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Black-Scholes Model History and Key Papers

This page is an overview of main events and papers related to the Black-Scholes option pricing model. Besides works of its main authors, Black, Scholes, and Merton, we will also investigate earlier ideas which influenced the model, and other researchers (many of them famous for other models) who played a role in its development, such as Bachelier, Samuelson, Treynor, Fama, or Miller.

On this page:

Option Trading and Pricing Before 1900

The publishing of the Black-Scholes model (spring 1973) roughly coincides with the start of option trading at the newly opened Chicago Board Options Exchange (26 April 1973) – two events which continued to reinforce one another's importance in the years that followed. However, both option trading and efforts to mathematically model option prices are much older.

Instruments similar to today's options have been around for more than two thousand years.

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(otherwise mainly known from geometry) reportedly bought rights to use olive presses, speculating that an upcoming olive harvest would be larger than expected. Option-like instruments were also traded during the 17th century Dutch tulip bubble.

The first organized option market was set up in late 17th century London, trading both puts and calls (the latter called "refusals"). In the US, option trading (though unstandardized and therefore very illiquid) dates back to the second half of 19th century.

We can assume that people trading option-like instruments in historical times might have taken efforts to understand and price them, but we can only guess how they did it, if at all.

Louis Bachelier (1900)

The first known work applying advanced mathematics to option pricing (and to finance in general) was by French mathematician Louis Bachelier. His thesis, titled *Theory of Speculation* [1], used the concept now known as Brownian motion (from physics) or Wiener process (from mathematics) to model stock option prices – the same concept that provides the foundation of Black-Scholes and many other financial models. The date of Bachelier's thesis defense, 29 March 1900, is sometimes mentioned as the origin of quantitative finance.

Like many other revolutionary ideas, Bachelier's work received rather mixed reaction at that time [15]. He got a pass, though not the highest grade for his thesis, and had it published in a prestigious journal. Nevertheless, his ideas, which he continued to develop in subsequent years, didn't have much influence in finance until many decades later.

Option Pricing Research in the 1960's

Bachelier's work was rediscovered for the financial community in the 1950's by none less than Paul Samuelson. A number of papers expanding and improving on Bachelier's ideas were published by different authors in the 1960's, some of them directly mentioned in the Black and Scholes paper in 1973.

While Bachelier got relatively close to the mathematics of the eventual Black-Scholes model, his work had a number of shortcomings, which the 1960's authors were trying to fix.

Besides slightly different underlying logic that lacked the key no-arbitrage principle of Black-Scholes, and besides different treatment of the model's inputs like volatility or interest rate,

prices can be negative. On the contrary, the Black-Scholes model assumes returns (not prices) to be normally distributed and therefore prices lognormally distributed. For example, for a stock currently trading at $10, the Bachelier version would consider a move of $20 to either side (to -$10 and $30) equally likely, which of course does not reflect the reality of most underlyings, especially on longer time horizon (exceptions where normal prices might be suitable include spreads and, perhaps, interest rates).

Some of the key 1960's works addressing the limitations of Bachelier's model include Case Sprenkle (*Warrant Prices as Indicators of Expectations and Preferences* [2]), James Boness (*Elements of a Theory of Stock-Option Value* [3]), and Paul Samuelson himself (*Rational Theory of Warrant Pricing* [4]).

They got very close to the eventual Black-Scholes model, with just small details remaining to fix. In particular, their option price formulas included arbitrary parameters, such as expected return of the underlying stock.

In a way, almost all of the Black-Scholes model had been developed before Black and Scholes, who only added the last, though very important step.

Black, Scholes, and Merton before 1973

The model is mostly known as Black-Scholes, quite unfairly excluding the name of Robert Merton (but it was him who first came up with the name "Black-Scholes model"). Not only is Merton's contribution to the model as significant as Black's and Scholes's, but all three were in close contact in the years and months leading to the publication of the model in 1973.

Fisher Black (1938-1995), the oldest of the three, received Ph.D. in applied mathematics from Harvard in 1964. His interest in quantitative finance was first ignited a year later, when he joined the consultancy firm Arthur D. Little and met Jack Treynor, who had just published several papers on asset valuation.

Under the mentorship of Treynor, Black started his own research in warrant pricing and the newly developed Capital Asset Pricing Model (CAPM). This model, which established the relationship between risk-free interest rate, a risky asset's return, and its risk (beta, closely related to variance and thereby volatility), was an essential influence in the later Black-Scholes model.

When Treynor left the firm for Merrill Lynch in 1966, Black inherited his case work. The two

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Myron Scholes (born 1941) received his Ph.D. from the University of Chicago in 1969. He was writing his dissertation under Eugene Fama (known as author of the Efficient Market Theory and the Fama-French model) and Merton Miller (mostly known for the Modigliani-Miller theorem). These two not only shaped Scholes's academic interests and future research, but, as it later turned out, played a significant role in getting the Black-Scholes model published.

In 1968, Scholes joined the Massachusetts Institute of Technology (MIT) Sloan School of Management, where he met Black. It was Michael Jensen (known for Jensen's alpha) who helped match Black and Scholes – he had known Scholes from his studies under Merton Miller and met Black on a consultancy project.

Robert Merton (born 1944) was already at MIT at that time, doing his Ph.D. under the leadership of Paul Samuelson – at the exact same time when Samuelson was intensely working on his warrant pricing research. In 1969 Samuelson and Merton published a paper titled *A Complete Model of Warrant Pricing that Maximizes Utility* [5], which addressed some limitations of Samuelson's earlier models and linked the warrant's price to stock price, a similar approach that Black was taking in his research.

After receiving Ph.D. in 1970, Merton became a colleague of Scholes at Sloan and started teaching the new derivative pricing methods to Master's students, before the Black-Scholes model was released to the wide public [17]. Samuelson continued to influence Black, Scholes, and Merton in the final shaping of their theory.

The Original Black-Scholes Paper (1973)

The paper that first introduced the model to the world, *The Pricing of Options and Corporate Liabilities* by Black and Scholes [7], was officially published in spring 1973, but it was far from a smooth process.

In an article from 1987 [11], Black recalls how they first submitted the paper to the Journal of Political Economy and then to the Review of Economics and Statistics, and got rejected by both. It was only after Eugene Fama and Merton Miller reviewed the paper and suggested it might be worth a second look that Journal of Political Economy eventually published it in the May-June 1973 issue.

In the meantime, Black and Scholes published empirical tests of the model in *The Valuation*

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Merton's Extension (1973)

Almost at the same time as Black and Scholes, Merton presented his own contributions to the model in a paper titled *Theory of Rational Option Pricing* [8]. This is also where he coined the name "Black-Scholes model".

In the paper he suggested several extensions to the model. The ability to account for dividends is the most widely known one, but even more importantly, Merton provided an alternative derivation of the Black-Scholes formula, valid under weaker assumptions and therefore more widely usable.

Futures Options: Black Model (1976)

It may be useful to remind ourselves of the historical context of the time when the Black-Scholes model was published – the end of Vietnam war, collapse of the Bretton-Woods system, Richard Nixon's policies and Watergate scandal, the 1973 oil crisis, stock market crash, high inflation, high interest rates, and the longest recession since World War II. High volatility and uncertainty contributed to increased need for risk management tools and innovations in the derivatives universe. Trading expanded both on and off exchanges.

In 1976, Fisher Black proposed a way to apply the Black-Scholes model to options on forwards and futures in *The Pricing of Commodity Contracts* [9].

The Black 1976 model, as it is now known, is mathematically almost identical to the Black-Scholes model (the Merton's extension), with the difference being the use of (discounted) futures price as underlying in place of spot price. The method is also applicable to other kinds of derivatives, such as bond options, swaptions, or interest rate caps and floors.

Black's work contributed to the introduction of futures options in early 1980's – among the first underlyings were T-bonds, S&P500, Deutsche Mark, gold, or live cattle.

Currency Options: Garman-Kohlhagen (1983)

Another important extension of the Black-Scholes model was introduced by Mark Garman and Steven Kohlhagen in *Foreign Currency Option Values* [10]. It enabled the use of Black-Scholes with currency options – the largest of all option markets, though less visible as most

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With currency pairs, two interest rates are entering the formula: the "domestic" rate (cost of funding, like Black-Scholes risk-free rate) and the "foreign" rate (interest earned on holding the foreign currency, which an option holder does not receive). Garman and Kohlhagen suggested that by plugging in the foreign interest rate in place of Merton's dividend yield, Black-Scholes model can be used to price foreign currency options, because (continuous) dividend yield and interest earned are mathematically the same thing.

Nobel Prize (1997)

In 1997, 24 years after the Black-Scholes model was first published, Scholes and Merton were awarded the Nobel Prize in Economics "for a new method to determine the value of derivatives". Unfortunately, having died of throat cancer two years earlier, Black was ineligible, but was repeatedly mentioned as contributor by the Royal Swedish Academy of Sciences, which awards the prize [13].

By receiving the Nobel Prize, Scholes and Merton joined their mentors – Paul Samuelson (Nobel Prize 1970) and Merton Miller (1990). Eugene Fama received the prize in 2013.

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Black-Scholes Formula (d1, d2, Call Price, Put Price, Greeks)
Black-Scholes Model Assumptions
Black-Scholes Inputs (Parameters)

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