. Scrooge the past for derivatives was bright with hope and innocence, and the present is dark and foreboding and the future, without changing our ways, presents a bleak picture. On the contrary, many in academics and those in practice have often asked for a glimpse of the past; that is, how we developed the technology and the model, and the past gives insights into the present. It was a time of innocence. It was a time of discovery. It is a tradition at these Nobel award ceremony lectures to describe the age of innocence. I am honored and thank the Nobel Prize Committee for this wonderful opportunity do so. I wish that Fischer Black were alive today to share this honor with us.

Twenty-five years is a tender age for the new academic and the new exchange industry. Fifteen years is still a young age for the new OTC industry. The Present, which I date from the late 1980s to current time, shows an industry that has experienced growing pains, and many, including regulators, are worried that it still has not come of age. And, will the Future be bleak? No, there will be failures, but the industries will thrive because derivative instruments will provide progressively lower-cost solutions to investor and entity problems than will competing alternatives. These lower-cost solutions will involve the unbundling and repackaging of coarse financial products into their constituent parts to satisfy client demands. The process will continue to evolve as advances in information technology drive down the cost of providing alternative and more productive solutions.

2. THE PAST

Although Black (1989) and Bernstein (1992) described their versions of the development of the option-pricing technology, this lecture, however, gives me an opportunity to add to their description through my recollection of things past. My formal training at the University of Chicago was in financial economics, statistics and economics. At Chicago, Merton Miller, the 1990 Nobel laureate, and Eugene Fama, a prolific scholar, stimulated my excitement in economics and a new branch of economics, which has come to be called financial economics. I also owe a similar and considerable debt to my fellow classmates at Chicago, most notably, Jack Gould, Michael Jensen and Richard Roll.

The three strands of financial economics that most set the tone for my future research were arbitrage and the notion of substitutes; the efficient markets hypothesis; and the capital asset pricing model.[1] These strands gave a mathematical basis to the models of finance, in a general equilibrium framework. Modigliani and Miller (see Miller (1988) for a retrospective) were making profound breakthroughs that provided a general equilibrium model for corporate finance. Their arbitrage arguments, which demonstrated how a firm's value was independent of how it financed its activities, had a profound effect on the way I analyze and model many problems in economics. The Fama (1965) and Samuelson (1965b) efficient-markets hypothesis that states that, in a well-functioning capital market, the dynamics of asset prices are described by a submartingale and that the best estimate of the value of a security is today's price, was revolutionary to economics. Their insights gave me an important framework to think about the dynamics of asset prices and how markets adjust to "news." It set the stage for empirical testing of how information was incorporated into security prices and gave me a vehicle to apply my statistics and computer skills in a financial economics context. For example, Jensen (1968) had used the concepts of the efficient-markets hypothesis to test whether mutual funds, which were professionally managed and spent considerable sums of money to discover undervalued assets, could outperform randomly-selected investments on a risk-adjusted basis. Roll (1970) had tested the efficiency of the bond market controlling for changes in expected returns impounded in bond prices. In my own work, Scholes (1972), I used the concepts of efficient markets and substitutes (arbitrage) to test the extent to which security prices were influenced by the size of the sales of large blocks of securities or by changes in the information set. Following on the work of Markowitz (1952, 1959), the Sharpe (1964), and Lintner (1965) the capital asset pricing model provided a general equilibrium model of asset prices under uncertainty. This became the fundamental model for measuring the risk of a security. It was elegant to condense the required relative rates of return on securities into a simple reduced-form equation that depended only on their "betas," a measure of their relative contribution to the risk of the optimal portfolio.

The capital structure models, the efficient-markets hypothesis, and the capital asset pricing model had the common central themes of arbitrage and market equilibrium: securities with similar economic risk had to exhibit similar returns to prevent arbitrage profits. This principle applies to all securities, whether they are common stock, bonds, or hybrid instruments. Through participation in seminar presentations at the University of Chicago, I became

[1] I am sure that Fischer Black would pick at least the efficient-markets hypothesis and the capital asset pricing model as most influential in the development of his thinking in financial economics.

generally aware of the nature of warrants and convertible bonds. I was unaware, however, of the interest in warrant pricing and the research that had been conducted at MIT on this topic in the 1960s even though I became an Assistant Professor at the Sloan School of Management at MIT in 1968.

I did not meet Robert Merton until the spring of 1969, when he was interviewing for a position at the Sloan School. We began interacting in the fall of 1969. We talked then about his current research on dynamic applications of the capital asset pricing model with changing opportunity sets and my work, at the time, including tests of the capital asset pricing model. We did not talk about warrant pricing even though Fischer Black and I were working on the problem. I guess we did not appreciate that each of us had an interest in this research area.

In the summer of 1968, a research project at Wells Fargo Bank in San Francisco convinced me that the passive management of assets could be a viable contender to actively managed portfolios. In my report to Wells Fargo Bank, I recommended that they initiate passive investment strategies and offer them to their clients, the forerunner to so-called "index funds." That fall, on the suggestion of Michael Jensen, I had lunch with Fischer Black, who he had met because of Jensen's research on mutual funds. Fischer was employed at Arthur D. Little, a consulting firm in Cambridge, Mass. We had several other lunches that fall and Fischer suggested that he was thinking of leaving Arthur D. Little to start his own consulting firm. At about the same time, John McQuown at Wells Fargo Bank asked whether I wanted to conduct research that would describe the tradeoff of risk and return in the market as a forerunner to introducing passive investment strategies to their clients. Without research, they were not willing to offer index-fund-like products to clients. Being an Assistant Professor, I was restricted as to the number of days I could consult. I asked Fischer whether he wanted to join forces on the project. It was obvious from our lunch discussions that he had very similar ideas, and was starting a research project with Jensen on measuring risk and return. We joined forces and worked together to test the capital asset pricing model (see Black, Jensen and Scholes (1972)). We developed the concept of the zero-beta portfolio to test the model. If we could create a zero beta-minimum variance portfolio by buying low beta stocks and selling high beta stocks and achieve realized returns on this portfolio that were significantly different from the interest rate this would violate the predictions of the original capital asset pricing model.

In the winter of 1969, I agreed to direct the Masters thesis of an MIT graduate student who had garnered a time series of warrant and underlying stock prices and wanted to apply the capital asset pricing model to value the warrants. I read all of the articles relating to warrant pricing in Paul Cootners' book of readings on The Random Character of Stock Prices (1964). One included paper, by Case Sprenkle and dated 1960, seemed the most relevant to me, but Sprenkle used an exogenously determined discount rate to discount the expected terminal value of the warrant to its present value.

What seemed apparent was that the expected return of the warrant could not be constant for each time period because the risk of the warrant changed with changes in the stock price and with changes in time to maturity. For example, if the warrant was far "in-the-money," that is, the underlying stock price was far above the exercise price, and the warrant was almost sure to be exercised, its price would change almost dollar for dollar with a change in the underlying stock price. The percentage change in the value of the warrant, however, would be greater than the percentage change in the value of the common stock because the warrant was a leveraged instrument. On the other hand, if the warrant was "out-of-the-money," that is, the underlying stock price was less than the exercise price, the warrant price would move far less than dollar for dollar with the price of the common stock (for example, $.5 for $1 move in the common). The percentage change in the price of the warrant, however, would be even greater than that of the in-the-money warrant.

As a result, the expected return on the warrant could not be constant each period if the beta of the stock was constant each period. I thought about using the capital asset pricing model to establish a zero-beta portfolio of common stock and warrants by selling enough shares of common stock per each warrant held each period to create a zero-beta portfolio. Given I could create a zero-beta portfolio, the expected return on the net investment in this portfolio would be equal to the riskless rate of interest. I knew that I would have to change the number of shares of stock each period to retain my zero-beta portfolio. But, after working on this concept, off and on, I still couldn't figure out analytically how many shares of stock to sell short to create a zero-beta portfolio.

Fischer and I continued working on tests of the capital asset pricing model and the development of investment products based on the implications of our research throughout 1969. In the summer or early fall of 1969, I discussed with Fischer my earlier experience with warrants, my attempt at creating the zero-beta portfolio, and my inability to determine the changing number of shares needed each period to create the zero-beta portfolio. He described to me his research on warrants and that he was frustrated in his inability to progress further than he had to that time. He showed me a sheet of paper, which described the relation between the return on the warrant and the underlying stock. Following on earlier work by Jack Treynor, Fischer had used a Taylor Series expansion of w(x,t), where "w" is the warrant price, "x" is the current stock price and "t" is time to maturity to show the relation between the change in the warrant price as a function of the change in the price of the common stock and a decrease in the time to maturity of the option. Ignoring terms of second order with regard to time, over a short period of time, this expansion was:

$$\Delta w(x, t) = w_1\ \Delta x + w_2\ \Delta t + \tfrac{1}{2}\, w_{11}\ \Delta x^2 \Delta t$$

where Δ is the change symbol, and the subscripts refer to partial derivatives with respect to the first or second arguments.

Not surprisingly, Fischer had used the capital asset pricing model to describe the relation between the expected return on the warrant and the market and the expected return on the common stock and the market. By substituting for the change in the warrant price as a function of changes in the stock price and time in the capital asset pricing relation, it became obvious on how to create a zero-beta portfolio that would have an expected rate of return equal to the interest rate (for we assumed a constant interest rate).

Consider the returns over a very short period of time on two alternative investment strategies: under (1), we acquire the warrant, and enough bonds earning at interest, r, per period, such that our investment in strategy (1) is the same as in alternative strategy (2), in which we buy w_1 of stock. The following is the investment and the return on these two alternative strategies:

	Investment		Return
(1)	Buy warrant	w	$w_1 \Delta x + w_2 \Delta t + \frac{1}{2} w_{11} \Delta x^2 \Delta t$
	Bonds	$w_1 x - w$	$r \Delta t(w_1 x - w)$
(2)	Buy Stock	$w_1 x$	$w_1 \Delta x$

The investment was constructed to be the same in strategy (1) and strategy (2). The risk appears to be the same in both strategies. The only uncertain term is Δx, the change in the stock price, and the total uncertainty due to changes in the stock price is the same in both strategies. Δx^2 involves the change in the stock price squared, a form of variance, which as Δt becomes small approaches $x^2\sigma^2$, the stock price squared times the instantaneous variance of the underlying returns on the common stock, which is assumed to be constant.

Since the risk is the same and the investment is the same under both strategies, to prevent arbitrage, the returns must be the same over a short period of time. After equating the returns on strategy (1) with the returns on strategy (2), and substituting for Δx^2, we find:

$$-r w + w_1 x r + w_2 + \frac{1}{2} w_{11} x^2\sigma^2 = 0$$

This is the Black-Scholes differential equation. The initial condition for a warrant or call option is that $w(x,t^*) = \text{Max}(x - c, 0)$, where t^* is the maturity date of the option, and c is the exercise price of the option. The only required inputs to value the option, other than its initial conditions, are r, the interest rate, and σ^2, the variance rate per unit time on the returns on the underlying stock. We were both amazed that the expected rate of return on the underlying stock did not appear in the differential equation.

Although the number of shares needed to create a zero-beta portfolio each period was w_1 it was not obvious to us how to find w_1. The next step in solving the problem was to realize that since the warrant valuation depended only on the variability of returns and not the expected return on the underlying common stock, it was arbitrary what expected return was assumed for the underlying common stock. The same warrant valuation equation would result because we had hedged out the risk of the common stock in establishing the zero-beta portfolio or the alternative replicating portfolio, as above. We assumed that the expected return on the common stock was equal to the interest rate over the next short period of time, or in terms of the capital-asset pricing model that the common stock had a zero beta.

With the assumption of constant return and variance of return, the distribution of returns on the underlying stock at expiration of the warrant would be lognormally distributed. We used the Sprenkle formulation to find the terminal value of the warrant using a constant interest rate as the expected rate of return on the stock. But, we wanted the present value of the warrant. The key here was to realize that although the warrant would have greater price variability than the underlying stock, if we assume that the stock had a zero beta, the warrant would have a zero beta. If the warrant had a zero beta each period of time, the warrant had also to return the interest rate, r, each period of time.

If we had decided to value the warrant using the actual expected return on the common stock or, for that matter, any other appreciation rate, the discount rate to value the warrant would depend on time and changes in the stock price. It does not for the zero-beta case. Using Sprenkle's formula with the assumption that the expected return on common stock and the discount rate for the warrant was equal to a constant interest rate, we obtained the Black-Scholes option-pricing formula.

$$w(x,t) = x\, N(d_1) - c\, e^{r(t-t^*)}\, N(d_2)$$

where N(d) is the cumulative normal density function, c is the exercise price, t* is the expiration date, and t is the current date, t*–t is the remaining number of periods in the life of the option, and "e" is the exponential operator. Lastly,

$$d_1 = [\ln x/c + (r + 1/2\sigma^2)\ (t^* - t)]\ /\ \sigma \sqrt{t^* - t}$$

$$d_2 = d_1 - \sigma \sqrt{t^* - t}$$

We checked the formula against the differential equation and, as we expected, it fit. We were sure that we had the correct formula for valuing call options or warrants, the right to buy an asset at a fixed price, the exercise price, at maturity of the right, its expiration date. With minor adjustments we could value a put option, the right to sell an asset under similar terms.

From the formula, we were finally able to compute w_1, which was equal to $N(d_1)$, the required number of shares to hedge the option. The number of shares will change over time and as the price of the underlying security changes with respect to the exercise price. But, given the assumptions it is a known quantity each time period.

The formulation also suggests the technology necessary to price any contingent claim that depends on an underlying asset's price (or even other state variables) and time. This is so even with differential known pay-outs, such as dividends on a stock or coupons on a bond, that are not received by the option holder. The technology suggests that what is necessary is to hedge the stochastic term, Δx, to create an alternative investment that is riskless. Merton (1973) formalized these relations.

We had spent a considerable amount of time working to finish up several other papers including our paper on testing the capital asset pricing model. As a result, we finished a draft of the paper sometime in the winter of 1970. We did not know whether our formulation was exact, but intuitively we thought investors could diversify away any residual risk that was left. For larger price changes in the common stock, the hedge position of being long the option and short the appropriate number of shares of stock would tend to make money whether the market went up or down, and would lose money on small changes in the market portfolio. The risk of the position appeared to be independent of market risk. We programmed the model and tried to understand the sensitivity of the price of the option to changes in the stock price, time to maturity, volatility, and the interest rate.

We presented a draft of the paper at a conference on capital market theory sponsored by Wells Fargo Bank in July of 1970. Later that summer, on vacation together, Fischer and I worked out the applications of the option-pricing framework to the pricing of risky debt and other capital structure issues. We viewed the common stock of a company with debt in its capital structure as a call option. The equity holders have an option to buy back the firm from the debt holders by paying off the face amount of the debt at its maturity. The equity holders will not buy back the firm from the debt holders at the maturity of the debt if the face amount of the debt is less than the value of the firm's assets; they will turn the remaining assets of the firm over to the debt holders. For us, it was exciting to realize that the equity of a corporation was an option, and that our framework applied far more broadly than the valuation of warrants or put and call options. The methodology provided a systematic approach that relied on arbitrage to value the capital structures of firms, and to understand how management decisions affect the relative values of debt and equity in the firm's capital structure.

As it turned out, Robert Merton, who had written an earlier paper on the valuation of warrants with Paul Samuelson (see Samuelson and Merton, 1969) following on Samuelson (1965a) early work on warrent valuation, had expected to attend our session at the Wells Fargo conference, but he overslept and missed the session. In the winter and spring of 1970, Fischer and I searched the academic literature to determine how close others were to our invention. Fischer and I realized that the Samuelson and Merton paper contained an equilibrium model to value warrants but they did not value the warrant continuously. Given that there was friendly rivalry between the two teams, Fischer and I wanted to progress, on our own, as far as we could prior to the conference.

After the conference, in the early fall, Robert Merton and I discussed the Black-Scholes valuation methodology and option-valuation formula. He was not convinced that using the capital asset pricing model framework was sufficient. It seemed to him that, as the interval of adjustment of the hedge became closer to continuous time, there might still be covariance between the hedged position and the market return. Merton and I speculated that one way that there would be no such covariance would be if the return on the option was perfectly correlated with the return on the stock in continuous time, and therefore the hedge was exact. Merton later proved that the hedged position in continuous time was riskless, and that the replicating portfolio argument was exact. Fischer and I used this derivation in the final version of the paper because it relied on arbitrage and not on any underlying model of capital market equilibrium. However, we still presented the capital asset pricing model derivation of the model, as it provided us with the many insights we used to unlock the puzzles of option pricing.

Merton (1973) then started working on his paper on various aspects of the option formula. He incorporated his alternative proof of the option-pricing model. He also showed that the right to exercise a call option prior to maturity is not valuable for a non-dividend paying stock, but valuable for a put option on a similar stock. He also showed how to incorporate changes in interest rates into the valuation methodology, and generalized the formula to handle other state variables.

To our dismay, when we submitted a version of our paper entitled "A Theoretical Valuation Formula for Options, Warrants, and Other Securities" (October, 1970) to the *Journal of Political Economy*, it was rejected without review. The *Review of Economics and Statistics* also rejected the paper. Fischer felt that the paper was rejected because he was not an academic; I felt that I was an unknown Assistant Professor and the paper would not be considered to be broad enough for those academic journals. With the help of Merton Miller and Eugene Fama, who took an interest in the paper and stepped in on our behalf, the *Journal of Political Economy* agreed to consider the paper if we revised it and broadened its applicability. We had planned to publish the corporate-finance-capital structure applications in a subsequent paper but we broadened the original paper and showed how corporate liabilities could be viewed as options.. The final version of the paper was published in 1973 in the *Journal of Political Economy* under the title "The Pricing of Options and Corporate Liabilities."

2.1 *The Aftermath*

In Black and Scholes (1972), we tested the option pricing model using data recorded in a transactions diary of a broker in the over-the-counter option's market provided to us by another Master's student at MIT. The diary listed the prices at which he sold options to his clients. Using simple estimates of the volatility, the model generally performed well. It produced profits if one could buy options at diary-market prices if the model indicated a higher value than the market and sell options at diary-market prices if the model indicated a lower value than the market. Each trading day, we assumed that the model could be used to determine the hedge ratio, the delta, and undertook these hedges (assuming that transaction costs were zero). We regressed the daily returns on our hedged portfolio on the market returns. As expected, the portfolio returns were uncorrelated with the market returns, but the model produced substantial and significant abnormal profits. The market appeared to ignore information available in the historical data on estimating volatility.

When we assumed that we could buy the undervalued and sell the overvalued options at model prices and hedge out the underlying stock risk, we incurred significant losses. These losses were incurred because using simple estimates of the volatility ignored information on future volatility that the market was using to price the options. When actual realized volatility over the life of the option was used to compute the model prices, buying undervalued and selling overvalued options at model prices generated returns that were insignificantly different from zero.

It became apparent to us that the transaction costs of dealing in the over-the-counter market were quite large. The dealers would only sell options. As a result, the market in put and call options was quite small. The world was about to change. In the early 1970s, various studies were commissioned to provide an economic justification for a new options exchange. As a result, The Chicago Board Options Exchange (CBOE) was born in 1973 almost simultaneously with the publication of the Black-Scholes and Merton option-pricing papers. The reduction in transaction costs and the transparency of the market were justifications enough for the subsequent success of the options market.

It is ironic that these empirical tests of the Black-Scholes model were published in the *Journal of Finance* in the proceedings volume of the *American Finance Association Meetings*, in May of 1972, a full year prior to the publication of the model itself. Although we did not present it as such, it is ironic that the methodology in the paper is generally the same as that used today by financial entities to manage the risks of their trading positions and to measure the performance of their traders.

2.2 *Historical Notes: From Theory to Practice*

Both the derivative exchange industry and the derivative academic industry grew significantly from 1973 to 1985. Financial economists started to interact with a broad set of practitioners and this led to a cross-fertilization of ideas among the participants in both industries.

The option-pricing technology was adopted simply because it reduced transaction costs. For without a model, traders could neither price securities with imbedded options with sufficient accuracy to compete against other traders with models, nor could they reduce the risk of their positions to employ their capital efficiently at a low enough cost to compete with other traders. Although it is hard to prove, I do think that the success of the CBOE and other exchanges, in part, can be attributable to option-pricing models. As traders became familiar with these models, bid-offer spreads narrowed. As traders became more familiar with risk-management techniques they could take on larger position sizes to support the market. With a deeper and more efficient market, investors began to use options to facilitate their own investment strategies.

In those formative years, notable extensions and additions to the basic framework include important contributions by Black (1975, 1976), Banz and Miller (1978), Breeden and Litzenberger (1978), Brennan and Schwartz (1979), Cox and Ross (1976), Cox, Ross and Rubinstein (1979), Geske (1979), Harrison and Kreps (1979), Magrabe (1978), Merton (see Merton, 1992a), Parkinson (1977), Richard (1978), Ross (1976), Rubinstein (1976), Scholes (1976), Sharpe (1978), and Vasicek (1977).

In 1971, Fischer Black left Boston to become a Professor at the University of Chicago. In 1972, Robert Merton and I became consultants to Donaldson, Lufkin and Jenrette (DLJ) to build mathematical models to price so-called "Down-and-Out Options" and to build their options technology to price call options in the event of a launch of the CBOE. Leo Pomerance, the head of the DLJ options group, was an options trader from the old school; he traded OTC options using intuition and experience without regard to a formal model. He later became the first chairman of the CBOE. At DLJ we forged a marriage of the old-time trader types, with their mental set, with young mathematical modeling types, with their model assumptions, to add value for the firm.

The spread of the option-valuation technology was rapid once the CBOE launched its first contracts on listed securities. Initially, many of the older-market-wise traders rejected using a model to price options. And, initially prices were not in line with prices predicted from using the Black-Scholes model adjusting for dividends and using relatively simple estimates of volatility to price the options. This left an opportunity for younger model-based traders to step in and profit from price discrepancies in the market. They used the model to price options and to determine the appropriate hedge ratios to reduce the risk of their positions. Generally, retaining these risks had zero present value because traders had little expertise in forecasting stock returns. By so doing they could undertake larger positions and enhance their profits by concentrating on risks that could add to their profits.

In Galai (1975), Dan Galai, one of my Ph.D. students as the University of Chicago, where I had returned in 1973, tested the pricing of options on the CBOE in the first year of its existence using the model with simple historical estimates of the volatility. He found that the profits on trading options; that is, buying undervalued contracts and selling overvalued contracts each day to maintain a neutral risk position, were even greater than those found in our original tests. His strategies could achieve greater profits by reducing positions if the prices of options return to model values prior to the expiration of the contract. Transaction costs could have reduced actual trading profits for other than the option dealers.

By the end of the first year of trading options, it was no longer possible to use simple estimates of the historical volatility to spot opportunities in the market. Many of the clearing firms, who financed the positions of the option traders, used the model and the hedge ratios to determine the net risk of each of these traders. Fischer had started a service to provide option prices and the share-equivalent positions (hedge ratios) on each of the options traded on the various exchanges. He used a more sophisticated estimate of volatility to price the options. He combined historical estimates adjusted for changes in stock-market levels, with the volatility implied by the prices of options. As is true even to this day, as the market-price level of securities increases relative to a previous level over a relatively short period of time, the volatility of stocks tends to fall. This result is due, in part, to a reduction in the leverage of the underlying equities. Given the rate of interest, the price of the common stock, the dividend yields, the exercise price, and the maturity date of the option, the model can be used to infer the implied volatility that the market is using to price the option. In fact, even today, options are described in terms of implied volatility. Traders are asked whether they want to buy or sell volatility. Although his volatility estimates held some cache for a while, advanced computer technology made Fischer's pricing sheets obsolete after a few years.

In fact, Texas Instruments marketed a hand-held calculator in 1977 that gave the Black-Scholes model values and hedge ratios. When I asked them for royalties, they replied that our work was in the public domain; when I asked, at least, for a calculator, they suggested that I buy one. I never did. Robert Merton and I continued to consult for DLJ. Working with Mathew Gladstein, we decided that the time might be appropriate to provide investors with a fund that protected their downside risk but allowed for some upside participation in the performance of the stock market. To achieve this goal, we decided that the assets of the fund would be held in two parts: in any six-month period, 90% of the assets would be held in U.S. Treasury bills and 10% of the assets would be used to buy a diversified portfolio of call options. In several papers, Merton, Scholes and Gladstein (1978, 1982) simulated the performance characteristics of such a strategy using the underlying stocks of the options that were traded in the various markets. The return characteristics were as predicted by the theory: losses were truncated and gains were less than a direct investment in the underlying stocks. The returns on the strategy were non-linearly related to the market. We always stressed the role of options as insurance. In early 1976, we attempted to launch Money Market/ Options Investments under the auspices of Phoenix Investment Counsel of Boston. Unfortunately, the fund raised only a small amount of money. Our simulation results indicated that fully-covered investment strategies; that is, a sale of an option on a position in the underlying stock (for example, long 100 shares of IBM and short a call option to buy 100 shares of IBM), would provide returns of only the premium received on the option approximately 60% of the time. Call-option holders would call their stock away if the stock price were above the exercise price on expiration of the contract and would not exercise call options if the stock price were below the exercise price at expiration. This strategy produces higher current income but with the possibility of capital losses just like a high-yield bond. The expected return, however, was less than the expected return on the money market-options strategy. At about this time other investment companies marketed the fully-covered strategy, which we thought exhibited inferior return characteristics for most investors, and naturally, to our dismay, were quite successful because of the promises of higher income (but at the unadvertised expense of expected capital losses.)

3. THE PRESENT

The past twenty years has seen a transformation of the entire financial services industry, first in the United States, and now around the world. During the 1970s and 1980s, regulations divided the activities of financial institutions into separate market segments. In the U.S., commercial banks handled deposits and made commercial loans; investment banks were involved in mergers, acquisitions and underwriting; brokerage companies sold stocks and bonds; savings and loans, along with banks, initiated and held mortgages; and, insurance companies sold life, and property and casualty insurance products. Many of the regulations were directed at preserving the profitability of these institutions by restricting competition, mainly at the expense of the users of these services. Each institution had a product focus; for example, deposits, or life insurance, or commercial loans. No financial company served a broad range of its clients' financial needs.

As happens at times, it is not possible for regulators to protect the profitability of the industries they regulate. In the U.S., mutual funds competed with banks in providing deposit services after banks were not permitted to pay market interest rates on deposits in the early 1970s. The growth of institutional investors managing pension funds and mutual funds forced the abolition of fixed commission rates to trade securities in the U.S. and around the world. The larger brokerage firms evolved to compete against the banks and the savings and loan associations in packaging and repackaging mortgages to broaden the extent of the market. Banks started to compete with brokerage, investment banks, and insurance companies in financing commercial real estate and financing highly-leveraged mergers and acquisitions, so-called "Leveraged Buyouts." It is nearly impossible to maintain regulations that restrict activities in one industry when new competitors not subject to costly regulations are attacking the profitable businesses of that industry.

The driving force behind today's tidal wave of financial innovation has been the reduction in the cost of computer and communications technology. This lower-cost technology has led to a globalization of the product and financial markets. Corporate and institutional needs have become more complex. Investors are demanding more services. Technology brings new competitors to the market who can offer similar and expanded services at lower cost than existing competitors can. The growth of lower cost providers of brokerage services such as Schwab, Fidelity, and Internet brokers are examples.

Financial service firms today must decide which clients to serve, determine those clients' needs and then decide which products and services add value for their clients as well as their own shareholders. Firms that were quite similar fifteen years ago have become very different today. For instance, J.P.

Morgan, a wholesale bank, today differs far more from Citicorp, a retail bank than it did in the early 1980s. Conversely, firms that were quite different from each other fifteen years ago have become quite similar today. It is hard to distinguish the activities of today's J.P. Morgan from UBS, from Goldman Sachs or Merrill Lynch. Meanwhile, A.I.G. and Travelers, both insurance companies, these days offer a number of services that are similar to those offered by Goldman Sachs or UBS. Investment banks no longer merely structure and advise in transactions but instead have moved to a more packaged, integrated, convenient financial-solutions approach, directed at solving the complex problems of their clients around the world.

The many advances in financial theory have enabled financial services firms to meet those complex needs more effectively and at lower cost than was possible previously. The marriage of business school and economics department graduates with engineers, mathematicians, physicists and computer scientists has led to more efficient and lower-cost financial engineering solutions to client problems.

To date, the major growth in the use of derivatives has been fueled by trends toward securitization and the increased understanding of the role that derivatives can play in the unbundling, packaging, and transferring of risks. No longer do financial service firms only sell the same products they buy from clients. Instead, they break the products down into their component parts and either sell the parts or recombine them into new and hybrid custom-tailored financial instruments. And, this unbundling and repackaging is only in the beginning stages of evolution.

With information asymmetries between clients and their financial service providers, it would be prohibitively expensive for a client to develop close relations with many financial service firms. To be productive, the financial service firm must learn the needs of its clients and understand their businesses. As a result, it can be expert to only a select client list. Clients find it inefficient to "shop" widely for new financial service firms. Creating custom-tailored solutions strengthens relations between the financial services firm and its clients. It would be too costly for each client to replicate the specialized expertise required to engineer financial theory solutions; such talent would be underutilized most of the time. It would be analogous to every corporation maintaining an entire full-service law firm on its premises. Notwithstanding many regulators' fears, it is not likely that all financial service firms will disappear if left to compete in the global arena. Product standardization will erode profits more quickly than in the past because more diverse entities, such as General Electric or Enron or accounting firms can compete in providing financial services using financial technology. New competition will enter various markets from global competitors. Although inefficient financial service firms will disappear more quickly than in the past, their clients will obtain more value-enhancing and less costly services from the remaining financial service firms. Financial products are becoming so specialized that, for the most part, it would be prohibitively expensive to trade them in organized markets.

Financial service firms have become the leaders in using derivatives in their risk-management programs. Using information and option-pricing technology, financial services firms can not only value their commitments, such as guarantees and other derivative contracts, but also are moving to understand the sensitivities of their holdings to various market factors. They can decide what risks to transfer and what risks to retain.

Tables 1 and 2 show the growth of derivative contracts trading since 1986 in both the exchange industry and in the OTC industry. The cells of the tables contain the "notional principal amounts outstanding" for various categories of derivative contracts. For example, the face amount of stock market index options (including call and put options) at the end of 1986 stood at $37.8 billion and by the end of 1996 grew to $380.2 billion.[2]

These tables indicate that the OTC market in derivatives has grown much faster than the exchange market in the last 10 years. In 1995, turnover on the major derivative exchanges around the world actually declined while OTC activity rose by 40 percent. The Bank for International Settlements estimated that outstanding OTC contracts exceeded $47.5 trillion in early 1995, much greater than the numbers reported in Table 2. To put these values into perspective, the value of all outstanding debt in Europe, Japan and North America totaled $25.8 trillion in 1995.

The growth of the OTC market will continue to outstrip the growth of the exchange market because the clients of the financial service firms need assistance to structure their financial programs. The current growth path is to provide more client-focused structured solutions to problems. Clients likely would find it less expensive to execute a program through their financial service firm than to execute it themselves in the exchange market. This is even more likely if the positions must be adjusted frequently to hedge risks.

Moreover, the relative growth of the OTC market is overstated because the exchange markets require that entities post margin on contracts each day. Futures contracts are settled at the end of each day. Forward contracts, such as swaps and options written by OTC firms such as caps and floors, are not settled each day. The product offerings are different. The financial service firms and their counterparts rely on each other's credit. Most financial service firms can post collateral on OTC contracts, which is very similar to settling the contracts as in the case of posting margin on an exchange. These entities will use either the financial futures and options markets or the OTC markets. They will use the industry that provides services at lower cost. Many entities, however, are not indifferent to posting collateral. In particular, many

[2] See "International Capital Markets, Developments, Prospects and Key Policy Issues," **International Monetary Fund** (September 1997) for the source of these statistics. The notional amount outstanding is not an economic measure of the size of the market. The notional amount of a swap or an option is the amount on which the contract is based. It is not the value that the security would trade at in the market. For example, if a call option to buy $100,000 of a major-market index trades at $5,000, the notional amount is recorded as $100,000 while the economic value is only $5,000. The economic value of swaps and options might be as low as 2% and 5% of the notional outstanding amounts of the contracts. These statistics provide estimates of the growth of the derivative market.

Table 1. Markets for Selected Derivative Financial Instruments: Notional Principal Amounts Outstanding: 1986-96 (In billions of U.S. dollars)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Interest rate futures	370.0	487.7	895.4	1,200.8	1,454.5	2,156.7	2,913.0	4,958.7	5,777.6	5,863.4	5,931.1
Interest rate options[1]	146.5	122.6	279.2	387.9	599.5	1,072.6	1,385.4	2,362.4	2,623.6	2,741.8	3,277.8
Currency futures	10.2	14.6	12.1	16.0	17.0	18.3	26.5	34.7	40.1	38.3	50.3
Currency options[1]	39.2	59.5	48.0	50.2	56.5	62.9	71.1	75.6	55.6	43.2	46.5
Stock market index futures	14.5	17.8	27.1	41.3	69.1	76.0	79.8	110.0	127.3	172.2	198.6
Stock market index options[1]	37.8	27.7	42.9	70.7	93.7	132.8	158.6	229.7	238.3	329.3	380.2
Total	618.3	729.9	1,304.8	1,766.9	2,290.4	3,519.3	4,634.4	7,771.1	8,862.5	9,188.2	9,884.6
North America	518.1	578.1	951.7	1,155.8	1,268.5	2,151.7	2,694.7	4,358.6	4,819.5	4,849.6	4,839.7
Europe	13.1	13.3	177.7	251.0	461.2	710.1	1,114.3	1,777.9	1,831.7	2,241.6	2,831.7
Asia-Pacific	87.0	138.5	175.4	360.0	560.5	657.0	823.5	1,606.0	2,171.8	1,990.1	2,154.0
Other	0.0	0.0	0.0	0.1	0.2	0.5	1.8	28.7	39.5	106.8	59.3

[1] Calls plus puts.

Table 2. Notional Principal Value of Outstanding Interest Rate and Currency Swaps of the Members of the International Swaps and Derivatives Association, 1987–June 1996 (In billions of U.S. dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	June 1996
Interest rate swaps										
All counterparties	682.9	1,101.2	1,502.6	2,311.5	3,065.1	3,850.8	6,177.3	8,815.6	12,810.7	15,584.2
Interbank (ISDA member)	206.6	341.3	547.1	909.5	1,342.3	1,880.8	2,967.9	4,533.9	7,100.6	-
Financial Institutions	300.0	421.3	579.2	817.1	985.7	1,061.1	1,715.7	2,144.4	3,435.0	-
Governments[1]	47.6	63.2	76.2	136.9	165.5	242.8	327.1	307.6	500.9	-
Corporations[2]	128.6	168.9	295.2	447.9	571.7	666.2	1,166.6	1,829.8	1,774.2	-
Currency swaps										
All counterparties (adjusted for reporting of both sides)	182.8	319.6	449.1	577.5	807.2	860.4	899.6	914.8	1,197.4	1,294.7
Interest rate options[3]	0.0	327.3	537.3	561.3	577.2	634.5	1,397.6	1,572.8	3,704.5	4,190.1
Total	865.6	1,657.1	2,489.0	3,450.3	4,449.5	5,345.7	8,474.5	11,303.2	17,712.6	21,068.9

[1] Including international institutions.
[2] Including others.
[3] Including caps, collars, floors, and swaptions.

OTC swap and option contracts have a financial entity and a corporation as counterparts because the corporation is willing to pay the financial entity to post margin for it in the futures or options market. That is, the financial services firm enters into a swap with a corporate entity, which does not post collateral, and the financial service firm hedges its market risk by entering into an offsetting swap with another financial service firm or by using the exchange-derivatives industry. In either case, the financial service firm posts collateral or margin on its transactions. It is the lower cost producer of margin services. Financial service firms have the capacity and the personnel to undertake the pricing of credit risk and can handle these transactions; many corporate entities currently do not.

To the extent that collateral is not posted on the obligation, one consequence of the these transactions is that the financial service firm and the corporation are exposed to each other's credit risk. The corporation buying a call option on an underlying debt instrument from the financial service firm has credit risk to the extent of the value of the call option. The financial service firm can fail to honor its obligation to deliver the underlying debt instrument. The financial service firm holding a put option, issued by the corporation, on the same debt instrument is a creditor of the corporation to the extent of the value of the put option. A swap contract, which states that the corporation will receive a fixed rate of interest on an underlying debt instrument and pay a floating rate of interest, is equivalent to the corporation being long a call option and short a put option.

The other major reason that the OTC industry will continue to grow faster than the exchange industry is that financial service firms and others need only to hedge the remaining factor risks of their portfolio positions, which is a far smaller amount than their gross contracting with their clients. Moreover, depending on the costs, they can hedge either with another financial service firm or in the exchange industry. The financial service firm that hedges factor risks retains the remaining risk, the so-called "basis risk," of its net positions.

Another reason for the growth of the OTC market has been that the outstanding amounts in Table 2 do not necessarily represent net exposures. It might be less expensive for a corporation or a financial service firm to enter into an offsetting derivative contract with another counterparty than it would be to unwind the initial contract. If it does, the contract volume increases but the net exposure falls.

3.1 *The Present: The Pathologies*

From the perspective of market commentators, many regulators, and the public, derivatives tend to top the list of suspects when the stock market turns downward or when entities announce unanticipated financial losses. The press, the public and regulators fear derivatives, in part, because they are new and, in part, because their growth has appeared to be so explosive over the last ten years. Although they vastly overstate the economic exposure, notional amounts as high as $45 trillion cause worry. The press and others credit the market crash of 1987 to portfolio insurance, an attempt to dynamically replicate the returns on options. Even in this time, market pundits warn that forms of dynamic hedging could foster a severe market downturn. Widely publicized losses attributed to derivative trading in the 1990s include: the leveraged-derivative contracts issued by Bankers Trust to firms such as Proctor and Gamble and Gibson Greeting (over $150 million in losses); the loss of $1.5 billion by Shell Sekiyu, the losses incurred by Orange County investing in inverse floaters; the bankruptcy of Metallgesellschaft and Barings Corporation (both over $1 billion in losses) and many other losses by financial service firms such as UBS, Salomon Brothers, etc. Obviously, many of these losses are overstated because there were gains made by the other side to these contracts: It is only the dead-weight costs to society that result in actual loss. For excellent discussions of the entire range of purported pathologies and an excellent review of the literature addressing these issues see Miller (1997), who argues that most, if not all, of the "diagnoses" of severe pathologies are misdiagnosed.

Yet, the growth of these industries depicted in Tables 1 and 2 clearly suggests that these instruments have added net value. It is hard to believe such growth could continue for so many years without value being realized by the clients of financial service firms, the shareholders of these firms and the exchanges. I have argued in Scholes (1995, 1996a) that the development of financial infrastructure might lag financial innovation. It is costly to develop controls and firm-wide understanding of new products that are in the prototype phase of their development. Prototypes are built using existing infrastructure. For an innovation as long lasting and profitable as derivatives, the OTC industry, the exchange industry and the academic industry find it profitable to build the infrastructure necessary to support them. Each of these industries has a vested interest in profiting from adding value that is sustainable, so each will attempt to invest in the cost-effective infrastructure necessary to preserve this value.

This is not to argue that we have seen the end of derivative failures. There will be losses sustained as in many other business activities. In 1997, the Governments of many countries in Asia could no longer support the losses of their financial institutions resulting from defaulted commercial and real estate loans. Although many banks had been economically bankrupt without the support of their Governments (that is; the value of their equity would have been effectively zero without Government implicit guarantees), the Governments allowed these banks to participate in any potential gains and sheltered them against bank runs by promising to pay off their depositors. These options were costly to society, and it will be difficult to prove that they were value enhancing. In part, other countries, through the grants made by the International Monetary Fund, as the lenders of last resort to these and other countries, may have written the put options that supported the activities of the financial institutions of the region and granting these options might have encouraged risk taking and even unprofitable activities.

Moreover, absent government guarantees, some brokerage houses and banks in Japan probably would be bankrupt, because while these entities had promised clients protection against loss on any decline in value of Japanese stocks, they did not hedge their commitments. Clients might have paid for these put options through higher commission rates in Japan. These Japanese financial service entities, however, suffered severe losses when their clients exercised these put rights during the decline in the value of Japanese stocks in the1990s. The entities currently are not required to value their commitments on a mark-to-the-market basis. As a result, neither regulators, nor investors nor even senior management could deduce the financial condition of the entities. In all probability, the extent of these losses could have been mitigated if risk management policies had been put in place.

4. THE FUTURE

The future will be a continuation of the present. Financial innovation will continue at the same or at even an accelerating pace because of the insatiable demand for lower-cost, more efficient solutions to client problems. Information and financial technology will continue to expand and so will the circle of understanding of how to use this technology. There is value to investing in education. Financial service firms will expand the use of this technology to manage their own activities. Otherwise, they will have to face mergers with other financial service entities. Although some would like to see derivatives wither in importance, they will not, for they have become essential mechanisms in the tool kit of financial innovation.

Scholes and Wolfson (1992) used the concepts of frictions and restrictions to illustrate how tax rules and other regulations affect investor and corporate behavior. As Merton (1992) argues, the functions of a financial system change far less than institutions. Institutions change because lower-cost solutions that reduce information asymmetries are found to facilitate transactions, to provide funding for large-scale investment projects, to transfer savings across borders and into the future, and provide more efficient risk-sharing and diversification mechanisms.

Most financial instruments are derivative contracts in one form or another. Black and Scholes (1973) pointed out that the equity holders of a firm with debt in its capital structure have an option to buy back the firm from its debtholders at maturity of the debt. The high-yield bond (the so-called "junk bond") is a riskier debt-option contract than more-highly rated corporate debt. Corporate debt and equity contracts are derivative to underlying investments. Other lines of research on so-called "real options" indicate that even the investment decisions of firms are better understood by using an option framework rather than a more conventional present-value-analysis framework.

Standard debt and equity contracts are institutional arrangements or boxes. They provide particular cash flows to investors with their own particular risk and return characteristics. These institutional arrangements survive only because they provide lower cost solutions than competing alternative arrangements. Competitive opportunities evolve over time with changing frictions and restrictions. Because of information asymmetries and regulatory restrictions, investors might require a higher rate of return to hold these standard-form contracts than contracts (now and in the future) of alternative design but of similar risk. Time will continue to blur the distinctions between debt and equity.

The firm's investment set is generally the composite of coarse bundles of payoffs. Firms issue claims to finance these activities, claims that themselves represent bundles of coarse cash flows. It will become more efficient for financial service firms to offer new derivative securities in various forms to break cash flows into finer gradients that can be tailored to the specific needs of demanders and suppliers of capital. In the process, dead-weight costs are mitigated, thereby reducing the cost of capital. The financial service firm can sell the newly created securities or retain them in whole or in part for its own account. It can create new products on its own name or use the OTC or exchange markets to hedge its risks. Given information asymmetries, it will use the lower-cost solution.

4.1 *Investor Demands*

In recent years, we have witnessed a movement from a limited number of investors holding an undiversified portfolio of their own home-country securities to many more investors holding diversified portfolios domestically and internationally. More and more investors around the world, who have never invested in financial products other than through social promises made by their governments, will become more willing to select from a broad class of "mutual-fund" type offerings. Although the diversity of products has grown, few tools are in place other than in academic circles that allow investors to make informed portfolio allocation decisions. As Franco Modigliani, the 1985 Nobel laureate, has argued, individuals want to smooth consumption over the life cycle. If it were more cost efficient, investors would want to insure against contingencies, control risks more efficiently, and plan their investments efficiently to meet life-cycle needs. As information and financial technology become more easily available, financial service firms will repackage investments to meet these investor demands, and this will spur financial innovation. The financial service firm will offer products in its own name that promise specific risk and return patterns; these firms will also offer products in the form of mutual funds. The classifications of investment products into stock funds, bond funds, growth, income, etc. will diminish in importance with reduced costs to understand risk, return, and contingent payoffs.

Even today, the boxes that define institutional-fund arrangements have blurred. For example, if a pension fund manager wants to achieve a stock-index fund return, she can invest with an index-fund provider that buys a diversified portfolio of the index-fund stocks. She can achieve the same result, however, in myriad other ways including using another manager who might claim to have expertise in the bond market and can provide an enhanced return over the index-fund return. To achieve this, the enhanced manager might undertake a complicated strategy. He might hold a portfolio of undervalued corporate and government bonds, hedge the credit risk of the corporate bonds by selling stock short, and hedge the price risk of interest rate movements by using futures or options. He might buy stock-index futures to achieve the systematic risk exposure of the stock-index fund. Given costs, the manager might be able to produce a return in excess of that achieved by holding the index fund directly while the systematic risks of the two offerings would be exactly the same.

The exchange industry will compete with the OTC industry to provide investment products. If the exchange industry can provide efficient margining systems for those investors who can not post collateral in a cost efficient manner, those products that become standardized will most likely be ideally suited for the exchange industry: it can address a larger set of participants in a lower-cost marketplace. The exchange industry complements the OTC industry; they will grow together.

4.2 *Corporate Demands for Derivatives*

Finance specialists have puzzled over the reasons why corporations hedge the risks of their cash flows. Under classical finance theory, it is often asked why shareholders of a firm pay it to incur costs to reduce risk when they can diversify on their own account. The firm's managers should act as if the firm is risk neutral. Smith and Stulz (1985) provide three reasons, all tied to the cost of financial distress, why a firm might hedge its cash flows. Because of the convexity of the tax schedule, a firm might issue more debt only after hedging its cash flows to reduce its expected operating losses and the resultant loss of tax benefits. Because of bankruptcy costs associated with high levels of debt, the firm that hedges can use more debt to finance its activities. As in Froot, Scharfstein, and Stein (1993), if the firm can hedge its cash flows, a reduction in the probability of financial distress reduces the expected costs of financial distress and, as a result, encourages investment in profitable projects that might have been foregone without such hedging. This argument is based on the observation that firms are reluctant to issue equity, and, instead, use retained earnings to finance investments before using the debt markets. Also, if a high-debt-to-equity firm were to become financially distressed it would not be possible to issue equity to finance business activities. Because owner-managers in smaller firms might not be able to diversify their holdings, hedging the cash flows of the firm might be a lower-cost alternative than selling off pieces of the firm to outsiders and using the proceeds to diversify. If corporations face these problems there are financial engineering solutions that might reduce their import.

The corporate use of derivatives is not limited to hedging. Some corporate financial strategists believe that they can outperform other market participants in forecasting the direction of interest rates or commodity prices. Stulz (1996) argues that firms that have such financial acumen can hedge their downside exposures by buying put options. This allows the financial officers of the firm to become more active managers. By buying put options or by reducing systematic risks, they can use more leverage and increase their personal stakes by reducing the costs of financial distress. This tactical use of derivatives probably explains a significant part of the growth of the use of derivatives attributable to financial service firms and corporations, as shown in Tables 1 and 2.

As reported in Stulz (1996), empirical evidence gathered from surveys of corporations indicates that large corporations without debt in their capital structures hedge cash flows more so than smaller corporations. And, those corporations that do hedge lift their hedges from time to time or do not fully hedge their exposures. It is these tactical uses of derivatives, an attempt to "beat" the market using highly leveraged strategies, that have been the cause of most of the reported financial losses. Obviously, the successful tactical users of derivatives are most often absent in press reports. It is unlikely, however, that corporate officials, on average, can outperform other market participants.

Large firms hedge cash flows, in part, to smooth reported financial earnings with the hope those smoother earnings will boost their price-to-earnings ratios. This might be a value-enhancing strategy if market participants can not discern whether the variability in earnings is caused by the firm's taking systematic exposures to market factors or by firm-specific risks.

The Present is still young. The Future will bring many new solutions to solve corporate problems. Many corporations and financial entities still need to learn and evaluate to what extent hedging and risk control can be beneficial to their activities. Smaller firms and product markets are just now becoming familiar with the risk control aspects of these financial instruments. It may be surprising that in the United States the top 8 banks account for 94% (almost $19 trillion) of the total outstanding notional amount in the OTC market as of the end of 1996.[3] As of this date, the knowledge base or the financial acumen needed to financial engineer solutions to client problems is highly concentrated.

As in Scholes (1995, 1996a), I argue that corporations will use risk management techniques to reduce their level of equity capital, and, as a result of risk management techniques, some firms that would have gone public will remain private. Equity capital is an expensive form of financing. There are large differences between the knowledge base of insiders and outsiders. Insiders can not fully divulge their plans to outsiders for the fear that competitors will profit from this knowledge, and generally must sell shares at a discount. Moreover, tax and other considerations make the corporate form of undertaking activities in the U.S. and in other countries very expensive.

Equity is a risk-management device. It is an "all purpose" risk cushion. The more equity a firm has, the more it cushions itself against outcomes that require it to go the capital markets in adverse times or when it might have to divulge its confidential operating plans to outside parties. Hedging, on the other hand, is targeted risk control. Hedging requires more refined knowl-

[3] See **International Monetary Fund, op. cit.**

edge of the firm, and an understanding of the interaction of investment returns and financing alternatives. Moreover, it requires that the firm be able to warrant to others that it will maintain a strategy of hedging its activities to support higher levels of debt. But as the costs to hedge fall relative to the costs of equity, firms will substitute hedging for equity.

Moreover, hedging provides ancillary benefits as a measurement tool to help calibrate how the firm is making money. In a diverse, decentralized organization, management information systems might not divulge the true source of profits within the organization; that is, did profits arise because systematic risk exposures produced positive returns, or because the entity possessed superior skills? Standard accounting neither provides risk management reports which decompose profitability into profits from market forces and profits from managerial efforts, whether the firm is a manufacturing or a financial firm, nor does it describe the sensitivities of the firm's profit and loss to market factors. As more entities use financial engineering skills, the current accounting system will be under considerable pressure for change, as will many of the current forms of regulations and restrictions.

Because of differences in the required knowledge of insiders and outsiders, the growth of the private equities market has reduced the disclosure costs of becoming a public corporation. Private equity allows expert management teams to leverage their activities. Private equity, however, is still an inefficient form of financing compared with potential lower-cost solutions. Ways will be found through financial engineering to provide private entities with the advantages of the public market–risk sharing, liquidity, and pricing signals–while retaining the advantages of the private market–lower disclosure and agency costs. Financial engineering will foster the growth of the private corporation, and convert entities into alternative forms.

Many firms hedge interest rate movements, foreign currency exposures, or commodity price exposures. Firms will learn to use stock-index options or futures to reduce their risk exposures. The firm can reduce the beta of its own stock by hedging stock-market risks. Moreover, with this approach, the firm does not have to target risks. It can just hedge its own market risks or other factor risks, or the general stock-market risk that affect its stock price. This reduces the economic risks of the firm to firm-specific risks, or residual risks, and reduces the need for equity to cushion adverse outcomes.

I believe that the corporate form we know today will not be long-lived. With more knowledge and a better understanding of the power of financial engineering and of how to reduce asymmetric information costs, the costs of using financial engineering solutions will continue to fall. As more firms learn how to use these solutions, their profits will be enhanced and more investment will follow the increase in demand. Risk management is only a step in the direction of producing synthetic entities.

The firm of the future might be an organizational form far different from those used today. Some entities, such as electricity producers, aircraft manufactures and users, natural resource producers and users, and financial service firms already are deciding what services to produce and what risks to retain; what services to rent and what risks to shed, based on their perceived competitive advantage.

Financial service firms are building large capital bases to make markets around the world, and to put into practice specific knowledge to engineer solutions for their clients on a global basis and to create long-lived derivative products for issue in their own names. Their profits are made from modeling and understanding markets and providing value-added solutions for clients. A risk-management system provides information on what risks to keep and what risks to hedge. In addition, it provides a way to reduce information asymmetries between senior management and employees, and to provide the incentive system necessary to align the interests of the employees and the firm's shareholders.

A risk-management system must also address how a financial service firm handles crisis situations. To preserve its franchise, a financial service firm can insure against adverse price movements or unforeseen contingencies by holding working capital as a reserve against adverse liquidity needs. Alternatively, the financial service firm might be able to buy options from the exchange markets or from the OTC markets (for example, lines of credit) at a lower dead-weight cost to insure against extreme price movements that could adversely affect its business. Maybe regulatory bodies, in effect, provide lower cost insurance.

Because of tax and regulatory costs, financial-service firms might find that working capital held in corporate form is too expensive relative to other alternatives. For example, clients of financial service firms hold large quantities of passive wealth in mutual funds, insurance companies, pension funds, and various trusts as investment vehicles for individual savings. Financial-service firms and other entities must hold working capital to insure against adverse contingencies. With options and other forms of contingent capital arrangements, it will become possible to mobilize the capital in these client passive investment vehicles and reduce the dead-weight costs of the current system. This could lower the cost of capital of financial service firms and the cost of providing financial services to their client base.

Once again, information and financial technology will expand to reduce the costs of information asymmetries. Understanding and developing markets for credit derivatives, understanding the implications of contingent capital options under asymmetric information, and understanding what is the most efficient mechanisms to hold capital will change organizational forms, the boxes, and blur the distinctions between debt and equity, corporations and partnerships, and the demanders and suppliers of capital. The evolution of option technology will open up entire new institutional structures.

5. CONCLUSION

We started in the Past, the age of innocence, and we progressed to the Present, the age of understanding, growth, and maturation. The growth has not been without pains. A considerable amount of additional understanding and development awaits the users of the derivative technology in the Future–the age of excitement. Advances in communications and computing technology will allow for greater reduction in asymmetric information costs. The future growth of innovation using the option-pricing technology will be as great or greater than in the past. Organizational forms will change dramatically in a global environment. The exchange industry will continue to grow; the OTC industry will continue to grow, and the research necessary by academics and practitioners to understand and to foster the evolution will be so great that the academic industry will become more important than in the past. The need for highly trained and skilled practitioners that understand the technology will continue to increase on a global basis. None of these three industries has retained its past form and none will retain its present form. These economic organizational forms always will evolve and respond to the demands of economic agents.

The capital asset pricing model, arbitrage and capital structure models, and the efficient markets hypothesis introduced me to key finance concepts that were the genesis of our development of the option-pricing technology. In a world of information asymmetries, derivative instruments provide lower cost solutions to financial contracting problems in a dynamic environment and these lower-cost solutions enhance economic efficiency.

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