17 The History of Option Pricing and Hedging

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This book is mainly about the mathematics of Professor Vinzenz Bronzin and his remarkable book on option pricing, published in 1908. This chapter concerns the wider history of option pricing and hedging where Bronzin's work shines out as a beautiful diamond. The study of the history of option pricing and hedging is much more than simply a study of the ancient past. It reveals more than this: It tells us where we came from, where we are, and possibly even gives us some hints about where we are going or, at least, what direction we should following. The put-call-parity, hedging options with options and some types of market-neutral delta hedging were understood and used at least a hundred years ago and is, in my view, still the foundation of what knowledgeable option traders use today. A careful study of the history, including several somewhat forgotten and ignored ancient sources, several of which have been recently rediscovered, tells us that many of the option traders as well as academics from history were much more sophisticated than most of us would have thought. Here, I will try to give a short (but still incomplete) and, hopefully, useful summary of the history of option pricing and hedging from my viewpoint today. The history of option pricing and hedging is far too complex and profound to be fully described within a few pages or even a book or two, but, hopefully, this contribution will encourage readers to search out more old books and papers and question the premises of modern text books that are often not revised with regard to the history option pricing.

17.1 Option Markets in the "Good Old Days"

The oldest surviving written records on forward contracts are probably Mesopotamian clay tablets dating all the way back to 1750 B.C. More modern derivative markets seems to appear from the 16th century onwards, running from Antwerp via Amsterdam to London, Chicago, and New York (see Gelderblom and Jonker 2003). Kairys and Valerio (1997) describe quite an active market in equity options in New York in the 1870s. Their description is very interesting and informative, but probably takes a wrong turn when they try to look at how the market priced options at that time. They basically conclude, partly based on their use of Black, Scholes and Merton-style methods, that put options were overpriced at that time – a judgement ensuing from their decision to exclude an important tail-event in this period:

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> "However, the put contracts benefited from the financial panic that hit the market in September, 1873. Viewing this as a "one-time" event, we repeat the analysis for puts, excluding any unexpired contracts written before the stock market panic" (Kairys and Valerio 1997).

It seems somewhat surprising that anyone would exclude a tail-event from an empirical analysis supporting a final analysis when the importance of accounting for tail events in option pricing and hedging should be "well understood". How tail-events ought to be approached or modelled naturally extends beyond the confines of our discourse and will only be touched on in this chapter.

When Cyrus Field finally succeeded in connecting Europe and America by cable in 1866, the international arbitrage of securities was made possible. Although American securities had already been purchased in considerable volume abroad after 1800, the absence of quick communication placed a definite limit on the amount of active trading in securities that could take place between the London and the New York markets (see Weinstein 1931). Nelson (1904), an option arbitrageur in New York, describes a relatively active international option and securities arbitrage market, where up to 500 messages per hour and typically 2,000 to 3,000 messages per day were sent between the London and the New York market via cable companies. Each message flashed over the wire system in less than a minute. Nelson describes many details about this arbitrage business: the cost of shipping shares, the cost of insuring shares, interest expenses, the possibilities for switching shares directly between someone long securities in New York and short in London and thereby saving shipping and insurance charges, and so forth. Holz (1905) describes several active option markets in Europe in the late 19th century. Deutsch (1910) depicts the different option exchanges in Europe: the London Stock Exchange, the Continental Bourse, the Berlin Bourse, and the Paris Bourse, and how potential arbitrage options were traded between these exchanges.

In a recent paper Mixon (2008) looks at option pricing in the past and compares it with the present. He concludes that:

> "Traders in the nineteenth century appear to have priced options the same way that twenty-first century traders price options. Empirical regularities relating implied volatility to realized volatility, stock prices, and other implied volatilities (including the volatility skew), are qualitatively the same in both eras" (Mixon 2008).

Several partly forgotten and overlooked works on options, will reveal to us that option traders and academics in the past were much more sophisticated than most of us would have thought. Bronzin (1908), who is the focal point of this book, is a clear example of this. We will also look at how many of the hedging and pricing principles used by traders today seem to have developed in a series of steps, many dating back as early as the 20th century.

17.2 The Put-Call-Parity in a Historical Perspective

One of the few surviving texts describing the financial markets in Amsterdam in the 17th century is *Confusión de Confusiones*[1] by Joseph de la Vega (1688). He describes a relatively active derivatives market in his day. Joseph de la Vega diffusely discusses the put-call-parity, even though his book was not intended to be teaching manual on the technicalities of the options market. The put-call-parity is very important as it is in many respects one of the most robust principles used in option pricing and hedging to have withstood the test of time. That is, option traders both then and today have actively use the put-call-parity in their trading.

From reading modern publications, journals, papers and books on options, we might easily get the impression that the put-call-parity was first understood and described by Professor Stoll (1969) in the Journal of Finance. However, looking into several overlooked and recently rediscovered texts, it becomes clear that Stoll only rediscovered what had probably been described in greater detail at least 60 years before his time. Knoll (2004) describes that the use of the put-call-parity for the purpose of avoiding potential usury can be traced back two thousand years. The surviving text from that period is at best obscure in its references to anything similar to the put-call-parity as we know it today from trading and financial economics.

Nelson's (1904) text on option trading, pricing, and hedging has been neglected and somewhat forgotten. He was an option arbitrageur in New York who published a book with the title "The A B C of Options and Arbitrage". He often cites the book written by Higgins (1902) and must clearly have been influenced by the former's writings[2]. Both Nelson, and Higgins can be considered to have written the first paper[3] to describe the put-call-parity in detail – in many ways, in much greater detail than the newly rediscovered authors such as Stoll (1969).

The put-call-parity of ancient literature seems to have served two main purposes:

1. As a pure arbitrage constraint,

[1] Interestingly, de la Vega's text from 1688 is also referred to by Professor Lesser in 1875 in a small booklet in German describing options.
[2] Another book that he refers to is by Castelli (1877).
[3] At least to my knowledge at the time of writing, but further research on the relations between Nelson and Higgins (1902) has to be done.

2. but also as a tool to create calls out of puts, puts out of calls and straddles out of calls or puts for the purpose of hedging options with options. In other words more than simply providing an arbitrage constraint, they provided a very important tool for transferring risk in an optimal and robust way between options, even in cases where no theoretical arbitrage opportunities between put and call options existed.

In order to understand the use of put and call parity in the early 20th century, one should read the whole of Nelson's book together with other texts from that period. Here, I will only offer a few quotations from Nelson (1904):

> "It may be worthy of remark that 'calls' are more often dealt than 'puts' the reason probably being that the majority of 'punters' in stocks and shares are more inclined to look on the bright side of things, and therefore more often 'see' a rise than a fall in prices.
> This special inclination to buy 'calls' and to leave the 'puts' severely alone dose not, however, tend to make 'calls' dear and 'puts' cheap, for it can be shown that the adroit dealer in options can convert a 'put' into a 'call,' a 'call' into a 'put', a 'call o' more' into a 'put-and-call,' in fact any option into another, by dealing against it in the stock. We may therefore assume, with tolerable accuracy, that the 'call' of a stock at any moment costs the same as the 'put' of that stock, and half as much as the put-and-call" (Nelson 1904).

Nelson also describes a series of ways for using the put-call-parity to convert various options into each other, again referring to Higgins (1902):

1. That a call of a certain amount of stock can be converted into a put-and-call of half as much by selling one-half of the original amount.
2. That a put of a certain amount of stock can be converted into a put-and-call of half as much by buying one-half of the original amount.
3. That a call can be turned into a put by selling all the stock.
4. That a put can be turned into a call by buying all the stock.
5. and 6. That a put-and-call of a certain amount of a stock can be turned into either a put or twice as much by selling the whole amount, or into a call of twice as much by buying the whole amount.

A closer study of Nelson's book clearly indicates the use of the put-call-parity both as an arbitrage constraint as well as a tool for hedging options with options.

In modern options literature on the topic of the continuous dynamic delta hedging of Black and Scholes (1973) and Merton (1973), all risk can be removed all the time subject to a series of theoretical assumptions. In their theoretical world, any option can be perfectly replicated by continuous dynamic delta hedging. Here, the put-call-parity is only applied as an arbitrage constraint.

To illustrate the use of the put-call-parity as something more than a simple arbitrage constrain let us take a look at an example. If you, as a market maker, have numerous customers coming who want to buy put options from you, then in the theoretical Black, Scholes and Merton world you can simply manufacture them risk-free based on the continuous dynamic delta hedging replication argument. In the Black, Scholes and Merton world you would not care whether there was someone you could acquire numerous call options from, except in pure arbitrage situations. In the real world, where dynamic delta replication fails to remove most risk, it would be important to obtain calls, if available, and convert them into puts for the purpose of reducing risk. If they were not obtainable, you would need to raise the price on the options, and/ or widen the bid-offer spread to recover from the risk you are unable to hedge away if only using dynamic delta hedging. The original description and use of the put-call-parity is fully consistent with and even "predicts" the theory that supply and demand for options will effect option prices.

Then again, in 1908, Bronzin derived the put-call-parity and seems to have used it as part of his hedging argument in his mathematical option pricing formulas/ models. In 1910 Henry Deutsch[4] described the put-call-parity, but in less detail than Higgins and Nelson. In his Ph.D. thesis at MIT, Kruizenga (1956) (and also Kruizenga 1964) rediscovered the put-call-parity, but this was in many ways less detailed than that of Nelson (1904).

Another neglected arbitrage trader who published a book is Reinach (1961). He describes how option traders hedged short positions in standard options by getting hold of embedded options on the same stock found in convertible bonds. Reinach also points out the importance of the put-call-parity for the options business, and I cite an interesting quotation from his book:

> "Although I have no figures to substantiate my claim, I estimate that over 60 per cent of all calls are made possible by the existence of Converters".

Converters were basically market makers converting puts into calls and calls into puts, and so on, using the put-call-parity. So as we can see, hedging options with options was a very important part of the options business.

We should also remember that the put-call-parity is basically fully consistent with any volatility smile. This is not the case with the Black, Scholes and Merton model, where the continuous delta hedging basically relies on the assumption of normally distributed returns. Bronzin (1908) seems in many ways

[4] The first version of this book was actually published in 1904, I refer to the second edition, published in 1910.

to offer a more flexible model in this respect as he suggested a whole series of distributions, whilst still taking the put-call-parity into account.

17.3 Delta Hedging in a Historical Perspective

Initial market-neutral delta hedging is when you put on a delta hedge just after buying or selling an option that makes the portfolio (option plus the stock) close to risk-neutral for small movements in the asset price. This is also often described as a static market-neutral delta hedge. When it comes to the option traders of previous eras, I actually prefer the description ‘initial market-neutral delta hedge’ rather than ‘static hedge’, because we know they often put on an initial delta hedge subsequent to option issue;, but we know little about whether they actually adjusted this hedge later on or not. Initial market-neutral delta option hedging of this kind was already described by Nelson (1904):

> “Sellers of options in London as a result of long experience, if they sell a call, straightway buy half the stock against which the call is sold; or if a put is sold; they sell half the stock immediately” (Nelson 1904).

In London at that time the market standard was the European-style option issued at-the-money. As rediscovered today, the delta for at-the-money options with a short term to maturity is approximately 50 percent, and, naturally, –50 percent for put options. Out-of-the-money options were not often traded in London and were known as “special options”. Of course, an option issued at-the-money will typically not stay at-the-money for long. It is unclear whether options were actively traded after issue in London in those days, or whether it was normal to keep the options until expiration.

The standard options in London were actually issued closer to an at-the-money forward; that is, the strike price was set just after the option was dealt and adjusted for cost-of-carrying the underlying stock:

> “The regular London option is always either a put or a call, or both, at the market price of the stock at the time the bargain is made, to which is immediately added the cost of carrying or borrowing the stock until the maturity of the option” (Nelson 1904).

Today we know that the delta for an option with a strike price equal to the forward price (also known as an at-the-money forward) has a theoretical delta very close to 50 percent (naturally -50 percent for put options). Well, we have basically rediscovered what they already knew in the early 20th century. We also know that the delta for approximately at-the-money or at-the-money-forward options is the most stable delta (see Haug 2003 and Haug 2007). The delta for at-the-money options is very robust even if you do not know the future volatility of the underlying asset. This is not the case for out-of-the money options, where the delta is very sensitive to the volatility value used in the model for calculating the delta. Today we also know that the volatility is stochastic and hard to predict.

Nelson (1904) identified more dynamic delta hedging where the option buyer buys and sells stocks against the option over the option's duration. In 1937 Gann also indicated some forms of auxiliary dynamic hedging. However, it is far from clear that they knew what the theoretical or "practical" market-neutral delta for options should be, other than for at-the-money options. Even today, with the latest in option models, we do not really know the correct delta or optimal practical delta. All we know is some theoretical model delta where the delta is very sensitive to the volatility used for any options that not are close to at-the-money; in practice, we do not know the future volatility. Again, especially for out-of-the money options, the delta is very sensitive to the volatility used as input in the model. This is true even with stochastic volatility models. Here, the delta for out-of-the money options is very sensitive both to the volatility level and the volatility of volatility, and both parameters are highly stochastic in practice. In other words, even stochastic volatility models that mainly rely on delta hedging to remove most risk are not robust in practice. And this is even without taking into account the possibility of jumps in the asset price.

In 1960[5] Sidney Fried described empirical relationships between warrants and the common stock price. The author gives several examples of how to try to construct a roughly market-neutral static delta hedge both by shorting warrants and going long on stocks or by buying warrants and shorting stocks. The hedge ratio that Fried described simply seems to be based on a combination of experience, the historical relationship between warrants and the stock price as well as some basic knowledge of the factors effecting the value of the warrant.

Fried's work is in many ways less sophisticated than that of Higgins (1902) and Nelson (1904), but at the same time contributes some new insights when it comes to the empirical relationships existing between the movements of the underlying stock and the price of the warrant.

In their book "Beat the Market" Thorp and Kassouf describe market-neutral delta hedging for any strike price or time to maturity. In 1969 Thorp suggested extending initial market-neutral delta hedging to dynamic discrete delta hedging:

> "We have assumed so far that a hedge position is held unchanged until expiration, then closed out. This static or 'desert island' strategy is not optimal. In practice intermediate decisions in the spirit of dynamic programming lead to considerably superior dynamic strategies. The methods, technical details, and probabilistic summary are

[5] The first version of this booklet was already published in 1949. My comments are based on the 1960 version.

> more complex so we defer the details for possibly subsequent publication" (Thorp 1969).

Another ignored text on delta hedging is a booklet published in 1970 by Arnold Bernhard & Co. It is somewhat unclear exactly who the author is, but it says "Written and Edited by the Publisher and Editors of The Value Line Convertible Survey". The authors describe market-neutral delta hedging for any strike price. The booklet gives several examples of buying convertible bonds or warrants and shorting stocks against them in a market-neutral delta hedge, which the authors call a balanced hedge. The booklet also reprints examples of tables with delta values (hedge ratios) for a series of warrants and convertible bonds that were distributed to traders on Wall Street. The booklet does not describe continuous-time delta hedging.

None of the people who described initial market-neutral delta hedging or discrete dynamic delta hedging before 1973 claimed they could remove all of the risk all the time. In this way, they were closer to the limitations presented in practice.

So far we can conclude that market-neutral delta hedging was well known and used by traders long before 1973. We know that initial market-neutral delta hedging was already actively used in the early nineteen hundreds in London for at-the-money options. Delta hedging was later extended and discussed by several authors.

It is well known today that delta hedging works extremely poorly when there are jumps in the underlying asset (see Haug 2007, Chapter 2, for a detailed discussion on this topic as well as further references). When the underlying asset jumps, it should be noted that the risk from holding options and simultaneously undertaking market-neutral delta hedging is not symmetrical. Hua and Wilmott (1995) give an excellent example of the asymmetry in the delta hedging replication error for long and short option positions. If you are delta hedging a long option position, the worst case scenario for you is that there is no crash. This is actually because delta hedging is inefficient in the presence of jumps; but, if you are long options, you will benefit from the hedging error when the market crashes.

It is interesting to learn from an experienced option arbitrage trader like Nelson, who possessed a basic understanding of market-neutral delta hedging in the early 19th century, that the most experienced option traders of his time had a tendency to be long options rather than short. Though this in no way guarantees the trader a profit or even positive expected returns, it does protect him from blow-ups when delta hedging fails.

Even after 1973, there were several academics who gave Thorp and Kassouf and their predecessors the credit for having been the first to promote delta hedging, and not Black and Scholes (1973) and Merton (1973). Even a book written in 1975 by a finance academic appears to credit Thorp and Kassouf

(1967) rather than Black and Scholes (1973), although the latter were listed in its bibliography:

> "Sidney Fried wrote on warrant hedges before 1950, but it was not until 1967 that the book 'Beat the Market' by Edward O. Thorp and Sheen T. Kassouf rigorously, but simply, explained the short warrant/ long common hedge to a wide audience" (Auster 1975).

17.4 Option Pricing Formulas Before Black, Scholes and Merton

On March 19, 1900, Bachelier defended his doctoral thesis on option pricing/ modelling. It was only in 1954 that Leonard Savage[6] and Paul Samuelson rediscovered Bachelier's thesis in a library (see Poundstone 2005). Bachelier's thesis was translated into English and reprinted in a book by Cootner (1964) that was reprinted again in 2000 (see also Davis and Etheridge 2006). His work is widely known today. He derived an option formula not unlike those we see today, but based on the assumption of the asset price being normally distributed. This gives a positive probability for a negative stock price and is not often used for stocks and other assets with limited liability features. The Bachelier formula is given by:

$$c = \left(S - X\right)N\left(d_1\right) + \sigma\sqrt{T}n\left(d_1\right), \tag{17.1}$$

where

$d_1 = \dfrac{S - X}{\sigma\sqrt{T}}$,

S = stock price
X = strike price of option
T = time to expiration in years
σ = volatility of the underlying asset price
$N\left(x\right)$ = the cumulative normal distribution function
$n\left(x\right)$ = the standard normal density function.

Bachelier says little about the hedging of options, but he describes the purchase of a future contract against a short call and draws a profit and loss (P&L) diagram at maturity, clearly demonstrating that this has the same payoff profile as a put, and can thus be seen as a loose description of the put-call-parity. In

[6] See Poundstone (2005) for more details on the rediscovery of Bachelier's work.

addition to this, Bachelier gives several examples of profit and loss profile for options against options, like bull spreads and call-back spreads (buying one call and selling two calls with a higher strike price against it). So already back then, Bachelier clearly had at least some intuition about how using combinations of futures and options could alter the risk-reward profile. Bachelier also describes in quite some detail Brownian motion mathematically.

Bronzin (1908) was also a master of early mathematical option pricing, as recently rediscovered by Hafner and Zimmermann (2007). Bronzin was a professor of mathematics, and his book on option pricing, originally published in German, will certainly be considered a classical treasure of option literature. Bronzin (1908) derived the put-call-parity and also developed several option-pricing formulas based on several alternative distributions of the asset price; these were rectangular, triangular, parabolic and exponential distributions as well as the normal distribution. I will not go into detail on Bronzin here as the rest of the book gives much more detailed information about his work.

Sprenkle (1961)[7] assumed that asset prices were log-normally distributed and that the stock price followed geometric Brownian motion.

$$dS = \mu S dt + \sigma S dz,$$

where μ is the expected rate of return on the underlying asset, σ is the volatility of the rate of return, and dz is a Wiener process, just as in the Black and Scholes (1973) and Merton (1973) analysis. In this way he ruled out the possibility of negative stock prices, consistent with limited liability. Furthermore, he allowed for positive drift in the underlying asset and derived the following option pricing formula based on this:

$$c = Se^{\mu T} N(d_1) - (1-k) X N(d_2), \tag{17.2}$$

where

$$d_1 = \frac{\ln(S/X) + (\mu + \sigma^2/2)T}{\sigma\sqrt{T}},$$

$$d_2 = d_1 - \sigma\sqrt{T},$$

and k is the adjustment for the degree of market-risk aversion.

James Boness (1964) also assumed a log-normal asset price and derived the following formula for the price of a call option:

[7] This is also reprinted in Cootner (1964).

$$c = SN(d_1) - Xe^{-\mu T} N(d_2) \tag{17.3}$$

$$d_1 = \frac{\ln(S/X) + (\mu + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T} \ .$$

Paul Samuelson (1965) also assumed the asset price follows geometric Brownian motion with positive drift, μ:

$$c = Se^{(\mu - w)T} N(d_1) - Xe^{-wT} N(d_2) \tag{17.4}$$

$$d_1 = \frac{\ln(S/X) + (\mu + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

where w is the average rate of growth in the value of the call. This is different from the Boness model in that the Samuelson model can account for the expected return from the option being larger than that of the underlying asset $w > \mu$.

McKean (1965) derived a formula for a perpetual American put option, but without assuming continuous delta hedging and risk neutrality as was later postulated by Merton (1973).

In 1969, Thorp derived an option formula similar to that of Sprenkle (1961) and Boness (1964). In the same paper he mentioned initial market-neutral delta hedging and suggested that discrete dynamic hedging must be superior. References to this paper are surprisingly absent in contemporary options literature. Could it be that it was published in the wrong journal?

An appraisal of early option-pricing literature shows that people were much more sophisticated than we might have thought. With the recent rediscovery of Bronzin, it is remarkable to discover how much was already known in the early 20th century.

17.5 Black, Scholes and Merton 1973

Modern options literature attributes the great breakthrough in option pricing and hedging to Black and Scholes (1973) and Merton (1973). In several modern textbooks, we are led to understand that option markets were hardly developed before 1973 and that option traders only had a few rules of thumbs for option pricing and hedging prior to this date.

It is quite clear that it was not the option-pricing formula itself that Black, Scholes and Merton came up with, but rather a new way of deriving it. The Boness formula is actually identical to the Black, Scholes and Merton 1973 formula, but the way in which Black, Scholes and Merton derived their formula, based on continuous dynamic delta hedging or alternatively based on CAPM allowed them to liberate themselves from the expected rate of return. In other words, it was not the formula itself that is considered to be their great achievement, but rather the method they devised for deriving it. This was also pointed out by Professor Rubinstein (2006):

> "The real significance of the formula to the financial theory of investment lies not in itself, but rather in how it was derived. Ten years earlier the same formula had been derived by Case M. Sprenkle (1962) and A. James Boness (1964)" (Rubinstein 2006).

In other words, the contribution made by Black, Scholes and Merton was essentially to extend the discrete delta hedging argument to continuous hedging and then to use this as an argument for risk-neutral valuation. In their 1973 paper, Black and Scholes refer to Thorp and Kassouf (1967)[8]:

> "One of the concepts that we use in developing our model is expressed by Thorp and Kassouf (1967). They obtain an empirical valuation formula for warrants by fitting a curve to actual warrant prices. Then they use this formula to calculate the ratio of shares of stock options needed to create a hedge position by going long in one security and short in the other. What they fail to pursue is the fact that in equilibrium, the expected return on such a hedge position must be equal to the return on a riskless asset. What we show below is that this equilibrium condition can be used to derive a theoretical valuation formula" (Black and Scholes 1973).

There is no doubt that extending discrete dynamic delta hedging to continuous dynamic delta hedging and using this to argue for risk-neutral valuation was a brilliant mathematical idea. However, option trading must also be based on what we can actually do in practice. Continuous dynamic delta hedging is based on a series of unrealistic assumptions like normally distributed returns, no jumps in the underlying asset price and constant volatility (or at best time-dependent deterministic volatility). Every model is only a model and that there are inconsistencies in some of its assumptions does not preclude its viability. The central question is whether the model is sensitive to breaks in its assumptions. If

[8] But they give no reference to Thorp (1969).

it is not sensitive, then the model can be considered robust; if not, it is typically non-robust. This question is an important issue that Merton (1998) himself pointed out:

> "A broader, and still open, research issue is the robustness of the pricing formula in the absence of a dynamic portfolio strategy that exactly replicates the payoffs to the option security. Obviously, the conclusion on that issue depends on why perfect replication is not feasible as well as on the magnitude of the imperfection. Continuous trading, is, of course, only an idealized prospect, not literally obtainable; therefore, with discrete trading intervals, replication is at best only approximate. Subsequent simulation work has shown that within the actual trading intervals available and the volatility levels of speculative prices, the error in replication is manageable, provided, however, that the other assumptions about the underlying process obtain [...]. Without a continuous sample path, replication is not possible and that rules out a strict no-arbitrage derivation. Instead, the derivation is completed by using equilibrium asset pricing models such as the Intertemporal CAPM Merton 1973 and the Arbitrage Pricing Theory Ross 1976" (Merton 1998).

Today we know that the Black, Scholes and Merton argument in favour of using dynamic delta hedging as an argument for risk-neutral valuation is not robust in practice. Delta hedging works very poorly when there are jumps in the underlying asset price, and jumps occur from time to time (see Haug and Taleb 2008 and Haug 2007, Chapter 2, for a more detailed discussion and supporting references). On the other hand, hedging options with options is very robust both for jumps and stochastic volatility in discrete time as well as in continuous time. Option traders also use delta hedging to remove some risk, but more in the way described and applied before 1973.

The Black, Scholes and Merton model is inconsistent with the volatility smile that we observe in basically any option market. On the other hand, hedging options with options and relying on the put-call-parity predicts that supply and demand for options will affect actual option prices and, therefore, lead to a volatility smile.

In the strict theoretical Black, Scholes and Merton world the implied volatility is the market's best estimate of the future expected volatility (standard deviation) of the underlying asset only. With a volatility smile, different strikes on the same underlying asset and the same time to maturity will typically yield different implied volatilities. Would a trader change his estimate of future volatility in the underlying asset simply because he changed the strike of the option? Clearly not. Many option traders and academics like to think of the volatility smile simply as a way to adjust or fix the Black, Scholes and Merton model to work better in practice. I used to think of it this way as well. That was before I carefully studied the history of option pricing and hedging. It now looks to me as though most of the robust hedging and pricing principles that knowledgeable option traders rely on were described and discovered in a series of steps before Black, Scholes and Merton. Whereby the last adaptation to further develop discrete dynamic delta hedging and see it culminate in continuous delta hedging seems to be the only method that an option trader is unable to usefully apply in practice, sophistocated though its mathematical basis may be. Nevertheless, I am sure this will provoke an ongoing discussion (see also Derman and Taleb 2005, Haug 2007, Haug and Taleb 2008, Hyungsok and Wilmott 2008).

We should also ask ourselves how so much knowledge from the past could be overlooked and partly forgotten? Modern option literature clearly makes no reference to many of the early discoveries in options pricing and hedging. Several reasons, I think, may be offered in answer to this question. Herbert Filer, in his book, first published in 1959, describes what must be considered reasonably active options markets in New York and Europe in the 1920s and early 1930s. Filer also mentions that during World War II no trading took place on the European Exchanges because they were closed. London options trading did not return until 1958. This may, in fact, be one of the reasons why much of the early options literature was partly forgotten and overlooked. In addition, it may also be that many academics tend to only look for references in a specific selection of academic journals which they collectively consider as being relevant and reliable: This, though, is a moot point.

17.6 Conclusion

We can conclude that option traders and academics in the past were much more sophisticated than most of us would have thought. Option pricing and hedging seems to have developed in a series of steps rather than with one or two big discoveries in the 1970s. We know from historical sources that market-neutral delta hedging, the put-call-parity, hedging options with options, and several mathematical option pricing formulas were known by the early 1900s, and were discussed and extended later. More than one hundred years ago, Bachelier (1900) and Bronzin (1908) published option pricing formulas which were very similar to those we use today. Almost every hedging and pricing technique used for options today was already known and used prior to 1973.

The history of option pricing is far more interesting than I would have initially supposed. Visiting libraries and antiquarian bookstores is an exiting hobby; there are possibly a few more historical diamonds to be found there. Personally, I prefer to divide research work on the history of options and derivatives into two parts:

1. What I would like to call derivatives archaeology: This is the more physical and very practical part of actually digging out forgotten and overlooked texts from libraries, antiquarian bookstores – even looking for clay tablets at potential archaeological sites. This is extremely fascinating and a great break from just sitting at your desk, reading and writing.
2. The second and equally important part consists in interpreting the historical records. This can be a long journey, as well, hunting for evidence in texts written in foreign or even ancient languages, which are hard to translate and where pages are possibly missing. After translating the texts, we then have to try to interpret them in the context of their time.

The recovery of Bronzin papers is a tour-de-force of financial archaeology. His work has now been translated and made accessible to a large number of interested people through the publication of this book. I will encourage more people to take up an interest in the history of option pricing and hedging, with financial archaeological investigations and the interpretation of the sources that are currently available.

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