VISUAL QUANTITATIVE FINANCE

A New Look at Option Pricing, Risk Management, and Structured Securities

MICHAEL LOVELADY

Visual Quantitative Finance

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Michael Lovelady

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Above all, for life itself, the Triune God of Creation—I always remember.

About the Author

Michael Lovelady, CFA, ASA, EA, works as an investment strategist and portfolio manager, where he specializes in blending traditional and quantitative styles, including reduced-volatility and yield-enhanced option strategies. Michael developed the synthetic annuity and is the author of *Profiting with Synthetic Annuities: Options Strategies to Increase Yield and Control Portfolio Risk*.

Prior to hedge fund management, Michael was a consulting actuary for Towers Watson and PricewaterhouseCoopers, where he worked with employers on the design and funding requirements of plans ranging from defined benefit and defined contribution to hybrid db/dc plans. His experience with retirement income strategies—both as an actuary from the liability side and as a fund manager from the asset side—gives him a unique perspective.

Michael has also been involved in teaching and creating new methods for making quantitative investing more accessible to students, trustees, and others interested in investment and risk management. He developed the investment profile—a graphical representation of risk and the basis of a simplified option pricing model, and visually intuitive presentations of structured securities.

During his career, Michael has served various organizations, including Hughes Aircraft, Boeing, Global Santa Fe, Dresser Industries, the Screen Actors Guild, The Walt Disney Company, Hilton Hotels, CSC, and the Depository Trust Company. He is a CFA charterholder, an Associate of the Society of Actuaries, and an ERISA Enrolled Actuary. He currently lives in Los Angeles..

Preface

Visual Quantitative Finance presents a simplified, but powerful view of financial mathematics. It is written for trustees, investors, advisors, students, and others interested in quantitative finance, risk management, options strategies, structured securities, or financial model building—or for those looking for new ways to explain these topics to someone else.

What makes this book different is its visual presentation of formulas and concepts that may be more intuitive, especially for those without quantitative backgrounds. By working directly with the mathematical building blocks of finance—*random variables*—rather than formulas derived from them, the underlying mechanism of option pricing becomes simple and transparent, creating many advantages:

- The Black-Scholes formula can be derived in a few easy steps, with no complicated formulas.
- The derivation of the option pricing formula highlights the framework for translating option pricing assumptions into future stock price patterns.
- This framework is the key—not only to option pricing, but also to structured securities and risk management in general.
- The visual display of random variables emphasizes the simplicity behind quantitative finance, allowing you to look inside the logic of risk metrics and the power of options to reshape risk-reward profiles.
- You don't need a prior knowledge of statistical mathematics. Although the tools are developed without stochastic formulas, they may be one of the best ways to learn them.
- Metrics that appear complicated when expressed in words or formulas become nothing more than simple lookups in a visual context.

The book provides an important perspective on options and their value in portfolio management. The material for the book was selected to reflect the change in investor attitudes that began with the 2000–2002 internet bubble and accelerated after the 2008 financial crisis. The change in attitudes has been described in numerous market surveys that indicate investors are (1) tired of traditional portfolios, (2) looking for creative solutions, and (3) not willing to invest in instruments they don't understand.

In response, the use of alternative strategies and the introduction of new funds have grown rapidly, with much of the activity focused on structured securities. Structured securities, ranging from simple covered call strategies to complex institutional hedges, are proving to be more effective than traditional securities at tailoring risk-reward profiles and generating new sources of income.

Even though the trends are clear and investor interest has never been higher, the challenge for many investors is to become comfortable with unfamiliar, often seemingly complex instruments. This is especially true for institutional trustees and retail investors who might not have experience with options or the mathematics behind them.

One method currently gaining traction is the visual presentation of concepts such as Value-at-Risk, which are more easily communicated in pictures than words. This book extends visual presentation to a variety of topics in hopes of making quantitative finance more accessible to a wider audience.

1

Introduction

Visual quantitative finance is a different take on the mathematics of investing. It emphasizes an intuitive view of risk and the interrelationships of option pricing, risk management, and structured securities. This chapter begins with an overview of current investment trends that serve as the backdrop for the material covered in the book. The trends include shifts in investor attitudes and the emergence of new investment alternatives being driven by the application of quantitative finance.

I also talk about the personal "discovery" that motivated me to write this book. Like most people involved in asset management, I have struggled often with two things: (1) how to dampen some of the stock market volatility—and losses—that have occurred too often over the last decade, and (2) how to generate higher levels of income in a historically low interest rate environment.

Over time, I have become convinced that adding options—not as trading instruments, but as long-term components of portfolios—is the best answer. But unless an investor really understands options, it is hard to fully commit to a strategy involving them. Unfortunately, really understanding options means getting a little technical—sometimes a lot more than a little. I laughed one day when I saw the title of a paper on computational methods (roughly the same subject as this book). The title was "An Introduction to Computational Finance Without Agonizing Pain. If you have tried to approach this subject, you probably know the feeling. I do.

My personal "discovery" was not really a discovery in the sense that I uncovered some new truth. For me, it was just one of those light-bulb moments when I saw past the differential equations to a simple, beautiful "picture." What I saw in the picture was an easier way to visualize option pricing. More than that, the picture contained enough information to break down seemingly complex risk metrics and structured securities into basic elements. The picture is a chart of an Excel spreadsheet, shown at the end of the chapter, and used as the framework for most of what is presented in this book.

Growth in Structured Securities

According to Bloomberg, investment banks sold $45.9 billion of SEC-registered structured securities in 2011 and another $11.1 billion in the first quarter of 2012. The securities offer customized risk-return and payoff profiles using derivatives based on underlying stocks, bonds, currencies, and commodities, with approximately 60% of these notes tied to equities (including the S&P 500 Index).[1]

Registered structured products are just the tip of the iceberg. Demand from institutions and retail investors, looking for better ways to invest, is prompting asset management firms and ETF providers to introduce new funds capable of smoothing market volatility and increasing yield. For instance, AQR Capital Management, the hedge fund company, launched four new mutual funds.

> July 13, 2012: AQR Capital Management announced Monday the launch of four new mutual funds .... The funds seek to provide equity-like returns with lower volatility and smaller drawdowns using an actively managed, risk-balanced approach.[2]

This is one in a string of announcements. Quant funds are rolling out more creative investment vehicles to meet market demand. Most of these vehicles offer forms of risk management and income features that traditional asset classes do not offer. And structured securities are often the means to do it.

Structured securities range from simple covered call strategies to complex institution hedging programs. What they have in common is the ability to tailor risk and reward profiles to match investor objectives in ways that are difficult to do with stocks and bonds.

On the retail side, more investors than ever use options strategies—not only as trades, but as integral parts of investment portfolios. On the institutional side, allocations to hedge funds and other alternatives using options strategies and structured securities are growing rapidly.

Both groups are interested in emerging strategies that combine the explicit use of hedging, insurance, and risk allocations in risk management instead of continuing to rely on traditional portfolio models. Also, in today's low-interest environment, both groups want access to greater yields, especially those not related to market direction. These investor goals have led to the growing importance of volatility-reducing quantitative methods, particularly methods related to options capable of boosting dividend yields.

Growing Emphasis on Low Volatility and Dividends

Some of 2012's most successful ETFs were funds that combined these themes, including the PowerShares S&P 500 Low Volatility Portfolio (NYSEArca: SPLV) and the iShares High Dividend Equity Index Fund (NYSEArca: HDV).

> Low-volatility ETFs debuted in 2011 with the launch of the PowerShares S&P 500® Low Volatility ETF (SPLV). Since inception, SPLV has exhibited 69% of the volatility in the S&P 500 Index [and] outperformed its cap-weighted benchmark in terms of absolute returns.[3]

In terms of relative performance, SPLV has delivered an excess return of 11.7% compared to the S&P 500. Many other ETFs have been introduced with variations on the low volatility strategy seeking to deliver market exposures measured by volatility rather than traditional cap-weighted benchmarks. Other funds, such as the Windhaven Portfolios at Charles Schwab & Co., add dynamic allocation strategies, adjusting portfolio allocations based on changing economic conditions. According to the brochure, this form of proactive risk management "strives to capture much of the up markets and less of the down."

Sage Quant Management filed with regulators in summer 2012 to offer a dividend-focused low-volatility fund to be listed as an ETF. In the filing, the company said that the fund might rely on derivatives such as futures and options contracts to "facilitate trading or to reduce transaction costs."

That is consistent with the theme of blending dividends and low volatility. And it is consistent with the work of Roger Clarke at Analytic Investors and others who have argued that it may be possible to pick up 40 to 60 basis points of risk-adjusted return. However, funds offered to retail investors have been reluctant to include derivatives simply because a lot of investors view them as dangerous. It appears that attitude is changing, at least when it comes to more conservative types of derivatives. Personally, I believe that including derivatives in the investment toolkit is a step forward in the nature of the funds offered to the retail investor.

After all, derivatives have been utilized in institutional investing for decades to provide exposure to absolute return strategies, long or short, and hedge overlays for pension plans and endowments. Partly, this is in response to the lack of risk management achievable through mean-variance portfolios and their counterparts in the retail space: life cycle and target date funds. It also is partly in response to the need for higher yields to match long-term discount assumptions, which is hard to achieve in a low-yield bond market. Because individual investors face the same challenges, products with derivative components are being offered in more variations by more firms.

That is not to say that everything is going smoothly.

Criticisms of Structured Securities

Criticism of structured securities is growing as fast as the demand. FINRA, the financial regulatory agency, has looked carefully at how these instruments are designed and marketed. Several published papers have warned investors about complexity, expense, and suitability. Some of the products are so misunderstood that investors are completely unaware of what they own or how much they could lose.

In 2008, many investors were burned. Structured products that were supposedly "principle-protected" were not. Investors at some of the largest and most respected investment management firms learned that their securities bought to earn income had overnight been "converted" into depreciated stocks. The losses were huge and unexpected.

In a *Forbes* article, "When will FINRA stop this insanity?" Seth Lipner says structured products are too complicated for ordinary investors to understand.

> They are, in reality, exotic derivatives... Isn't it clear by now that these newfangled financial products exist just to enrich Wall Street at the expense of naive investors? Isn't it enough already?[4]

Other criticisms center not on the danger, but on the fact that they don't add anything that investors can't get through simpler and less expensive instruments. One report concluded:

> These products add nothing to retail investors' portfolios that can't be acquired from investments already available in the market in the form of less risky, less complicated, or less costly products.[5]

Because these products "add nothing," they may fail even the most basic regulatory "reasonable basis" rules for suitability to sell to retail investors.

Despite the criticism, the trend is clear. Investors don't want the roller coaster that investing has become in the last decade. Financially engineered products are not going away, nor is the demand for people who can build them and explain them.

Demand for Quantitative Skills

On the hiring front, recruiters are saying that stock pickers are "out" and quantitative analysts are "in." The role of quants at hedge funds for complex trading has been steady, but it seems the demand for quant talent for more mainstream investing applications is increasing. Firms are changing their emphasis on risk, giving it more weight in the balance between risk and return. Instead of selecting return targets and then minimizing the risk involved in achieving them, the new design order is to determine acceptable levels of risk first and then go for returns. Here is an excerpt from a recent job posting at T. Rowe Price:

> The T. Rowe Price investment approach strives to achieve superior performance but is always mindful of the risks incurred relative to the potential rewards.

The job posting explains the "greatly expanded" capabilities in Quantitative Research, including portfolio analytics and modeling and the outlook for continued growth.

> These are key areas of focus for the firm where we anticipate a strong growth in demand.[6]

The job requirements for this T. Rowe Price job listing include a Ph.D.; a CFA; a Master's degree in quantitative finance, science, engineering, or mathematics; and proficiency with analytic modeling platforms such as MatLab, R, or S-plus.

Direction of Quantitative Finance

It might seem that at least one branch of quantitative finance would become less complex as it enters the mainstream, but that is apparently not happening yet. How is it possible for the average investor to understand a security that requires a Ph.D. to design? Paul Wilmott, Michael Thomsett, and many others have advocated the practical use of quantitative methods, emphasizing more transparency in the use of derivatives. In 2008, Wilmott blogged:

> In my view the main reason why quantitative finance is in a mess is because of complexity and obscurity. Quants are

> making their models increasingly complicated, in the belief that they are making improvements. This is not the case.... finance is not a hard science, one in which you can conduct experiments for which the results are repeatable. Finance, thanks to it being underpinned by human beings and their wonderfully irrational behaviour, is forever changing. It is therefore much better to focus your attention on making the models robust and transparent rather than ever more intricate.[7]

He describes a "sweet spot" in quant finance. The sweet spot is where models are not too elementary to be of practical use, but not so abstract that even the inventors don't really understand them. He adds, "I teach on the Certificate in Quantitative Finance, and in that, our goal is to make quant finance practical, understandable, and, above all, safe."

I agree. That is why I have targeted a particular sweet spot in this book: the aspects of quantitative finance that are most helpful in designing and communicating structured securities.

This book introduces a new framework to illustrate the mechanics of option pricing. The logic behind option pricing serves as the basis for much of financial engineering, for building structured securities and evaluating alternative investment strategies. What makes the method different is that it uses a simplified spreadsheet to illustrate the "matrix" nature of the building blocks of quantitative finance: random variables. In random variable form, the underlying probabilities are kept transparent and are *not* condensed into formulas.

By keeping the probabilities separate, a number of calculations become much easier to understand, which, in turn, makes the securities evaluated on the same basis easier to understand.

I am excited about writing this book because of something that I stumbled across a few years ago that made the entire subject of quantitative finance easier for me. It involved a simple way to replicate complicated formulas. For me, the breakthrough came one night while I was practicing my putting stroke. I had an idea and decided to play with that instead.

When I Realized It Might Be Easier

Starbucks, late. I clearly remember looking at the number: $11.93. It was only 1 cent higher than the number I had gotten using the Black-Scholes formula, $11.92. But I wasn't using the Black-Scholes formula. I was using a spreadsheet—a simple one.

After a few years as a hedge fund manager, I had finally settled into a strategy I felt comfortable with. What I didn't know how to do was describe it. I didn't even know what to call it. For lack of anything better, I called it a synthetic annuity. I used *synthetic* because of the risk-management features that I guessed would qualify as a synthetic hedge, and *annuity* because it involved selling options to generate monthly income.

I knew I needed to devote time to communicating the strategy in a way that the average investor could understand. At a minimum, I needed to put it in context of the various traditional and hedge fund strategies. I struggled with this. Because it involved trading options, I was concerned that it would get the typical bad rap of being too risky or too complex, neither of which I think is true. But it was a form of managed structured security, so I would have to explain the basics of structured securities and how they worked.

The previous day, I had been flipping through one of my go-to texts, McDonald's *Derivative Markets*, looking for something that might give me a starting point. I saw this:

> The Black-Scholes formula arises from a straightforward lognormal probability calculation using risk-neutral probabilities. The contribution of Black and Scholes was not the particular formula but rather the appearance of the risk-free rate in the formula. (p. 613)[8]

I had already been thinking about Black-Scholes, having just reread Peter Bernstein's beautifully written books on the history and evolution in investment thinking, *Capital Ideas* and *Capital Ideas Evolving*. Bernstein referred to options and the pricing model as "the most powerful financial invention in history." And I remembered the emphasis Paul Samuelson put on option pricing when he gave his advice to anyone entering the investment field: "Learn the Black-Scholes option-pricing model."[9]

My immediate interest was more in tailoring risk and reward profiles, but I had reached a point where I needed to construct a reasonable basis for comparing alternative structures. I was skeptical about using the Black-Scholes framework because of its well-publicized limitations, such as not handling fat tails and assuming constant volatility.

Then I changed my mind. I wasn't trying to weigh something precisely, so I didn't need a very accurate scale. I was measuring the difference in two things, which even an inaccurate scale can do. And using Black-Scholes had the advantage of making the structure approximately hedgeable, which is more important in my work than being precise.

So I decided to try what McDonald had suggested: to derive the Black-Scholes formula. I could either start with a differential equation or start with a spreadsheet approximation. I chose the spreadsheet. I was hoping to build something that would fit on a page or two of Excel—and I'm not crazy about differential equations.

I began with one of the assumptions used to derive the Black-Scholes formula:

> Continuously compounded returns on the stock are normally distributed.

Excel has a built-in function for the standard version of the normal distribution. That was the first step. Then I went through the process of converting it into a stock return distribution and then a stock price distribution. The option payoff was straightforward, as was weighting the payoffs by probabilities.

The entire calculation fit in six columns, and there were no complicated formulas. It was symmetric and simple.

Too bad it was wrong.

Try Again

That night at Starbucks, I decided to try again. Something was nagging at me. A piece was missing. I knew that volatility affects stock price simulations. The more volatile, the more the distribution of prices is dragged down. But I had not included anything in this spreadsheet to account for that.

I was aware of the fact that, in Monte Carlo simulations, adjustments are made to the distribution being sampled so that returns are not overstated. I wondered if that was what I needed to add.

I went back to the book. On page 597, McDonald said:

> [W]e need to subtract 1/2 times the variance.

That was the term I had been thinking about.

I wrote the following on a napkin:

$$\text{Mean} - 1/2 \text{ variance} = 0.0\% - 0.5 \times 0.30^2 = 0 - .5 \times .09 = -0.045 = -4.5\%$$

Worth a shot. So I plugged that into the spreadsheet.

It worked. Then I tried using different assumptions, and it still worked. I still thought it was too easy to be right, but this time I couldn't show that it was wrong.

The Spreadsheet

Because the adjustment (1/2 variance) has important implications, I want to show you what the spreadsheet looked like before the adjustment. In the next chapter, I will correct the mistake and walk through the spreadsheet components step by step.

To get a reference point, I priced an option with the Black-Scholes formula. I assumed a one-year term, 30% volatility, and $100 for the current stock price and the option strike. I also assumed 0% interest and no dividends. The Black-Scholes price was $11.92.

Then I started building the spreadsheet.

At the top, I entered the pricing assumptions. Then I started filling in the body of the sheet, following the rule that "continuously compounded stock returns are normally distributed."

When dealing with a normal distribution, the usual place to start is with the standard normal distribution. This is just a special case in which the mean or average value is 0 and the standard deviation is 1. Excel has a built-in function, so I filled in the first two columns with an approximate version that fit on two pages. (I divided it into 81 points, ranging from –4 standard deviation to +4 standard deviations in 0.1 increments. To handle the tails, I put everything outside 4 standard deviations in the two endpoints.) I knew it would not be exact, but it would work for a first try.

Next, I used a common rule of statistics to transform the standard normal distribution into a normal distribution with a standard deviation of 30% and a mean of 0. I remembered that "continuous compounding" meant using the EXP function. That gave me the stock prices. Knowing the stock price makes it easy to calculate the option payoff. The option payoff is just the difference between the stock price and the strike price, not less than zero.

The only thing left to do was weight each option payoff by its probability and add the numbers. The answer was $14.63, shown in Cell F95. I am intentionally showing you the wrong version so that I can focus on the correction in the next chapter. What is important here is the basic format.

When I was finished, the spreadsheet looked like Figures 1a and 1b.

This spreadsheet describes a simple world. In this world, stock returns, stock prices, and option payoffs are linked to each other, and each of them can be only one of 81 different values.

Columns A and B are constants representing the approximated standard normal distribution. Here are the other column formulas:

Column C = Column A × 0.30

Column D = EXP[Column C]

Column E = MAX[0, Column D – Strike price]

Column F = Column B × Column E

The option price is the total of Column F.

◇	A	B	C	D	E	F	G
1	**OPTION PRICING**						
2							
3	Time in Years		1.0000				
4	Stock Price		$ 100.00				
5	Option Strike Price		$ 100.00				
6	Risk Free Rate		0.000%				
7	Dividend Rate		0.000%				
8	Annualized Volatility		30.000%				
9							
10	Standard	Discrete	Stock	Stock	Call Option	Weighted	
11	Deviation	Probability	Return	Price	Payoff	Call Payoff	
12							
13	-4	0.00004	-120.00%	$ 30.12	$ -	$ -	
14	-3.9	0.00002	-117.00%	$ 31.04	$ -	$ -	
15	-3.8	0.00003	-114.00%	$ 31.98	$ -	$ -	
16	-3.7	0.00004	-111.00%	$ 32.96	$ -	$ -	
17	-3.6	0.00006	-108.00%	$ 33.96	$ -	$ -	
18	-3.5	0.00009	-105.00%	$ 34.99	$ -	$ -	
19	-3.4	0.00012	-102.00%	$ 36.06	$ -	$ -	
20	-3.3	0.00017	-99.00%	$ 37.16	$ -	$ -	
21	-3.2	0.00024	-96.00%	$ 38.29	$ -	$ -	
22	-3.1	0.00033	-93.00%	$ 39.46	$ -	$ -	
23	-3	0.00044	-90.00%	$ 40.66	$ -	$ -	
24	-2.9	0.00060	-87.00%	$ 41.90	$ -	$ -	
25	-2.8	0.00079	-84.00%	$ 43.17	$ -	$ -	
26	-2.7	0.00104	-81.00%	$ 44.49	$ -	$ -	
27	-2.6	0.00136	-78.00%	$ 45.84	$ -	$ -	
28	-2.5	0.00176	-75.00%	$ 47.24	$ -	$ -	
29	-2.4	0.00224	-72.00%	$ 48.68	$ -	$ -	
30	-2.3	0.00284	-69.00%	$ 50.16	$ -	$ -	
31	-2.2	0.00355	-66.00%	$ 51.69	$ -	$ -	
32	-2.1	0.00440	-63.00%	$ 53.26	$ -	$ -	
33	-2	0.00541	-60.00%	$ 54.88	$ -	$ -	
34	-1.9	0.00657	-57.00%	$ 56.55	$ -	$ -	
35	-1.8	0.00790	-54.00%	$ 58.27	$ -	$ -	
36	-1.7	0.00941	-51.00%	$ 60.05	$ -	$ -	
37	-1.6	0.01110	-48.00%	$ 61.88	$ -	$ -	
38	-1.5	0.01296	-45.00%	$ 63.76	$ -	$ -	
39	-1.4	0.01498	-42.00%	$ 65.70	$ -	$ -	
40	-1.3	0.01714	-39.00%	$ 67.71	$ -	$ -	
41	-1.2	0.01942	-36.00%	$ 69.77	$ -	$ -	
42	-1.1	0.02179	-33.00%	$ 71.89	$ -	$ -	
43	-1	0.02420	-30.00%	$ 74.08	$ -	$ -	
44	-0.9	0.02661	-27.00%	$ 76.34	$ -	$ -	
45	-0.8	0.02896	-24.00%	$ 78.66	$ -	$ -	
46	-0.7	0.03122	-21.00%	$ 81.06	$ -	$ -	
47	-0.6	0.03331	-18.00%	$ 83.53	$ -	$ -	
48	-0.5	0.03520	-15.00%	$ 86.07	$ -	$ -	
49	-0.4	0.03681	-12.00%	$ 88.69	$ -	$ -	
50	-0.3	0.03812	-9.00%	$ 91.39	$ -	$ -	
51	-0.2	0.03909	-6.00%	$ 94.18	$ -	$ -	
52	-0.1	0.03968	-3.00%	$ 97.04	$ -	$ -	
53	0	0.03988	0.00%	$ 100.00	$ 0.00	$ 0.00	
54	0.1	0.03968	3.00%	$ 103.05	$ 3.05	$ 0.12	

Figure 1.1a Option pricing, first attempt

◇	A	B	C	D	E	F	G
1	OPTION PRICING						
2							
10	Standard	Discrete	Stock	Stock	Call Option	Weighted	
11	Deviation	Probability	Return	Price	Payoff	Call Payoff	
12							
52	-0.1	0.03968	-3.00%	$ 97.04	$ -	$ -	
53	0	0.03988	0.00%	$ 100.00	$ 0.00	$ 0.00	
54	0.1	0.03968	3.00%	$ 103.05	$ 3.05	$ 0.12	
55	0.2	0.03909	6.00%	$ 106.18	$ 6.18	$ 0.24	
56	0.3	0.03812	9.00%	$ 109.42	$ 9.42	$ 0.36	
57	0.4	0.03681	12.00%	$ 112.75	$ 12.75	$ 0.47	
58	0.5	0.03520	15.00%	$ 116.18	$ 16.18	$ 0.57	
59	0.6	0.03331	18.00%	$ 119.72	$ 19.72	$ 0.66	
60	0.7	0.03122	21.00%	$ 123.37	$ 23.37	$ 0.73	
61	0.8	0.02896	24.00%	$ 127.12	$ 27.12	$ 0.79	
62	0.9	0.02661	27.00%	$ 131.00	$ 31.00	$ 0.82	
63	1	0.02420	30.00%	$ 134.99	$ 34.99	$ 0.85	
64	1.1	0.02179	33.00%	$ 139.10	$ 39.10	$ 0.85	
65	1.2	0.01942	36.00%	$ 143.33	$ 43.33	$ 0.84	
66	1.3	0.01714	39.00%	$ 147.70	$ 47.70	$ 0.82	
67	1.4	0.01498	42.00%	$ 152.20	$ 52.20	$ 0.78	
68	1.5	0.01296	45.00%	$ 156.83	$ 56.83	$ 0.74	
69	1.6	0.01110	48.00%	$ 161.61	$ 61.61	$ 0.68	
70	1.7	0.00941	51.00%	$ 166.53	$ 66.53	$ 0.63	
71	1.8	0.00790	54.00%	$ 171.60	$ 71.60	$ 0.57	
72	1.9	0.00657	57.00%	$ 176.83	$ 76.83	$ 0.50	
73	2	0.00541	60.00%	$ 182.21	$ 82.21	$ 0.44	
74	2.1	0.00440	63.00%	$ 187.76	$ 87.76	$ 0.39	
75	2.2	0.00355	66.00%	$ 193.48	$ 93.48	$ 0.33	
76	2.3	0.00284	69.00%	$ 199.37	$ 99.37	$ 0.28	
77	2.4	0.00224	72.00%	$ 205.44	$ 105.44	$ 0.24	
78	2.5	0.00176	75.00%	$ 211.70	$ 111.70	$ 0.20	
79	2.6	0.00136	78.00%	$ 218.15	$ 118.15	$ 0.16	
80	2.7	0.00104	81.00%	$ 224.79	$ 124.79	$ 0.13	
81	2.8	0.00079	84.00%	$ 231.64	$ 131.64	$ 0.10	
82	2.9	0.00060	87.00%	$ 238.69	$ 138.69	$ 0.08	
83	3	0.00044	90.00%	$ 245.96	$ 145.96	$ 0.06	
84	3.1	0.00033	93.00%	$ 253.45	$ 153.45	$ 0.05	
85	3.2	0.00024	96.00%	$ 261.17	$ 161.17	$ 0.04	
86	3.3	0.00017	99.00%	$ 269.12	$ 169.12	$ 0.03	
87	3.4	0.00012	102.00%	$ 277.32	$ 177.32	$ 0.02	
88	3.5	0.00009	105.00%	$ 285.77	$ 185.77	$ 0.02	
89	3.6	0.00006	108.00%	$ 294.47	$ 194.47	$ 0.01	
90	3.7	0.00004	111.00%	$ 303.44	$ 203.44	$ 0.01	
91	3.8	0.00003	114.00%	$ 312.68	$ 212.68	$ 0.01	
92	3.9	0.00002	117.00%	$ 322.20	$ 222.20	$ 0.00	
93	4	0.00004	120.00%	$ 332.01	$ 232.01	$ 0.01	
94							
95		1.00000				$ 14.63	
96							

Figure 1.1b Option pricing, first attempt (Continued)

As an example in reading the spreadsheet, look at Row 53. It is one of the 81 possible outcomes. In this outcome, the stock return is 0%, the stock price is $100, and the option payoff is $0. The probability that this particular outcome will occur is 3.98776%.

Similarly, in Row 63 at the one standard deviation point, the stock return is 30%, the corresponding stock price is $134.99 (the fact this differs from $130 is explained later), and the option payoff (the difference between the stock price and the option strike price of $100) is $34.99. The probability that this particular outcome will occur is 2.41971%.

Notice that the only positive values for the option payoff are in Rows 54–93. These 40 outcomes are the only numbers factored into the option price. The last column shows the weighted values of the option payoffs.

Looking at Column F, the value of the option is concentrated between 0 and 3 standard deviations. The highest contributions occur at around 1 standard deviation, with a weighted value of $0.85. In the tail of the distribution, the payoffs are very high but the probabilities are very low. For instance, even though the payoff goes as high as $232.01 in Row 93, the effect on the value of the option is only 1 cent. The probability at this point is so low that a high payoff has almost no effect.

Visualizing the Result

Figure 1.2 is a graph of the spreadsheet. The call option payoffs are shown on the right side of the graph, and the values for these payoffs are on the right axis. The probabilities of the payoffs are shown as the normal distribution curve. The probability values are on the left axis.

The option price is the weighted average option payoff, where the weights are the probabilities. In other words, this is Column E (the option payoff) times Column B (the corresponding probabilities), or as shown here in Figure 1.3.

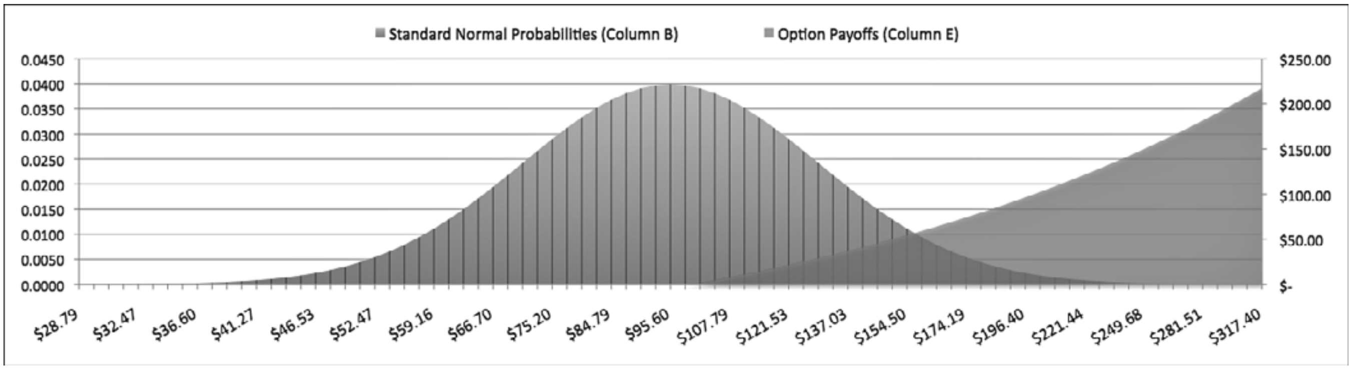

Figure 1.2 Stock option payoffs with probabilities

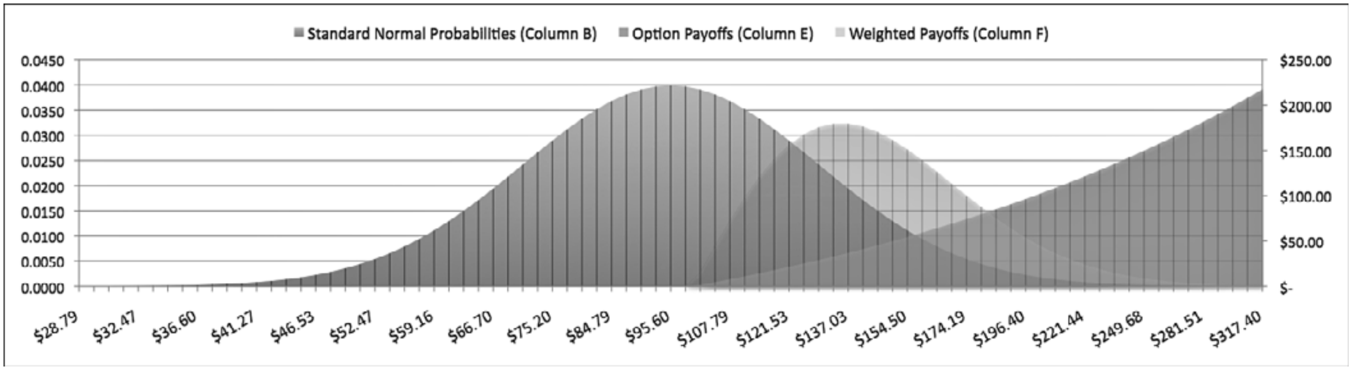

Figure 1.3 Weighted stock option payoffs

The middle section is the curve representing the option price. The sum of these values is equal to the option price. The relative height of the curve shows which stock prices contribute most to its value. In this view, even though the payoff grows large on the right side, the probabilities of those payoffs are growing smaller at a even faster rate, so high payoffs contribute relatively less than payoffs closer to the center of the graph.

What It Means and Why It Works: A Nontechnical Overview

At this point, why this works may not be obvious. But assuming that it does, it gives a nice interpretation of option pricing. It is just the weighted average of option payoffs, assuming that stock returns are normally distributed.

But why is it logical to assume that stock returns are normally distributed? Normal distributions occur naturally in science and statistics, with some of the earliest work on these distributions linked to observations about purely random events. In fact, normal distributions describe the frequencies of random events. So are stock prices random?

The Efficient Market Hypothesis, one of the best-known and most controversial ideas in investing, says they are. The EMH has been tested over decades and against massive amounts of data, and it seems to be just as predictive and controversial today as when it was first introduced. The conclusion of the EMH is that neither technical nor fundamental analysis of stocks helps to predict stock prices in the future.

The reason for this is the efficiency of large, liquid markets to absorb and digest new information almost immediately as it becomes known, with stock prices moving to their new price points before investors can take advantage of the information. That is, stock prices reflect all currently known information. The next move in price depends only on information that is not known yet and, therefore, is random.

If the EMH is true, stock prices should follow the mathematics of random movements such as Brownian motion, random walks, and stochastic processes. And if you can describe stock prices, the option payoffs and option values that depend on them can be described as well. What this means is that only one simple idea is behind the mechanics of option pricing: the unpredictability of stock prices.

It Doesn't Get Too Complicated

The spreadsheet illustrates the basic framework for everything presented in this book. It doesn't get too complicated. That is the beauty of the method. The underlying assumptions are transparent, and the logic can be broken into simple steps.

The challenge to those of you without quantitative backgrounds might be the terminology. In finance, statistics, and stochastic math, the terminology is challenging to everyone. One of the advantages of having a relatively compact spreadsheet is that you can always go back to specific cells and exact formulas whenever you need clarification about what something means.

An Integrated View of Risk Management

I have asked myself many times why Paul Samuelson thought studying Black-Scholes was so important. I don't think it is just for the purpose of pricing options. I think it is because the mathematics of option pricing give us a roadmap to risk management. Risk management, in its simplest terms, is a three-step process:

1. Think about what might happen in the future.
2. Know which of those outcomes will hurt you and how likely they are.
3. Decide what to do about it.

Most people weigh the cost of risk management against doing nothing. If the cost of insurance is too high, you can self-insure. But the factors involved are mainly financial.

In the capital markets, another factor is at work. It is hope, which is related to a historical precedence of mean reversion. Most investors believe that markets that fall will also rise again at some point. If you can suffer the pain, you will be rewarded in the end. Maybe. The turbulence of the 2000–2002 and 2008–2009 markets makes it harder to ignore previous bear markets, and consider the Japanese experience, with a 75% decline in the equity market over a 20-year period.

The desire of investors to impose some downside protection is understandable and requires some form of risk management. The three generally recognized ways to manage risk are diversifying, hedging, and buying insurance, and all are related to options. Diversification can be enhanced through options, delta hedging was the most elegant interpretation of option pricing, and put options are the purest form of market risk insurance.

The process of defining possible future events, assigning probabilities to those events, and using that information to price risk is the same as the process of pricing options. In that sense, option pricing is the central analytic framework for quantitative finance, risk management, and options-related structured securities.

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