GOLDEN GATE UNIVERSITY
SCHOOL OF BUSINESS

FI 346 DERIVATIVE MARKETS

Summer 1999

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Office Hours	Tuesday, 4:00-6:00, at Los Altos or by Appointment
Classes	Saturday, 9:30 am – 1:30 pm, Los Altos
Credits	3 units.
Prerequisite	FI 340 Investments[1]

Course Description Theoretical and practical applications in the futures, options and other derivative markets. Topics included: forwards; futures; swaps; options; hedging strategies; the random walk (Brownian motion) model of stock prices; the Black-Scholes analytical model and the binomial models. Risk management techniques and computer applications are discussed.

Course Objective To develop a sound knowledge of the valuation methods of options and understanding the functions of various derivatives in financial risk management.

Software ***OptionLab***, Mantic Software Corporation. Loveland, CO.

Required

Hull, John. **Introduction to Futures & Options Markets**. 3rd ed. Englewood Cliffs, New Jersey: Prentice Hall, 1998.

Futures & Options Strategy Guide. Chicago Mercantile Exchange®

The Wall Street Journal[2]

Recommended

Rubinstein, Mark. **Derivatives: a PowerPlus Picture Book**. (www.in-the-money.com) 1998.

Smithson, Charles, Clifford Smith, Jr., with D. Sykes Wilford. **Managing Financial Risk, A Guide to Derivative Products, Financial Engineering, and Value Maximization**. Bur Ridge, Illinois: Irwin, 1995.

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[1] If the subject of futures and options was never covered in your investment class, you may have some catch-up to do. Make a copy of my FI340 handout: "Introduction to Derivatives" and study it before you attend the class. It is available at GGU Los Altos library reference desk upon request.

[2] Student subscriptions to *The Wall Street Journal* are available. Check with your instructor.

Class Administration And Assignments

1. Attendance is required. Please contact the instructor if a conflict should prevent you from attending the class.
2. The class schedule gives the reading assignments. Students **must** read the chapters before they are covered in class. Students are encouraged to study some of the math concepts necessary to understand the valuation formulae[3].
3. Assigned homework should be turned in at the beginning of next meeting. No late work would be accepted without the instructor's prior consent. We will review some of the assignments in class, if time permits.
4. Beside the homework assignments, Please study all the quiz questions at the end of each chapter.
5. Always bring the Friday's *The Wall Street Journal* to the class.
6. Work on the ***OptionLab*** at the lab.
7. A complementary copy of computer software ***DerivaGem*** comes with the textbook. All your homework should be done by hand. However, you can use the software to check your answers to the questions, calculate the implied volatility and explore ideas of your own.
8. Please download or order the freeware ***The Options Toolbox/The Index Toolbox*** from CBOE's web site.
9. For the latest information on various derivative securities and development in the industry, visit the following web sites:

http://www.cbot.com	Chicago Board of Trade
http://www.cme.com	Chicago Mercantile Exchange
http://www.cboe.com	Chicago Board Option Exchange
http://www.fenews.com	Financial Engineering News
http://www.margrabe.com	William Margrabe's ***Derivative 'Zine***
http://www.in-the-money.com	Mark Rubinstein's web site
www.cob.vt.edu/finance/faculty/dmc/derivs/drvsites.htm	Don Chance's web site.
http://www.jpmorgan.com	JP Morgan's ***RiskMetrics*** can be found here
http://pw2.netcom.com/~bschacht/var/wps.html	Value-at-Risk Resources
http://www.cob.ohio-state.edu/dept/fin/overview.htm	OSU Visual Finance Library

Exam Exams will be open-book. Please bring your calculator with you. No computer software is allowed. Students should consult the current Golden Gate University Bulletin for university policies regarding incomplete and withdrawals. In addition, students should refer to the Bulletin for University policies regarding academic integrity.

Grading

Assignments …………………………..	30%
Midterm …………………..…….	30%
Final Exam ………………………..…	40%

[3] Review materials on probability and basic calculus can be found at GGU Los Altos library reserve desk.

Class Schedule and Assignments[4]

Week	Date	Topics and Readings	Assignments
1	5/22	**I. Overview** "Derivatives" CBS 60 Minutes Documentary Ch. 1 Introduction Ch. 2 Mechanics of Futures and Forward Markets Ch. 7 Mechanics of Options Markets	"Calculus of Risk" (http://www.sciam.com/1998/0598issue/0598stix.html) 1.2, 1.16; 2.10, 2.16; 7.1, 7.2, 7.6.
2	6/5	**II. Forward and Futures** Ch. 3 The Determination of Forward & Futures Prices Ch. 4 Hedging Strategies Using Futures	3.4, 3.8, 3.10, 3.11; 4.9, 4.11, 4.12.
3	6/12	**III. Swaps and Structured Notes** Ch. 6 Swaps	6.1, 6.2, 6.13, 6.14.
4	6/19	**IV. Options** Ch. 8: Basic Properties of Stock Options Ch. 9 Trading Strategies Involving Options CME: ***Strategy Guide***	Computer Lab: ***OptionLab*** 8.3, 8.4, 8.6, 8.7, 8.12; 9.1, 9.3, 9.7, 9.13, 9.14. Ä **Midterm Exam** (due 6/19)
5	6/26	"Model of the Behavior of Stock Prices" (Handout) Ch.11 Pricing of Stock Options Using Black-Scholes	Math Review: ***Probability*** 11.1, 11.3, 11.9, 11.10, 11.13.
6	7/3	Ch.12 Options on Stock Indices and Currencies Ch.13 Options on Futures	12.4, 12.5, 12.9, 12.10; 13.1, 13.8, 13.9, 13.10.
7	7/10	Ch.10 An Introduction to Binomial Tree Ch.16 Valuing Options Using Binomial Trees **Handout**: Exotic Options	10.5, 10.6; 16.1, 16.2; Exercises on Exotics.
8	7/17	**V. Financial Risk Management** Ch.14 Hedging Positions in Options and the Creation of Options Synthetically Ch. 17 Biases in the Black-Scholes Model	14.4, 14.9, 14.10, 14.16; 17.6.
9	7/24	Ch. 15 Value at Risk **Harvard Business School Case (9-297-069)**	15.1, 15.4, 15.8, 15.11. http://www.gsm.uci.edu/~jorion/oc/case.html
10	7/31	Ä **Final Exam**	

[4] The above schedule and assignments are for guidance only and may change in the event of extenuating circumstances.

Annotated Bibliography[5]

1900 Bachelier, L., "Theorie de la Speculation," Annales de I'Ecole Normale Superieure 17 (1900), pp. 21-86, translated into English by A.J. Boness in *The Random Character of Stock Market Prices,* edited by P.H. Cootner (MIT Press 1967), pp. 17-78.

The first mathematical description of a continuous-time continuous-state stochastic process (arithmetic Brownian motion), amazingly with the goal of valuing options (French rentes); although that goal was only partially realized, the paper - a thesis submitted to the Academy of Paris - anticipated Einstein's work on Brownian motion by six years as well as the mathematical basis for Black-Scholes formula (which is based on geometric Brownian motion) by 73 years; forgotten, but rediscovered by financial economists in the 1960's. [Black-Scholes Formula]

1916 Cassel, G., "The Present Situation on the Foreign Exchanges," *Economic Journal* 26 (March 1916), pp. 62-65.

Origin of the theory of purchasing power parity to explain differences in international interest rates. [Introduction]

1930 Fisher, I., *The Theory of Interest* (Macmillan 1930).

One of classic works in economics written in the twentieth century; among its many contributions to economic thought is the Fisher equation relating the nominal interest rate to the real interest rate and the rate of inflation. [Introduction]

1930 Keynes, J.M., *A Treatise on Money,* Volume 2 (Macmillan 1930).

Assuming that hedgers are naturally net short so that speculators are naturally net long, Keynes argues that hedgers will pay a risk premium to speculators resulting in what he called "normal backwardation": futures prices which are downward biased estimates of expected future spot prices. [Forwards and Futures]

1931 Hotelling, H., "The Economics of Exhaustible Resources," *Journal of Political Economy* 39, No. 2 (April 1931), pp. 1371 75.

Develops the "Hotelling Principle" which states that, under certainty and perfect competition, the net price (price minus extraction cost) of an exhaustible resource should rise at the riskless return over time as long as it pays to extract some of the resource and leave some unextracted; this condition arises from the requirement that each producer be indifferent between current and future production. [Forwards and Futures]

1939 Kaidor, N., "Speculation and Economic Stability," *Review of Economic Studies* 7, No. 1 (October 1939), pp. 1-27.

Origin of the concept of convenience yield to explain backwardation. [Forwards and Futures]

1953 Arrow, K.J., "The Role of Securities in the Optimal Allocation of Risk-Bearing," *Review of Economic Studies* 31, No. 2 (April 1964), pp. 91-96 (originally published in French in *EconomLitrie,* CNRS, Paris (1953), pp. 41-47).

Best known for its invention of the concept of state-contingent claims, this article also contains the first published occurrence of the idea that an incomplete forward market can be effectively completed by opportunities for portfolio revision over time - the key idea behind modern option pricing theory. Valuable extensions of these ideas are contained in Dreze, J.H., "Market Allocation Under Uncertainty," *European Economic Review* 2 (Winter 1970), pp. 133-165; in particular, it is shown there that the prices of state-contingent claims can be regarded as products of subjective probabilities and risk aversion adjustments, that the present value of an asset can be viewed as its (discounted) expected value where the state-contingent prices equal the subjective probabilities that would adhere in an economy with risk-neutral preferences, and that option-like securities can substitute for state-contingent claims in completing the market. [Introduction, Binomial Option Pricing Model]

1957 Houthakker, H.S., "Can Speculators Forecast Prices?" *Review of Economics and Statistics* 39, No. 2 (May 1957), pp 143-151.

Empirical examination of whether or not futures prices are greater or less than expected future spot prices; concludes that for wheat, cotton and corn during 1937-1957, the futures prices were typically less than corresponding future spot prices, suggesting that long positions in futures was profitable, although the expected profit may have been just compensation for risk. (Forwards and Futures]

1958 Brennan, M.J., "The Supply of Storage," *American Economic Review* 48, No. 1 (March 1958), pp. 50-72.

Explains how risk aversion determines the exact location of the forward price between the arbitrage bounds caused by convenience yield. [Forwards and Futures]

1958 Telser, L.G., "Futures Trading and the Storage of Cotton and Wheat," *Journal of Political Economy* 66, No. 2 (June 1958), pp. 233-255.

Contradicts Houthakker (May 1957) and finds that futures prices are unbiased predictors of future spot prices; examines cotton from 1926-1950 and wheat from 1927-1954. [Forwards and Futures]

1959 Osborne, M.F.M., "Brownian Motion in the Stock Market," *Operations Research* 7 (March-April 1959), pp. 145-173.

Proposes that stock ' prices follow a random walk, and the first paper to advocate lognormal (as opposed to normal) distributions for security returns; apparently written without knowledge of Bachelier's much earlier related paper; also anticipates much later work which justifies lognormal distributions as the outcome of an equilibrium in which investors have logarithmic utility functions. [Black-Scholes Formula]

[5] Source: Rubinstein, M., *Derivatives: A PowerPlus Picture Book* (In-the-Money, 1998), 343-354.

1962 Sprenkle, C.M., "Warrant Prices as Indicators of Expectations and Preferences," *Yale Economic Essays 1* (1962), pp. 172-231.

Derives what was later to be called the Black-Scholes formula by integrating the option payoff assuming a lognormal distribution for the underlying asset price; formula contains the expected asset return and a risk-adjusted discount rate; did not realize that arbitrage arguments could be used to justify replacing both of these with the riskless return. [Black-Scholes Formula]

1964 Boness, A.J.. "Elements of a Theory of Stock-Option Value," *Journal of Political Economy* 72. No. 2 (April 1964), pp. 163-175.

Specializes Sprenkle's formula for the case when investors are assumed to have risk-neutral preferences and obtains the what later became known as the Black-Scholes formula (see equation (4), page 170); did not realize that arbitrage arguments could be used to justify using the riskless return. [Black-Scholes Formula]

1964 Kruizenga, R.J., "Introduction to the Option Contract," in *The Random Character of Stock Market Prices,* edited by P.H. Cootner (MIT Press 1967), pp. 377-41 1.

Uses payoff diagrams and a payoff algebra to analyze individual options and portfolios of options. [Introduction to Options]

1967 Thorp, E.O. and S.T. Kassoff, *Beat the Market: A Scientific Stock Market System* (Random House 1967).

An early application of primitive option pricing techniques and payoff diagrams to the pricing of warrants, including the use of "zeroprofit lines" partially anticipating the Black-Scholes delta hedging argument; see, in particular pages 81-83. [Introduction to Options]

1967 Shelton, J.P., "The Relation of the Pricing of a Warrant to the Price of Its Associated Common Stock," *Financial Analysts Journal* 23, Nos. 3 and 4 (May-June and July-August 1967), pp. 143-151 and 88-99.

An early regression approach to option pricing; state-of-the-art in 1967 but now obsolete. [introduction to Options]

1969 Stoll, H.R., "The Relationship Between Put and Call Option Prices," *Journal of Finance* 24, No. 5 (December 1969), pp. 802-824.

Proof of the put-call parity relation for otherwise identical European options. [Introduction to Options]

1971 Hirshleifer, J., "Liquidity. Uncertainty and the Accumulation of Information," University of California at Los Angeles, working paper (January 1971).

The first paper to examine the joint implications of the resolution of uncertainty over time and the irreversibility of physical investments; explains the demand for liquidity as arising from the coexistence of uncertainty that is partially dispelled over time, the ability to defer commitments, and the partial irreversibility of longer-term physical investments. [Corporate Securities and Credit Derivatives]

1972 Rosenberg, B., "The Behavior of Random Variables with Nonstationary Variance and the Distribution of Security Prices," University of California at Berkeley, unpublished working paper (December 1972).

Perhaps the first paper to propose a stochastic volatility model of stock prices; first a random change in the prior local volatility is drawn: this determines the volatility of the new lognormal distribution from which the next return is drawn: capable of explaining excess kurtosis of realized frequency distributions. [Alternative Option Pricing Models]

1973 Merton, R.C., "The Relationship Between Put and Call Option Prices: Comment," *Journal of Finance* 28, No. 1 (March 1973), pp. 183-184.

The observation that the put-call parity relation holds only for European options since it may pay, particularly for American puts, to exercise options early. [Introduction to Options]

1973 Black, F. and M. Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 81, No. 3 (May-June 1973), pp. 637-659.

The classic paper on derivatives pricing based on the idea that a self-financing dynamic strategy in an option and its underlying asset is riskless, leading to the Black-Scholes formula; in addition, shows that the theory can be applied to corporate securities (stocks and bonds) since they can interpreted as options; an early working paper with almost the same results was written under the title "A Theoretical Valuation Formula for Options, Warrants, and Other Securities" dated October 1, 1970. [Black-Scholes Formula]

1973 Merton, R.C., "Theory of Rational Option Pricing," *Bell Journal of Economics and Management Science* 4, No. 1 (Spring 1973), pp. 141-183.

A complementary paper to Black-Scholes developing the general arbitrage relations and extending the new option pricing theory in a number of ways including to payouts and uncertain interest rates. [Introduction to Options, Black-Scholes Formula]

1974 Merton, R.C., "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance* 29, No. 2 (May 1974), pp. 449-470.

Extended development of Black-Scholes methodology to the pricing of non-callable and non-convertible zero-coupon corporate debt without safety covenants; shows how the default premium is a function of underlying firm volatility and bond maturity. [Corporate Securities and Credit Derivatives)

1975 Cox, J.C. and S.A. Ross, "The Pricing of Options for Jump Processes," University of Pennsylvania, unpublished working paper (April 1995).

The binomial model for pricing options where one move (up or down) is a small change with very high risk-neutral probability, and the other move is a large change in the other direction with very small risk-neutral probability; as the number of moves in the tree is increased over a fixed total time interval, the small change gets smaller, the large change remains fixed but its probability approaches zero. [Binomial Option Pricing Model]

1975 McCulloch, J.H., "The Tax-Adjusted Yield Curve," *Journal of Finance* 30, No. 2 (June 1975), pp. 811-830.

Probably the most widely used procedure for estimating the term structure of riskless returns from the concurrent prices of coupon bonds, dealing in particular with the problem that different bonds have different timing to their coupon payments; applies the interpolation method of cubic splines. (Forwards and Futures, Fixed Income Options].

1975 Black, F., "Fact and Fantasy in the Use of Options," *Financial Analysts Journal* 31, No. 4 (July-August 1975), pp. 36-41, 61-72.

Sound advice about how to use the Black-Scholes formula in practice. [Black-Scholes Formula]

1975 Cox, J.C., "Notes on Option Pricing 1: Constant Elasticity of Variance Diffusions." unpublished document, Stanford University (September 1975).

Five page unpublished typewritten notes providing the original derivation of the constant elasticity of variance diffusion model - a generalization of Black-Scholes formula which builds in a negative correlation between the underlying asset price and its local volatility. A version of the working paper was published as "The Constant Elasticity of Variance Option Pricing Model," in *Journal of Portfolio Management* (Special Issue: **A** Tribute to Fischer Black, December 1996), pp. 15-17. [Alternative Option Pricing Models]

1976 Black, F., "The Pricing of Commodity Contracts," *Journal of Financial Economics* 3, No. 1 (January-March 1976), pp. 167-179.

Derives the Black-Scholes type formula for options on futures, known in practice as the "Black formula". [Black-Scholes Formula]

1976 Cox, J.C. and S.A. Ross, "The Valuation of Options for Alternative Stochastic Processes," *Journal of Financial Economics* 3, No. 1 (January-March 1976), pp. 145-166.

Provides the "Cox-Ross" shortcut to valuing options: whenever it is known that an option can be replicated by a dynamic self-financing trading strategy utilizing only its underlying asset and cash, then it can be valued relative to its current underlying asset price as if it were traded in a risk-neutral economy where the option, its underlying asset and cash all have the same expected return. (Binomial Option Pricing Model, Black-Scholes Formula]

1976 Merton, R.C., "Option Pricing When Underlying Stock Returns are Discontinuous," *Journal of Financial Economics 3,* No. 1 (January-March 1976), pp. 125-144.

Generalization of the Black-Scholes formula for possible (Poisson) jumps in the underlying asset price; uses risk-neutral arguments permitted by the assumption that jump movements (but not necessarily continuous movements) n the underlying asset price are uncorrelated with aggregate wealth: concludes that the option value is a weighted average of Black-Scholes values, one value for each possible number of jumps over the life of the option. [Alternative Option Pricing Models]

1976 Ross, S.A., "Options and Efficiency." *Quarterly Journal of Economics* 90, No. 1 (February 1976), pp. 75-89.

Shows that in place of state-contingent .]aims, a full set of standard calls can also complete the market; and shows how to identify their single underlying portfolio. [Portfolio Optimization and Performance Measurement]

1976 Black, F. and J.C. Cox, "Valuing Corporate Securities: Some Effects of Bond Indenture Provisions," *Journal of Finance* 31, No. 2 (May 1976), pp. 351-368.

Extension of the Black-Scholes methodology (and Merton's May 1994 article) to the valuation of corporate securities to include a protective covenant whereby the firm must declare bankruptcy even before it defaults if its value falls below a certain level; similar to a down-and-out barrier option. [Corporate Securities and Credit Derivatives)

1976 Latane, H.A. and R.J. Rendleman. "Standard Deviations of Stock Prices Ratios Implied in Option Prices," *Journal of Finance* 31, No, 2 (May 1976), pp. 369-382.

The first article to use implied volatilities to compare related option prices. [Volatility]

1976 Garman, M., "A General Theory of Asset Valuation under Diffusion State Processes," University of California at Berkeley, unpublished working paper (July 1976).

Early unpublished generalized equilibrium model based on no riskless arbitrage and multivariate diffusion processes for security prices, allowing among other things for purely stochastic volatility. (Alternative Option Pricing Models]

1976 Black, F., "Studies of Stock Price Volatility Changes," *Proceedings of the 1976 Meetings of the American Statistical Association, Business and Economics Statistics Section* (August 1976), pp. 177-181.

Early discussion of the empirical behavior of the local volatility of an underlying asset, which contrary to the Black-Scholes assumptions, moves like random variable; in particular, about how this volatility varies inversely with its underlying asset price. (Volatility, Alternative Option Pricing Models]

1976 Rubinstein, M., "The Valuation of Uncertain income Streams and the Pricing of Options," *Bell Journal of Economics 7,* No. 2 (Autumn 1976), pp. 407-425.

The Black-Scholes formula is derived from an equilibrium capital asset pricing model in which the market consensus preferences have the property of constant proportional risk aversion and underlying asset returns are subjectively lognormal; unlike the Black-Scholes derivation, continuous trading opportunities are not required. (Black-Scholes Formula]

1976 Garman, M., "An Algebra for Evaluating Hedge Portfolios," *Journal of Financial Economics* 3, No. 4 (October 1976), pp. 403-427.

Develops static replication in which a piecewise-linear payoff line is replicated by a portfolio of options, and shows that the general arbitrage relations are sufficient as well as necessary for there to be no buy-and-hold riskless arbitrage opportunities among a portfolio of options on the same underlying asset. [Introduction to Options, Dynamic Strategies]

1977 Schwartz, E.S., "The Valuation of Warrants: Implementing a New Approach," *Journal of Financial Economics* 4, No. 1 (January 1977), pp. 79-93.

The first application of finite difference numerical methods for solving differential equations to the numerical valuation of options. [Numerical Methods]

1977 Boyle, P., "Options: A Monte-Carlo Approach," *Journal of Financial Economics* 4, No. 3 (May 1977), pp. 323-338.

The first application of Monte-Carlo numerical techniques to the valuation of European options, sped up by use of control variates. [Numerical Methods)

1977 Merton, R.C., "On the Pricing of Contingent Claims and the Modigliani-Miller Theorem," *Journal of Financial Economics* 5, No. 2 (November 1977), pp. 241-250.

The original Black-Scholes argument is couched in terms of replicating cash with a position in the asset and the option: article suggests it is better to think in terms of replicating the option with a position in the asset and cash. [Introduction to Options]

1977 Myers, S.C., "Determinants of Corporate Borrowing," *Journal of Financial Economics* 5, No.2 (November 1977), pp. 147-176.

The first paper to interpret corporate investments as options; in particular, current investments have embedded options which are the opportunities they open to make profitable subsequent investments. (Corporate Securities and Credit Derivatives).

1977 Vasicek, O., "An Equilibrium Characterization of the Term Structure," *Journal of Financial Economics* 5, No 2 (November 1977), pp. 177-188.

First published model of bond pricing built on a diffusion process imposed directly on the shortest-term spot interest rate; has the feature that on a given date, the ratio of the local expected excess return of any bond divided by its local volatility (the market price of risk) is the same, irrespective of the maturity of the bond; a special case combining a constant market price of risk with an Ornstein-Uhlenbeck process - a single factor (current shortest-term riskless return) constant volatility mean reverting process - results in a closed-form formula for the current value of a zero-coupon bond. [Fixed Income Options]

1977 Brennan, M.J. and E.S. Schwartz, "Convertible Bonds: Valuation of Optimal Strategies for Call and Conversion," *Journal of Finance* 32, No. 5 (December 1977), pp. 1699-1716.

Extension of the Black-Scholes pricing methodology (and Merton's May 1974 article) to the pricing of corporate debt which is both convertible by the investor into the underlying asset and callable by the firm issuing the bond. An extension of this to uncertain interest rates can be found in Brennan, M.J. and E.S. Schwartz, "Analyzing Convertible Bonds," *Journal of Financial and Quantitative Analysis* 15, No. 4 (November 1980), pp. 907-929. [Corporate Securities and Credit Derivatives]

1978 Margrabe, W., "The Value of an Option to Exchange One Asset for Another," *Journal of Finance* 33, No. 1 (March 1978), pp. 177-186.

Early exotic option article, extending the Black-Scholes formula to random strike prices, which are (in risk-neutral terms) jointly lognormal with the underlying asset price. [Exotic Options and Real Options]

1978 Hakansson, N.H., "Welfare Aspects of Options and Supershares," *Journal of Finance* 33, No. 3 (June 1978), pp. 754-776.

Investigates implications from assuming that the only source of disagreement among investors being the subjective probabilities attached to outcomes of the market portfolio. Since investors' conditional subjective probabilities regarding individual security returns are the same, then state-contingent claims on the market portfolio would be the only securities needed by the market. - [Portfolio Optimization and Performance Measurement)

1978 Ross, S.A., "A Simple Approach to the Valuation of Risky Streams," *Journal of Business* 51, No. 3 (July 1978), pp. 453475.

Rules for calculating the present values of payoffs, generally received at several dates over time, which are linear functions of other variables, assuming no riskless arbitrage opportunities. [Forwards and Futures]

1978 Brennan, M.J. and E.S. Schwartz, "Finite Difference Methods and Jump Processes Arising from Contingent Claims: A Synthesis," *Journal of Financial and Quantitative Analysis* 13, No. 3 (September 1978), pp. 461-474.

Clear review of explicit and implicit finite difference numerical techniques for pricing options. [Numerical Methods]

1978 Breeden, D.T. and R.H. Litzenberger, "Prices of State-Contingent Claims Implicit in Option Prices," *Journal of Business* 51, No. 4 (October 1978), pp. 621-651.

Shows how to recover the risk-neutral probability distribution from the current prices Of standard European options on the same underlying asset with the same time-to-expiration, when there exist a continuum of options spanning all strike prices; individual risk neutral probabilities are similar to the prices of butterfly spreads with arbitrarily short distances between the constituent strike prices. [implied Binomial Trees]

1979 Brennan, M.J., "The Pricing of Contingent Claims in Discrete-Time Models," *Journal of Finance* 34, No. 1 (March 1979), pp. 53-68.

Shows that consensus constant proportional risk aversion is not only sufficient but also necessary to produce the Black-Scholes formula without continuous trading opportunities in a market where the underlying asset returns are subjectively lognormally distributed; extension of Rubinstein's Autumn 1976 article. [Fixed Income Options]

1979 Brennan, M.J. and E.S. Schwartz, "A Continuous-Time Approach to the Pricing of Bonds," *Journal of Banking and Finance* 3, No. 3 (July 1979), pp. 133-155.

A model of bond pricing built on a two-factor diffusion process, using the shortest-term and longest-term spot interest rates; although no closed-form solution is forthcoming and numerical methods must be used to solve the differential equation for bond prices, the model allows for a much more complex evolution in the term structure than is possible with single-factor models. [Fixed Income Options]

1979 Geske, R., "The Valuation of Compound Options," *Journal of Financial Economics,* No. 1 (March 1979), pp. 63-81.

Original derivation of a Black-Scholes type formula for pricing compound options - exotic options whose underlying asset is itself interpreted as an option. (Exotic Options and Real Options, Corporate Securities and Credit Derivatives)

1979 Tourinho, O.A., "The Option Value of Reserves of Natural Resources," University of California at Berkeley, unpublished working paper (September 1979).

The first paper to analyze natural resources as an option; paradox of why they are recovered is circumvented by assuming that extraction costs grow faster than the rate of interest. [Corporate Securities and Credit Derivatives]

1979 Harrison, J.M. and D.M. Kreps, "Martingales and Arbitrage in Multiperiod Securities Markets," *Journal of Economic Theory* 20, No. 3 (July 1979), pp. 381-408.

Formal mathematical development of the relation between risk-neutral probabilities and no riskless arbitrage opportunities; formalizes the notion of self-financing strategies. [Binomial Option Pricing Model, Black-Scholes Formula]

1979 Cox, J.C., S.A. Ross and M. Rubinstein, "Option Pricing: A Simplified Approach," *Journal of Financial Economics* 7, No. 3 (September 1979), pp. 229-263.

The classic article developing the binomial option pricing model, showing that in the continuous-time limit it can converge to the Black-Scholes formula, and emphasizing the advantage of the binomial model in valuing American options. [Binomial Option Pricing Model]

1979 Rendleman, R.J-. and B.J. Bartter, "Two-State Option Pricing," *Journal of Finance* 34, No. 5 (December 1979), pp. 1093-1110.

A less popular, but simultaneously and independently developed treatment of the binomial option pricing model. [Binomial Option Pricing Model]

1979 Goldman, B.M., H.B. Sosin and M.A. Gatto, "Path Dependent Options: Buy at the Low, Sell at the High," *Journal of Finance* 34, No. 5 (December 1979), pp. 11 1 1-1 128.

One of the first papers to apply Black-Scholes logic to nonstandard or exotic options; formula derived for the valuation of what are now known as lookback options. [Exotic Options and Real Options]

1980 Rendleman, R.J. and B.J. Bartter, "The Pricing of Options on Debt Securities," *Journal of Financial and Quantitative Analysis* 15, No. 1 (March 1980), pp. 11-24.

First binomial model for bond options: assumes that the shortest-term spot return follows a recombining binomial process and that the unbiased expectations hypothesis holds: bonds of different maturities all have the same expected return over the next binomial period. [Binomial Option Pricing Model. Fixed Income Options)

1980 Leland, H.E., "Who Should Buy Portfolio Insurance?" *Journal of Finance* 35, No. 2 (May 1980), pp. 581-594.

Why some investors should prefer convex payoff lines, while others should prefer concave payoff lines? Emphasizes hedging motives: the rate an investor's risk aversion changes as his wealth changes relative to the rate of change for the market as a whole. [Dynamic Strategies]

1981 Harrison, J.M. and S.R. Pliska, "Martingales and Stochastic Integrals in the Theory of Continuous Trading," *Stochastic Processes and Their Applications 11* (1981), pp. 215-260.

Continuation of Harrison and Kreps (1979). [Black-Scholes Formula]

1981 Cox, J.C., J.E. Ingersoll and S.A. Ross, "The Relation Between Forward Prices and Futures Prices," *Journal of Financial Economics* 9, No. 4 (December 1981), pp. 321-346.

Shows that under no riskless arbitrage opportunities, perfect markets and certainty of future spot rates, otherwise identical forwards and futures contracts will have forward prices and futures prices which are equal. [Forwards and Futures]

1981 Rubinstein, M. and H.E. Leland, "Replicating Options with Positions in Stock and Cash," *Financial Analysts Journal 37,* No. 4 (July-August 1981), pp. 63-72.

A very simple and readable treatment of the implications of the idea that options can be replicated with a dynamic self-financing asset-cash trading strategy. [Introduction to Options, Binomial Option Pricing Model]

1981 Brennan, M.J. and R. Solanki, "Optimal Portfolio Insurance," *Journal of Financial and Quantitative Analysis* 16, No. 3 (September 1981), pp. 279-300.

Given an investor's utility function and a lognormal distribution governing an underlying portfolio, derives the investor's optimal payoff function (that maximizes his expected utility). [Dynamic Strategies]

1982 Stulz, R.M., "Options on the Minimum or the Maximum of Two Risky Assets: Analysis and Applications," *Journal of Financial Economics 1* 0, No. 2 (July 1982), pp. 161-185.

An early exotic options article extending dynamic replication to payoffs which depend on the prices of two underlying assets. [Exotic Options and Real Options]

1982 Baldwin, C., "Optimal Sequential Investment When Capital is Not Readily Reversible," *Journal of Finance* 37, No. 3 (July 1982), pp. 763-782.

Argues that firms with market power should demand a premium over ordinarily calculated net present value as compensation for the loss of future flexibility from undertaking irreversible investments. [Corporate Securities and Credit Derivatives].

1982 Engle, R.K., "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica* 50, No. 4 (July 1982), pp. 987-1008.

Initiates a new and now quite popular approach to forecasting variance; proposes the linear ARCH(Q) model of time-series variance; states that the current local variance equals the sum of two terms: a constant plus a weighted average of the q past squared returns; explicitly takes account of volatility clustering over time. [Volatility, Alternative Option Pricing Models]

1983 Rubinstein, M., "Displaced-Diffusion Option Pricing," *Journal of Finance* 38, No. 1 (March 1983), pp. 213-217.

Extension of the Black-Scholes formula to allow for underlying assets which have a future price which equals a positive constant plus a risk-neutral lognormal random variable. [Alternative Option Pricing Models]

1983 Garman, M. and S. Kohihagen, "Foreign Currency Option Values," *Journal of International Money and Finance* 2, No. 3 (December 1983), pp. 231-237.

Original derivation of a Black-Scholes type formula for foreign currency options, showing that the key feature that the payout return in the formula should be replaced the foreign riskiess return. [Binomial Option Pricing Model]

1983 Ball, C.A. and W.N. Torous, "Bond Price Dynamics and Options," *Journal of Financial and Quantitative Analysis* 18, No. 4 (December 1983), pp. 517-531.

Pricing model for options on bonds assuming that the price of the underlying bond starts and ends at known levels, and in between meanders randomly but with a force drawing it toward the known terminal bond value, growing, like a magnet, more powerful as the maturity approaches. [Fixed Income Options]

1983 Cox, J.C. and H.E. Leland, "On Dynamic Investment Strategies," Massachusetts Institute of Technology and University of California at Berkeley, unpublished working paper (December 1983).

In most other work, optimal self-financing dynamic strategies are derived from prespecified risk preferences: in this unpublished paper, the inverse problem is solved; given a proposed dynamic strategy, how ran we tell if it will be self-financing, has path-independent outcomes, and is consistent with expected utility maximization? the paper concentrates on a situation involving a choice between a single risky asset (market portfolio) following geometric Brownian motion, and cash with an exogenously specified constant riskless return; a key result is that path-independent dynamic strategies are a necessary condition for expected utility maximization. [Dynamic Strategies]

1984 Rubinstein, M., "A Simple Formula for the Expected Rate of Return of an Option over a Finite Time Period," *Journal of Finance* 39, No. 5 (December 1984), pp. 1503-1509.

Proof that assuming the Black-Scholes formula and subjectively lognormal underlying asset prices, the expected payoff of a standard European option over a finite horizon shorter or equal to its life is the Black-Scholes value of the option with slightly altered inputs. [Black-Scholes Formula)

1985 Cox, J.C., J.E. Ingersoll and S.A. Ross, "A Theory of the Term Structure of Interest Rates," *Econometrica* 53, No. 2 (March 1985), pp. 385-408.

Derivation of the closed-form Cox-Ingersoll-Ross formula for the pricing of options on fixed income securities from within a general equilibrium model: based on a single-factor (current shortest-term riskless return) diffusion with mean reversion and local volatility which varies positively with the square root of the logarithm of the factor. [Fixed Income Options]

1985 Cox, J.C. and M. Rubinstein, *Options Markets* (Prentice-Hall 1985).

Classic text on options markets, containing the most detailed exposition of the binomial option pricing model; although superseded by newer texts in dealing with more recent developments in derivatives markets, continues to remain the best discussion of the economic theory behind option pricing. [general source]

1985 Rubinstein, M., "Nonparametric Tests of Alternative Option Pricing Models Using All Reported Trades and Quotes on the 30 Most Active CBOE Option Classes from August 23, 1976 through August 31, 1978," *Journal of Finance* 40, No. 2 (June 1985), pp. 455-480.

Detailed and extremely careful transaction by transaction test of the Black-Scholes formula applied to individual stocks in the late 1970's: test compares the implied volatilities of otherwise identical calls that differ only either by strike price or by time-to-expiration using relatively weak Nonparametric statistics; despite this, documents statistically significant biases from the Black-Scholes formula, but which may not be economically significant. [Empirical Tests]

1985 Rubinstein, M., "Alternative Paths to Portfolio Insurance," *Financial Analysts Journal* 41, No. 4 (July-August 1985), pp. 42-52.

Compares alternative ways of implementing a floor in a payoff function, in particular stop-loss orders, rolling over short-term options, and Black-Scholes type dynamic strategies. [Dynamic Strategies)

1985 Leland, H.E., "Option Pricing and Replication with Transactions Costs," *Journal of Finance* 40, No. 5 (December 1985),pp. 1283-1301.

Incorporates proportional trading costs into the cost and discrete-time replicating strategy of a payoff function which is either everywhere convex or everywhere concave: for convex payoffs, trading costs are equivalent to an increase in the volatility; for a concave payoffs, trading costs are equivalent to a reduction in the volatility. [Dynamic Strategies]

1986 French, K.R. and R. Roll, "Stock Return Variances: The Arrival of Information and the Reaction of Traders," *Journal of Financial Economics* 17, No. 1 (September 1986), pp. 5-26.

Shows that stock volatility is much higher per hour (1 3 to 1 00 times) when exchanges are open than when they are closed; for example three-day weekend variance is only slightly higher than single trading day variance; affects the timing adjustments that should be made when translating historical observations into estimates of volatility. [Volatility]

1986 Bollerslev, T., "Generalized Autoregressive Conditional Heteroskedasticity," *Journal of Econometrics* 31, No. 3 (April 1986), pp. 307-327.

Proposes the linear GARCH(P, q) model of time-series variance - the most popular extension of the Engle's ARCH(Q) model; states that the current local variance equals the sum of three terms: a constant plus a weighted average of the q past squared returns plus a second weighted average of the p past local variances; explicitly takes account of volatility clustering over time even when p = q 1. [Volatility, Alternative Option Pricing Models]

1986 Ho, T.S.Y. and S.-B. Lee, "Term Structure Movements and Pricing Interest Rate Contingent Claims," *Journal of Finance* 41, No. 5 (December 1986), pp. 101 1-1029.

First model for pricing options on bonds which is calibrated to be consistent with the current price of bonds of different maturities; takes the form of a no riskless arbitrage binomial model of the short-term riskless return; resulting binomial tree can be used to value a large variety of contingent claims including bond options and callable bonds. [Binomial Option Pricing Model, Fixed Income Options]

1987 Hull, J. and A. White, "The Pricing of Options on Assets with Stochastic Volatilities," *Journal of Finance* 42, No. 2 (June 1987), pp. 281-300.

One of the first analytic models for valuing options with a random local volatility which is uncorrelated with the underlying asset price; uses risk-neutral arguments permitted by the assumption that volatility is uncorrelated with aggregate wealth; concludes that the option value is a weighted average of Black-Scholes values, one value for each possible level of the average realized volatility over the life of the option. An extension of this article to local volatility correlated with the asset price can be found in Hull, J. and A. White, 'An Analysis of the Bias in Option Pricing Caused by Stochastic Volatility," *Advances in Futures and Options Research* 3 (1988), pp. 29-61. [Alternative Options Pricing Models]

1987 Barone-Adesi, G. and R.E. Whaley, "Efficient Analytic Approximation of American Option Values," *Journal of Finance* 42, No. 2 (June 1987), pp. 301-320,

Computationally fast, reasonably accurate (for short-maturity options), and non-recursive algorithm for approximating the values of standard American calls and puts. This article is an extension of earlier work found in Macmillan, L.W., "Analytic Approximation for the American Put Option," *Advances in Futures and Options Research 1,* Part A:Options (1986), pp. 119-139. (Numerical Methods]

1987 Schaefer, S. and E.S. Schwartz, "Time-Dependent Variance and the Pricing of Options on Bonds," *Journal of Finance* 42, No. 5 (December 1987), pp. 1113-1128.

Single-factor diffusion model of bond prices in which the local variance is proportional to bond duration. (Fixed Income Options]

1988 Seidenverg, E., "A Case of Confused Identity," *Financial Analysts Journal* 44, No. 4 (July-August 1988), pp. 63-67.

Shows how the stop-loss, start-gain dynamic strategy comes short of replicating the payoff of a call: and uses this difference to provide an alternative proof and interpretation of the multiperiod binomial option pricing formula. (Binomial Option Pricing Model]

1989 Garman, M., "Semper Tempus Fugit," RISK 2, No. 5 (May 1989), pp. 34-35.

Binomial calculation of the risk-neutral expected life of an American option. [Binomial Option Pricing Model]

1989 Jamshidian, F., "An Exact Bond Pricing Model," *Journal of Finance* 44, No. 1 (March 1989), pp. 205-209.

Extends Vasicek (1977) to closed-form formula for the values of European options on zero-coupon bonds; shows that an option on a portfolio of zero-coupon bonds is equivalent to a portfolio of options each on a single discount bond, thereby extending Vasicek even further to options on coupon bonds. (Fixed Income Options)

1989 Duffie, D., *Futures Markets* (Prentice-Hall 1989).

The best text exclusively devoted to forwards and futures covering both institutional and theoretical aspects of futures markets. [Forwards and Futures]

1990 Black, F., E. Derman and W. Toy, "A One-Factor Model of Interest Rates and Its Applications to Treasury Bond Options," *Financial Analysts Journal* 46, No. 1 (January-February 1990), pp. 33-39.

Develops single-factor (shortest-term spot rate) binomial model for fixed income derivatives where the tree is calibrated to be consistent with the current term structure of spot returns and its exogenously estimated volatilities. [Fixed Income Options]

1990 Brennan, M.J., "Latent Assets," *Journal of Finance* 45, No. 3 (Presidential Address to the American Finance Association, July 1990), pp. 709-730.

Considers the "paradox" that anyone mines gold, when gold is held almost exclusively for investment purposes, the cost of mining increases more slowly than the rate of interest and the mine cannot be expropriated; gold should then be similar to a perpetual payout protected standard American option which it would therefore never pay to exercise. [Forwards and Futures]

1990 Nelson, D.B. and K. Ramaswamy, "Simple Binomial Processes as Diffusion Approximations in Financial Models," *Review of Financial Studies* 3, No. 3 (Fall 1990), pp. 393-430.

Shows how path-independent binomial trees which are not recombining can, by adjusting the move sizes, be transformed into a recombining tree which has the same continuous-time limit. [implied Binomial Trees]

1990 Hull, J. and A. White, "Pricing Interest Rate Derivative Securities," *Review of Financial Studies* 3, No. 4 (Winter 1990), pp. 573-592.

Shows that the single-factor models of Vasicek (1977) and Cox-Ingersoll-Ross (1985) can be extended in the spirit of Ho and Lee (1986) to be consistent with the concurrent term structure of interest returns and either exogenously estimated current volatilities of all spot returns, or exogenously estimated current volatilities of all forward returns. [Fixed Income Options]

1991 Nelson, D., "Conditional Heteroskedasticity in Asset Returns: A New Approach," *Econometrica* 59, No. 2 (March 1991), pp. 347-370.

Proposes the linear EGARCH(P, q) model of time-series variance - an extension of the Bollersiev's GARCH(P, q) model; states that the current local variance equals the sum of three terms: a constant plus a weighted average of functions of the q past squared returns plus a second weighted average of the p past local variances; the functions of the q past squared returns explicitly take account of an asymmetric response of current local volatility to the direction of past returns. [Volatility, Alternative Option Pricing Models]

1991 He, H., "Convergence from Discrete-Time to Continuous-Time Contingent Claims Prices," *Review of Financial Studies* 4, No. 3 (Fall 1991), pp. 523-546.

Generalization of the binomial option pricing model to options on more than one underlying asset, while preserving its dynamic arbitrage properties and its convergence to a multivariate lognormal risk-neutral return distribution. [Exotic Options and Real Options]

1992 Heath, D., R. Jarrow and A. Morton, "Bond Pricing and the Term Structure of Interest Rates: A New Methodology for Contingent Claims Valuation," *Econometrica* 60, No. I (January 1992), pp. 77-105.

Develops a multiple factor fixed income continuous-time derivatives model which includes several earlier models developed by others as special cases; in the spirit of Ho and Lee (1986), their model is consistent with the current prices of all zero-coupon bonds by imposing exogenous stochastic properties directly on the evolution of forward rates. [Fixed Income Options]

1992 Ingersoll, J.E. and S.A. Ross. "Waiting to Invest: Investment and Uncertainty," *Journal of Business* 65. No. 1 (January 1992), pp. 1-29

Current acceptance of a real investment project and its delayed acceptance are mutually exclusive; as result, the project should not be currently accepted just because its present value is positive; in addition to the effect of the current term structure on this tradeoff, the article considers also the influence of uncertainty of future spot rates; shows that this uncertainty can substantially enhance the option value of waiting and should affect the aggregate level of investment in the economy. [Corporate Securities and Credit Derivatives]

1992 Bernstein, P.L. *Capital Ideas: The Improbable Origins of Modem Wall Street* (Free Press 1992).

A popularly written history, primarily of the contribution of academics to financial practice from Bachelier in 1900 to the 1990 Nobel Prize awarded for research in financial economics; provides bibliographical accounts of Louis Bachelier, Fischer Black, Alfred Cowles, Charles Dow, Eugene Fama, Hayne Leland, John McQuown, Harry Markowitz, Robert Merton, Merton Miller, Franco Modigliani, M.F.M Osborne,Harry Roberts, Barr Rosenberg, A.D. Roy, Mark Rubinstein, Paul Samuelson, Myron Scholes, William Sharpe, James Tobin, Jack Treynor, James Vertin, John Burr Williams, and Holbrook Working, many of the living drawn from personal interviews: includes chapters on the Black-Scholes formula and portfolio insurance. [general source]

1992 Longstaff, F.A. and E.S. Schwartz, "Interest Rate Volatility and the Term Structure: A Two-Factor General Equilibrium Model," *Journal of Finance* 47, No. 4 (September 1992), pp. 1259-1282.

Two factor general equilibrium model of the term-structure, where the shortest-term interest rate and its volatility are the two factors: leads to closed-form solutions for bond prices and options. [Fixed Income Options]

1993 Heston, S.L., "A Closed-Form Solution for Options with Stochastic Volatility and Applications to Bond and Currency Options," *Review of Financial Studies* 6, No. 2 (Summer 1993), pp. 327-343.

Generalization of the Hull-White stochastic volatility model (June 1987) to permit arbitrary correlation between the price and volatility of the underlying asset as well as stochastic interest rates; a measure of risk preference toward volatility (price of volatility risk) enters as a parameter, the same for all options with the same time-to-expiration on the same underlying asset. (Alternative Option Pricing Models]

1993 He, H. and H.E. Leland, "On Equilibrium Asset Price Processes," *Review of Financial Studies* 6, No. 3 (Fall 1993), pp. 593-617.

Derives necessary and sufficient conditions (in the form of a partial differential equation) governing the relation between consensus risk preferences and the stochastic process of the market portfolio that must hold in equilibrium; assumes an economy with cash and a single risky asset (market portfolio), the risky asset return conforms to a diffusion process, a constant riskiess return that is exogenously specified, and investors maximize a state-independent utility function of wealth at some future date. [Implied Binomial Trees]

1993 Wilmot, P., J. Dewynne and S. Howison, *Option Pricing: Mathematical Models and Computation* (Oxford Financial Press 1993).

A highly mathematical text, emphasizing differential equations and finite difference methods, covering both standard and exotic options. [general source]

1994 Dupire, B., "Pricing with a Smile," *RISK* 7, No 1 (January 1994), pp. 18-20.

Discusses a differential equation, a sort of dual to the Black-Scholes differential equation - but under circumstances in which the local volatility can be an arbitrary continuous function of time and the concurrent level of the underlying asset price - which relates the local volatility to the second derivative of option value with respect to its strike price (the price of a state-contingent claim) and to the first derivative of the option value with respect to its time-to-expiration. [Implied Binomial Trees]

1994 Derman, E. and 1. Kani, "Riding on the Smile," *RISK* 7, No. 2 (February 1994), pp. 32-39.

Recovering the unique recombining binomial tree which simultaneously fits all the prices of standard European options on the same underlying asset, where available options span all strike prices and times-to-expiration corresponding to nodes in the tree. [Implied Binomial Trees]

1994 Rubinstein, M., "Implied Binomial Trees," *Journal of Finance* 49, No. 3 (Presidential Address to the American Finance Association, July 1994), pp. 771-818.

Generalization of the binomial option pricing model for arbitrarily specified expiration-date risk-neutral probability distributions; and new methods for recovering the expiration-date risk-neutral probability distribution from the prices of otherwise identical standard European options with different strike prices. [Binomial Option Pricing Model, Implied Binomial Trees]

1994 Dixit, A.K. and R. S. Pindyck, *Investment Under Uncertainty* (Princeton University Press 1994).

Text integrating much of the work on real options with an emphasis on its roots in the economics literature. [Exotic Options and Real Options, Corporate Securities and Credit Derivatives]

1994 Hull, J. and A. White, "Numerical Procedures for Implementing Term Structure Models 1: Single-Factor Models," *Journal of Derivatives* 2, No. 1 (Fall 1994), pp. 7-16,

Shows how to use trinomial trees to implement the pricing of several one-factor fixed income option pricing models designed to be consistent with the initial term structure, including Ho and Lee (December 1986) and Hull and White (Winter 1990). A companion paper to this for two-state variable models is in *Journal of Derivatives* 2, No. 2 (Winter 1994), pp. 37-48. A more recent paper containing yet further results for one-factor models is in *Journal of Derivatives* 3, No. 3 (Spring 1996), pp. 25-36. (Fixed Income Options]

1994 Leland, H.E., "Corporate Debt Value, Bond Covenants and Optimal Capital Structure," *Journal of Finance* 49, No. 4 (September 1994), pp. 1213-1252.

Extension of the Black and Cox (May 1976) article to the closed-form pricing of corporate debt with protective covenants, differential taxation, and bankruptcy costs; uses the trick of assuming debt is perpetual and allowing for endogenous determination of bankruptcy or continuously rolling-over very short-term debt with bankruptcy only triggered when the firm's net worth becomes negative. In H.E. Leland, "Bond Prices, Yield Spreads and Optimal Capital Structure with Default Risk" University of California at Berkeley, working paper (November 1994), this is extended to the case of continuously rolled-over debt of arbitrary maturity permitting a comparative statics analysis of debt maturity. [Corporate Securities and Credit Derivatives]

1995 Hull, J. and A. White, "The Impact of Default Risk on the Prices of Options and Other Derivative Securities," *Journal of Banking and Finance* 19, No. 2 (May 1995), pp. 299-322.

One of the best of many recent papers on credit derivatives. [Corporate Securities and Credit Derivatives]

1995 Litzenberger, R.H. and N. Rabinowitz, "Backwardation in Oil Futures Markets: Theory and Empirical Evidence," *Journal of Finance* 50, No. 5 (December 1995), pp. 1517-1545.

The Hotelling Principle (Hotelling April 1931) cannot explain the typically observed backwardation in commodities futures markets without relying on unrealistically quickly rising extraction costs; paper builds a model under uncertainty where because of the option value of delayed extraction, backwardation is necessary for current production; as a corollary, the higher the volatility of the underlying commodity, the greater the option value of postponed extraction and the greater the backwardation required for current production to occur. (Forwards and Futures, Exotic Options and Real Options]

1996 Jarrow, R.A., *Modeling Fixed Income Securities and Interest Rate Options* (McGraw-Hill 1996).

Text on fixed income options relying primarily on binomial trees as a pedagogic device. [Fixed Income Options]

1996 Trigeorgis, L., *Real Options.- Managerial Flexibility and Strategy in Resource Allocation* (MIT Press 1996).

Text integrating much of the work on real options with an emphasis on its roots in the finance literature. [Exotic Options and Real Options)

1996 Bergman, Y.Z., B.D. Grundy and Z. Wiener, "General Properties of Option Prices," *Journal of Finance* 51, No. 5 (December 1996), pp. 1573-1610.

Given a constant riskless return and a univariate diffusion process for the underlying asset price (a continuous-time continuous state process where the local volatility is a continuous function only of the concurrent underlying asset price and time), the paper shows that any European derivative (with an arbitrary continuous payoff function, not just calls and puts) at all times in its life inherits the key features of its payoff function: upper and lower delta bounds, monotonicity, convexity or concavity. [introduction to Options]

1996 Jackwerth, J.C., "Recovering Risk Aversion from Option Prices and Realized Returns," University of California at Berkeley, working paper (August 1996).

State-contingent prices are explained by consensus risk-aversion and consensus subjective probabilities; paper shows how option prices (which imply the state-contingent prices) and realized return frequencies (which proxy for subjective probabilities) can be used to recover consensus risk-aversion; in particular, this is done in a way which is insensitive to the Problem of the presence of infrequently observed but significant return events. [implied Binomial Trees]

1996 Leland, H.E., "Performance Measurement of Portfolios Using Derivatives or Dynamic Strategies," University of California at Berkeley, working paper (November 1996).

In a Black-Scholes setting, the traditional mean-variance analysis applied to the performance measurement of portfolios containing significant derivatives positions or using dynamic investment strategies is inadequate because it assumes normal rather than lognormal distributions and takes no account of investor preference toward skewness and higher-order moments; paper shows that option positions priced according to the Black-Scholes formula will be expected to exhibit apparent risk-adjusted over- or under-performance of the market; paper shows how to modify the traditional mean-variance approach to correct for these errors. [Portfolio Optimization and Performance Measurement]

1996 Jackwerth, J.C. and M. Rubinstein, "Recovering Probability Distributions from Option Prices," *Journal of Finance 51,* No. 5 (December 1996), pp. 1611-1631.

Using the S&P **500** Index as an example, article argues that at least since the stock market crash of 1987, the Black-Scholes lognormality assumption is not supported by either observed underlying asset returns or distributions implied in exchange-traded European option prices; article compares alternative means of recovering these distributions from option prices; extension of Rubinstein's July 1994 article. [implied Binomial Trees]

1996 Jackwerth, J.C. and M. Rubinstein, "Recovering Stochastic Processes from Option Prices," University of California at Berkeley, working paper (December 1996).

An empirical comparison of alternative option pricing approaches - Black-Scholes, CEV, jump-diffusion, stochastic volatility, implied binomial trees, and two naive trader models - using the metric of prediction of future implied volatility smiles from current information. [Empirical Tests]

1996 Leland, H.E., "Options and Expectations," *Journal of Portfolio Management* (Special Issue: A Tribute to Fischer Black, December 1996), pp. 43-51.

Why should some investors buy and others sell options? Why should investors buy or sell exotic path-dependent options? As a complement to the author's earlier article (May 1980) which primarily looked at hedging motives (based on differences in risk aversion from the market consensus), this article examines speculative motives (based on differences in beliefs from the market consensus). [Dynamic Strategies, Exotic Options and Real Options]

1997 Dybvig, P.H. and L.C.G. Rogers, "Recovery of Preferences from Observed Wealth in a Single Realization," *Review of Financial Studies 10,* No. 1 (Spring 1997), pp. 151-174.

In the binomial option pricing model where the underlying asset is interpreted as the portfolio of risky assets held by an investor, and given that at each node he chooses his optimal allocation of wealth between this portfolio and cash, observing only his allocations along the single realized path through the tree permits inference of what his allocations would have been at all other nodes (that were not realized) in the tree. [Dynamic Strategies]

1997 Duffie, D. and J. Pan, "An Overview of Value at Risk," *Journal of Derivatives* 4, No. 3 (Spring 1997), pp. 7-49.

Excellent discussion of "value at risk" (VaR), the new popular risk measure for derivatives portfolios discusses alternative means of estimation and sensitivity to distributional assumptions. [Portfolio Optimization and Performance Measurement]

1997 Hull, J.C., *Options, Futures and Other Derivatives,* 3rd Edition (1st Edition 1989) (Prentice-Hall 1997).

The most well-rounded standard derivatives text currently available. [general source] 1997 Miller, M., *Merton Miller on Derivatives,* (Wiley 1997). A discussion of recent allegations against derivatives arising from publicized corporate and public fund loses and lawsuits. [general source]

1997 Minton, B.A., "An Empirical Examination of Basic Valuation Models for Plain-Vanilla U.S. Interest Rate Swaps," *Journal of Financial Economics* 44, No. 2 (May 1997), pp. 251-277.

Compares empirically the two basic ways to value plain-vanilla interest rate swaps - as a portfolio of a long and a short bond, and as a sequence of short-term forward contracts spanning the life of the swap, showing that price differences may relate to differences in the default risk between these two replicating strategies. (Forwards and Futures]

1997 Routledge, B.R., D.J. Seppi and C.S. Spatt, "Equilibrium Forward Curves for Commodities," Carnegie Mellon University, working paper (June 1997).

Derives a model for pricing forward contracts on commodities used for consumption or production purposes. As in Litzenberger and Rabinowitz's December 1995 article, the authors solve for an endogenously determined stochastic process for convenience yield. While Litzenberger and Rabinowitz base their approach on the value of the commodity for its use in production, this paper considers the option created from holding the commodity in non-negative inventory. In particular, they derive endogenously a correlation between the underlying commodity spot price and its convenience yield. [Forwards and Futures]

1997 Zhang, P.G., *Exotic Options: A Guide to Second Generation Options* (World Scientific 1997).

A virtually complete survey of exotic options focusing on closed-form solution methods and explaining their uses and history. (Exotic Options and Real Options]

1997 Toft, K.B. and B. Prycyk, "Options on Levered Equity: Theory and Empirical **Tests**,*" Journal of Finance* 52, No. 3 (July 1997). 1151-1180.

Derives an option pricing formula for Leland's (September 1994) model of levered corporate equity; as predicted, explains part of the smile biases of the Black-Scholes formula by the amount of corporate leverage and the average time-to-maturity of the debt; the greater the leverage and the shorter debt maturity, the more pronounced the smile bias; extension of Geske's March 1979 article. [Corporate Securities and Credit Derivatives]

1997 Broadie, M. and P. Glasserman, "Monte Carlo Methods for Pricing High-Dimensional American Options: An Overview," *Net Exposure: The Electronic Journal of Financial Risk,* Issue 3 (December 1997), pp. 15-37.

In response to the demand for derivatives whose value depends on several random variables, a considerable literature has developed applying enhanced Monte Carlo techniques. This literature is surveyed in this paper. [Numerical Methods]

1998 Derman, E. and 1. Kani, "Stochastic Implied Trees: Arbitrage Pricing with Stochastic Term and Strike Structure of Volatility," *International Journal of Theoretical and Applied Finance 1,* No. 1 (January 1998), pp. 61 -1 1 0.

Extension of methods for implied binomial trees to allow volatility to depend on a second random variable, possibly in addition to the underlying asset price. [Implied Binomial Trees]

1998 Constantinides, G.M.. "Transactions Costs and the Volatility Implied by Option Prices," University of Chicago, working paper (January 1998).

Derives upper and lower bounds on standard European option prices in the presence of proportional transactions costs and plausible limits on investor risk aversion; shows that these bounds, considering realistic trading costs, cannot by themselves explain the volatility smile for S&P 500 Index options. [Implied Binomial Trees]

1998 Ritchken, P. and R. Trevor, "Pricing Options Under Generalized GARCH and Stochastic Volatility Process," Case Western Reserve University and Macquarie University, working paper (February 1998).

Uses tree models to price options on underlying assets which have uncertain volatility conforming to generalized discrete-time GARCH processes. Several bivariate diffusion models previously used to price options are shown to be limiting cases of these discrete-time processes, including the models of Hull and White (June 1987) and Heston (Summer 1993). [Alternative Option Pricing Models]

1998 Das, S.R. and Sundaram , R.K., "Of Smiles and Smirks: A Term Structure Prospective," Harvard University and New York University, working paper (March 1998).

One way to distinguish between a jump process and stochastic volatility (both of which ran explain excess kurtosis) is to compare the way their higher-order moments depend on the sampling interval; paper derives algebraic expressions for these moments for both types of processes as functions of the sampling interval. [Volatility, Alternative Option Pricing Models].

1998 Rubinstein, M., "Edgeworth Binomial Trees," *Journal of Derivatives* 5, No. 3 (Spring 1998), pp. 20-27.

Provides a simple way to incorporate opinions about the skewness and kurtosis (as well as volatility) of the risk-neutral expiration date distribution into option pricing, and with the help of the method of implied binomial trees, into calculating hedging parameters and valuing American options. [implied Binomial Trees]

1998 McDonald, R.L. and Schroder, M.D., "A Parity Result for American Options," *Journal of Computational Finance 1*, No. 3 (Spring 1998), pp. 5-13,

Shows that when the underlying asset price is governed by geometric Brownian motion (as assumed by Black-Scholes) or by a discrete binomial process (where ud = 1), then a standard American put has the same value as an otherwise identical standard American put, but where the underlying asset price and strike price have been transposed and the riskless and payout returns have also been transposed. [Binomial Option Pricing Model]

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Separates the components of option dollar profit into profits from directional changes in the underlying asset price from profit due to option mispricing relative to the underlying asset. The key is to define the "true relative value" of the option by using the future value of a self-financing dynamic option replication strategy as a Monte-Carlo control variate. Also shows that if the benchmark formula used to assess attribution is a good guess of the formula used by the market to price options, then the second source of profit may itself be subdivided into profit from superior volatility forecasting and profit from using a superior option valuation formula. [Portfolio Optimization and Performance Measurement]

1998 Stix, G., "A Calculus of Risk." *Scientific American* (May 1998), pp. 92-97.

Possibly the best popular description of the emerging significance of the modern derivatives markets, together with a brief but accurate discussion of modern option pricing theory - the kind of article you might politely suggest a curious relative read to find out what you are up to. [general source]

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A detailed development of the history of the use of derivatives and their institutional and regulatory environment, emphasizing the important and positive role of derivatives in shaping modern financial global markets. Also provides brief sketches of the dark side of the role of derivatives as represented by the 1987 market crash, the 1992-93 European Monetary System crisis, Metailgesellschaft, Barings, Bankers Trust/Proctor Gamble, Orange Country, and the 1994 Mexican peso devaluation. [general source]

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