CHAPTER 1

products and markets: equities, commodities, exchange rates, forwards and futures

The aim of this Chapter...

... is to describe some of the basic financial market products and conventions, to slowly introduce some mathematics, to hint at how stocks might be modeled using mathematics, and to explain the important financial concept of 'no free lunch.' By the end of the chapter you will be eager to get to grips with more complex products and to start doing some proper modeling.

In this Chapter...

- an introduction to equities, commodities, currencies and indices
- the time value of money
- fixed and floating interest rates
- futures and forwards
- no arbitrage, one of the main building blocks of finance theory

1.1 INTRODUCTION

This first chapter is a very gentle introduction to the subject of finance, and is mainly just a collection of definitions and specifications concerning the financial markets in general. There is little technical material here, and the one technical issue, the 'time value of money,' is extremely simple. I will give the first example of 'no arbitrage.' This is important, being one part of the foundation of derivatives theory. Whether you read this chapter thoroughly or just skim it will depend on your background.

1.2 EQUITIES

The most basic of financial instruments is the **equity, stock** or **share**. This is the ownership of a small piece of a company. If you have a bright idea for a new product or service then you could raise capital to realize this idea by selling off future profits in the form of a stake in your new company. The investors may be friends, your Aunt Joan, a bank, or a venture capitalist. The investor in the company gives you some cash, and in return you give him a contract stating how much of the company he owns. The **shareholders** who own the company between them then have some say in the running of the business, and technically the directors of the company are meant to act in the best interests of the shareholders. Once your business is up and running, you could raise further capital for expansion by issuing new shares.

This is how small businesses begin. Once the small business has become a large business, your Aunt Joan may not have enough money hidden under the mattress to invest in the next expansion. At this point shares in the company may be sold to a wider audience or even the general public. The investors in the business may have no link with the founders. The final point in the growth of the company is with the quotation of shares on a regulated stock exchange so that shares can be bought and sold freely, and capital can be raised efficiently and at the lowest cost.

Figures 1.1 and 1.2 show screens from Bloomberg giving details of Microsoft stock, including price, high and low, names of key personnel, weighting in various indices etc. There is much, much more info available on Bloomberg for this and all other stocks. We'll be seeing many Bloomberg screens throughout this book.

In Figure 1.3 I show an excerpt from *The Wall Street Journal Europe* of 5th January 2000. This shows a small selection of the many stocks traded on the New York Stock Exchange. The listed information includes, from left to right, highest stock price in previous 52 weeks, lowest price in previous 52 weeks, stock name, dividend payment, dividend as percentage of stock price, PE ratio, volume traded (in thousands), highs and lows for the day, closing price and change in price since the previous day's close. The **PE** or **price-to-earnings ratio** is the ratio of the stock price to the earnings of the company per share. High PE ratio means that investors believe that the company has good growth prospects. At least, that's the theory.

The behavior of the quoted prices of stocks is far from being predictable. In Figure 1.4 I show the Dow Jones Industrial Average over the period August 1964 to February 1999. In Figure 1.5 is a time series of the Glaxo–Wellcome share price, as produced by Bloomberg.

If we could predict the behavior of stock prices in the future then we could become very rich. Although many people have claimed to be able to predict prices with varying degrees

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MSFT US $  C 95+15/16 Q  Q↑94 15/16/95Q                        DL18 Equity DES
As of Sep10 DELAYED Vol 17,227,500 Op 95 1/16 Q  Hi 95 5/16 Q  Lo 94 Q
                              DESCRIPTION                          Page  1 /10
MSFT US                       MICROSOFT CORP              12) CN All News/Research
Computer Software                                         13) CWP Company Web Page
CUSIP 594918104                                           14) HH Hoover's Handbook
Microsoft Corporation develops, manufactures, licenses, sells, and supports
software products.  The Company offers operating system software, server
application software, business and consumer applications software, software
development tools, and Internet and intranet software.  Microsoft also develops
the MSN network of Internet products and services.
```

	STOCK DATA	Round Lot	100	8)DVD	DIVIDENDS - None	
1)GPO	Current Price	USD	95		Indicated Gross Yld	
	52Wk High 7/19/1999	USD	100 3/4		Dividend Growth	
	52Wk Low 10/ 8/1998	USD	43 7/8		Ex-Date Type	Amt
	YTD Chng (37.00%)	USD	25 21/32			
2)TRA	1 Yr Total Return		82.25%		3/29/99 Split	2 for 1
3)CH1	Shares Out as of 4/30		5103.859M	EARNINGS	- Ann Date 10/20/99	(Est)
	Market Cap	USD	484866.63M	9)ERN	Trailing 12mo EPS USD	1.395
Float	3576.78M Short Int		24.823M	10)EE	Est EPS 6/2000 USD	1.566
5)BETA	Beta vs. SPX		1.25	11)GE	P/E 68.10 Est P/E	60.66
6)OCM	Options avail & Stk Marginable			LT Growth	25.21 Est PEG	2.41

Par Value = .0000125

Figure 1.1 Details of Microsoft stock. Source: Bloomberg L.P.

of accuracy, no one has yet made a completely convincing case. In this book I am going to take the point of view that prices have a large element of randomness. This does *not* mean that we cannot model stock prices, but it does mean that the modeling must be done in a probabilistic sense. No doubt the reality of the situation lies somewhere between complete predictability and perfect randomness, not least because there have been many cases of market manipulation where large trades have moved stock prices in a direction that was favorable to the person doing the moving. Having said that, I will digress slightly in Chapter 3 where I describe some of the popular methods for supposedly predicting future stock prices.

To whet your appetite for the mathematical modeling later, I want to show you a simple way to simulate a random walk that looks something like a stock price. One of the simplest random processes is the tossing of a coin. I am going to use ideas related to coin tossing as a model for the behavior of a stock price. As a simple experiment start with the number 100 which you should think of as the price of your stock, and toss a coin. If you throw a head multiply the number by 1.01, if you throw a tail multiply by 0.99. After one toss your number will be either 99 or 101. Toss again. If you get a head multiply your *new* number by 1.01 or by 0.99 if you throw a tail. You will now have either $1.01^2 \times 100$, $1.01 \times 0.99 \times 100 = 0.99 \times 1.01 \times 100$ or $0.99^2 \times 100$. Continue this process and plot your value on a graph each time you throw the coin. Results of one

Page DL18 Equity **DES**
Hit 1 <GO> for a more detailed company management profile (MGMT).
MSFT US **MICROSOFT CORP** **Page 2 /10**

One Microsoft Way	T:425-882-8080 F:425-936-8000
Bldg 8 Southwest	2) http://www.microsoft.com/msft/
Redmond,WA 98052-6399	TR AG ChaseMellon Shareholder Services
United States	**# OF EMPLOYEES** 27,055
WILLIAM H GATES III	CHAIRMAN/CEO
STEVEN A BALLMER	PRESIDENT
ROBERT J HERBOLD	EXEC VP/COO
GREGORY B MAFFEI	SENIOR VP/CFO
TIM HALLADAY	INVESTOR RELATIONS CONTACT
STEVE SCHIRO	VP:CONSUMER CUSTOMER UNIT

Type Common Stock	PAR **$** .00001	**3)WGT** MEMBER	TICKER	WEIGHT
PRIMARY EXCHANGE	NASDAQ N-Mkt	S&P 500 INDEX	SPX	4.368%
COUNTRY	United States	NASDAQ 100 STOCK	NDX	14.287%
FISCAL YEAR END	JUNE	S&P 100 INDEX	OEX	8.752%
SIC Code 7372	PREPAKG SOFTW	TRIB WORLD INDEX	TRIB	5.245%
VALOREN	000951692	AMEX INSTITUTION	XII	6.540%
WPK Number	870747	AMEX COMPUTER TE	XCI	23.453%
SEDOL	2588173	PHILA NATIONAL O	XOC	21.223%
Sicovam	903099	CBOE TECHNOLOGY	TXX	4.157%
ISIN	US5949181045	S&P INDUSTRIALS	SPXI	5.316%
		S&P CAPITAL GOOD	SPCAPC	15.140%

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Princeton:609-279-3000 Singapore:226-3000 Sydney:2-9777-8686 Tokyo:3-3201-8900 Sao Paulo:11-3048-4500
I741-53-0 11-Sep-99 15:35:41

Bloomberg PROFESSIONAL

Figure 1.2 Details of Microsoft stock continued. Source: Bloomberg L.P.

particular experiment are shown in Figure 1.6. Instead of physically tossing a coin, the series used in this plot was generated on a spreadsheet like that in Figure 1.7. This uses the Excel spreadsheet function RAND() to generate a uniformly distributed random number between 0 and 1. If this number is greater than one half it counts as a 'head' otherwise a 'tail.'

Time Out...

More about coin tossing

Notice how in the above experiment I've chosen to *multiply* each 'asset price' by a factor, either 1.01 or 0.99. Why didn't I simply *add* a fixed amount, 1 or − 1, say? This is a very important point in the modeling of asset prices; as the asset price gets larger so do the changes from one day to the next. It seems reasonable to model the asset price changes as being proportional to the current level of the asset, since they are still random but the magnitude of the randomness depends on the level of the asset. This will be made more precise in later chapters, where we'll see how it is important to model the return on the asset, its percentage change, rather than its absolute value.

If we use the multiplicative rule we get an approximation to what is called a **lognormal random walk**, also **geometric random walk**. If we use the additive rule we get an approximation to a **Normal** or **arithmetic random walk**.

As an experiment, using Excel try to simulate both the arithmetic and geometric random walks, and also play around with the probability of a rise in asset price; it doesn't have to be one half. What happens if you have an arithmetic random walk with a probability of rising being less than one half?

1.2.1 Dividends

The owner of the stock theoretically owns a piece of the company. This ownership can only be turned into cash if he owns so many of the stock that he can take over the company and keep all the profits for himself. This is unrealistic for most of us. To the average investor the value in holding the stock comes from the **dividends** and any growth in the stock's value. Dividends are lump sum payments, paid out every quarter or every six months, to the holder of the stock.

The amount of the dividend varies from year to year depending on the profitability of the company. As a general rule companies like to try to keep the level of dividends about the same each time. The amount of the dividend is decided by the board of directors of the company and is usually set a month or so before the dividend is actually paid.

When the stock is bought it either comes with its entitlement to the next dividend (**cum**) or not (**ex**). There is a date at around the time of the dividend payment when the stock goes from cum to ex. The original holder of the stock gets the dividend but the person who buys it obviously does not. All things being equal a stock that is cum dividend is better than one that is ex dividend. Thus at the time that the dividend is paid and the stock goes ex dividend there will be a drop in the value of the stock. The size of this drop in stock value offsets the disadvantage of not getting the dividend.

This jump in stock price is in practice more complex than I have just made out. Often capital gains due to the rise in a stock price are taxed differently from a dividend, which

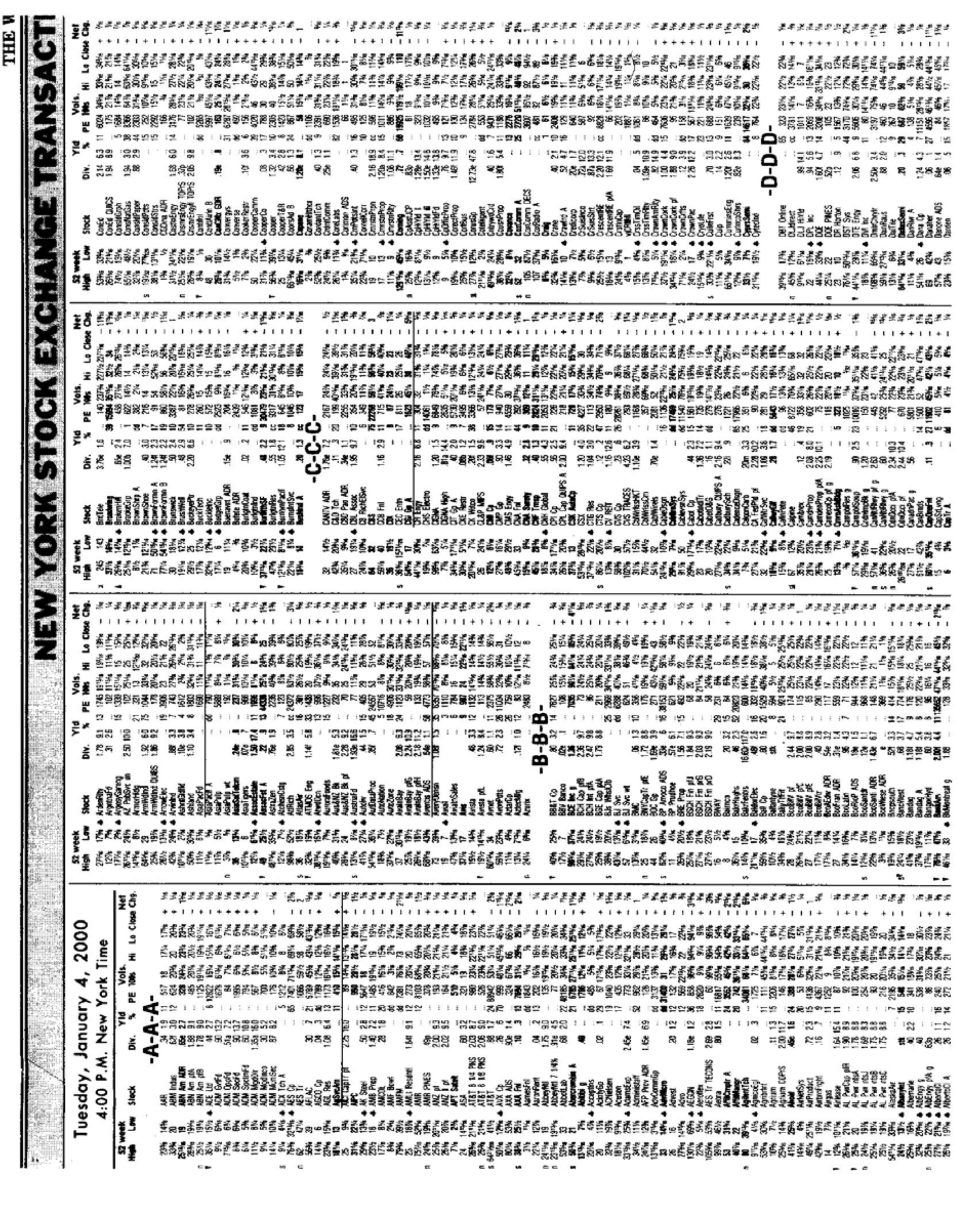


Figure 1.3 The *Wall Street Journal Europe* of 5th January 2000. Reproduced by permission of Dow Jones & Company, Inc.

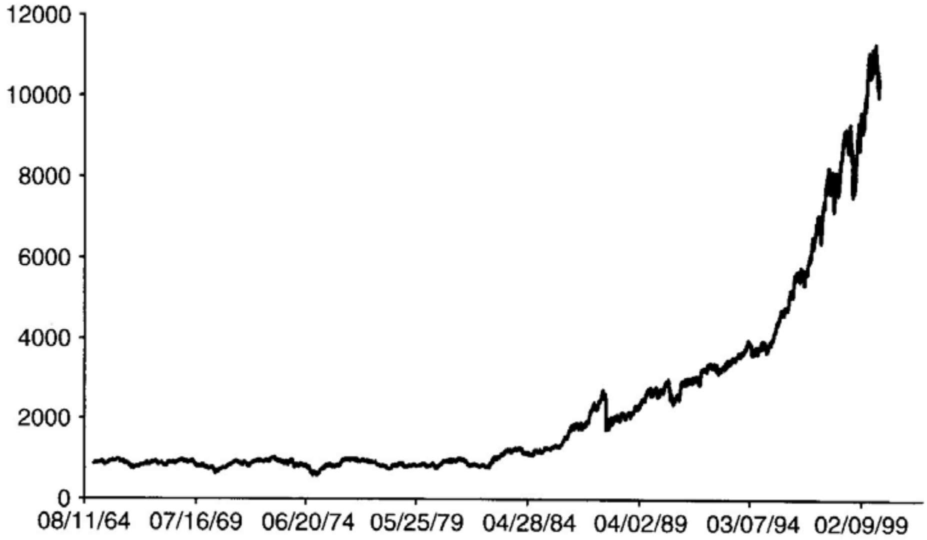


Figure 1.4 A time series of the Dow Jones Industrial Average from August 1964 to February 1999.

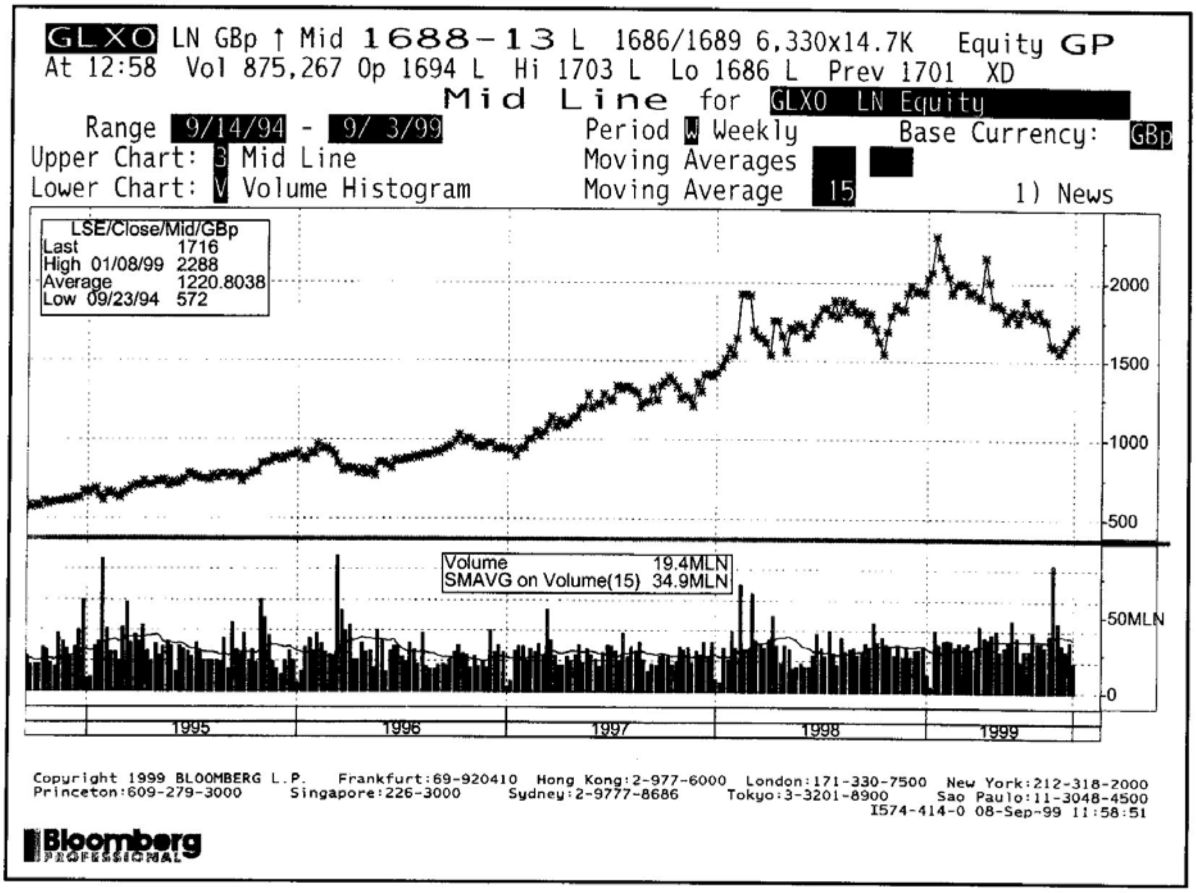


Figure 1.5 Glaxo–Wellcome share price (volume below). Source: Bloomberg L.P.

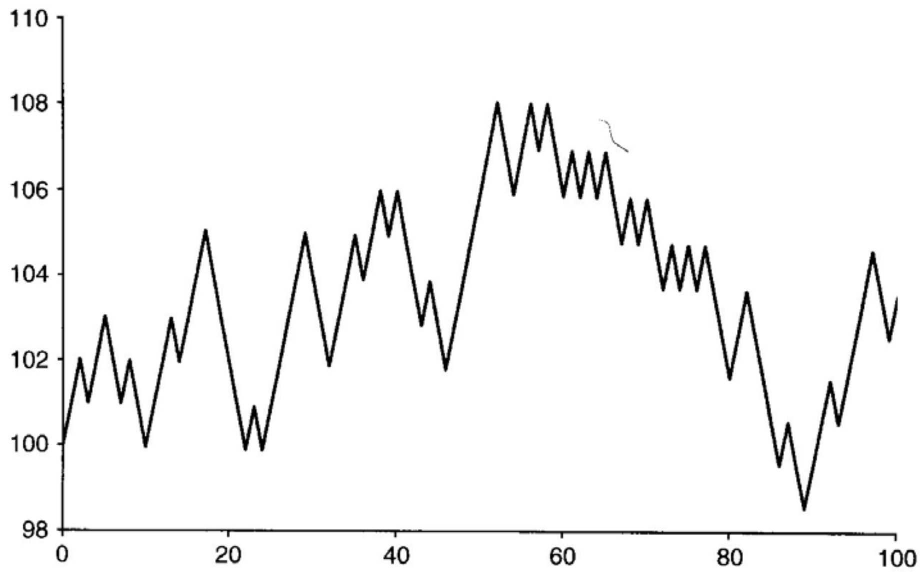


Figure 1.6 A simulation of an asset price path?

	A	B	C	D	E
1	**Initial stock price**	**100**		**Stock**	
2	**Up move**	**1.01**		100	
3	**Down move**	**0.99**		99	
4	**Probability of up**	**0.5**		98.01	
5				97.0299	
6		=B1		96.0596	
7				97.0202	
8				97.9904	
9	=D6*IF(RAND()>1-B4,B2,B3)			[illegible]	
10				97.9806	
11				98.96041	
12				99.95001	
13				98.95051	
14				97.961	
15				98.94061	
16				99.93002	
17				100.9293	
18				99.92003	
19				100.9192	
20				101.9284	
21				100.9091	
22				99.90004	
23				98.90104	
24				99.89005	
25				100.889	
26				99.88007	
27				98.88127	
28				97.89245	
29				96.91353	
30				95.94439	
31				96.90384	

Figure 1.7 Simple spreadsheet to simulate the coin-tossing experiment.

is often treated as income. Some people can make a lot of risk-free money by exploiting tax 'inconsistencies.'

1.2.2 Stock splits

Stock prices in the US are usually of the order of magnitude of $100. In the UK they are typically around £1. There is no real reason for the popularity of the number of digits, after all, if I buy a stock I want to know what percentage growth I will get, the absolute level of the stock is irrelevant to me, it just determines whether I have to buy tens or thousands of the stock to invest a given amount. Nevertheless there is some psychological element to the stock size. Every now and then a company will announce a **stock split** (Figure 1.8). For example, the company with a stock price of $900 announces a three-for-one stock split. This simply means that instead of holding one stock valued at $900, I hold three valued at $300 each.[1]

1.3 COMMODITIES

Commodities are usually raw products such as precious metals, oil, food products etc. The prices of these products are unpredictable but often show seasonal effects. Scarcity

<HELP> for explanation, <MENU> for similar functions. DL18 **Equity DVD**
Hit # <GO> to view details.

DIVIDEND/SPLIT SUMMARY Page 1/ 1

MSFT US MICROSOFT CORP Currency

12 Month Yield n.a.
Indicated Yield n.a.

Graph Selections **GRAPH NOT AVAILABLE**
B-Both
G-Gross Yield
Y-Adjust for Splits

Range 1990 to 1999 Type **1-All** Frequency **Irregular**

	Declared	Ex-Date	Record	Payable	Amount	Type
1)	1/25/99	3/29/99	3/12/99	3/26/99	2 for 1	Stock Split
2)	1/26/98	2/23/98	2/ 6/98	2/20/98	2 for 1	Stock Split
3)	11/12/96	12/ 9/96	11/22/96	12/ 6/96	2 for 1	Stock Split
4)	4/25/94	5/23/94	5/ 6/94	5/20/94	2 for 1	Stock Split
5)	6/ 3/92	6/15/92	6/ 3/92	6/12/92	3 for 2	Stock Split
6)	5/ 8/91	6/27/91	6/18/91	6/26/91	3 for 2	Stock Split
7)	3/13/90	4/16/90	3/26/90	4/13/90	2 for 1	Stock Split

Figure 1.8 Stock split info for Microsoft. Source: Bloomberg L.P.

[1] In the UK this would be called a two-for-one split.

of the product results in higher prices. Commodities are usually traded by people who have no need of the raw material. For example they may just be speculating on the direction of gold without wanting to stockpile it or make jewelry. Most trading is done on the futures market, making deals to buy or sell the commodity at some time in the future. The deal is then closed out before the commodity is due to be delivered. Futures contracts are discussed below.

Figure 1.9 shows a time series of the price of pulp, used in paper manufacture.

1.4 CURRENCIES

Another financial quantity we shall discuss is the **exchange rate**, the rate at which one currency can be exchanged for another. This is the world of **foreign exchange**, or **Forex** or **FX** for short. Some currencies are pegged to one another, and others are allowed to float freely. Whatever the exchange rates from one currency to another, there must be consistency throughout. If it is possible to exchange dollars for pounds and then the pounds for yen, this implies a relationship between the dollar/pound, pound/yen and dollar/yen exchange rates. If this relationship moves out of line it is possible to make **arbitrage profits** by exploiting the mispricing.

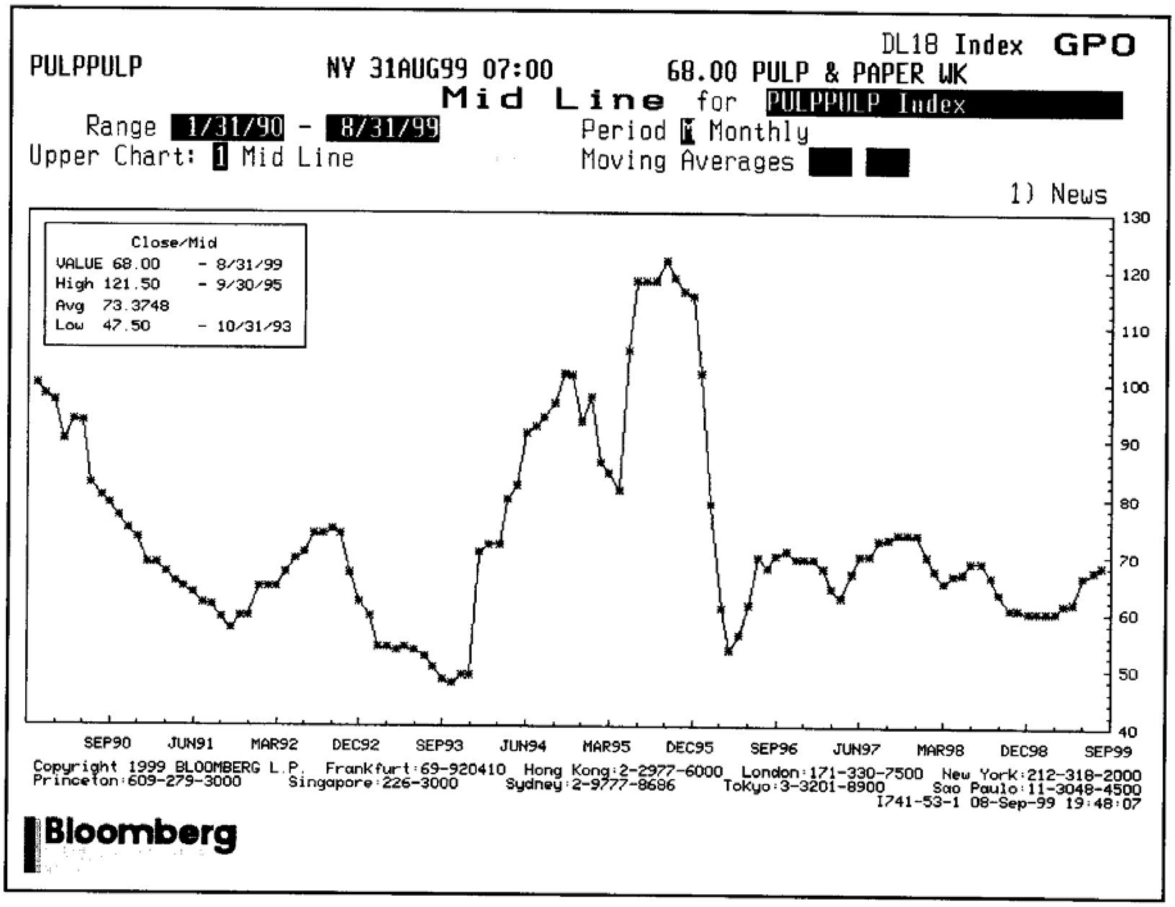


Figure 1.9 Pulp price. Source: Bloomberg L.P.

CURRENCY TRADING

Tuesday, January 4, 2000

DOLLAR EXCHANGE RATES

The New York foreign exchange mid-range rates below apply to trading among banks in amounts of $1 million and more, as quoted at 4 p.m. Eastern time by Reuters and other sources. Retail transactions provide fewer units of foreign currency per dollar. Rates for the 11 Euro currency countries are derived from the latest dollar-euro rate using the exchange ratios set 1/1/99.

Country	U.S. $ equiv. Tue	U.S. $ equiv. Mon	Currency per U.S. $ Tue	Currency per U.S. $ Mon
Argentina (Peso)	1.0001	1.0002	.9999	.9998
Australia (Dollar)	.6551	.6582	1.5266	1.5192
Austria (Schilling)	.07491	.07462	13.349	13.402
Bahrain (Dinar)	2.6525	2.6525	.3770	.3770
Belgium (Franc)	.0256	.0255	39.1325	39.2885
Brazil (Real)	.5408	.5495	1.8490	1.8200
Britain (Pound)	1.6370	1.6371	.6109	.6108
1-month forward	1.6372	1.6373	.6108	.6108
3-months forward	1.6371	1.6373	.6108	.6108
6-months forward	1.6365	1.6368	.6111	.6109
Canada (Dollar)	.6887	.6913	1.4521	1.4465
1-month forward	.6892	.6919	1.4510	1.4453
3-months forward	.6902	.6929	1.4489	1.4433
6-months forward	.6915	.6943	1.4462	1.4404
Chile (Peso) (d)	.001890	.001894	529.05	527.85
China (Renminbi)	.1208	.1208	8.2799	8.2798
Colombia (Peso)	.0005238	.0005306	1909.00	1884.50
Czech. Rep. (Koruna)				
Commercial rate	.02839	.02814	35.226	35.541
Denmark (Krone)	.1385	.1379	7.2186	7.2491
Ecuador (Sucre)				
Floating rate	.00004202	.00004598	23800.00	21750.00
Finland (Markka)	.1734	.1727	5.7678	5.7908
France (Franc)	.1572	.1565	6.3633	6.3887
1-month forward	.1575	.1569	6.3488	6.3736
3-months forward	.1582	.1576	6.3205	6.3460
6-months forward	.1592	.1586	6.2800	6.3054
Germany (Mark)	.5273	.5250	1.8966	1.9049
1-month forward	.5285	.5262	1.8922	1.9004
3-months forward	.5308	.5285	1.8838	1.8921
6-months forward	.5343	.5319	1.8717	1.8800
Greece (Drachma)	.003120	.003113	320.52	321.26
Hong Kong (Dollar)	.1286	.1286	7.7773	7.7763
Hungary (Forint)	.004044	.004034	247.30	247.90
India (Rupee)	.02300	.02302	43.480	43.435
Indonesia (Rupiah)	.0001396	.0001417	7165.00	7055.00
Ireland (Punt)	1.3094	1.3040	.7637	.7669
Israel (Shekel)	.2413	.2436	4.1436	4.1053
Italy (Lira)	.0005324	.0005303	1878.33	1885.83
Japan (Yen)	.009681	.009843	103.29	101.60
1-month forward	.009730	.009893	102.77	101.08
3-months forward	.009825	.009989	101.79	100.11
6-months forward	.009974	.010141	100.26	98.61
Jordan (Dinar)	1.4085	1.4085	.7100	.7100
Kuwait (Dinar)	3.2927	3.2895	.3037	.3040
Lebanon (Pound)	.0006634	.0006634	1507.50	1507.50
Malaysia (Ringgit)	.2632	.2632	3.8001	3.8000
Malta (Lira)	2.4691	2.4643	.4050	.4058
Mexico (Peso)				
Floating rate	.1045	.1063	9.5700	9.4050
Netherland (Guilder)	.4678	.4659	2.1378	2.1463
New Zealand (Dollar)	.5209	.5255	1.9198	1.9029
Norway (Krone)	.1260	.1266	7.9388	7.8969
Pakistan (Rupee)	.01929	.01927	51.850	51.890
Peru (new Sol)	.2841	.2840	3.5200	3.5215
Philippines (Peso)	.02509	.02503	39.850	39.950
Poland (Zloty)	.2427	.2418	4.1195	4.1350
Portugal (Escudo)	.005142	.005121	194.49	195.26
Russia (Ruble) (a)	.03632	.03643	27.530	27.450
Saudi Arabia (Riyal)	.2666	.2666	3.7510	3.7508
Singapore (Dollar)	.6039	.6038	1.6560	1.6562
Slovak Rep. (Koruna)	.02434	.02427	41.077	41.202
South Africa (Rand)	.1643	.1632	6.0875	6.1288
South Korea (Won)	.0008909	.0008869	1122.50	1127.50
Spain (Peseta)	.006196	.006171	161.41	162.05
Sweden (Krona)	.1195	.1195	8.3671	8.3668
Switzerland (Franc)	.6429	.6391	1.5555	1.5647
1-month forward	.6454	.6416	1.5494	1.5585
3-months forward	.6498	.6459	1.5389	1.5483
6-months forward	.6567	.6527	1.5228	1.5321
Taiwan (Dollar)	.03276	.03188	30.525	31.365
Thailand (Baht)	.02683	.02702	37.265	37.015
Turkey (Lira)	.00000186	.00000185	536260.00	539255.00
United Arab (Dirham)	.2722	.2723	3.6731	3.6729
Uruguay (New Peso)				
Financial	.08607	.08608	11.619	11.618
Venezuela (Bolivar)	.001538	.001540	650.00	649.25
SDR	1.3820	1.3761	.7236	.7267
Euro	1.0313	1.0268	.9696	.9739

Special Drawing Rights (SDR) are based on exchange rates for the U.S., German, British, French, and Japanese currencies. Source: International Monetary Fund.
a-Russian Central Bank rate. Trading band lowered on 8/17/98. b-Government rate. d-Floating rate; trading band suspended on 9/2/99.

The 3-month and 6-month forward rates for France, Germany, Japan and Switzerland appearing in the Foreign Exchange column were incorrectly calculated for the period beginning with August 13 and ending with October 7. Corrected data is available from Readers' Reference Service (413) 592-3600.

Euro					102.33
62,500 Euro-cents per unit.					
102	Jan	2	1.70	...	...
102	Feb	31	2.42	...	0.01
102	Mar	69	2.92	...	...
104	Feb	10	1.41	...	...
104	Mar	153	1.95	...	0.01
106	Jan	5	0.12	...	...
106	Feb	10	0.80	...	0.01
106	Mar	2	1.15	...	0.01
110	Mar	29	0.40	...	0.01
Australian Dollar					65.97
50,000 Australian Dollars-European Style.					
66	Mar	...	0.01	20	1.11
British Pound					163.46
31,250 Brit. Pounds-European Style.					
162	Feb	...	0.01	20	0.83
166	Feb	20	1.00	...	0.01
Euro					102.33
62,500 Euro-European style					
102	Jan	20	1.72	40	1.13
62,500 Euro-European style.					
102	Jan	10	1.26	...	...
102	Mar	...	0.01	12	1.41
106	Jan	8	0.25	...	0.01
Japanese Yen					98.52
6,250,000J.Yen-100ths of a cent per unit.					
95	Jan	...	0.01	3	0.13
96	Jan	...	0.01	2	0.38
98	Mar	...	0.01	2	2.26
Swiss Franc					63.72
62,500 Swiss Francs-European Style.					
64	Jan	16	0.86	...	...
65	Mar	...	0.01	16	1.42
62,500 Swiss Francs-cents per unit.					
62	Jan	5	2.31	...	0.01
62	Mar	...	0.01	5	0.38
63	Feb	5	1.95	5	0.60
63	Mar	10	2.40	...	...
64	Feb	...	0.01	1	0.82
64	Mar	124	1.67	...	...
66	Feb	20	0.55	2	1.98

Call Vol ...... 1,586 Open Int ... 12,719
Put Vol .... 277 Open Int ... 9,240

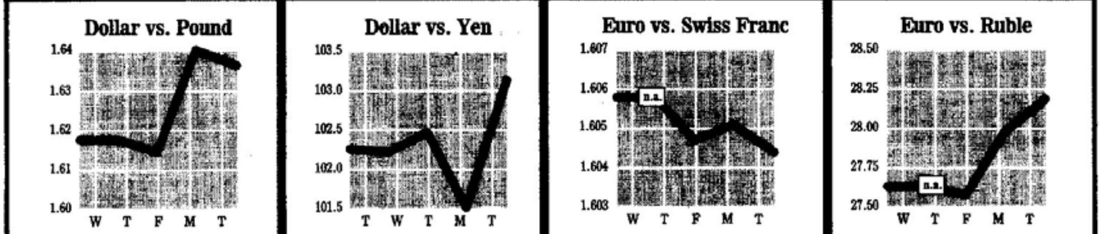
r - None of these particular options were traded on this day;
s - No option in this particular month at this strike price

Currency	Tue.	Prev.	Currency	Tue.	Prev.
Dan Kr.	7.4429	7.4404	Swed Kr.	8.6215	8.5520
Nor Kr.	8.1500	8.0620	Slov Tolar	198.80	198.89
Aust Dollar	1.5677	1.5346	Nz Dollar	1.9745	1.9331
Czech Crown	36.270	36.063	Est Kroon	15.647	15.647
Gr Drachma	330.40	329.85	Hun Forint	254.52	254.53
Cypr Pound	0.5775	0.5767			

J.P. Morgan calculates the daily exchange rate indices based upon a 1990 average equalling 100. Depreciation or appreciation of each currency is against a basket of 18 other currencies, weighted by each country's 1990 bilateral manufactures trade pattern.

Currency	Tue.	Prev.	Currency	Tue.	Prev.
Dollar	105.4	105.4	Sterling	106.1	106.4
Sw Franc	103.6	103.1	Can Dlr	80.2	80.6
Yen	155.1	158.2	Nor Krone	92.9	93.6

CURRENCY CROSSRATES



	Dollar	Pound	SF	Peseta	Ruble	Escudo	Zloty	DFL	Yen	Lira	Punt	DM	FF	Markka	Euro	CDN	BF	ATS
Austria	13.364	21.871	8.5769	.08270	.48813	.06864	3.2454	6.2442	.12957	.00711	17.472	7.0355	2.0977	2.3143	13.760	9.2073	.34111	---
[illegible]																		
Canada	1.4515	2.3754	0.9315	.00898	.05302	.00745	.35248	.67817	.01407	.00077	1.8976	.76413	.22784	.25136	1.4945	---	.03705	.10861
[illegible]																		
Finland	5.7745	9.4504	3.7060	.03573	.21092	.02966	1.4023	2.6981	.05599	.00307	7.5495	3.0400	.90642	---	5.9457	3.9784	.14739	.43209
[illegible]																		
Germany	1.8995	3.1087	1.2191	.01175	.06938	.00976	.46128	.88752	.01842	.00101	2.4834	---	.29816	.32895	1.9558	1.3087	.04848	.14214
[illegible]																		
Italy	1880.5	3077.6	1206.9	11.637	68.686	9.6581	456.67	878.64	18.232	---	2458.6	990.00	295.18	325.66	1936.3	1295.6	47.999	140.71
[illegible]																		
Netherlands	2.1403	3.5027	1.3736	.01324	.07817	.01099	.51974	---	.02075	.00114	2.7981	1.1267	.33595	.37064	2.2037	1.4745	.05463	.16015
[illegible]																		
Portugal	194.71	318.66	124.96	1.2049	7.1118	---	47.283	90.975	1.8878	.10354	254.56	102.50	30.563	33.719	200.48	134.15	4.9698	14.570
[illegible]																		
Spain	161.59	264.46	103.71	---	5.9023	.82993	39.242	75.503	1.5667	.08593	211.27	85.072	25.365	27.984	166.39	111.33	4.1246	12.092
[illegible]																		
U.K.	.61103	---	.39215	.00378	.02232	.00314	.14838	.28550	.00592	.00032	.79886	.32168	.09591	.10582	.62915	.42098	.01560	.04572
[illegible]																		

Figure 1.10 The *Wall Street Journal Europe* of 5th January 2000, currency exchange rates. Reproduced by permission of Dow Jones & Company, Inc.

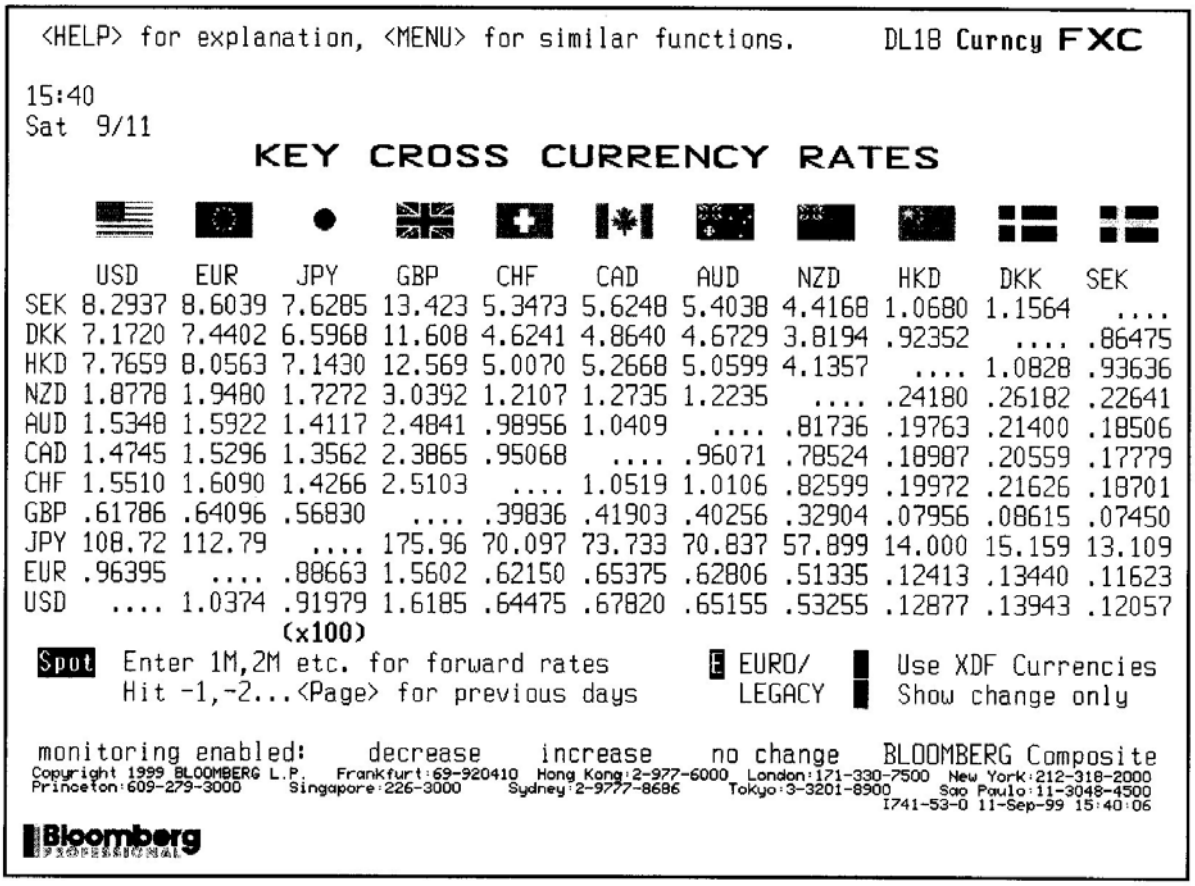
Figure 1.10 is an excerpt from *The Wall Street Journal Europe* of 5th January 2000. At the bottom of this excerpt is a matrix of exchange rates. A similar matrix is shown in Figure 1.11 from Bloomberg.

Although the fluctuation in exchange rates is unpredictable, there is a link between exchange rates and the interest rates in the two countries. If the interest rate on dollars is raised while the interest rate on pounds sterling stays fixed we would expect to see sterling depreciating against the dollar for a while. Central banks can use interest rates as a tool for manipulating exchange rates, but only to a degree.

At the start of 1999 Euroland currencies were fixed at the rates shown in Figure 1.12.

1.5 INDICES

For measuring how the stock market/economy is doing as a whole, there have been developed the stock market **indices**. A typical index is made up from the weighted sum of a selection or **basket** of representative stocks. The selection may be designed to represent the whole market, such as the Standard & Poor's 500 (S&P500) in the US or the Financial Times Stock Exchange index (FTSE100) in the UK, or a very special part of a market. In Figure 1.4 we saw the DJIA, representing major US stocks. In Figure 1.13 is shown JP Morgan's Emerging Market Bond Index. The EMBI+ is an index of emerging market debt



<HELP> for explanation, <MENU> for similar functions. DL18 **Curncy FXC**

15:40
Sat 9/11

KEY CROSS CURRENCY RATES

	USD	EUR	JPY	GBP	CHF	CAD	AUD	NZD	HKD	DKK	SEK
SEK	8.2937	8.6039	7.6285	13.423	5.3473	5.6248	5.4038	4.4168	1.0680	1.1564	....
DKK	7.1720	7.4402	6.5968	11.608	4.6241	4.8640	4.6729	3.8194	.92352	....	.86475
HKD	7.7659	8.0563	7.1430	12.569	5.0070	5.2668	5.0599	4.1357	....	1.0828	.93636
NZD	1.8778	1.9480	1.7272	3.0392	1.2107	1.2735	1.2235	....	.24180	.26182	.22641
AUD	1.5348	1.5922	1.4117	2.4841	.98956	1.0409	....	.81736	.19763	.21400	.18506
CAD	1.4745	1.5296	1.3562	2.3865	.95068	....	.96071	.78524	.18987	.20559	.17779
CHF	1.5510	1.6090	1.4266	2.5103	....	1.0519	1.0106	.82599	.19972	.21626	.18701
GBP	.61786	.64096	.56830	....	.39836	.41903	.40256	.32904	.07956	.08615	.07450
JPY	108.72	112.79	....	175.96	70.097	73.733	70.837	57.899	14.000	15.159	13.109
EUR	.96395	....	.88663	1.5602	.62150	.65375	.62806	.51335	.12413	.13440	.11623
USD	....	1.0374	.91979	1.6185	.64475	.67820	.65155	.53255	.12877	.13943	.12057

(x100)

Spot Enter 1M,2M etc. for forward rates
Hit -1,-2...<Page> for previous days

E EURO/ LEGACY
Use XDF Currencies
Show change only

monitoring enabled: decrease increase no change BLOOMBERG Composite

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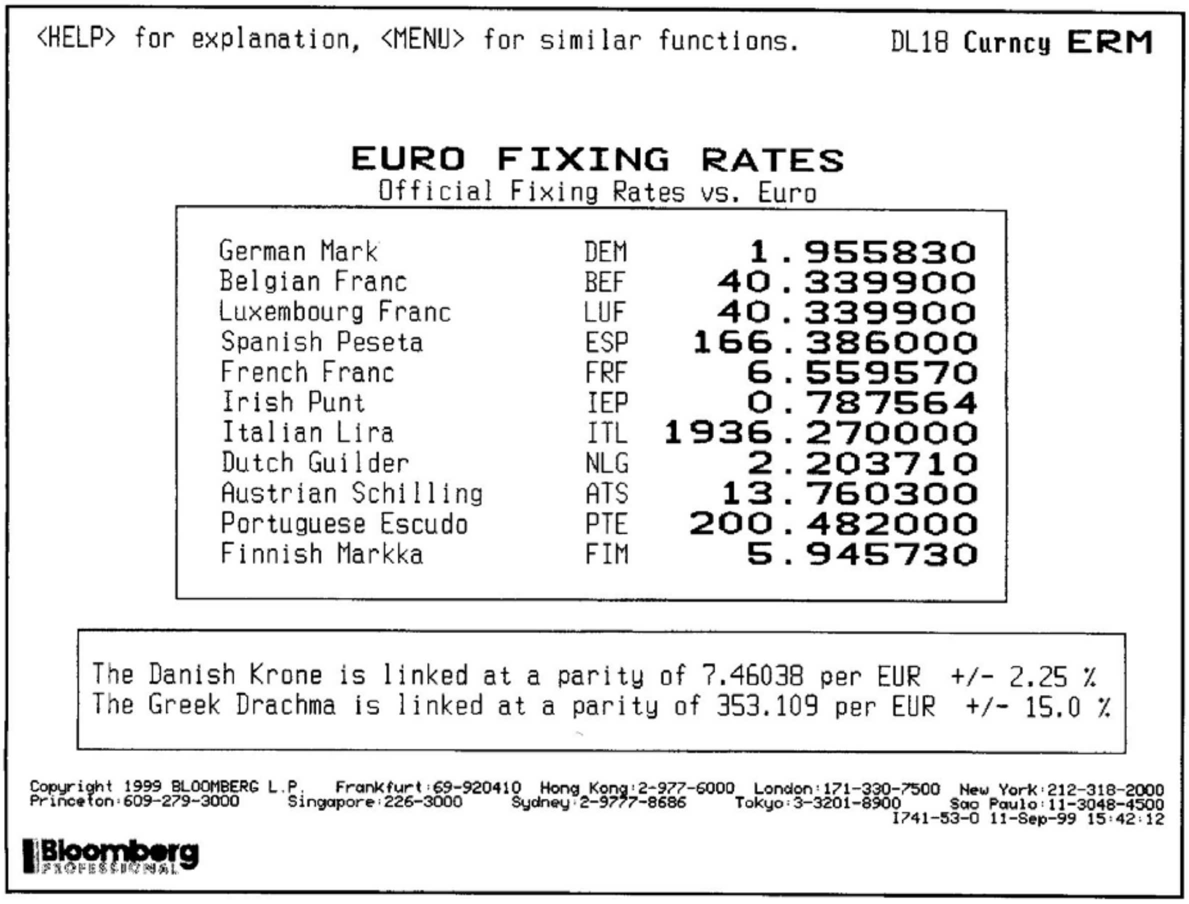
Bloomberg PROFESSIONAL

Figure 1.11 Key cross currency rates. Source: Bloomberg L.P.



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EURO FIXING RATES

Official Fixing Rates vs. Euro

German Mark	DEM	1.955830
Belgian Franc	BEF	40.339900
Luxembourg Franc	LUF	40.339900
Spanish Peseta	ESP	166.386000
French Franc	FRF	6.559570
Irish Punt	IEP	0.787564
Italian Lira	ITL	1936.270000
Dutch Guilder	NLG	2.203710
Austrian Schilling	ATS	13.760300
Portuguese Escudo	PTE	200.482000
Finnish Markka	FIM	5.945730

The Danish Krone is linked at a parity of 7.46038 per EUR +/- 2.25 %
The Greek Drachma is linked at a parity of 353.109 per EUR +/- 15.0 %

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Figure 1.12 Euro fixing rates. Source: Bloomberg L.P.

Figure 1.13 JP Morgan's EMBI+.

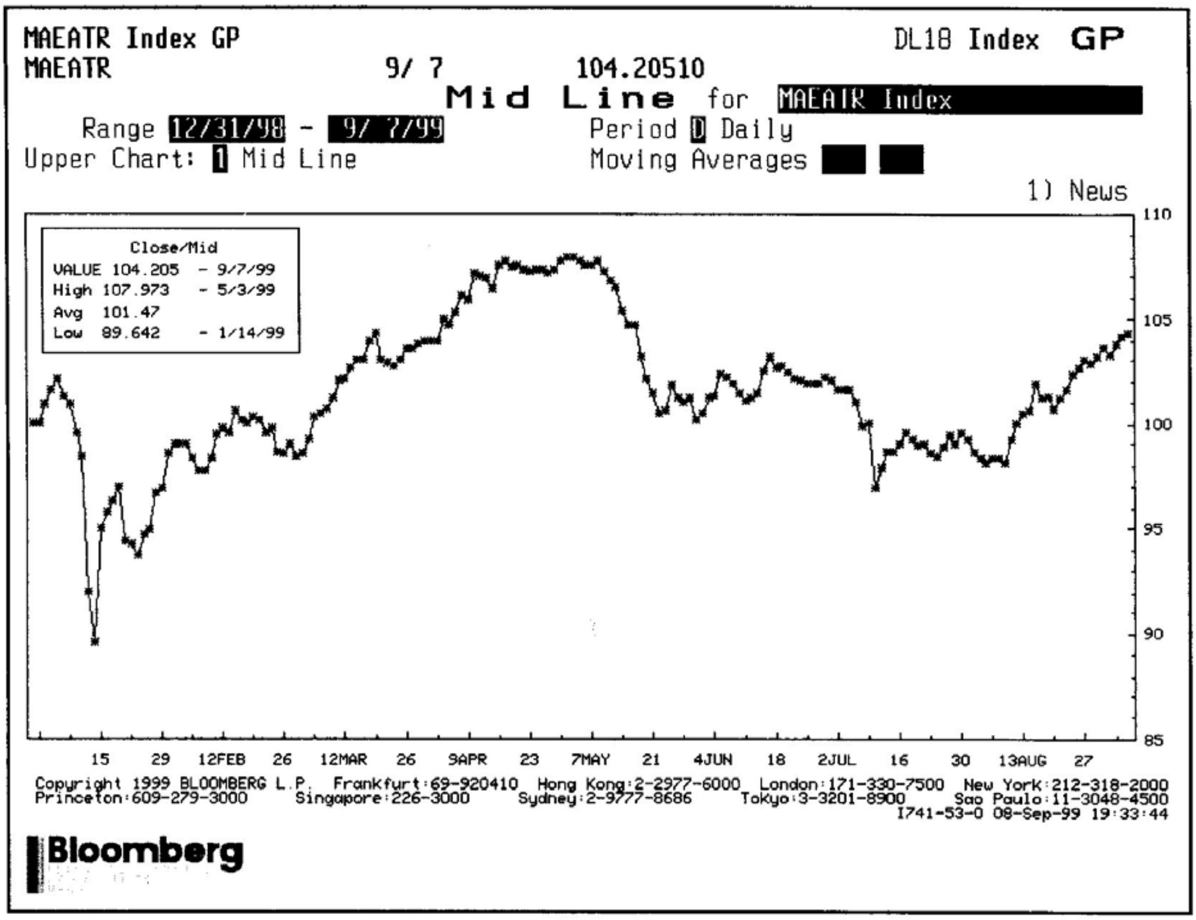
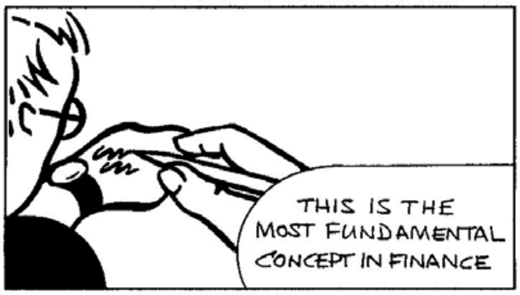


Figure 1.14 A time series of the MAE All Bond Index. Source: Bloomberg L.P.

instruments, including external-currency-denominated Brady bonds, Eurobonds and US dollar local markets instruments. The main components of the index are the three major Latin American countries, Argentina, Brazil and Mexico. Bulgaria, Morocco, Nigeria, the Philippines, Poland, Russia and South Africa are also represented.

Figure 1.14 shows a time series of the MAE All Bond Index which includes peso and US dollar denominated bonds sold by the Argentine Government.

1.6 THE TIME VALUE OF MONEY



The simplest concept in finance is that of the **time value of money**; $1 today is worth more than $1 in a year's time. This is because of all the things we can do with $1 over the next year. At the very least, we can put it under the mattress and take it out in one year. But instead of putting it under the mattress we could invest it in a gold mine, or a new company. If those are too risky, then lend the money to someone who is willing to take the risks and will give you back the dollar with a little bit extra, the **interest**. That is what banks do, they borrow your money and invest it in various risky ways, but by spreading their risk over many investments they reduce their overall risk. And by borrowing money from many people they can invest in ways that the average individual cannot. The banks compete for your money by offering high interest rates. Free markets and the ability to quickly and cheaply change banks ensure that interest rates are fairly consistent from one bank to another.

Time Out...

Symbols

It had to happen sooner or later, and the first chapter is as good as anywhere. Our first mathematical symbol is nigh. Please don't be put off by the use of symbols if you feel more comfortable with numbers and concrete examples. I know that math is the one academic subject that can terrify adults, just because of poor teaching in schools. If you fall into this category, just go with the flow, concentrate on the words, the examples and the Time Outs, and before you know it...

I am going to denote interest rates by r. Although rates vary with time I am going to assume for the moment that they are constant. We can talk about several types of interest. First of all there is **simple** and **compound interest**. Simple interest is when the interest you receive is based only on the amount you initially invest, whereas compound interest is when you also get interest on your interest. Compound interest is the only case of relevance. And compound interest comes in two forms, **discretely compounded** and **continuously compounded**. Let me illustrate how they each work.

Suppose I invest \$1 in a bank at a discrete interest rate of r paid once *per annum*. At the end of one year my bank account will contain

$$1 \times (1 + r).$$

If the interest rate is 10% I will have one dollar and ten cents. After two years I will have

$$1 \times (1 + r) \times (1 + r) = (1 + r)^2,$$

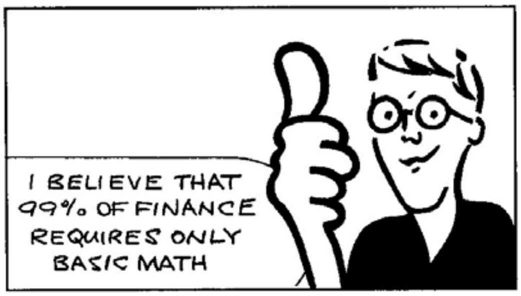
or one dollar and twenty-one cents. After n years I will have $(1 + r)^n$. That is an example of discrete compounding.

Now suppose I receive m interest payments at a rate of r/m *per annum*. After one year I will have

$$\left(1 + \frac{r}{m}\right)^m. \qquad (1.1)$$

Now I am going to imagine that these interest payments come at increasingly frequent intervals, but at an increasingly smaller interest rate: I am going to take the limit $m \to \infty$. This will lead to a rate of interest that is paid continuously. Expression (1.1) becomes[2]

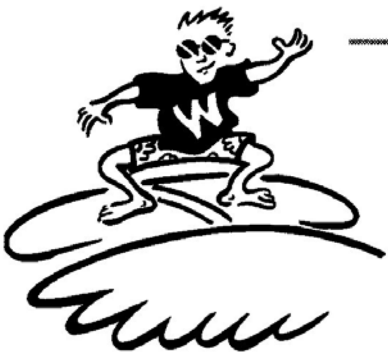
$$\left(1+\frac{r}{m}\right)^m = e^{m \log\left(1+\frac{r}{m}\right)} \sim e^r.$$



That is how much money I will have in the bank after one year if the interest is continuously compounded. And similarly, after a time t I will have an amount

$$\left(1+\frac{r}{m}\right)^{mt} \sim e^{rt} \tag{1.2}$$

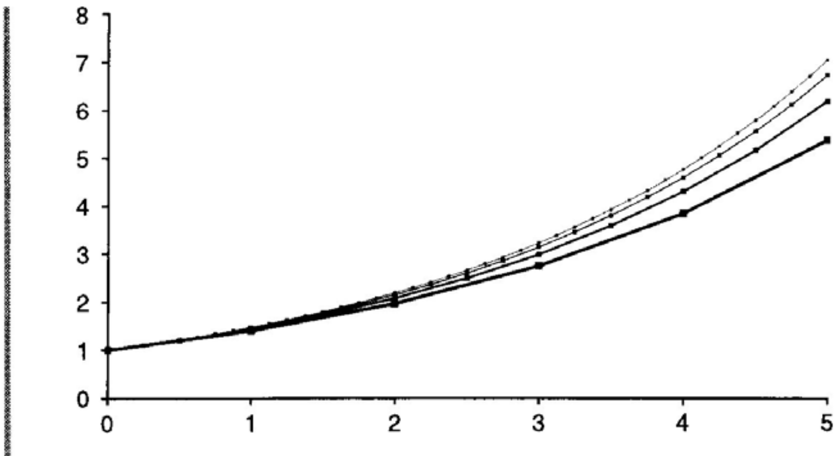
in the bank. Almost everything in this book assumes that interest is compounded continuously.



Time Out...

The math so far

Let's see m getting larger and larger in an example. I produced the next figure in Excel.



As m gets larger and larger, so the curve seems to get smoother and smoother, eventually becoming the exponential function. We'll be seeing this function a lot. In Excel the exponential function e^x (also written $\exp(x)$) is EXP( ).

[2] The symbol $\sim$, called 'tilde' is like 'approximately equal to,' but with a slightly more technical, in a math sense, meaning. The symbol $\to$ means 'tends to.'

What mathematics have we seen so far? To get to (1.2) all we needed to know about are two functions, the **exponential function** e (or exp) and the **logarithm** log, and Taylor series. Believe it or not, you can appreciate almost all finance theory by knowing these three things together with 'expectations.' I'm going to build up to the basic Black–Scholes and derivatives theory assuming that you know all four of these. Don't worry if you don't know about these things yet, in Chapter 4 I review these requisites.

En passant, what would the above figures look like if interest were simple rather than compound? Which would you prefer to receive?

Another way of deriving the result (1.2) is via a differential equation. Suppose I have an amount $M(t)$ in the bank at time t, how much does this increase in value from one day to the next? If I look at my bank account at time t and then again a short while later, time $t + dt$, the amount will have increased by

$$M(t + dt) - M(t) \approx \frac{dM}{dt}dt + \cdots,$$

where the right-hand side comes from a Taylor series expansion. But I also know that the interest I receive must be proportional to the amount I have, M, the interest rate, r, and the timestep, dt. Thus

$$\frac{dM}{dt}dt = rM(t)\,dt.$$

Dividing by dt gives the ordinary differential equation

$$\frac{dM}{dt} = rM(t)$$

the solution of which is

$$M(t) = M(0)\,e^{rt}.$$

If the initial amount at $t = 0$ was \$1 then I get (1.2) again.

Time Out...

Differential equations

Our first **differential equation**, hang on in there, it'll become second nature soon. Whenever you see d something over d something else you know you're looking at a slope, or gradient, also known as rate of change or sensitivity. So here we've got the rate of change of money with time, i.e. rate of growth of money in the bank. You don't need to know how I solved this differential equation really. In Chapter 4 I explain all about slope, sensitivities and differential equations.

This first differential equation is an example of an **ordinary differential equation**, there is only one **independent variable** t. M is the **dependent variable**, its value depends on t. We'll also be seeing **partial differential equations** where there is more than one independent variable. And we'll also see quite a few **stochastic differential equations**. These are equations with a random term in them, used for modeling the randomness in the financial world.

For the next few chapters there will be no more mention of differential equations. Whew.

This equation relates the value of the money I have now to the value in the future. Conversely, if I know I will get one dollar at time T in the future, its value at an earlier time t is simply

$$\frac{1}{e^{r(T-t)}} = e^{-r(T-t)}.$$

I can relate cashflows in the future to their **present value** by multiplying by this factor. As an example, suppose that r is 5% i.e. $r = 0.05$, then the present value of \$1,000,000 to be received in two years is

$$\$1,000,000 \times e^{-0.05\times 2} = \$904,837.$$

The present value is clearly less than the future value.

Interest rates are a very important factor determining the present value of future cashflows. For the moment I will only talk about one interest rate, and that will be constant. In later chapters I will generalize.

1.7 FIXED-INCOME SECURITIES

In lending money to a bank you may get to choose for how long you tie your money up and what kind of interest rate you receive. If you decide on a fixed-term deposit the bank will offer to lock in a fixed rate of interest for the period of the deposit, a month, six months, a year, say. The rate of interest will not necessarily be the same for each period, and generally the longer the time that the money is tied up the higher the rate of interest, although this is not always the case. Often, if you want to have immediate access to your money then you will be exposed to interest rates that will change from time to time, since interest rates are not constant.

These two types of interest payments, **fixed** and **floating**, are seen in many financial instruments. **Coupon-bearing bonds** pay out a known amount every six months or year etc. This is the **coupon** and would often be a fixed rate of interest. At the end of your fixed term you get a final coupon and the return of the **principal**, the amount on which the interest was calculated. **Interest rate swaps** are an exchange of a fixed rate of interest for a floating rate of interest. Governments and companies issue bonds as a form of borrowing. The less creditworthy the issuer, the higher the interest that they will have to pay out. Bonds are actively traded, with prices that continually fluctuate.

1.8 INFLATION-PROOF BONDS

A very recent addition to the list of bonds issued by the US government is the **index-linked bond**. These have been around in the UK since 1981, and have provided a very successful way of ensuring that income is not eroded by inflation.

In the UK inflation is measured by the **Retail Price Index** or **RPI**. This index is a measure of year-on-year inflation, using a 'basket' of goods and services including mortgage interest payments. The index is published monthly. The coupons and principal of the index-linked bonds are related to the level of the RPI. Roughly speaking, the amounts of the coupon and principal are scaled with the increase in the RPI over the period from the issue of the bond to the time of the payment. There is one slight complication in that the actual RPI level used in these calculations is set back *eight months*. Thus the base measurement is eight months before issue and the scaling of any coupon is with respect to the increase in the RPI from this base measurement to the level of the RPI eight months before the coupon is paid. One of the reasons for this complexity is that the initial estimate of the RPI is usually corrected at a later date.

Figure 1.15 shows the UK gilts prices published in *The Financial Times* of 11th January 2000. The index-linked bonds are on the right. The figures in parentheses give the base for the index, the RPI eight months prior to the issue of the gilt.

In the US the inflation index is the **Consumer Price Index** (**CPI**). A time series of this index is shown in Figure 1.16.

UK GILTS PRICES

	Notes	... Yield ... Int	Red	Price £	+ or –	... 52 week ... High	Low
Shorts" (Lives up to Five Years)							
Treas 8½pc 2000	✠	8.49	5.54	100.13	......	103.51	100.13
Conv 9pc 2000		8.96	5.56	100.47	–.01	104.36	100.40
Treas 13pc 2000		12.57	6.03	103.44xd	–.01	111.61	103.44
Treas 8pc 2000		7.89	6.35	101.42	+.01	105.82	101.41
Treas Fltg Rate 2001		–	0.24	100.16	......	100.81	100.11
Treas 10pc 2001		9.63	6.43	103.80	+.02	110.36	103.77
Conv 9½pc 2001	✠	9.11	6.43	104.33xd	+.03	110.88	104.28
Conv 9¾pc 2001	✠	9.29	6.43	104.91	+.03	111.79	104.85
Treas 7pc 2001		6.94	6.44	100.93	+.08	106.51	100.75
Conv 10pc 2002	✠	9.34	6.57	107.04	+.11	116.41	106.82
Treas 7pc 2002		6.92	6.45	101.19	+.11	108.13	100.95
Conv 9½pc 2002	✠	8.92	6.57	106.45	+.12	115.64	106.21
Treas 9¾pc 2002		9.07	6.57	107.54	+.13	117.29	107.28
Exch 9pc 2002	✠	8.47	6.57	106.21	+.14	115.62	105.92
Conv 9¾pc 2003	✠	8.92	6.57	109.33	+.17	120.19	108.99
Treas 8pc 2003		7.64	6.42	104.78	+.17	114.74	104.45
Treas 10pc 2003		8.98	6.46	111.34	+.19	123.52	110.99
Treas 13¾pc 2000–3	✠	13.22	6.03	104.02xd	–.01	112.93	104.02
Treas 6½pc 2003		6.47	6.34	100.53	+.19	110.21	100.15
Treas 11½pc 2001–4		10.89	6.49	105.62	+.04	113.56	105.58
Treas 10pc 2004	✠	8.83	6.46	113.22	+.23	126.55	112.80
Five to Fifteen Years							
Treas 5pc 2004		5.25	6.24	95.28	+.23	98.80	94.53
Funding 3½pc 1999–4		3.89	6.06	90.03xd	+.19	98.95	89.66
Conv 9½pc 2004	✠	8.40	6.28	113.12	+.26	126.43	112.66
Treas 6¾pc 2004		6.61	6.22	102.19	+.25	113.28	101.39
Conv 9½pc 2005		8.30	6.23	114.46	+.27	128.16	113.68
Exch 10½pc 2005	✠	8.74	6.23	120.16	+.30	135.46	119.38
Treas 12½pc 2003–5	✠	10.39	6.46	120.32	+.21	135.55	119.85
Treas 8½pc 2005		7.63	6.16	111.41	+.32	125.31	110.35

	Notes	... Yield ... Int	Red	Price £	+ or –	... 52 week ... High	Low
Conv 9¾pc 2006	✠	8.10	6.06	120.41	+.43	136.21	119.10
Treas 7¾pc 2006		7.13	6.14	108.69	+.38	122.40	107.42
Treas 8pc 2002–6		7.75	6.66	103.29	+.12	111.73	103.05
Treas 7½pc 2006		6.95	6.08	107.89	+.40	121.62	106.44
Treas 11¾pc 2003–7	✠	10.31	6.57	114.02xd	+.16	126.29	113.72
Treas 8½pc 2007		7.42	6.06	114.56xd	+.45	129.86	112.98
Treas 7¼pc 2007		6.72	5.98	107.93	+.46	122.55	106.17
Treas 13½pc 2004–8	✠	10.67	6.22	126.56	+.24	142.61	126.15
Treas 9pc 2008		7.46	5.94	120.68	+.55	138.52	118.77
Treas 8pc 2009	✠	6.86	5.73	116.70	+.55	132.91	114.73
Treas 5¾pc 2009		5.70	5.63	100.93	+.58	114.67	99.10
Treas 6¼pc 2010		5.92	5.57	105.51	+.59	118.76	103.35
Conv 9pc Ln 2011		6.99	5.58	128.75	+.69	145.31	126.38
Treas 9pc 2012		6.85	5.50	131.48	+.75	147.74	128.45
Treas 5½pc 2008–12		5.63	5.76	97.70	+.39	112.26	95.68
Treas 8pc 2013		6.34	5.29	126.13	+.60	139.64	122.43
Treas 7¾pc 2012–15		6.54	5.61	118.59	+.64	133.56	116.18
Over Fifteen Years							
Treas 8pc 2015		6.05	5.04	132.13	+.81	144.12	127.70
Treas 8¾pc 2017		6.03	4.90	145.04	+1.00	156.08	139.82
Exch 12pc 2013–17	✠	7.44	5.60	161.31	+.96	183.80	158.27
Treas 8pc 2021		5.57	4.73	143.69	+1.45	153.21	137.64
Treas 6pc 2028		4.84	4.50	124.06	+1.55	132.62	116.63
Undated							
Consols 4pc	✠	5.03	–	79.50	+1.30	87.19	73.95
War Loan 3½pc		4.82	–	72.66	+1.17	79.83	67.14
Conv 3½pc '61 Aft.	✠	4.13	–	84.66	+1.17	95.68	79.14
Treas 3pc '66 Aft.	✠	5.38	–	55.72	+.80	61.93	51.78
Consols 2½pc	✠	4.93	–	50.67	+.79	56.93	46.78
Treas. 2½pc		4.96	–	50.41	+.51	55.17	46.70

	Notes	... Yield ... (1)	(2)	Price £	+ or –	... 52 week ... High	Low
Index-Linked	(b)						
2½pc '01	(78.3)	3.72	4.35	203.28	+.09	206.02	201.90
2½pc '03	(78.8)	3.17	3.48	201.96	+.18	207.83	201.24
4⅜pc '04	(135.6)	2.70	2.93	128.72	+.13	134.77	127.26
2pc '06	(69.5)	1.85	2.02	235.96xd	+.29	239.80	230.16
2½pc '09	(78.8)	1.85	1.97	217.78	+.39	221.45	208.87
2½pc '11	(74.6)	1.96	2.06	229.97	+.62	235.62	219.11
2½pc '13	(89.2)	1.94	2.03	194.34	+.66	199.07	183.57
2½pc '16	(81.6)	1.91	1.99	215.37	+.67	221.10	203.03
2½pc '20	(83.0)	1.83	1.89	218.00	+.88	221.68	203.17
2½pc '24	(97.7)	1.72	1.78	192.00xd	+.88	195.05	176.32
4⅛pc '30	(135.1)	1.65	1.70	191.40xd	+.78	194.33	174.35

Prospective real redemption rate on projected inflation of (1) 5% and (2) 3%. (b) Figures in parentheses show RPI base for indexing (ie 8 months prior to issue) and have been adjusted to reflect rebasing of RPI to 100 in February 1987. Conversion factor 3.945. RPI for April 1999: 165.2 and for November1999: 166.7.

Other Fixed Interest

	Notes	... Yield ... Int	Red	Price £	+ or –	... 52 week ... High	Low
Asian Dev 10¼pc 2009		8.23	6.60	124½	......	140 31/32	124½
B'ham 11½pc 2012		8.04	6.40	143	......	158¾	142
Leeds 13½pc 2006		9.93	6.80	136	......	152	136
Liverpool 3½pc Irred.		5.38	5.40	65	......	73	55
LCC 3pc '20 Aft.		5.33	5.30	56¼	......	64	50
Manchester 11½pc 2007		8.97	6.70	128¼	......	151¾	128¼
Met. Wtr. 3pc 'B'		3.33	6.40	90	......	93⅛	85
N'wide Anglia 3⅞pc IL 2021		–	2.90	196¾	......	200½	174 31/32
4¼pc IL 2024		–	2.90	192½	......	196¾	169

● 'Tap' stock. All UK Gilts are tax-free to non-residents on application. E Auction basis. xd Ex dividend. Closing mid-prices are shown in pounds per £100 nominal of stock. Prospective real Index-Linked redemption yields are calculated by HSBC Bank plc from Gemma closing prices. ✠ Indicative price.

Figure 1.15 UK gilts prices from *The Financial Times* of 11th January 2000. Reproduced by permission of *The Financial Times*.

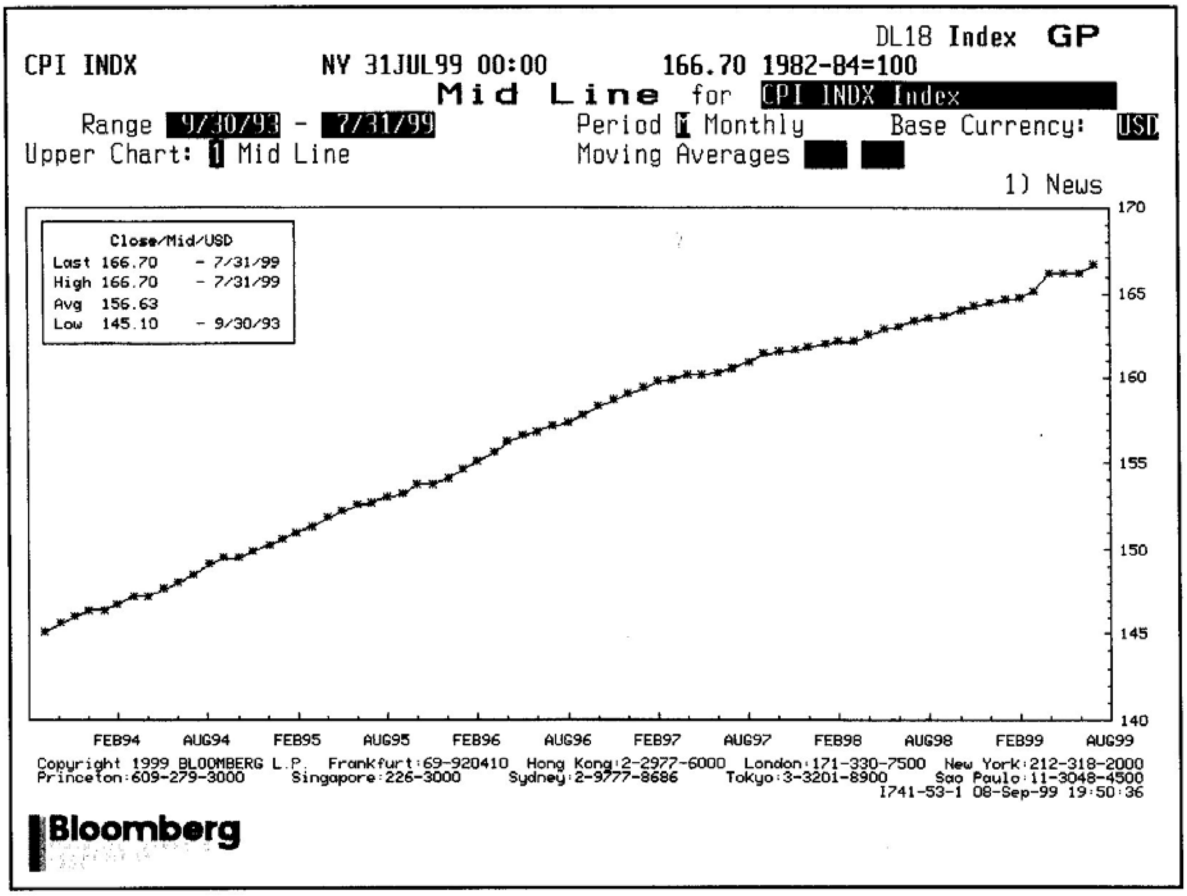
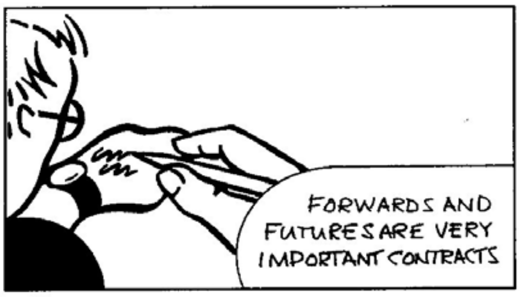


Figure 1.16 The CPI index. Source: Bloomberg L.P.

I will not pursue the modeling of inflation or index-linked bonds in this book. I would just like to say that the dynamics of the relationship between inflation and short-term interest rates is particularly interesting. Clearly the level of interest rates will affect the rate of inflation directly through mortgage repayments, but also interest rates are often used by central banks as a tool for keeping inflation down.

1.9 FORWARDS AND FUTURES



A **forward contract** is an agreement where one party promises to buy an asset from another party at some specified time in the future and at some specified price. No money changes hands until the **delivery date** or **maturity** of the contract. The terms of the contract make it an obligation to buy the asset at the delivery date, there is no choice in the matter. The asset could be a stock, a commodity or a currency.

The amount that is paid for the asset at the delivery date is called the **delivery price**. This price is set at the time that the forward contract is entered into, at an amount that gives the forward contract a value of zero initially. As we approach maturity the value of *this particular forward contract* that we hold will change in value, from initially zero to, at maturity, the difference between the underlying asset and the delivery price.

In the newspapers we will also see quoted the **forward price** for different maturities. These prices are the delivery prices for forward contracts of the quoted maturities, should we enter into such a contract *now*.

Try and distinguish between the value of a particular contract during its life, and the specification of the delivery price at initiation of the contract. It's all very subtle. You might think that the forward price is the market's view on the asset value at maturity, but this is not quite true as we'll see shortly. In theory, the market's expectation about the value of the asset at maturity of the contract is irrelevant.

A **futures contract** is very similar to a forward contract. Futures contracts are usually traded through an exchange, which standardizes the terms of the contracts. The profit or loss from the futures position is calculated every day and the change in this value is paid from one party to the other. Thus with futures contracts there is a gradual payment of funds from initiation until maturity.

Because you settle the change in value on a daily basis, the value of a futures contract at any time during its life is zero. The futures price varies from day to day, but must at maturity be the same as the asset that you are buying.

I'll show later that, provided interest rates are known in advance, forward prices and futures prices of the same maturity must be identical.

Forwards and futures have two main uses, in speculation and in hedging. If you believe that the market will rise you can benefit from this by entering into a forward or futures contract. If your market view is right then a lot of money will change hands (at maturity or every day) in your favor. That is speculation and is very risky. Hedging is the opposite, it is avoidance of risk. For example, if you are expecting to get paid in yen in six months' time, but you live in America and your expenses are all in dollars, then you could enter into a futures contract to lock in a guaranteed exchange rate for the amount of your yen income. Once this exchange rate is locked in you are no longer exposed to fluctuations in the dollar/yen exchange rate. But then you won't benefit if the yen appreciates.

1.9.1 A first example of no arbitrage

Although I won't be discussing futures and forwards very much they do provide us with our first example of the **no-arbitrage** principle. I am going to introduce some more mathematical notation now, it will be fairly consistent throughout the book. Consider a forward contract that obliges us to hand over an amount $\$F$ at time T to receive the underlying asset. Today's date is t and the price of the asset is currently $\$S(t)$, this is the **spot price**, the amount for which we could get immediate delivery of the asset. When we get to maturity we will hand over the amount $\$F$ and receive the asset, then worth $\$S(T)$. How much profit we make cannot be known until we know the value $\$S(T)$, and we can't know this until time T. From now on I am going to drop the '\$' sign from in front of monetary amounts.

We know all of F, $S(t)$, t and T, is there any relationship between them? You might think not, since the forward contract entitles us to receive an amount $S(T) - F$ at expiry and this is unknown. However, by entering into a special portfolio of trades *now* we can eliminate all randomness in the future. This is done as follows.

Enter into the forward contract. This costs us nothing up front but exposes us to the uncertainty in the value of the asset at maturity. Simultaneously sell the asset. It is called **going short** when you sell something you don't own. This is possible in many markets, but with some timing restrictions. We now have an amount $S(t)$ in cash due to the sale of the asset, a forward contract, and a short asset position. But our net position is zero. Put the cash in the bank, to receive interest.

When we get to maturity we hand over the amount F and receive the asset. This cancels our short asset position regardless of the value of $S(T)$. At maturity we are left with a guaranteed $-F$ in cash as well as the bank account. The word 'guaranteed' is important because it emphasizes that it is independent of the value of the asset. The bank account contains the initial investment of an amount $S(t)$ with added interest, this has a value at maturity of

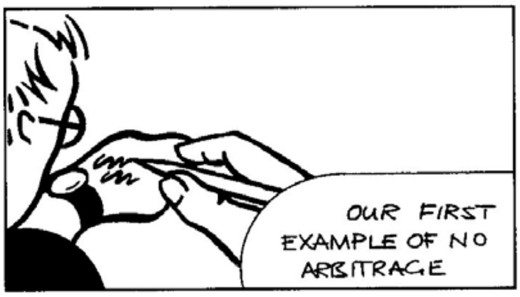
$$S(t)e^{r(T-t)}.$$

Our net position at maturity is therefore

$$S(t)e^{r(T-t)} - F.$$

Since we began with a portfolio worth zero and we end up with a predictable amount, that predictable amount should also be zero. We can conclude that

$$F = S(t)e^{r(T-t)}. \quad (1.3)$$



This is the relationship between the spot price and the forward price. It is a linear relationship, the forward price is proportional to the spot price.

The cashflows in this special hedged portfolio are shown in Table 1.1.

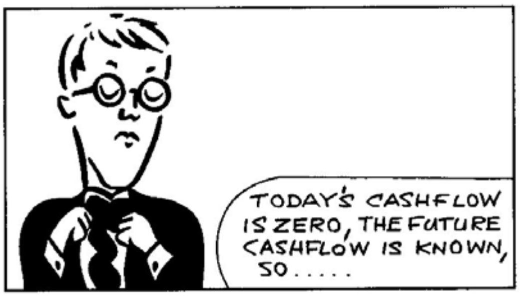


Table 1.1 Cashflows in a hedged portfolio of asset and forward.

Holding	**Worth today (t)**	**Worth at maturity (T)**
Forward	0	$S(T) - F$
–Stock	$-S(t)$	$-S(T)$
Cash	$S(t)$	$S(t)e^{r(T-t)}$
Total	0	$S(t)e^{r(T-t)} - F$

Time Out...

No arbitrage again

Example: The spot asset price S is 28.75, the one-year forward price F is 30.20 and the one-year interest rate is 4.92%. Are these numbers consistent with no arbitrage?

$$F - Se^{r(T-t)} = 30.20 - 28.75e^{0.0492\times 1} = 0.0001.$$

This is effectively zero to the number of decimal places quoted.

If we know any three out of S, F, r and $T-t$ we can find the fourth, assuming there are no arbitrage possibilities. Note that the forward price in no way depends on what the asset price is expected to do, whether it is expected to increase or decrease in value.

In Figure 1.17 is a path taken by the spot asset price and its forward price. As long as interest rates are constant, these two are related by (1.3).

If this relationship is violated then there will be an arbitrage opportunity. To see what is meant by this, imagine that F is less than $S(t)e^{r(T-t)}$. To exploit this and make a riskless arbitrage profit, enter into the deals as explained above. At maturity you will have $S(t)e^{r(T-t)}$ in the bank, a short asset and a long forward. The asset position cancels when

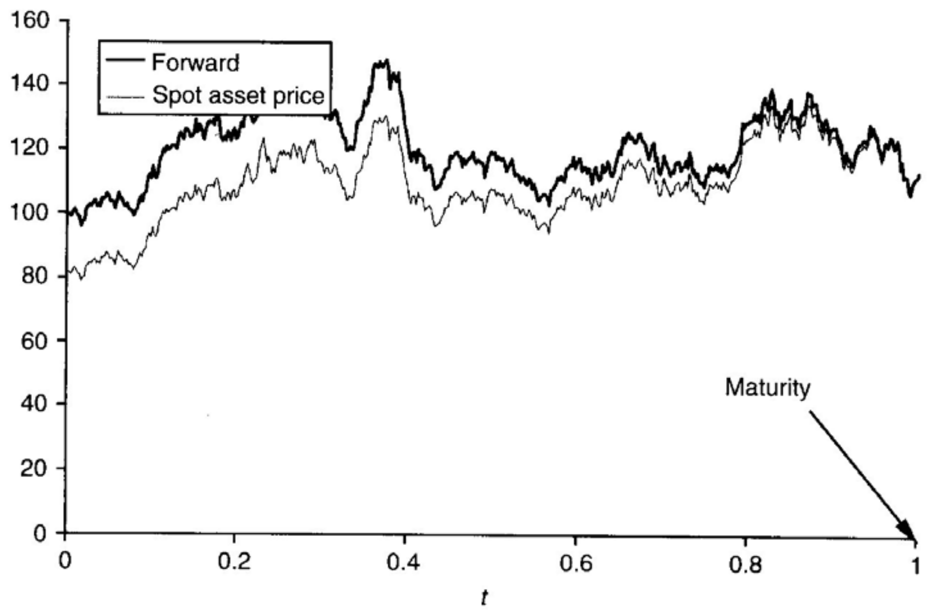


Figure 1.17 A time series of a spot asset price and its forward price.

you hand over the amount F, leaving you with a profit of $S(t)e^{r(T-t)} - F$. If F is greater than that given by (1.3) then you enter into the opposite position, going short the forward. Again you make a riskless profit. The standard economic argument then says that investors will act quickly to exploit the opportunity, and in the process prices will adjust to eliminate it.

1.10 MORE ABOUT FUTURES

Futures are usually traded through an exchange. This means that they are very liquid instruments and have lots of rules and regulations surrounding them. Here are a few observations on the nature of futures contracts.

Available assets A futures contract will specify the asset which is being invested in. This is particularly interesting when the asset is a natural commodity because of nonuniformity in the type and quality of the asset to be delivered. Most commodities come in a variety of grades. Oil, sugar, orange juice, wheat etc. futures contracts lay down rules for precisely what grade of oil, sugar, etc. may be delivered. This idea even applies in some financial futures contracts. For example, bond futures may allow a range of bonds to be delivered. Since the holder of the short position gets to choose which bond to deliver he naturally chooses the cheapest.

The contract also specifies how many of each asset must be delivered. The quantity will depend on the market.

Delivery and settlement The futures contract will specify when the asset is to be delivered. There may be some leeway in the precise delivery date. Most futures contracts are closed out before delivery, with the trader taking the opposite position before maturity. But if the position is not closed then delivery of the asset is made. When the asset is another financial contract, settlement is usually made in cash.

Margin I said above that changes in the value of futures contracts are settled each day. This is called **marking to market**. To reduce the likelihood of one party defaulting, being unable or unwilling to pay up, the exchanges insist on traders depositing a sum of money to cover changes in the value of their positions. This money is deposited in a **margin account**. As the position is marked to market daily, money is deposited or withdrawn from this margin account.

Margin comes in two forms, the **initial margin** and the **maintenance margin**. The initial margin is the amount deposited at the initiation of the contract. The total amount held as margin must stay above a prescribed maintenance margin. If it ever falls below this level then more money (or equivalent in bonds, stocks etc.) must be deposited. The levels of these margins vary from market to market.

Margin has been much neglected in the academic literature. But a poor understanding of the subject has led to a number of famous financial disasters, most notably Metallgesellschaft and Long-Term Capital Management. We'll discuss the details of these cases in Chapter 24, and we'll also be seeing how to model margin and how to margin hedge.

1.10.1 Commodity futures

Futures on commodities don't necessarily obey the no-arbitrage law that led to the asset/future price relationship explained above. This is because of the messy topic of storage. Sometimes we can only reliably find an upper bound for the futures price. Will the futures price be higher or lower than the theoretical no-storage-cost amount? Higher. The holder of the futures contract must compensate the holder of the commodity for his storage costs. This can be expressed in percentage terms by an adjustment s to the risk-free rate of interest.

But things are not quite so simple. Most people actually holding the commodity are benefiting from it in some way. If it is something consumable, such as oil, then the holder can benefit from it immediately in whatever production process they are engaged in. They are naturally reluctant to part with it on the basis of some dodgy theoretical financial calculation. This brings the futures price back down. The benefit from holding the commodity is commonly measured in terms of the **convenience yield** c:

$$F = S(t)e^{(r+s-c)(T-t)}.$$

Observe how the storage cost and the convenience yield act in opposite directions on the price. Whenever

$$F < S(t)e^{r(T-t)}$$

the market is said to be in **backwardation**. Whenever

$$F > S(t)e^{r(T-t)}$$

the market is in **contango**.

1.10.2 FX futures

There are no problems associated with storage when the asset is a currency. We need to modify the no-arb. result to allow for interest received on the foreign currency r_f. The result is

$$F = S(t)e^{(r-r_f)(T-t)}.$$

The confirmation of this is an easy exercise.

1.10.3 Index futures

Futures contracts on stock indices are settled in cash. Again, there are no storage problems, but now we have dividends to contend with. Dividends play a role similar to that of a foreign interest rate on FX futures. So

$$F = S(t)e^{(r-q)(T-t)}.$$

Here q is the dividend yield. This is clearly an approximation. Each stock in an index receives a dividend at discrete intervals, but can these all be approximated by one continuous dividend yield?

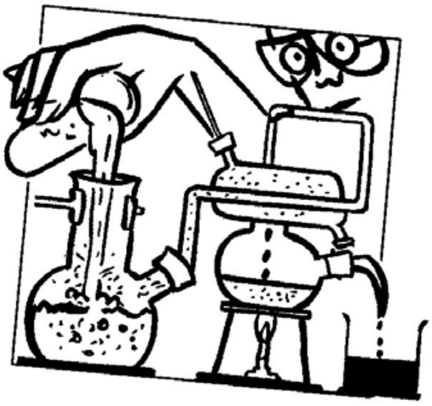
1.11 SUMMARY

The above descriptions of financial markets are enough for this introductory chapter. Perhaps the most important point to take away with you is the idea of no arbitrage. In the example here, relating spot prices to futures prices, we saw how we could set up a very simple portfolio which completely eliminated any dependence on the future value of the stock. When we come to value derivatives, in the way we just valued a forward, we will see that the same principle can be applied albeit in a far more sophisticated way.

FURTHER READING

- For general financial news visit `www.bloomberg.com` and `www.reuters.com`. CNN has online financial news at `www.cnnfn.com`. There are also online editions of *The Wall Street Journal*, `www.wsj.com`, *The Financial Times*, `www.ft.com` and *Futures and Options World*, `www.fow.com`.
- For more information about futures see the Chicago Board of Trade website `www.cbot.com`.
- Many, many financial links can be found at Wahoo!, `www.io.com/~gibbonsb/wahoo.html`.
- See Bloch (1995) for an empirical analysis of inflation data and a theoretical discussion of pricing index-linked bonds.
- In the main, we'll be assuming that markets are random. For insight about alternative hypotheses see Schwager (1990, 1992).
- See Brooks (1967) for how the raising of capital for a business might work in practice.
- Cox, Ingersoll & Ross (1981) discuss the relationship between forward and future prices.

CHAPTER 2
derivatives



The aim of this Chapter...

... is to describe the basic forms of option contracts, make the reader comfortable with the jargon, explain the relevant pages of financial newspapers, give a basic understanding of the purpose of options, and to expand on the 'no free lunch,' or no-arbitrage, idea. By the end of the chapter you will be familiar with the most common forms of derivatives.

In this Chapter...

- the definitions of basic derivative instruments
- option jargon
- no arbitrage and put-call parity
- how to draw payoff diagrams
- simple option strategies

2.1 INTRODUCTION

The previous chapter dealt with some of the basics of financial markets. I didn't go into any detail, just giving the barest outline and setting the scene for this chapter. Here I introduce the theme that is central to the book, the subject of options, a.k.a. derivatives or contingent claims. This chapter is nontechnical, being a description of some of the most common option contracts, and an explanation of the market-standard jargon. It is in later chapters that I start to get technical.

Options have been around for many years, but it was only on 26th April 1973 that they were first traded on an exchange. It was then that The Chicago Board Options Exchange (CBOE) first created standardized, listed options. Initially there were just calls on 16 stocks. Puts weren't even introduced until 1977. In the US options are traded on CBOE, the American Stock Exchange, the Pacific Stock Exchange and the Philadelphia Stock Exchange. Worldwide, there are over 50 exchanges on which options are traded.

2.2 OPTIONS

If you are reading the book in a linear fashion, from start to finish, then the last topics you read about will have been futures and forwards. The holder of future or forward contracts is *obliged* to trade at the maturity of the contract. Unless the position is closed before maturity the holder must take possession of the commodity, currency or whatever is the subject of the contract, regardless of whether the asset has risen or fallen. Wouldn't it be nice if we only had to take possession of the asset if it had risen?

The simplest **option** gives the holder the *right* to trade in the future at a previously agreed price but takes away the obligation. So if the stock falls, we don't have to buy it after all.

> A **call option** is the right to buy a particular asset for an agreed amount at a specified time in the future

As an example, consider the following call option on Iomega stock. It gives the holder the right to buy one of Iomega stock for an amount $25 in one month's time. Today's stock price is $24.5. The amount '25' which we can pay for the stock is called the **exercise price** or **strike price**. The date on which we must **exercise** our option, if we decide to, is called the **expiry** or **expiration date**. The stock on which the option is based is known as the **underlying asset**.

Let's consider what may happen over the next month, up until expiry. Suppose that nothing happens, that the stock price remains at $24.5. What do we do at expiry? We could exercise the option, handing over $25 to receive the stock. Would that be sensible? No, because the stock is only worth $24.5, either we wouldn't exercise the option or if we really wanted the stock we would buy it in the stock market for the $24.5. But what if the stock price rises to $29? Then we'd be laughing, we would exercise the option, paying $25 for a stock that's worth $29, a profit of $4.

We would exercise the option at expiry if the stock is above the strike and not if it is below. If we use S to mean the stock price and E the strike then at expiry the option is worth

$$\max(S - E, 0).$$

This function of the underlying asset is called the **payoff function**. The 'max' function represents the optionality.

Why would we buy such an option? Clearly, if you own a call option you want the stock to rise as much as possible. The higher the stock price the greater will be your profit. I will discuss this below, but our decision whether to buy it will depend on how much it costs; the option is valuable, there is no downside to it unlike a future. In our example the option was valued at $1.875. Where did this number come from? The valuation of options is one of the subjects of this book, and I'll be showing you how to find this value later on.

What if you believe that the stock is going to fall, is there a contract that you can buy to benefit from the fall in a stock price?

> A **put option** is the right to *sell* a particular asset for an agreed amount at a specified time in the future

The holder of a put option wants the stock price to fall so that he can sell the asset for more than it is worth. The payoff function for a put option is

$$\max(E - S, 0).$$

Now the option is only exercised if the stock falls below the strike price.

Figure 2.1 is an excerpt from *The Wall Street Journal Europe* of 5th January 2000 showing options on various stocks. The table lists closing prices of the underlying stocks and the last traded prices of the options on the stocks. To understand how to read this let us examine the prices of options on Gateway. Go to 'Gateway' in the list. The closing price on 4th January was $65.5, and is written beneath 'Gateway' several times. Calls and puts are quoted here with strikes of $60 and $65, others may exist but are not mentioned in the newspaper for want of space. The available expiries are January and March. Part of the information included here is the volume of the transactions in each series, we won't worry about that but some people use option volume as a trading indicator. From the data, we can see that the January calls with a strike of $60 were worth $6.875. The puts with same strike and expiry were worth $2. The March calls with a strike of $60 were worth $10.5 and the puts with same strike and expiry were worth $6. Note that the higher the strike, the lower the value of the calls but the higher the value of the puts. This makes sense when you remember that the call allows you to buy the underlying for the strike, so that the lower the strike price the more this right is worth to you. The opposite is true for a put since it allows you to sell the underlying for the strike price.

There are more strikes and expiries available for options on indices, so let's now look at the Index Options section of *The Wall Street Journal Europe* 5th January 2000, this is shown in Figure 2.2.

U.S. LISTED OPTIONS QUOTATIONS

Tuesday, January 4, 2000

Volume and close for actively traded equity options with results for corresponding put or call contract as of 3 p.m. Volume figures are unofficial. Open interest is total outstanding for all exchanges and reflects previous trading day. Close when possible is shown for the underlying stock on primary market. CB-Chicago Board Options Exchange. AM-American Stock Exchange. PB-Philadelphia Stock Exchange. PC-Pacific Stock Exchange. NY-New York Stock Exchange. XC-Composite. c-Call. p-Put.

MOST ACTIVE CONTRACTS

Option	Strike		Vol.	Exch.	Last	Net Chg	3 pm Close	Open Int.
Micsft	Jan	100	p 13,675	XC	9/16	+ 1/16	115 3/8	109,572
Disney	Jan	27 1/2	13,388	XC	3 7/8	+ 1 5/16	31 1/16	95,848
AmOnline	Jan	80	11,888	XC	5 1/8	− 2 1/4	78 1/2	211,536
Micsft	Jan	90	p 10,448	XC	3/16	...	115 3/8	140,712
Intel	Jan	70	p 9,805	XC	7/16	+ 1/16	85 3/8	158,564
DellCptr	Jan	45	p 8,784	XC	1 1/8	+ 1/2	48	81,720
Disney	Feb	30	6,982	XC	2 9/16	+ 13/16	31 1/16	4,152
Intel	Jan	90	6,457	XC	2 3/16	− 7/16	85 3/8	148,840
Cisco	Jan	90	p 6,344	XC	3/4	+ 1/4	104 3/16	53,396
Bk of Am	Jan	47 1/2	6,196	XC	1 3/8	− 1 5/16	45 5/16	16,968
Compaq	Jan	30	6,161	XC	1 3/8	− 11/16	28 13/16	256,144
Intel	Jan	80	6,053	XC	7 1/2	− 1 1/8	85 3/8	169,968
Qualcom	Jan	77 1/2	p 6,049	XC	1/16	...	162 3/8	31,856
AmOnline	Jan	90	6,039	XC	2 1/8	− 1 1/4	78 1/2	211,516
Yahoo	Jan 02	135	p 6,002	XC	6 1/8	− 1	481	160
Yahoo	Jan	450	5,857	XC	66	+ 2 1/8	481	27,424
Disney	Jan	30	p 5,619	XC	9/16	− 9/16	31 1/16	32,984
AmOnline	Jan	100	5,383	XC	1 1/16	− 7/16	78 1/2	261,988
Micsft	Jan	125	5,052	XC	1 1/16	− 3/16	115 3/8	65,676
CBS Cp	Feb	60	5,010	XC	2 5/16	− 1 13/16	57	2,211
DellCptr	Feb	45	p 4,772	XC	2 1/2	+ 3/4	48	46,540
Intel	Jan	85	4,571	XC	4 1/2	− 5/8	85 3/8	148,724
CMGI Inc	Jan	320	4,504	XC	28	− 11	307	16,305
Atl R	Feb	85	4,500	XC	4 3/4	− 2 1/4	80 5/8	740
DellCptr	Jan	50	4,456	XC	1 1/2	− 1 3/8	48	187,664
Cmpuwr	Jan	30	4,385	XC	6 7/8	− 1/8	36 9/16	15,858
MCI Wrld	Jan	46 5/8	p 4,332	XC	1	+ 1/4	80	49,432
Compaq	Apr	20	4,227	XC	10	− 3/4	28 13/16	52,660
Caterp	Aug	50	4,154	XC	6	+ 1	48 7/8	240
Disney	Jan	30	4,004	XC	1 13/16	+ 13/16	31 1/16	100,672
Citigrp	Jan	55	3,907	XC	1/2	− 9/16	50 1/16	87,340
LoralSp	Feb	22 1/2	3,811	XC	2 3/8	+ 3/16	22	777
Cendant	Feb	25	3,797	XC	1 7/16	− 7/16	23 3/4	64,845
Intel	Jan	95	3,706	XC	1	− 3/16	85 3/8	70,272
GMagic	Feb	5	3,687	XC	1 5/8	+ 1	5	156,147
Compaq	Feb	30	3,647	XC	2 3/8	− 5/8	28 13/16	34,532
DellCptr	Jan	55	3,610	XC	7/16	− 5/8	48	133,160
SunMicro	Apr	45	p 3,572	XC	1	+ 1/16	73	92,732
ETradeGr	Jan	30	3,564	XC	2	− 1/16	28 5/16	78,180
MerrLyn	Jan	80	3,534	XC	2 5/8	− 1 3/8	77 1/8	48,848

Option	Strike	Exp.	-Call- Vol.	-Call- 3 pm	-Put- Vol.	-Put- 3pm
ACTV	35	Jan	186	5 3/8	2503	2 3/16
38 5/8	45	Jan	92	1 1/4	2380	8 1/2
AT&T	45	Jan	1144	7	95	1/4
51 13/16	50	Jan	147	2 7/8	596	1 1/16
51 13/16	55	Jan	665	13/16	185	4 1/8
Abbt L	35	May	1725	3	3	3 1/4
A M D	15	Jan	14	14 3/4	500	1/16
29 5/8	25	Jan	1868	5 1/2	143	15/16
29 5/8	25	Feb	1720	6 3/4	10	1 5/8
29 5/8	30	Jan	1557	2 11/16	356	2 13/16
AdvRdio	22 1/2	Feb	485	1 11/16	...	...
Alcatl	35	Jan	...	...	600	3/8
AlterraHl	5	Feb	...	...	500	5/8
6	7 1/2	Feb	350	5/16	500	2 1/4
Amazon	65	Jan	66	20 3/4	785	1 3/4
86	80	Jan	385	10 1/2	626	6 3/8
86	85	Jan	1203	8 1/8	295	8 1/4
86	90	Jan	1331	6	316	12
86	95	Jan	685	4 1/2	10	12
86	95	Jul	21	20 1/2	500	26 1/8
86	100	Jan	1043	3	131	18 5/8
AmOnline	57 1/2	Jan	5	21 5/8	580	1/2
78 1/2	65	Jan	118	14 3/4	702	1 1/4
78 1/2	70	Jan	847	11	1810	2 5/16
78 1/2	75	Jan	2564	7 1/2	1113	4
78 1/2	75	Feb	808	11 1/8	208	7
108 1/16	100	Jan	1023	10 3/8	415	2 1/2
108 1/16	105	Jan	520	6 7/8	224	4 1/4
Enron	40	Feb	1006	3 1/2	...	...
41 7/16	45	Apr	533	2 3/4	...	...
Equant	115	Jan	715	5 1/4	...	...
EricTel	60	Jan	573	6 1/4	1315	1 1/2
65 1/8	65	Feb	517	5 1/2	605	5 5/8
65 1/8	65	Apr	525	8 3/4	527	7 1/2
eToys	25	Jan	200	3 7/8	578	2 11/16
26 3/8	35	Jan	883	15/16	20	9 5/8
26 3/8	40	Jan	528	1/2	2	13 1/2
ExodsCm	90	Jan	504	8 3/8	64	9 3/4
87 5/16	95	Feb	558	10 5/8	...	...
Exxon	70	Apr	500	9 3/8	10	1 1/2
FEMSA	40	Jul	8	8 7/8	1000	4 5/8
F N M	50	Jan	837	7 3/8	225	3/8
FUnion	30	Feb	1819	2 1/2	193	1 1/2
30 11/16	35	Feb	1749	3/4	22	4 5/8
Firstar	20	Jan	2460	15/16	20	1 1/16
Gateway	50	Mar	...	...	520	2 1/2
65 1/2	60	Jan	46	6 7/8	573	2
65 1/2	60	Mar	25	10 1/2	533	6
65 1/2	65	Jan	2354	3 5/8	516	4 1/4
Gen El	135	Jan	62	11 7/8	1137	1 1/8
145 3/4	140	Jan	503	8 1/8	873	2 1/4
145 3/4	145	Jan	884	[illegible]	479	4
92 1/2	95	Jan	...	...	700	5
OceanEgy	7 1/2	Feb	1010	3/4	...	...
Oracle o	30	Mar	1510	87	...	...
Oracle	70	Jan	58	39 1/2	565	1/8
108	75	Jan	53	33 1/2	1254	5/16
108	115	Mar	563	12 7/8	127	17 7/8
108	120	Jan	2574	4	81	14 1/2
108	120	Feb	504	8	7	18 1/8
PRI Auto	65	Feb	500	7 1/8	...	...
ParmTc	20	Jan	1011	1 7/8	701	1 3/4
19 3/8	22 1/2	Jan	2147	13/16	29	3 7/8
19 3/8	25	Feb	689	1 1/4	206	5 1/8
19 3/8	35	Feb	2140	5/16	...	...
PepsiCo	32 1/2	Apr	...	...	507	7/8
36 5/16	37 1/2	Jan	697	1/2	85	7/16
PetrlGeo	20	Feb	...	...	550	3 5/8
Pfizer	30	Jan	438	1 3/4	546	3/4
31	30	Feb	161	2 1/2	818	1 3/8
31	30	Jun	63	4	1238	2 9/16
31	35	Jan	733	1/4	92	4 1/4
31	35	Feb	498	5/8	6	4 3/8
31	35	Mar	497	1 1/16	1037	4 7/8
Ph Mor	25	Jan	717	9/16	1307	1 3/4
23 7/8	25	Feb	1051	1 7/16	110	2 9/16
23 7/8	25	Mar	275	2 1/16	1130	3 1/4

Figure 2.1 The *Wall Street Journal Europe* of 5th January 2000, Stock Options. Reproduced by permission of Dow Jones & Company, Inc.

INDEX OPTIONS TRADING

Tuesday, January 4, 2000

Volume, close, net change and open interest for all contracts. Volume figures are unofficial. Open interest reflects previous trading day. p-Put. c-Call. The totals for call and put volume and open interest are midday figures.

CHICAGO

CB MEXICO INDEX(MEX)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Jun	90	c	5	19 3/8	− 1 3/8	13
Mar	110	c	10	4 1/4	− 1 1/8	46
Call Vol.			15	Open Int.		116
Put Vol.			0	Open Int.		338

CB TECHNOLOGY(TXX)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Jan	650	p	10	1/8	− 6 1/8	26
Feb	820	p	10	8 1/8	+ 1 3/8	10
Feb	900	p	60	17 1/4	+ 3 1/2	30
Call Vol.			0	Open Int.		319
Put Vol.			80	Open Int.		381

DJ INDUS AVG(DJX)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Jan	90	p	540	1/16	...	9,881
Jan	92	p	180	1/16	...	1,546
Feb	92	p	150	3/16	...	150
Mar	92	c	1	21 1/2	− 1	1
Jun	92	p	5	1 1/2	+ 5/16	9,117
Jan	96	p	13	1/8	+ 1/16	23,136
Feb	96	p	23	9/16	+ 1/4	1,340
Mar	96	p	50	1	+ 3/16	10,585
Jun	96	p	795	1 7/8	+ 1/4	6,974
Jan	100	p	35	5/16	+ 3/16	9,841
Feb	100	p	112	1 1/16	+ 1/4	2,983
Mar	100	c	82	13 1/4	− 3 3/4	258
Mar	100	p	15	1 3/8	+ 7/16	9,170
Jun	100	p	5	2 3/4	+ 3/4	5,023
Jan	102	p	1,088	5/16	+ 1/8	4,358
Feb	102	p	365	1 1/16	+ 1/4	1,750
Mar	102	p	30	1 13/16	+ 3/8	3,147
Jan	104	c	111	9 1/8	− 7/8	2,654
Jan	104	p	449	1/2	+ 1/4	3,671
Feb	104	p	4	1 3/16	...	227
Mar	104	c	2	10 1/4	− 1 5/8	1,051
Mar	104	p	8	1 5/8	+ 3/8	2,367
Jun	104	p	5	3 1/2	+ 3/4	1,632
Jan	105	p	1,281	3/4	+ 3/8	959
Jan	106	c	10	7 7/8	− 1	377
Jan	106	p	28	3/4	+ 3/8	1,999
Mar	106	c	8	9 3/8	− 2 1/4	783
Mar	106	p	1	2 5/16	+ 5/16	757
Jun	106	c	2	12 1/2	+ 1/8	3
Jan	108	c	23	4 1/2	− 3 5/8	618
Jan	108	p	159	1 3/8	+ 9/16	2,157
Feb	108	p	25	2 1/2	+ 5/8	272
Mar	108	c	8	7 3/8	− 3	3,594
Mar	108	p	8	3 1/8	+ 9/16	4,769
Jun	108	c	12	10 1/4	− 2 3/4	311
Jan	109	c	6	3 7/8	− 3 3/8	30
Jan	109	p	43	1 1/2	+ 11/16	689
Jan	110	c	143	2 3/4	− 3 1/8	1,519
Jan	110	p	213	1 13/16	+ 13/16	5,035
Feb	110	c	13	4 5/8	− 2	63
Feb	110	p	58	3	+ 15/16	514
Mar	110	c	34	5 7/8	− 2 5/8	7,029

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Feb	470	c	2	27 7/8	− 4	8
Feb	470	p	1	8	+ 3/8	615
Jan	480	c	15	11	− 14 3/4	19
Mar	480	p	1	15 1/2	− 1/8	2,364
Jan	485	c	2	10	− 6 7/8	9
Jan	490	c	4	9 3/8	− 1 3/4	75
Feb	490	c	86	12 3/8	− 6 3/8	219
Mar	490	c	3	23	− 2	100
Mar	490	p	3	18 1/2	+ 1/2	100
Feb	500	c	400	8 1/4	− 5	186
Feb	500	p	100	20 3/4	+ 1 1/4	195
Jan	510	c	5	2	− 2 1/4	5
Feb	510	c	10	5 3/4	− 3 1/4	21
Mar	520	c	3	6 1/2	− 3 3/4	5
Call Vol.			533	Open Int.		8,978
Put Vol.			266	Open Int.		14,765

S & P 100 INDEX(OEX)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Mar	540	p	33	1 1/8	+ 1/4	486
Jan	550	p	796	1/16	− 1/16	6,551
Jan	560	p	60	3/16	+ 1/16	1,498
Feb	560	p	10	5/8	...	272
Jan	580	p	226	1/4	+ 1/8	1,195
Feb	580	p	32	3/4	+ 1/8	231
Jan	600	p	400	3/16	...	3,531
Feb	600	c	1	187	− 17	1
Feb	600	p	14	1	+ 1/8	1,088
Jan	610	c	1	172	− 18	25
Jan	610	p	251	5/16	+ 1/16	1,200
Jan	620	p	95	3/8	+ 1/8	2,490
Feb	620	c	1	165	− 19	10
Feb	620	p	43	2	...	496
Mar	620	p	81	4 3/8	+ 1 1/8	712
Jan	630	p	29	3/8	+ 1/16	1,623
Jan	640	c	3	144	− 12 1/2	199
Jan	640	p	50	7/16	− 1/16	2,022
Feb	640	c	1	146	− 19	31
Feb	640	p	60	3 1/8	+ 3/4	838
Mar	640	p	41	5 1/8	+ 1 3/4	315
Apr	640	p	6	6 1/4	+ 1/8	32
Jan	650	p	36	9/16	− 3/16	4,315
Jan	660	p	90	1	+ 1/2	3,318
Feb	660	c	1	125	− 7 1/4	5
Feb	660	p	42	4 1/8	+ 1	1,083
Mar	660	c	4	132	− 18	59
Mar	660	p	90	7	+ 1	789
Apr	660	p	2	8 7/8	+ 2 1/8	4
Jan	670	c	18	99 1/2	− 31 1/2	137
Jan	670	p	413	1 1/4	+ 1/4	2,349
Feb	670	p	44	4 7/8	+ 7/8	125
Jan	680	c	706	102	− 7 3/8	1,309
Jan	680	p	244	1 9/16	+ 7/16	3,464
Feb	680	p	92	6	+ 2 1/8	223
Mar	680	p	76	10 1/4	+ 3 1/2	1,657
Jan	690	p	291	1 3/4	+ 3/8	4,583
Feb	690	c	4	91	− 14 1/4	11
Feb	690	p	171	6 1/2	+ 2 1/4	1,977
Jan	695	p	283	2 3/8	+ 7/8	1,415
Jan	700	c	124	73	− 18 7/8	6,023
Jan	700	p	968	2 1/4	+ 5/8	12,174
Feb	700	p	278	7 1/2	+ 2	1,305
Mar	700	p	7	10	+ 1/2	2,731
Apr	700	p	3	18 1/2	+ 5 1/2	98
Jan	705	p	245	2 5/8	+ 5/8	1,569
Jan	710	c	74	61 1/2	− 19 1/2	2,386
Jan	710	p	726	3 1/4	+ 1 3/8	7,712
Feb	710	p	6	9 3/8	+ 2 3/4	580
Jan	715	p	237	3 1/4	+ 1 1/4	3,720

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Feb	1500	c	669	12	− 12 1/4	5,484
Feb	1500	p	55	78 1/2	+ 9	116
Mar	1500	c	1,001	32 1/2	− 4 1/2	13,524
Mar	1500	p	17	83	+ 8	740
Jan	1525	c	541	3/4	− 3 1/4	5,628
Jan	1525	p	203	97	+ 16	278
Feb	1525	c	181	7 3/4	− 8 1/4	1,861
Mar	1525	c	1,606	15	− 25 1/2	7,549
Mar	1525	p	500	114	+ 28	218
Jan	1550	c	789	3/8	− 5/8	13,957
Feb	1550	c	221	3 5/8	− 4 7/8	3,059
Feb	1550	p	2	111	+ 25	77
Mar	1550	c	1,397	11	− 5 1/2	9,956
Jan	1575	c	10	3/8	+ 1/8	2,102
Feb	1575	c	6	2	− 3 5/8	1,779
Mar	1575	c	209	6 3/4	− 6	619
Mar	1575	p	10	152 1/2	+ 38 1/2	11
Feb	1600	c	155	1	− 1 7/16	1,925
Mar	1600	c	502	3 3/4	− 3 1/4	9,199
Mar	1650	c	55	1 1/4	− 1 3/4	2,052
Jan	1700	p	1	267	+ 15	373
Mar	1700	c	100	1	− 1/8	1,416
Mar	1700	p	3	264	+ 22	32
Call Vol.			36,803	Open Int.		820,987
Put Vol.			45,134	Open Int.		975,013

AMERICAN

COMP TECH(XCI)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Jan	860	p	3	16 1/4	...	...
Jan	1120	c	22	259 3/4	+ 160 1/8	22
Jan	1170	p	3	7	+ 2 7/8	3
Call Vol.			22	Open Int.		71
Put Vol.			6	Open Int.		60

JAPAN INDEX(JPN)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Mar	170	c	2	25 1/4	+ 3 3/4	651
Mar	175	c	9	21	− 1	39
Jan	180	p	30	11/16	− 1/8	125
Mar	180	c	8	17 1/2	+ 3 1/2	3,390
Jan	185	c	10	9 5/8	+ 1/8	10
Jan	185	p	10	11/16	+ 1/4	91
Feb	185	p	10	3	− 3/4	10
Mar	185	c	1	14 3/8	− 1 1/4	99
Jan	190	p	35	2 1/8	+ 1/16	145
Mar	190	c	156	10 3/4	− 1 1/2	252
Jan	195	c	1	3 5/8	− 7/8	42
Feb	195	p	35	5 3/4	− 4 1/8	39
Mar	195	c	4	8 1/4	− 1/8	101
Call Vol.			556	Open Int.		23,806
Put Vol.			120	Open Int.		7,561

MS CYCLICAL(CYC)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Jan	520	p	125	3 1/8	...	125
Feb	520	p	2,000	7 1/2	− 1/2	5,000
Feb	560	c	2,000	22	− 4	5,000
Jan	590	c	20	4 1/2	− 7 1/2	400
Call Vol.			2,020	Open Int.		12,676
Put Vol.			2,125	Open Int.		11,224

MS HITECH 35(MSH)

Strike			Vol.	3 pm Close	Net. Chg.	Open Int.
Jan	1560	c	50	310 1/4	+ 10 1/4	39
Jan	1570	c	850	303 3/4	− 36 1/4	865
Jan	1580	c	50	291 1/4	+ 23 1/2	14
Feb	1600	p	275	45	+ 10	260
Jan	1610	p	60	14 3/4	− 8 1/8	21
Jan	1630	c	4	218 3/8	− 11 7/8	3

Figure 2.2 The *Wall Street Journal Europe* of 5th January 2000, Index Options. Reproduced by permission of Dow Jones & Company, Inc.

In Figure 2.3 are the quoted prices of the March and June DJIA calls against the strike price. Also plotted is the payoff function *if the underlying were to finish at its current value at expiry*, the current closing price of the DJIA was 10997.93.

This plot reinforces the fact that the higher the strike the lower the value of a call option. It also appears that the longer time to maturity the higher the value of the call. Is it obvious that this should be so? As the time to expiry decreases what would we see happen? As there is less and less time for the underlying to move, so the option value must converge to the payoff function.

Time Out...

Plotting

When plotting using Excel you'll find it best to use the 'XY Scatter' option. This allows you to get the correct scale on the horizontal axis without any hassle. Also, don't use the smoothing option as it can give spurious wiggles in the plots.

One of the most interesting features of calls and puts is that they have a nonlinear dependence on the underlying asset. This contrasts with futures which have a linear dependence on the underlying. This nonlinearity is very important in the pricing of options, the randomness in the underlying asset and the curvature of the option value with respect to the asset are intimately related.

Calls and puts are the two simplest forms of option. For this reason they are often referred to as **vanilla** because of the ubiquity of that flavor. There are many, many more

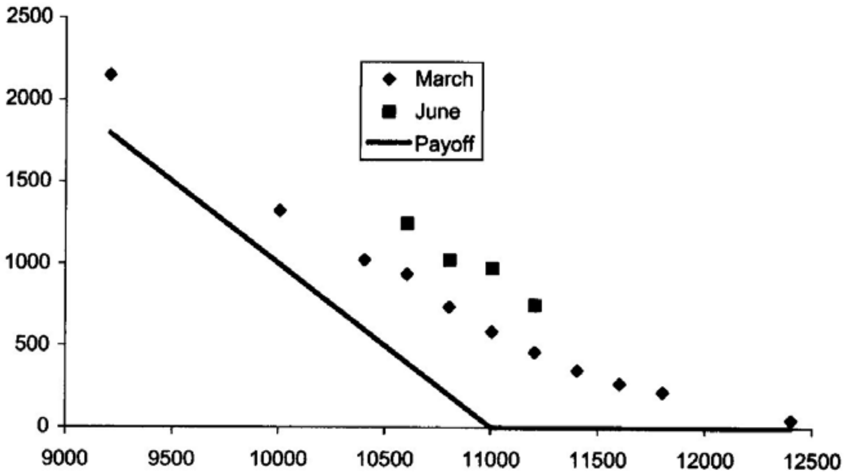
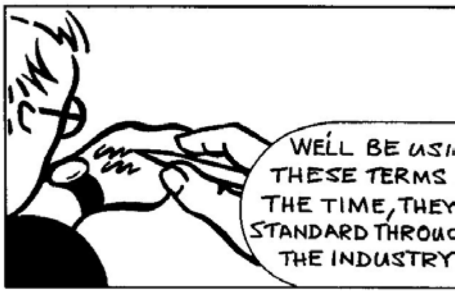


Figure 2.3 Option prices versus strike, March and June series of DJIA.

kinds of options, some of which will be described and examined later on. Other terms used to describe contracts with some dependence on a more fundamental asset are **derivatives** or **contingent claims.**

Figure 2.4 shows the prices of call options on Glaxo–Wellcome for a variety of strikes. All these options are expiring in October. The table shows many other quantities that we will be seeing later on.

2.3 DEFINITION OF COMMON TERMS



The subjects of mathematical finance and derivatives theory are filled with jargon. The jargon comes from both the mathematical world and the financial world. Generally speaking the jargon from finance is aimed at simplifying communication, and to put everyone on the same footing.[1] Here are a few loose definitions to be going on with, some you have already seen and there will be many more throughout the book.

GLXO LN GBp ↑ 1688 −13 L 5s L 1686/1689 L Trd Equity OCM
At 12:50 Vol 854,194 Op 1694 L Hi 1703 L Lo 1686 L Prev 1701
OPTION MONITOR 3 COMP Center: 1687 1 <GO> to Edit Spreadsheet

	BID m	ASK m	LAST m	1CHG m	IVBD	IVAS	BEST	DEBS	GABS	VEBS	THEO	7DEC
GLXO LN CALLS	Bid Price	Ask Price	Last Trade	1 Day Net Change	Imp Volat Bid	Imp Volat Ask	Best Price	Delta Best Price	Gamma Best Price	Vega Best Price	Theo. Value	7 Day Decay
GLXOCT99	1686.0	1689.0	1688.0	-13.0			1687					
1) 1200	489.50	504.50	509.50	unch	N.A.	69.97	504.50	.942	.0003	.674	494.09	4.6870
2) 1250	440.00	455.00	460.00	unch	N.A.	63.58	455.00	.936	.0003	.689	444.92	4.6853
3) 1300	390.50	405.50	410.50	unch	N.A.	57.36	405.50	.928	.0004	.837	396.33	4.6828
4) 1350	342.00	357.00	362.00	unch	N.A.	52.29	357.00	.915	.0005	.853	348.72	4.8888
5) 1400	294.50	309.50	314.50	unch	N.A.	48.07	309.50	.895	.0007	1.018	302.62	5.2385
6) 1450	249.00	264.00	268.50	unch	29.45	45.11	264.00	.864	.0008	1.194	258.66	5.8316
7) 1500	203.00	218.00	224.00	unch	30.67	42.27	220.00	.823	.0011	1.538	217.53	6.3538
8) 1600	125.00	137.50	136.00	-6.00	29.86	37.59	136.00	.706	.0017	2.013	146.02	7.0423
9) 1700	69.00	76.00	80.00	unch	30.95	34.02	76.00	.516	.0020	2.280	90.956	7.4785
10) 1800	32.00	38.00	40.00	unch	30.62	33.12	37.00	.319	.0019	2.005	52.713	6.2390
11) 1900	16.00	20.00	21.50	unch	32.84	35.47	20.00	.190	.0013	1.552	28.386	4.8611
12) 2000	6.00	9.00	9.00	unch	32.53	35.83	9.00	.099	.0008	1.041	14.273	2.9660
13) 2100	2.00	4.00	3.50	unch	32.32	36.52	3.50	.044	.0005	.581	6.728	1.4568
14) 2200		2.00	1.00	unch	N.A.	38.08	1.00	.015	.0002	.232	2.968	.5272
15) 2300		1.50	.50	unch	N.A.	41.58	.50	.008	.0001	.132	1.262	.2929
16) 2400		1.00	.50	unch	N.A.	43.98	.50	.007	.0001	.126	.502	.2977
17) 2500		1.00	.50	unch	N.A.	48.40	.50	.007	.0001	.101	.195	.3010

Figure 2.4 Prices for Glaxo–Wellcome calls expiring in October. Source: Bloomberg L.P.

[1] I have serious doubts about the purpose of most of the math jargon.

- **Premium**: The amount paid for the contract initially. How to find this value is the subject of much of this book.
- **Underlying (asset)**: The financial instrument on which the option value depends. Stocks, commodities, currencies and indices are going to be denoted by S. The option payoff is defined as some function of the underlying asset at expiry.
- **Strike (price)** or **exercise price**: The amount for which the underlying can be bought (call) or sold (put). This will be denoted by E. This definition only really applies to the simple calls and puts. We will see more complicated contracts in later chapters and the definition of strike or exercise price will be extended.
- **Expiration (date)** or **expiry (date)**: Date on which the option can be exercised or date on which the option ceases to exist or give the holder any rights. This will be denoted by T.
- **Intrinsic value**: The payoff that would be received if the underlying is at its current level when the option expires.
- **Time value**: Any value that the option has above its intrinsic value. The uncertainty surrounding the future value of the underlying asset means that the option value is generally different from the intrinsic value.
- **In the money**: An option with positive intrinsic value. A call option when the asset price is above the strike, a put option when the asset price is below the strike.
- **Out of the money**: An option with no intrinsic value, only time value. A call option when the asset price is below the strike, a put option when the asset price is above the strike.
- **At the money**: A call or put with a strike that is close to the current asset level.
- **Long position**: A positive amount of a quantity, or a positive exposure to a quantity.
- **Short position**: A negative amount of a quantity, or a negative exposure to a quantity. Many assets can be sold short, with some constraints on the length of time before they must be bought back.

2.4 PAYOFF DIAGRAMS

The understanding of options is helped by the visual interpretation of an option's value at expiry. We can plot the value of an option at expiry as a function of the underlying in what is known as a **payoff diagram**. At expiry the option is worth a known amount. In the case of a call option the contract is worth $\max(S - E, 0)$. This function is the bold line in Figure 2.5.

Figure 2.6 shows Bloomberg's standard option valuation screen and Figure 2.7 shows the value against the underlying and the payoff.

The payoff for a put option is $\max(E - S, 0)$, this is the bold line plotted in Figure 2.8.

Figure 2.9 shows Bloomberg's option valuation screen and Figure 2.10 shows the value against the underlying and the payoff.

These payoff diagrams are useful since they simplify the analysis of complex strategies involving more than one option.

Make a mental note of the thin lines in all of these figures. The meaning of these will be explained very shortly.

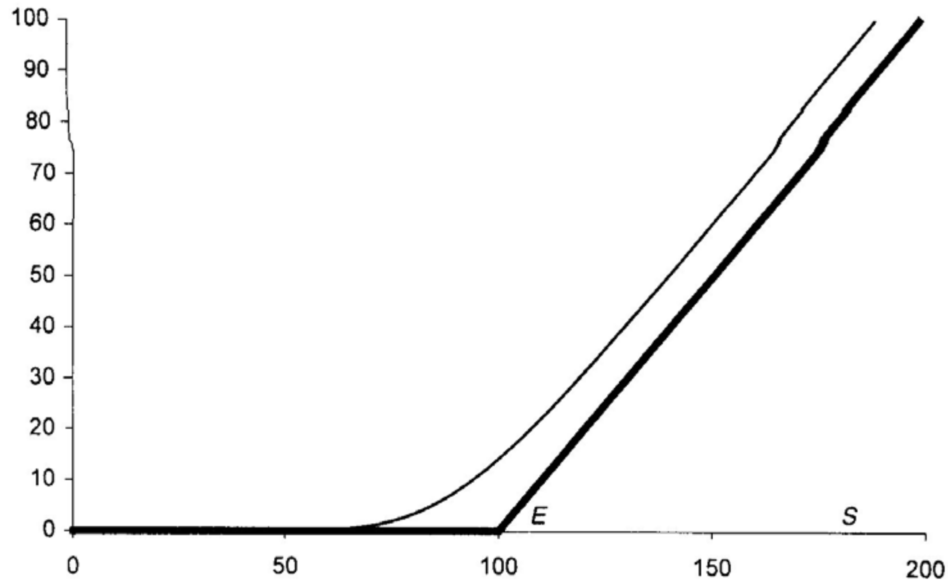


Figure 2.5 Payoff diagram for a call option.

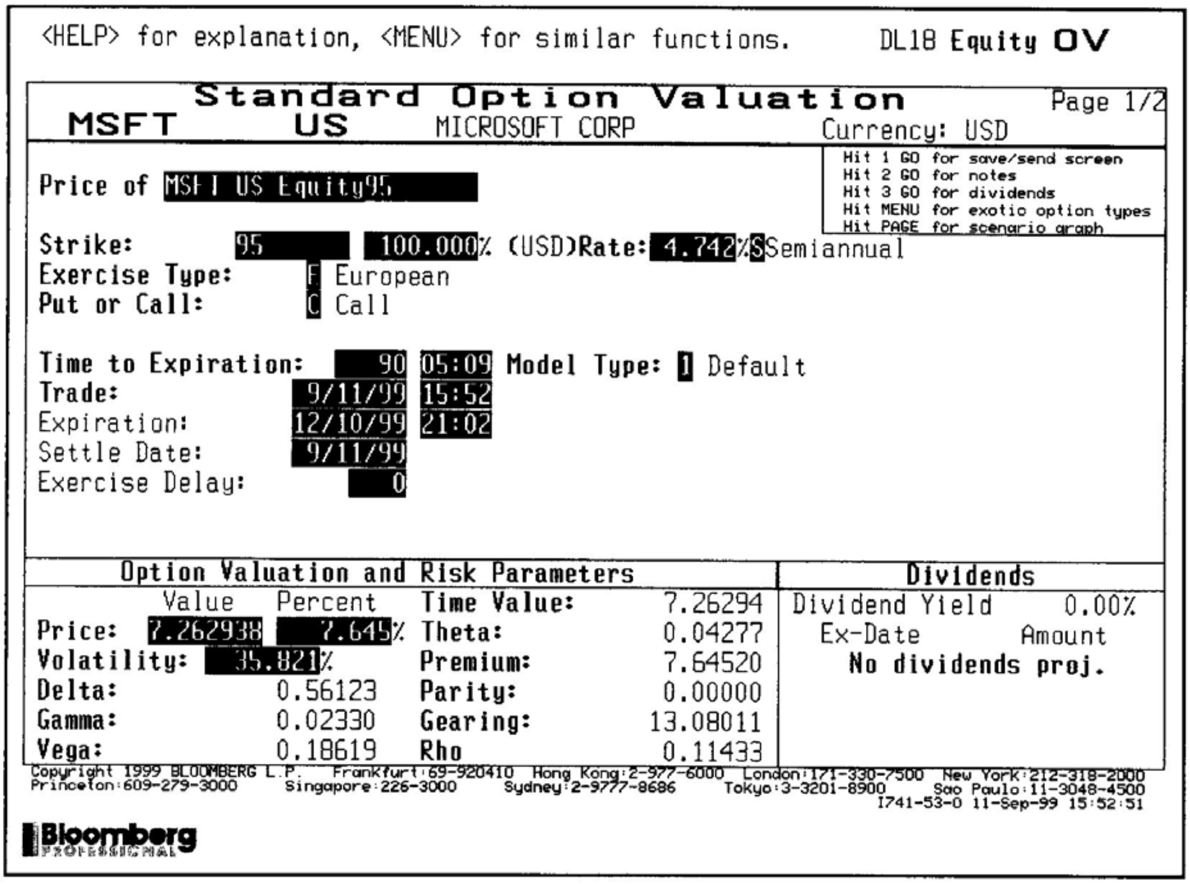


Figure 2.6 Bloomberg option valuation screen, call. Source: Bloomberg L.P.

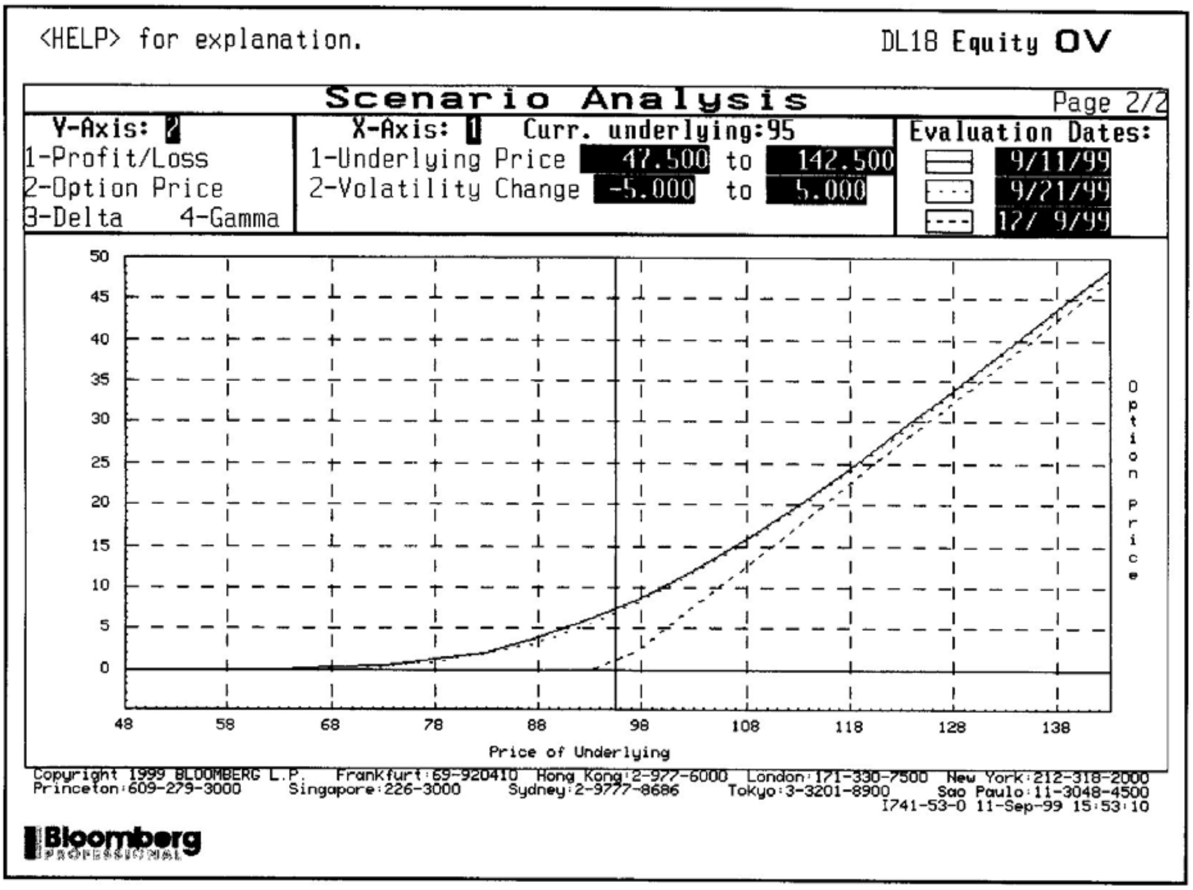


Figure 2.7 Bloomberg scenario analysis, call. Source: Bloomberg L.P.

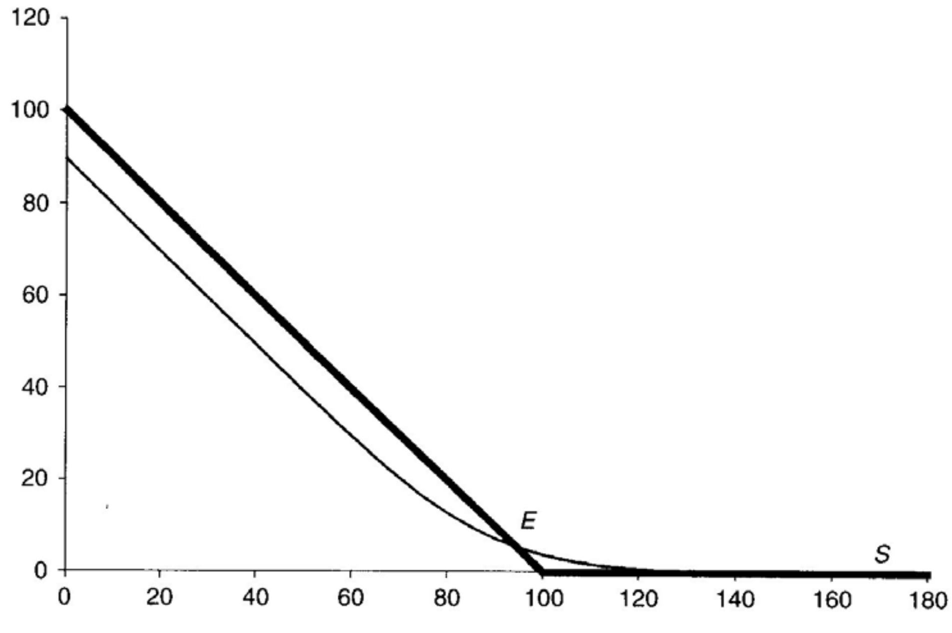


Figure 2.8 Payoff diagram for a put option.

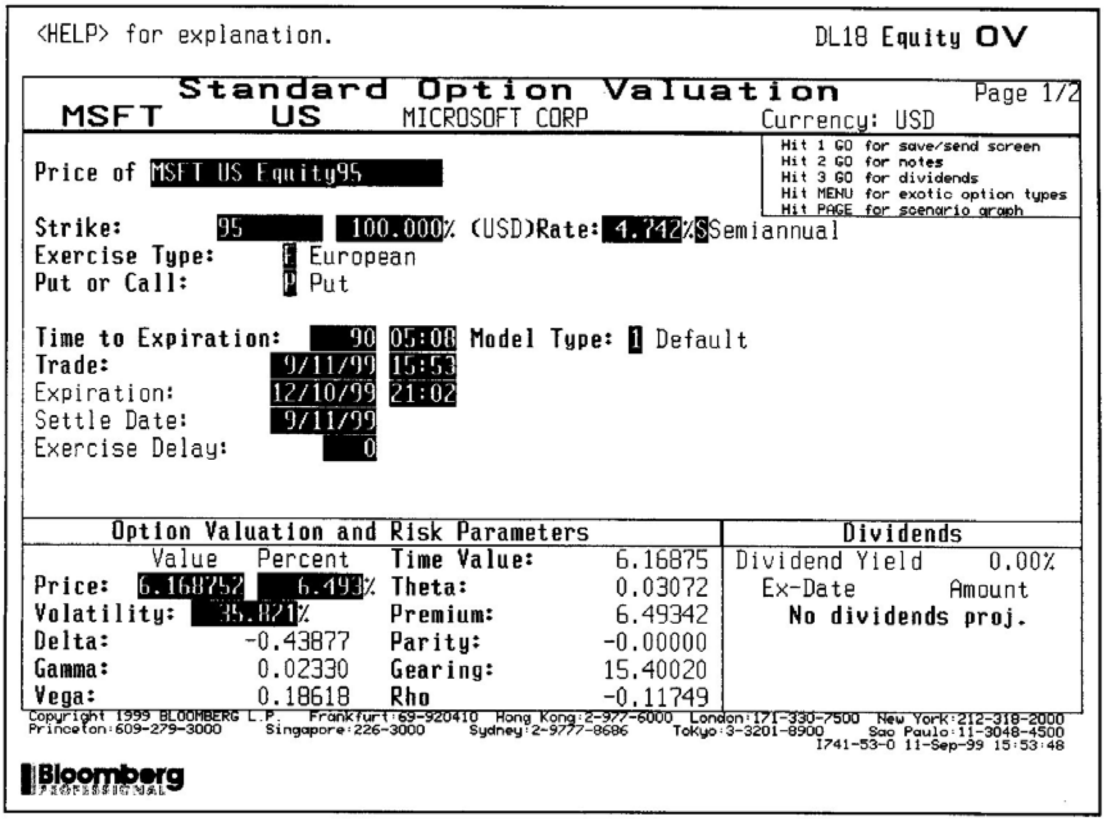


Figure 2.9 Bloomberg option valuation screen, put. Source: Bloomberg L.P.

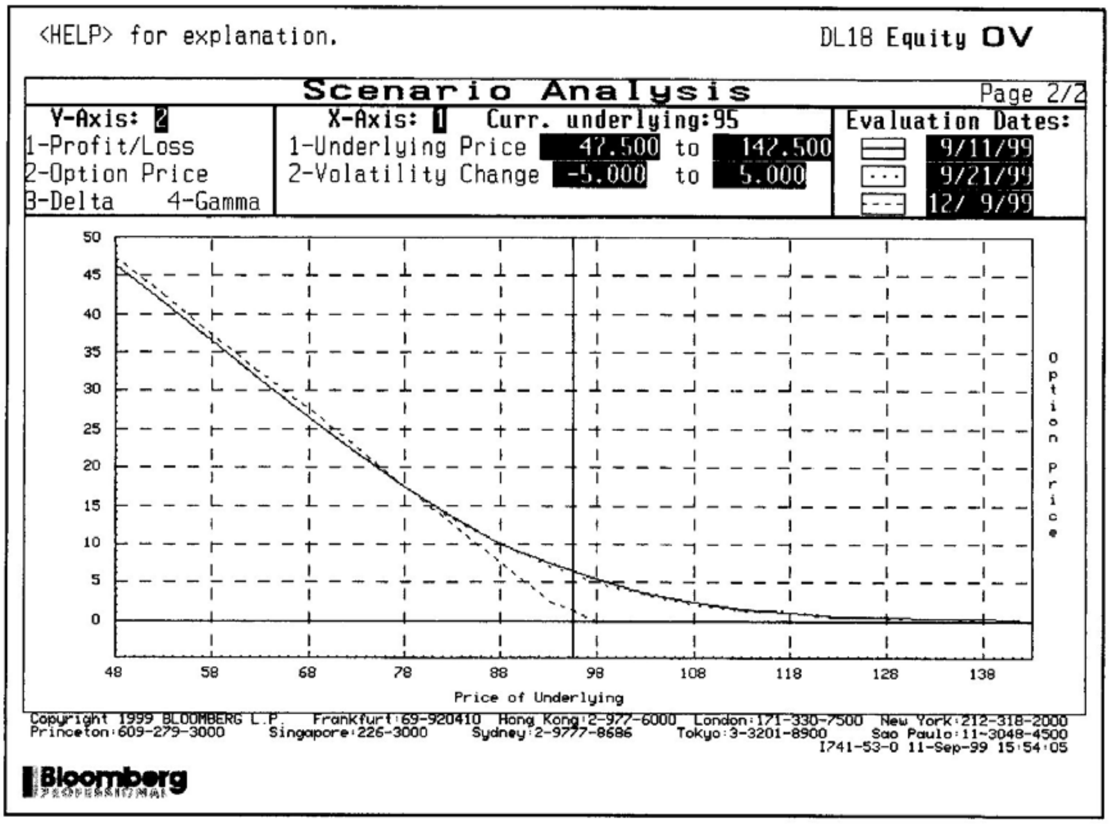


Figure 2.10 Bloomberg scenario analysis, put. Source: Bloomberg L.P.

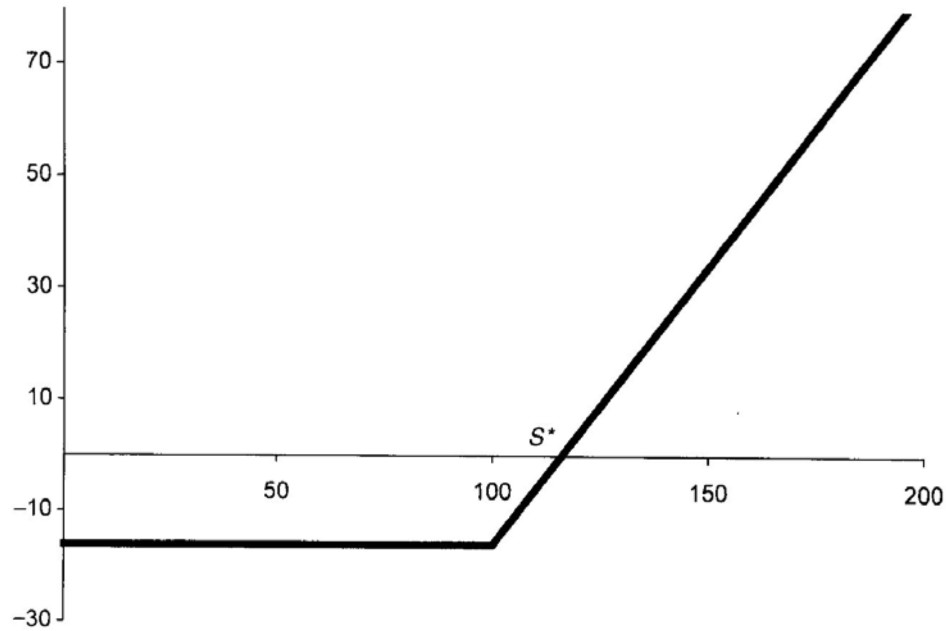


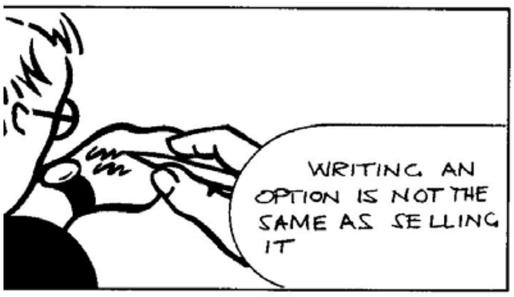
Figure 2.11 Profit diagram for a call option.

2.4.1 Other representations of value

The payoff diagrams shown above only tell you about what happens at expiry, how much money your option contract is worth at that time. It makes no allowance for how much premium you had to pay for the option. To adjust for the original cost of the option, sometimes one plots a diagram such as that shown in Figure 2.11. In this **profit diagram** for a call option I have subtracted off from the payoff the premium originally paid for the call option. This figure is helpful because it shows how far into the money the asset must be at expiry before the option becomes profitable. The asset value marked S^* is the point which divides profit from loss; if the asset at expiry is above this value then the contract has made a profit, if below the contract has made a loss.

As it stands, this profit diagram takes no account of the time value of money. The premium is paid up front but the payoff, if any, is only received at expiry. To be consistent one should either discount the payoff by multiplying by $e^{-r(T-t)}$ to value everything at the present, or multiply the premium by $e^{r(T-t)}$ to value all cashflows at expiry.

Figure 2.12 shows Bloomberg's call option profit diagram. Note that the profit today is zero; if we buy the option and immediately sell it we make neither a profit nor a loss (this is subject to issues of transaction costs).



2.5 WRITING OPTIONS

I have talked above about the rights of the purchaser of the option. But for every option that is sold, someone somewhere must be liable if the option is exercised. If I hold a call option entitling me to buy a stock some time in the future, who do I buy this stock from? Ultimately, the stock must be delivered by the person who **wrote** the option. The **writer** of an option is the person who promises

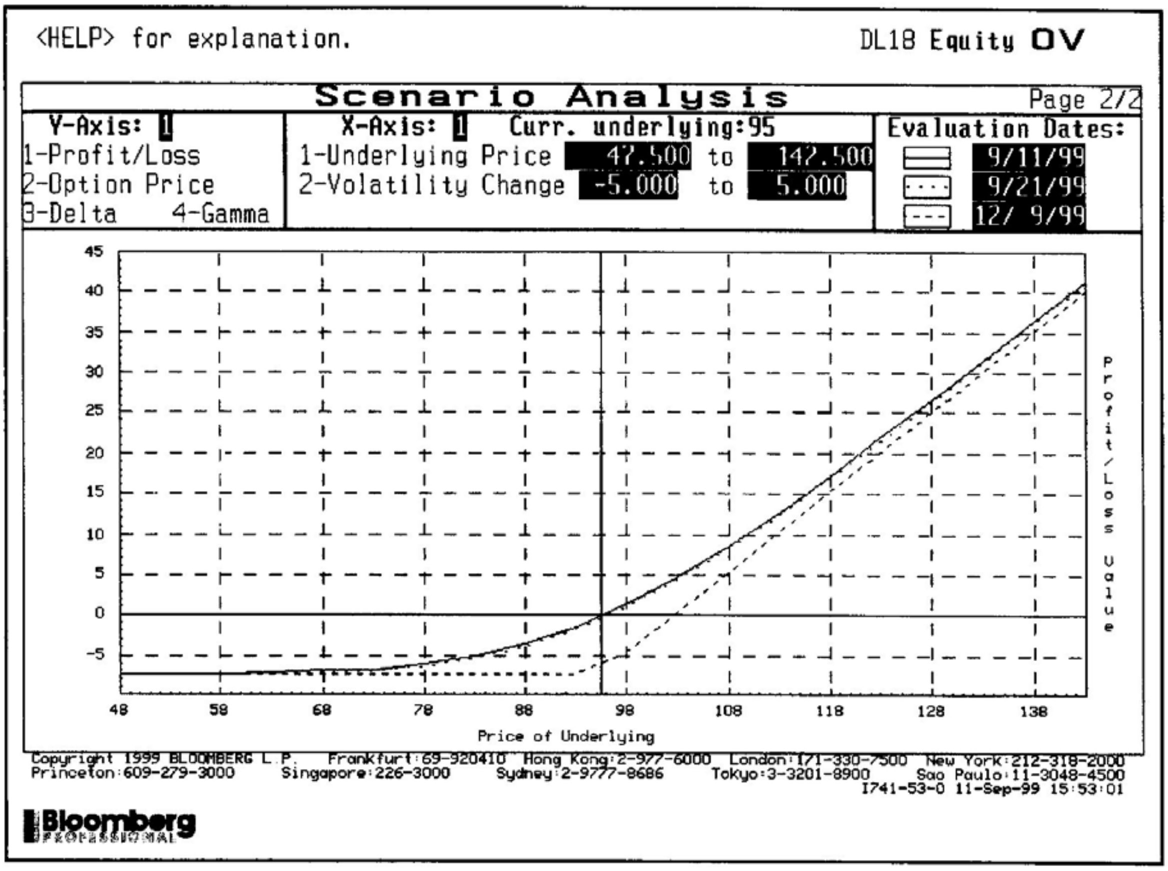


Figure 2.12 Profit diagram for a call. Source: Bloomberg L.P.

to deliver the underlying asset, if the option is a call, or buy it, if the option is a put. The writer is the person who receives the premium.

In practice, most simple option contracts are handled through an exchange so that the purchaser of an option does not know who the writer is. The holder of the option can even sell the option on to someone else via the exchange to close his position. However, regardless of who holds the option, or who has handled it, the writer is the person who has the obligation to deliver or buy the underlying.

The asymmetry between owning and writing options is now clear. The purchaser of the option hands over a premium in return for special rights, and an uncertain outcome. The writer receives a guaranteed payment up front, but then has obligations in the future.

2.6 MARGIN

Writing options is very risky. The downside of buying an option is just the initial premium, the upside may be unlimited. The upside of writing an option is limited, but the downside could be huge. For this reason, to cover the risk of default in the event of an unfavorable outcome, the **clearing houses** that register and settle options insist on the deposit of a margin by the writers of options. Clearing houses act as counterparty to each transaction. Margin was described in Chapter 1.

2.7 MARKET CONVENTIONS

Most of the simpler options contracts are bought and sold through exchanges. These exchanges make it simpler and more efficient to match buyers with sellers. Part of this simplification involves the conventions about such features of the contracts as the available strikes and expiries. For example, simple calls and puts come in **series**. This refers to the strike and expiry dates. Typically a stock has three choices of expiries trading at any time. Having standardized contracts traded through an exchange promotes liquidity of the instruments.

Some options are an agreement between two parties, often brought together by an intermediary. These agreements can be very flexible and the contract details do not need to satisfy any conventions. Such contracts are known as **over the counter** or **OTC** contracts. I give an example at the end of this chapter.

2.8 THE VALUE OF THE OPTION BEFORE EXPIRY

We have seen how much calls and puts are worth at expiry, and drawn these values in payoff diagrams. The question that we can ask, and the question that is central to this book, is 'How much is the contract worth *now*, before expiry?' How much would you pay for a contract, a piece of paper, giving you rights in the future? You may have no idea what the stock price will do between now and expiry in six months, say, but clearly the contract has value. At the very least you know that there is no downside to owning the option, the contract gives you specific rights but no *obligations*. Two things are clear about the contract value before expiry: the value will depend on how high the asset price is today and how long there is before expiry.

The higher the underlying asset today, the higher we might expect the asset to be at expiry of the option and therefore the more valuable we might expect a call option to be. On the other hand a put option might be cheaper by the same reasoning.

The dependence on time to expiry is more subtle. The longer the time to expiry, the more time there is for the asset to rise or fall. Is that good or bad if we own a call option? Furthermore, the longer we have to wait until we get any payoff, the less valuable will that payoff be simply because of the time value of money.

I will ask you to suspend disbelief for the moment (it won't be the first time in the book) and trust me that we will be finding a 'fair value' for these options contracts. The aspect of finding the 'fair value' that I want to focus on now is the dependence on the asset price and time. I am going to use V to mean the value of the option, and it will be a function of the value of the underlying asset S at time t. Thus we can write $V(S, t)$ for the value of the contract.

We know the value of the contract *at expiry*. If I use T to denote the expiry date then at $t = T$ the function V is known, it is just the payoff function. For example if we have a call option then

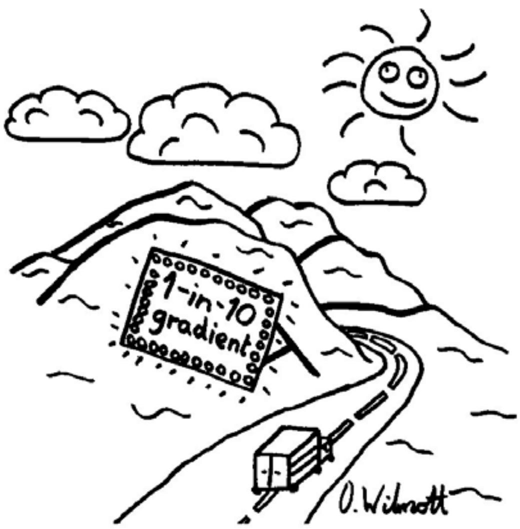
$$V(S, T) = \max(S - E, 0).$$

This is the function of S that I plotted in the earlier payoff diagrams. Now I can tell you what the fine lines are in Figures 2.5 and 2.8, they are the values of the contracts $V(S, t)$ *at some time before expiry*, plotted against S. I have not specified how long before expiry, since the plot is for explanatory purposes only.

Time Out...

Functions of two variables

The option value is a function of two variables, asset price S and time t. If it helps, think of V as being the height of a mountain with the two variables being distances in the northerly and westerly directions. Later we're going to be looking at the slope of this mountain in each of the two directions... these will be sensitivities of the option price to changes in the asset and in time. These slopes or gradients are what you experience in your car when you see a sign such as '1-in-10 gradient.' That is precisely the same as a slope of 0.1.



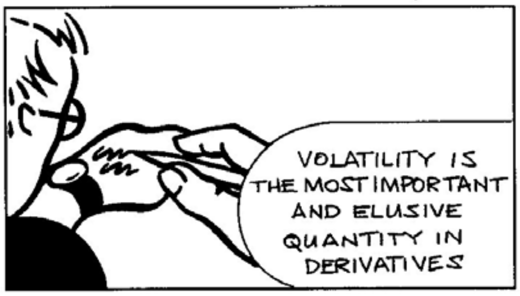
2.9 FACTORS AFFECTING DERIVATIVE PRICES

The two most important factors affecting the prices of options are the value of the underlying asset S and the time to expiry t. These quantities are **variables** meaning that they inevitably change during the life of the contract; if the underlying did not change then the pricing would be trivial. This contrasts with the **parameters** that affect the price of options.

Examples of parameters are the interest rate and strike price. The interest rate will have an effect on the option value via the time value of money since the payoff is received in the future. The interest rate also plays another role which we will see later. Clearly the strike price is important, the higher the strike in a call, the lower the value of the call.

If we have an equity option then its value will depend on any dividends that are paid on the asset during the option's life. If we have an FX option then its value will depend on the interest rate received by the foreign currency.

There is one important parameter that I have not mentioned, and which has a major impact on the option value. That parameter is the **volatility**. Volatility is a measure of the amount of fluctuation in the asset price, a measure of the randomness. Figure 2.13 shows two asset price paths, the more jagged of the two has the higher volatility. The technical definition of volatility is the 'annualized standard deviation of the asset returns.' I will show how to measure this parameter in Chapter 6.



Volatility is a particularly interesting parameter because it is so hard to estimate. And having estimated it, one finds that it never stays constant and is unpredictable.

The distinction between parameters and variables is very important. I shall be deriving equations for the value of options, partial differential equations. These equations will involve differentiation with respect to the variables, but the parameters, as their name suggests, remain as parameters in the equations.

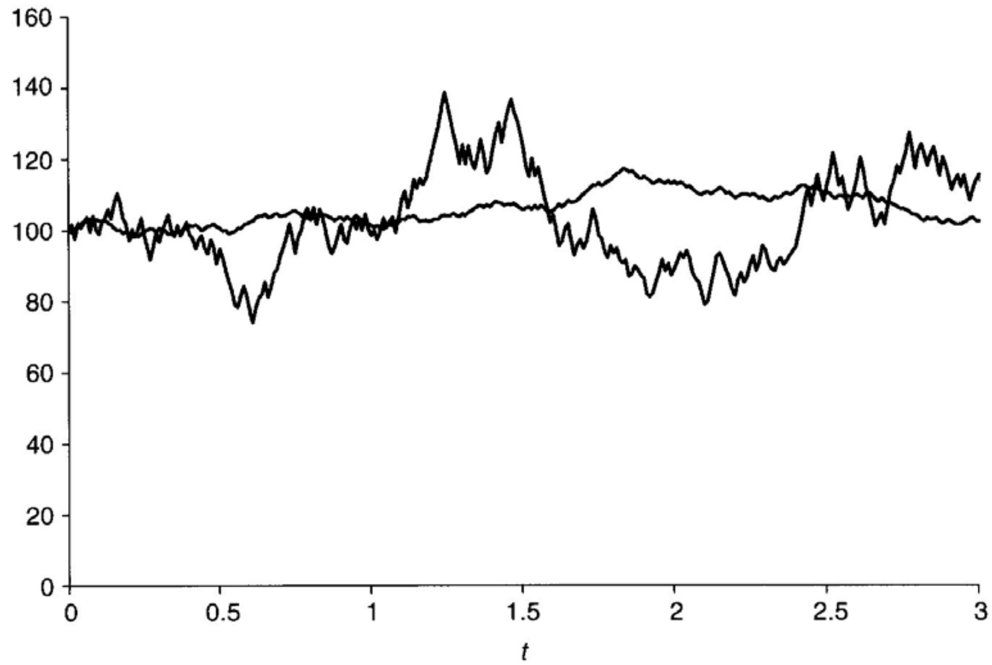
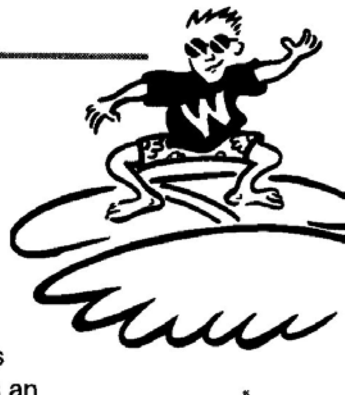


Figure 2.13 Two asset price paths, one is much more volatile than the other.



Time Out...

Volatility

Remember our first coin tossing experiment back in Chapter 1? Try this again, but instead of multiplying by a factor of 1.01 or 0.99, use factors of 1.02 and 0.98. Now plot the time series. This is an example of a more volatile path. If you're feeling strong, try the following experiment.

Play around with different scale factors, 1.01 and 0.99, 1.02 and 0.98, 1.05 and 0.95, keeping them symmetric about 1 to start with. Now try different 'timescales,' i.e. toss the coin only once every two units of time, then once every four units. Would you call a path with large but infrequent moves as volatile as one with smaller but more frequent moves?

2.10 SPECULATION AND GEARING

If you buy a far out-of-the-money option it may not cost very much, especially if there is not very long until expiry. If the option expires worthless, then you also haven't lost very much. However, if there is a dramatic move in the underlying, so that the option expires in the money, you may make a large profit relative to the amount of the investment. Let me give an example.

Example Today's date is 14th April and the price of Wilmott Inc. stock is $666. The cost of a 680 call option with expiry 22nd August is $39. I expect the stock to rise significantly between now and August, how can I profit it I am right?

Buy the stock Suppose I buy the stock for $666. And suppose that by the middle of August the stock has risen to $730. I will have made a profit of $64 per stock. More importantly my investment will have risen by

$$\frac{730 - 666}{666} \times 100 = 9.6\%.$$

Buy the call If I buy the call option for $39, then at expiry I can exercise the call, paying $680 to receive something worth $730. I have paid $39 and I get back $50. This is a profit of $11 per option, but in percentage terms I have made

$$\frac{\text{value of asset at expiry} - \text{strike} - \text{cost of call}}{\text{cost of call}} \times 100 = \frac{730 - 680 - 39}{39} \times 100 = 28\%.$$

This is an example of **gearing** or **leverage**. The out-of-the-money option has a high gearing, a possible high payoff for a small investment. The downside of this leverage is that the call option is more likely than not to expire completely worthless and you will lose all of your investment. If Wilmott Inc. remains at \$666 then the stock investment has the same value but the call option experiences a 100% loss.

Highly leveraged contracts are very risky for the writer of the option. The buyer is only risking a small amount; although he is very likely to lose, his downside is limited to his initial premium. But the writer is risking a large loss in order to make a probable small profit. The writer is likely to think twice about such a deal unless he can offset his risk by buying other contracts. This offsetting of risk by buying other related contracts is called **hedging**.

Gearing explains one of the reasons for buying options. If you have a strong view about the direction of the market then you can exploit derivatives to make a better return, if you are right, than buying or selling the underlying.

2.11 EARLY EXERCISE

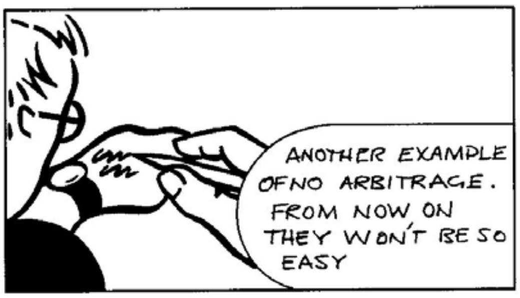
The simple options described above are examples of **European options** because exercise is only permitted *at expiry*. Some contracts allow the holder to exercise *at any time* before expiry, and these are called **American options**. American options give the holder more rights than their European equivalent and can therefore be more valuable, and they can never be less valuable. The main point of interest with American-style contracts is deciding *when* to exercise. In Chapter 5 I will discuss American options, and show how to determine when it is *optimal* to exercise, so as to give the contract the highest value.

Note that the terms 'European' and 'American' do not in any way refer to the continents on which the contracts are traded.

Finally, there are **Bermudan options**. These allow exercise on specified dates, or in specified periods. In a sense they are halfway between European and American since exercise is allowed on some days and not on others.

2.12 PUT-CALL PARITY

Imagine that you buy one European call option with a strike of E and an expiry of T and that you write a European put option with the same strike and expiry. Today's date is t.



The payoff you receive at T for the call will look like the line in the first plot of Figure 2.14. The payoff for the put is the line in the second plot in the figure. Note that the sign of the payoff is negative, you *wrote* the option and are liable for the payoff. The payoff for the portfolio of the two options is the sum of the individual payoffs, shown in the third plot. The payoff for this portfolio of options is

$$\max(S(T) - E, 0) - \max(E - S(T), 0) = S(T) - E,$$

where $S(T)$ is the value of the underlying asset at time T.

The right-hand side of this expression consists of two parts, the asset and a fixed sum E. Is there another way to get exactly this payoff? If I buy the asset today it will cost me $S(t)$ and be worth $S(T)$ at expiry. I don't know what the value $S(T)$ will be but I do know how to guarantee to get that amount, and that is to buy the asset. What about the E

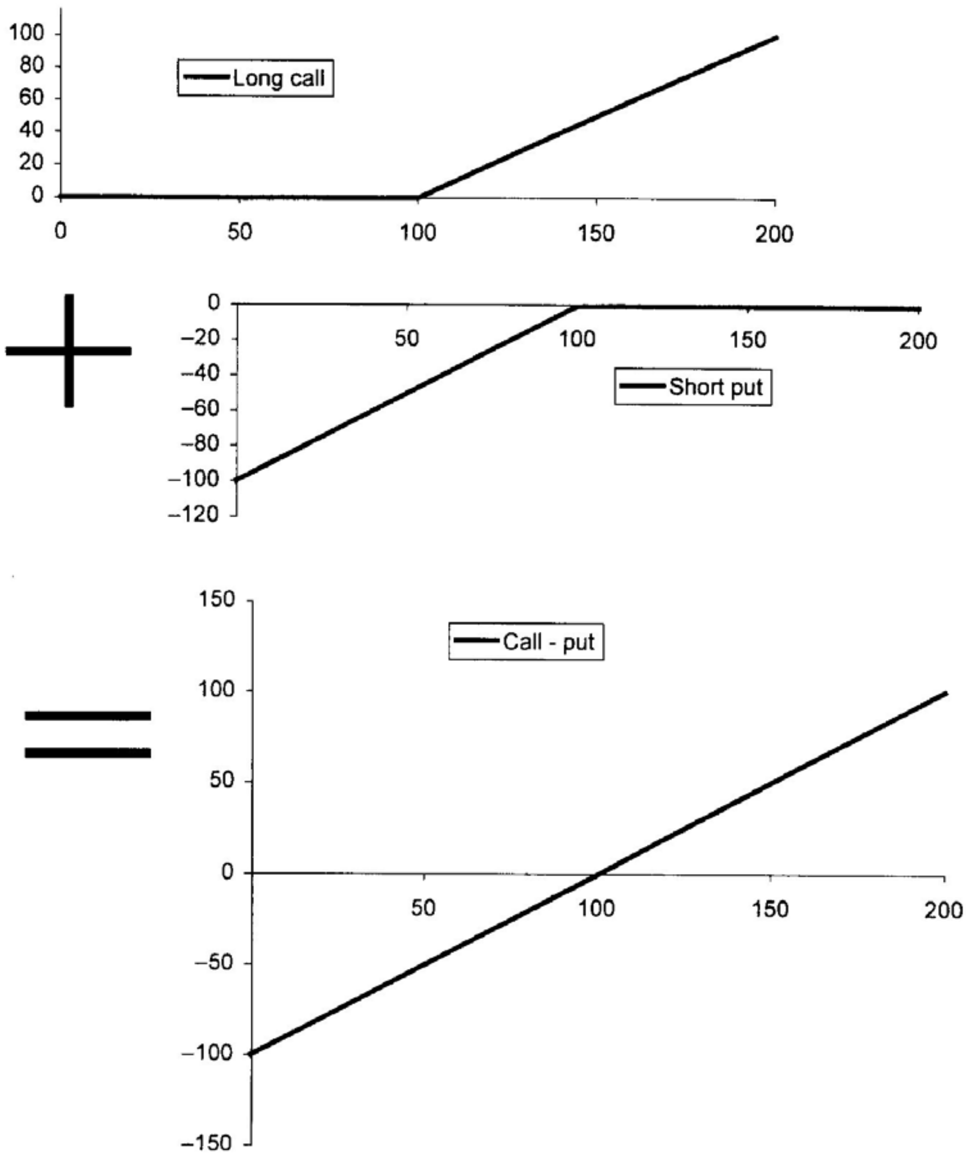


Figure 2.14 Schematic diagram showing put-call parity.

term? To lock in a payment of E at time T involves a cash flow of $Ee^{-r(T-t)}$ at time t. The conclusion is that the portfolio of a long call and a short put gives me exactly the same payoff as a long asset, short cash position. The equality of these cashflows is independent of the future behavior of the stock and is model independent:

$$C - P = S - Ee^{-r(T-t)},$$

where C and P are today's values of the call and the put respectively. This relationship holds at any time up to expiry and is known as **put-call parity**. If this relationship did not hold then there would be riskless arbitrage opportunities.

In Table 2.1 I show the cashflows in the perfectly hedged portfolio. In this table I have set up the cashflows to have a guaranteed value of zero at expiry.

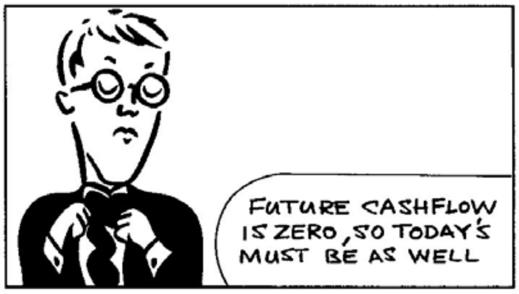


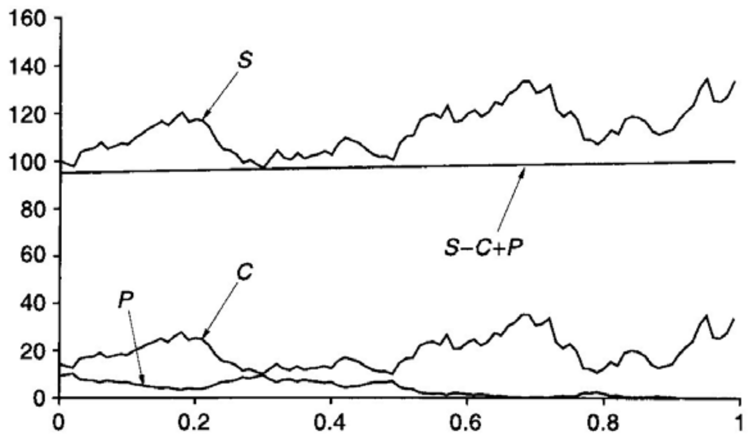
Table 2.1 Cashflows in a hedged portfolio of options and asset.

Holding	Worth today (t)	Worth at expiry (T)
Call	C	$\max(S(T) - E, 0)$
−Put	$-P$	$-\max(E - S(T), 0)$
−Stock	$-S(t)$	$-S(T)$
Cash	$Ee^{-r(T-t)}$	E
Total	$C - P - S(t) + Ee^{-r(T-t)}$	0

Time Out...

A simulation of put-call parity

Below are four plots, all with time along the horizontal axis. The first is of some asset price. The second is the value of a call option on that asset. You don't need to know details of the contract, such as strike and expiry. Nor do you need to know how I calculated the value. The third plot is of a put option (same strike and expiry as the call, whatever they were). The fourth plot is stock value minus call value plus put value. Observe how it grows exponentially, just like cash in the bank. This is a graphical illustration of put-call parity.



2.13 BINARIES OR DIGITALS

The original and still most common contracts are the vanilla calls and puts. Increasingly important are the **binary** or **digital options**. These contracts have a payoff at expiry that is discontinuous in the underlying asset price. An example of the payoff diagram for one of these options, a **binary call**, is shown in Figure 2.15. This contract pays $1 at expiry, time T, if the asset price is then greater than the exercise price E. Again, and as with the rest of the figures in this chapter, the bold line is the payoff and the fine line is the contract value some time before expiry.

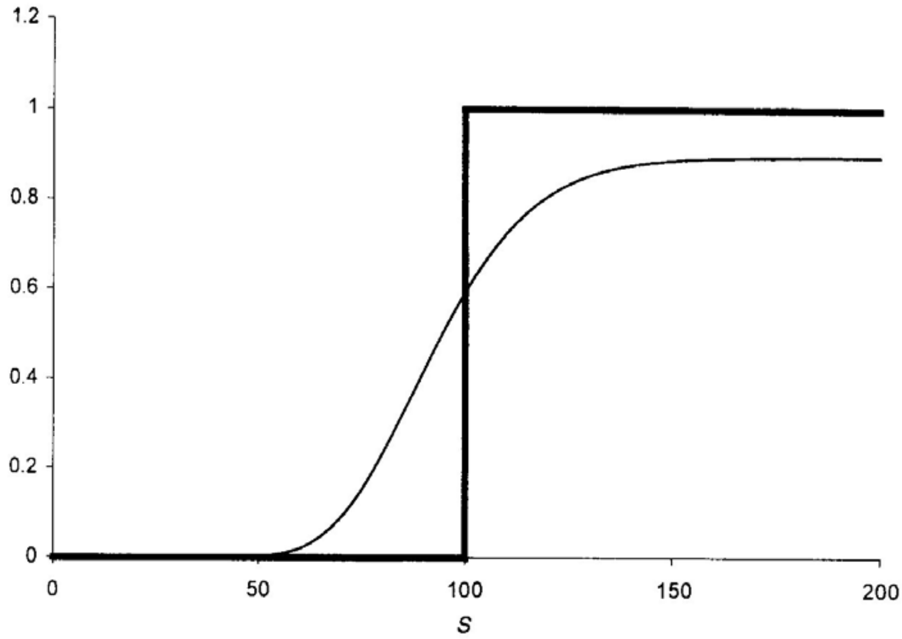


Figure 2.15 Payoff diagram for a binary call option.

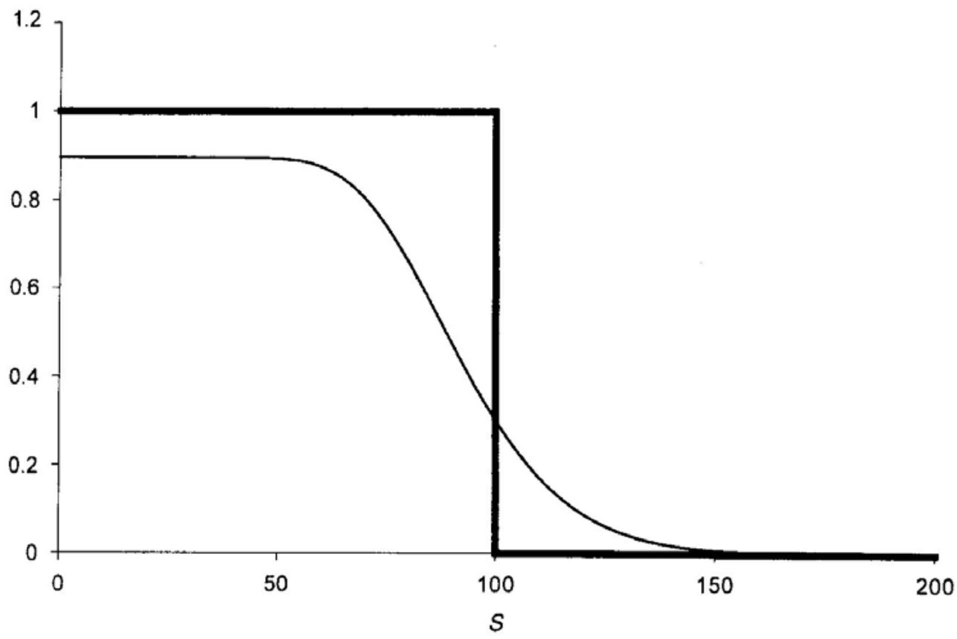


Figure 2.16 Payoff diagram for a binary put option.

Why would you invest in a binary call? If you think that the asset price will rise by expiry, to finish above the strike price then you might choose to buy either a vanilla call or a binary call. The vanilla call has the best upside potential, growing linearly with S beyond the strike. The binary call, however, can never pay off more than the $1. If you expect the underlying to rise dramatically then it may be best to buy the vanilla call. If you believe that the asset rise will be less dramatic then buy the binary call. The gearing of the vanilla call is greater than that for a binary call if the move in the underlying is large.

Figure 2.16 shows the payoff diagram for a **binary put**, the holder of which receives $1 if the asset is *below* E at expiry. The binary put would be bought by someone expecting a modest fall in the asset price.

There is a particularly simple binary put-call parity relationship. What do you get at expiry if you hold both a binary call and a binary put with the same strikes and expiries? The answer is that you will always get $1 regardless of the level of the underlying at expiry. Thus

$$\text{Binary call} + \text{Binary put} = e^{-r(T-t)}.$$

What would the table of cashflows look like for the perfectly hedged digital portfolio?

2.14 BULL AND BEAR SPREADS

A payoff that is similar to a binary option can be made up with vanilla calls. This is our first example of a **portfolio of options** or an **option strategy**.

Suppose I buy one call option with a strike of 100 and write another with a strike of 120 and with the same expiration as the first then my resulting portfolio has a payoff that is shown in Figure 2.17. This payoff is zero below 100, 20 above 120 and linear in between. The payoff is continuous, unlike the binary call, but has a payoff that is superficially similar. This strategy is called a **bull spread** because it benefits from a bull, i.e. rising, market.

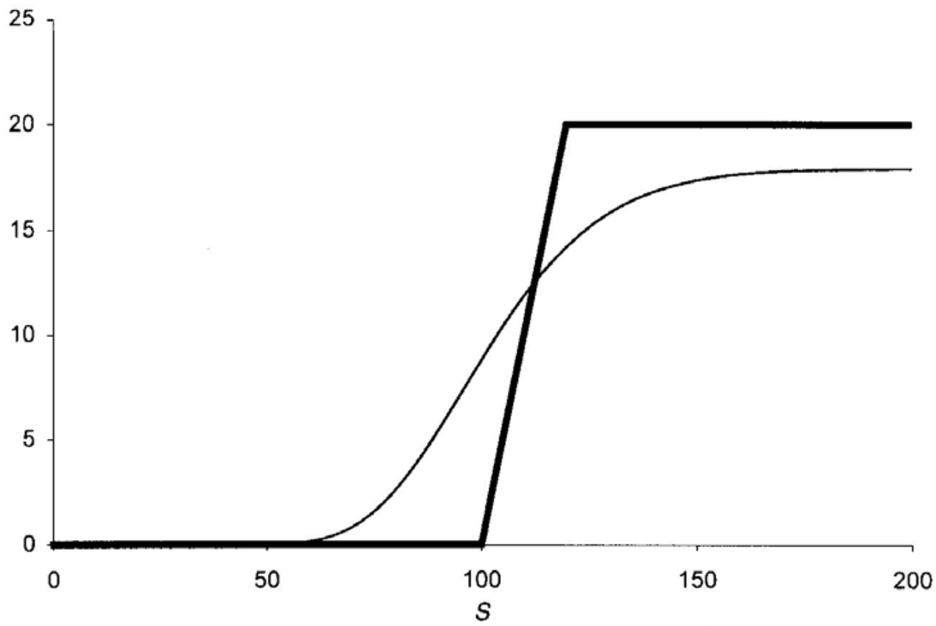


Figure 2.17 Payoff diagram for a bull spread.

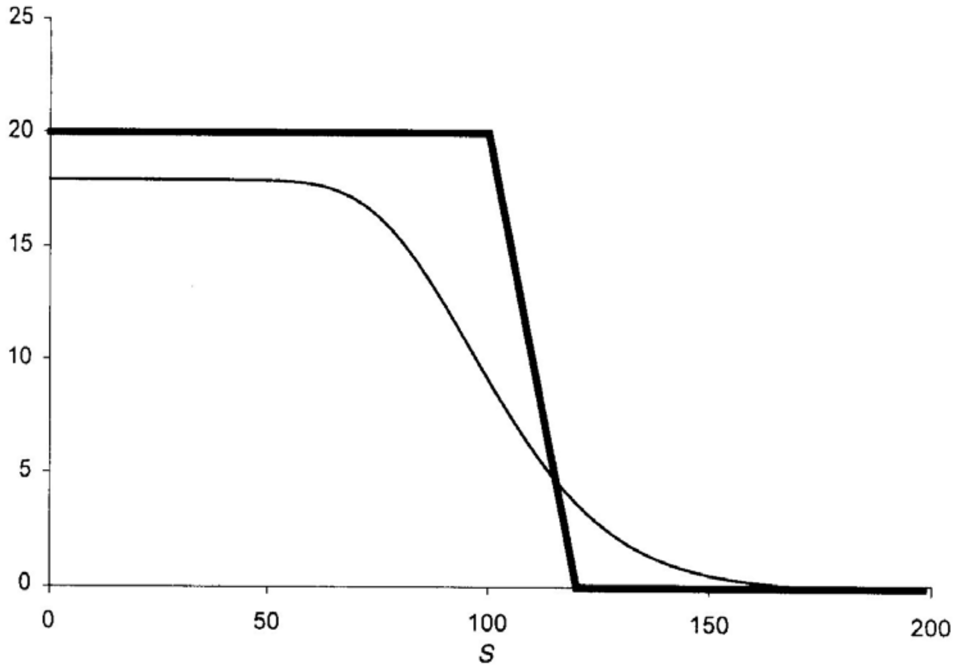


Figure 2.18 Payoff diagram for a bear spread.

The payoff for a general bull spread, made up of calls with strikes E_1 and E_2, is given by

$$\frac{1}{E_2 - E_1}(\max(S - E_1, 0) - \max(S - E_2, 0)),$$

where $E_2 > E_1$. Here I have bought/sold $(E_2 - E_1)^{-1}$ of each of the options so that the maximum payoff is scaled to 1.

If I write a put option with strike 100 and buy a put with strike 120 I get the payoff shown in Figure 2.18. This is called a **bear spread**, benefitting from a bear, i.e. falling, market. Again, it is very similar to a binary put except that the payoff is continuous.

Because of put-call parity it is possible to build up these payoffs using other contracts. A strategy involving options of the same type (i.e. calls or puts) is called a **spread**.

2.15 STRADDLES AND STRANGLES

If you have a precise view on the behavior of the underlying asset, you may want to be precise in your choice of option; simple calls, puts, and binaries may be too crude.

The **straddle** consists of a call and a put with the same strike. The payoff diagram is shown in Figure 2.19. Such a position is usually bought at the money by someone who expects the underlying to either rise or fall, but not to remain at the same level. For example, just before an anticipated major news item stocks often show a 'calm before the storm.' On the announcement the stocks suddenly move either up or down depending on whether or not the news was favorable to the company. They may also be bought by technical traders who see the stock at a key support or resistance level and expect the stock to either break through dramatically or bounce back.

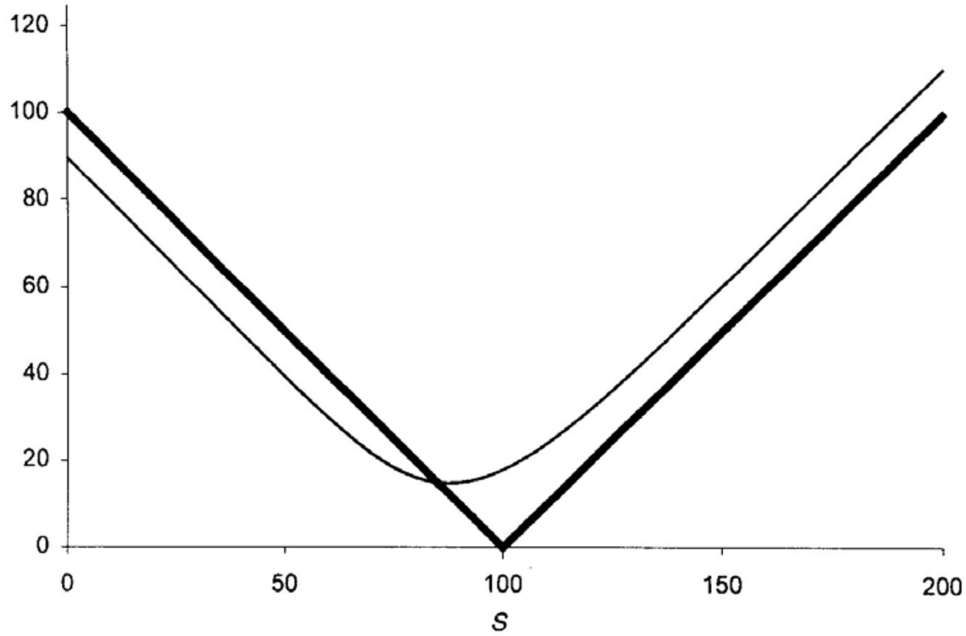


Figure 2.19 Payoff diagram for a straddle.

The straddle would be sold by someone with the opposite view, someone who expects the underlying price to remain stable.

Figure 2.20 shows the Bloomberg screen for setting up a straddle. Figure 2.21 shows the profit and loss for this position at various times before expiry. The profit/loss is the option value less the upfront premium.

The **strangle** is similar to the straddle except that the strikes of the put and the call are different. The contract can be either an **out-of-the-money strangle** or **an in-the-money strangle**. The payoff for an out-of-the money strangle is shown in Figure 2.22. The motivation behind the purchase of this position is similar to that for the purchase of a straddle. The difference is that the buyer expects an even larger move in the underlying one way or the other. The contract is usually bought when the asset is around the middle of the two strikes and is cheaper than a straddle. This cheapness means that the gearing for the out-of-the-money strangle is higher than that for the straddle. The downside is that there is a much greater range over which the strangle has no payoff at expiry, for the straddle there is only the one point at which there is no payoff.

There is another reason for a straddle or strangle trade that does not involve a view on the direction of the underlying. These contracts are bought or sold by those with a view on the direction of volatility, they are one of the simplest **volatility trades**. Because of the relationship between the price of an option and the volatility of the asset one can speculate on the direction of volatility. Do you expect the volatility to rise? If so, how can you benefit from this? Until we know more about this relationship, we cannot go into this in more detail.

Straddles and strangles are rarely held until expiry.

A strategy involving options of different types (i.e. both calls and puts) is called a **combination**.

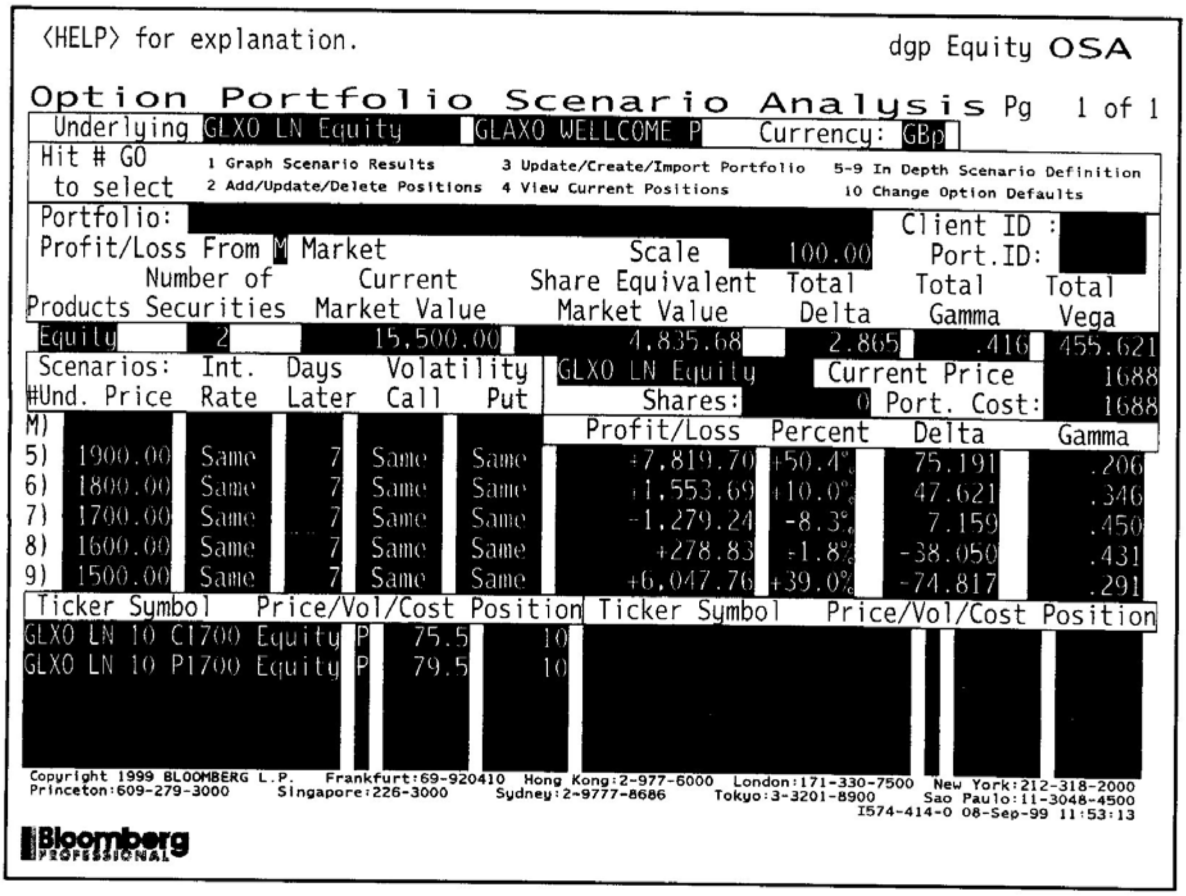


Figure 2.20 A portfolio of two options making up a straddle. Source: Bloomberg L.P.

2.16 RISK REVERSAL

The **risk reversal** is a combination of a long call, with strike above the current spot, and a short put with a strike below the current spot. Both have the same expiry. The payoff is shown in Figure 2.23.

The risk reversal is a very special contract, popular with practitioners. Its value is usually quite small and related to the market's expectations of the behavior of volatility.

2.17 BUTTERFLIES AND CONDORS

A more complicated strategy involving the purchase and sale of options with *three* different strikes is a **butterfly spread.** Buying a call with a strike of 90, writing two calls struck at 100 and buying a 110 call gives the payoff in Figure 2.24. This is the kind of position you might enter if you believe that the asset is not going anywhere, either up or down. Because it has no large upside potential (in this case the maximum payoff is 10) the position will be relatively cheap. With options, cheap is good.

The **condor** is like a butterfly except that four strikes, and four call options, are used. The payoff is shown in Figure 2.25.

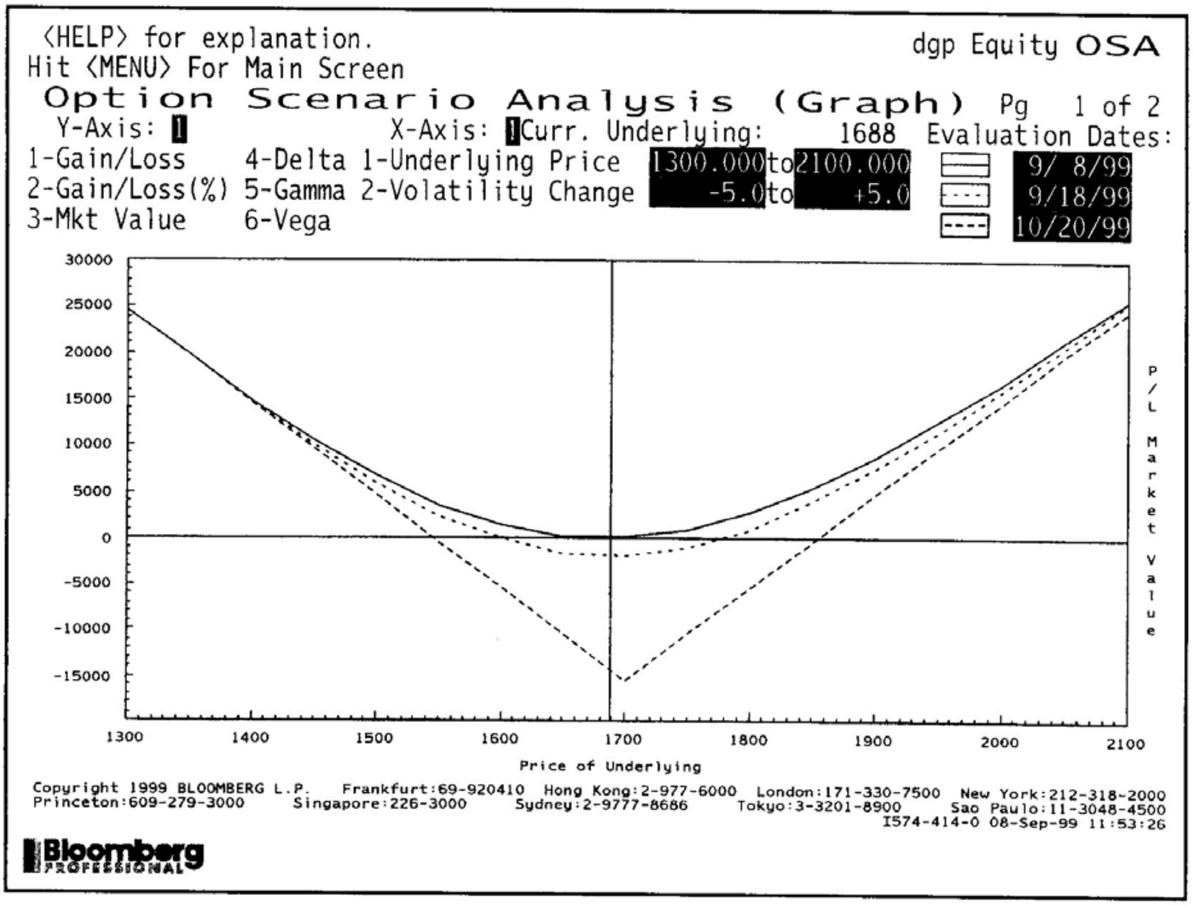


Figure 2.21 Profit/loss for the straddle at several times before expiry. Source: Bloomberg L.P.

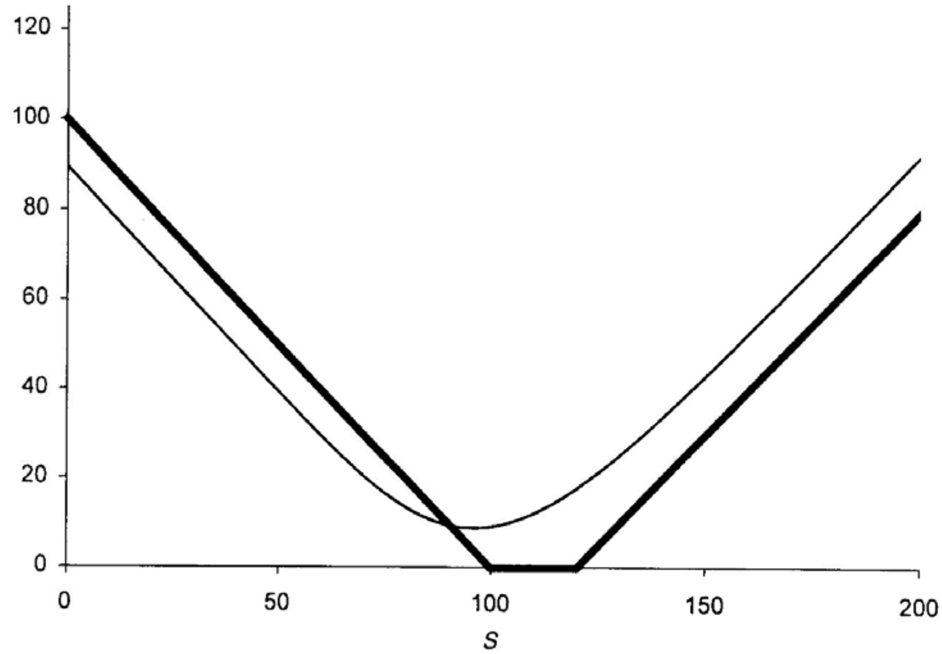


Figure 2.22 Payoff diagram for a strangle.

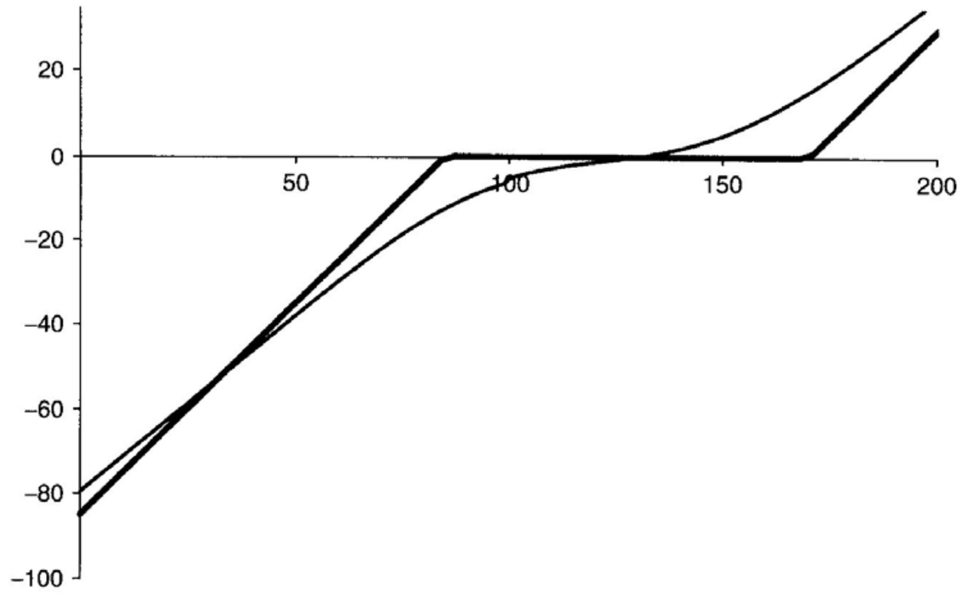


Figure 2.23 Payoff diagram for a risk reversal.

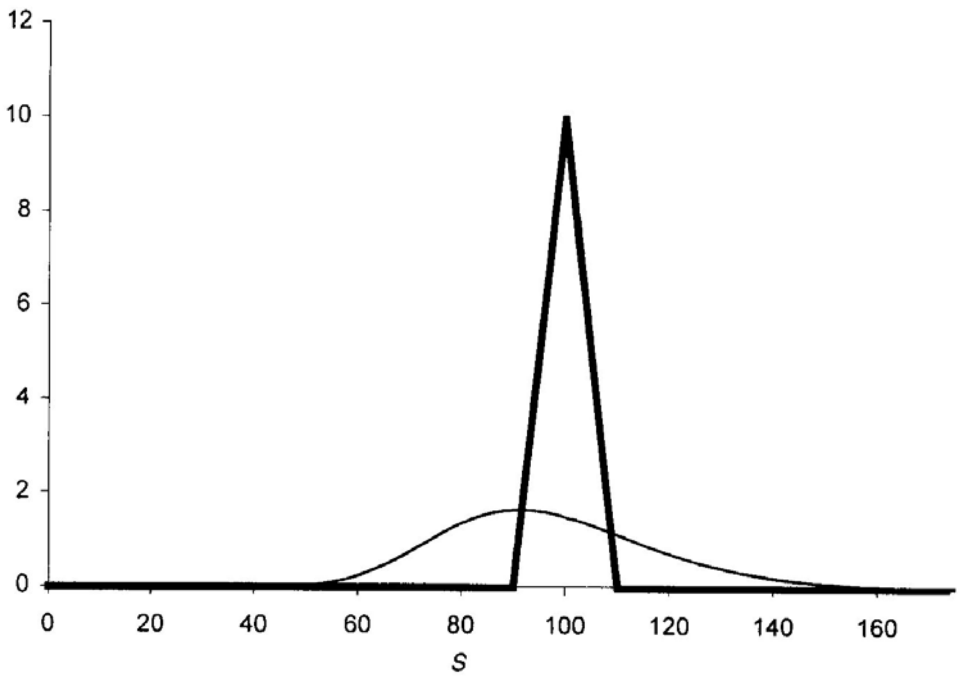


Figure 2.24 Payoff diagram for a butterfly spread.

2.18 CALENDAR SPREADS

All of the strategies I have described above have involved buying or writing calls and puts with different strikes *but all with the same expiration.* A strategy involving options with different expiry dates is called a **calendar spread.** You may enter into such a position if you have a precise view on the timing of a market move as well as the direction of the

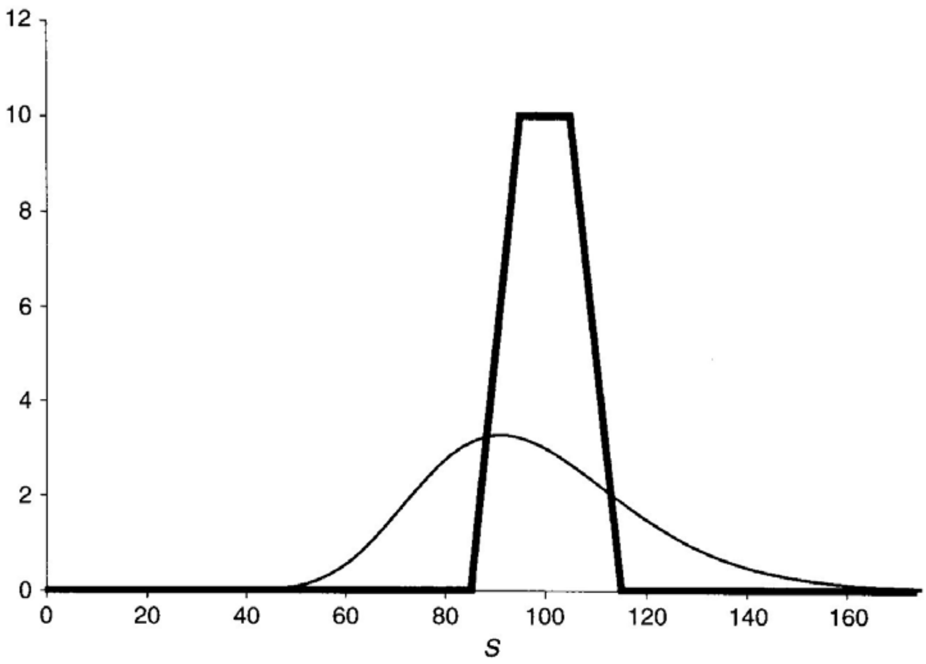


Figure 2.25 Payoff diagram for a condor.

move. As always the motive behind such a strategy is to reduce the payoff at asset values and times which you believe are irrelevant, while increasing the payoff where you think it will matter. Any reduction in payoff will reduce the overall value of the option position.

2.19 LEAPS AND FLEX

LEAPS or **long-term equity anticipation securities** are longer-dated exchange-traded calls and puts. They began trading on the CBOE in the late 1980s. They are standardized so that they expire in January each year and are available with expiries up to three years.

LEAPS-LONG TERM

		DJ INDUS AVG – CB				
Dec 01	104	p	42	7¾	+ ¾	475
Dec 01	140	p	44	22¼	+ 2½	106
		S & P 100 INDEX – CB				
Dec 01	140	c	5	38	+ 6	105
		S & P 500 INDEX – CB				
Dec 00	70	p	60	7/16	+ ⅛	8993
Dec 00	90	p	5	1 3/16	+ ¼	15789
Dec 00	100	p	4	1 15/16	+ ½	18242
Dec 00	110	p	85	2¾	+ ¼	15068
Dec 00	112½	p	1	3	+ ⅜	7496
Dec 00	115	p	22	3⅝	+ ⅝	19282
Dec 00	117½	p	10	7⅝	+ 1⅜	839
Dec 00	120	p	52	4⅜	+ ⅝	17787
Dec 00	125	p	6	5⅛	+ ⅝	5809
Dec 00	130	p	18	6¼	+ ⅞	7322
Dec 00	140	p	90	9	+ 1¼	10159
Dec 00	145	p	2	9½	+ ¾	935
Call Volume			**39**	**Open Int 6,469,087**		
Put Volume			**20**	**Open Int 4,671,720**		

Figure 2.26 *The Wall Street Journal Europe* of 5th January 2000, LEAPS. Reproduced by permission of Dow Jones & Company, Inc.

They come with three strikes, corresponding to at the money and 20% in and out of the money with respect to the underlying asset price when issued.

Figure 2.26 shows LEAPS quoted in *The Wall Street Journal Europe*.

In 1993 the CBOE created **FLEX** or **FLexible EXchange-traded options** on several indices. These allow a degree of customization, in the expiry date (up to five years), the strike price and the exercise style.

2.20 WARRANTS

A contract that is very similar to an option is a **warrant**. Warrants are call options issued by a company on its own equity. The main differences between traded options and warrants are the timescales involved, warrants usually have a longer lifespan, and on exercise the company issues new stock to the warrant holder. On exercise, the holder of a *traded* option receives stock that has already been issued. Exercise is usually allowed any time before expiry, but after an initial waiting period.

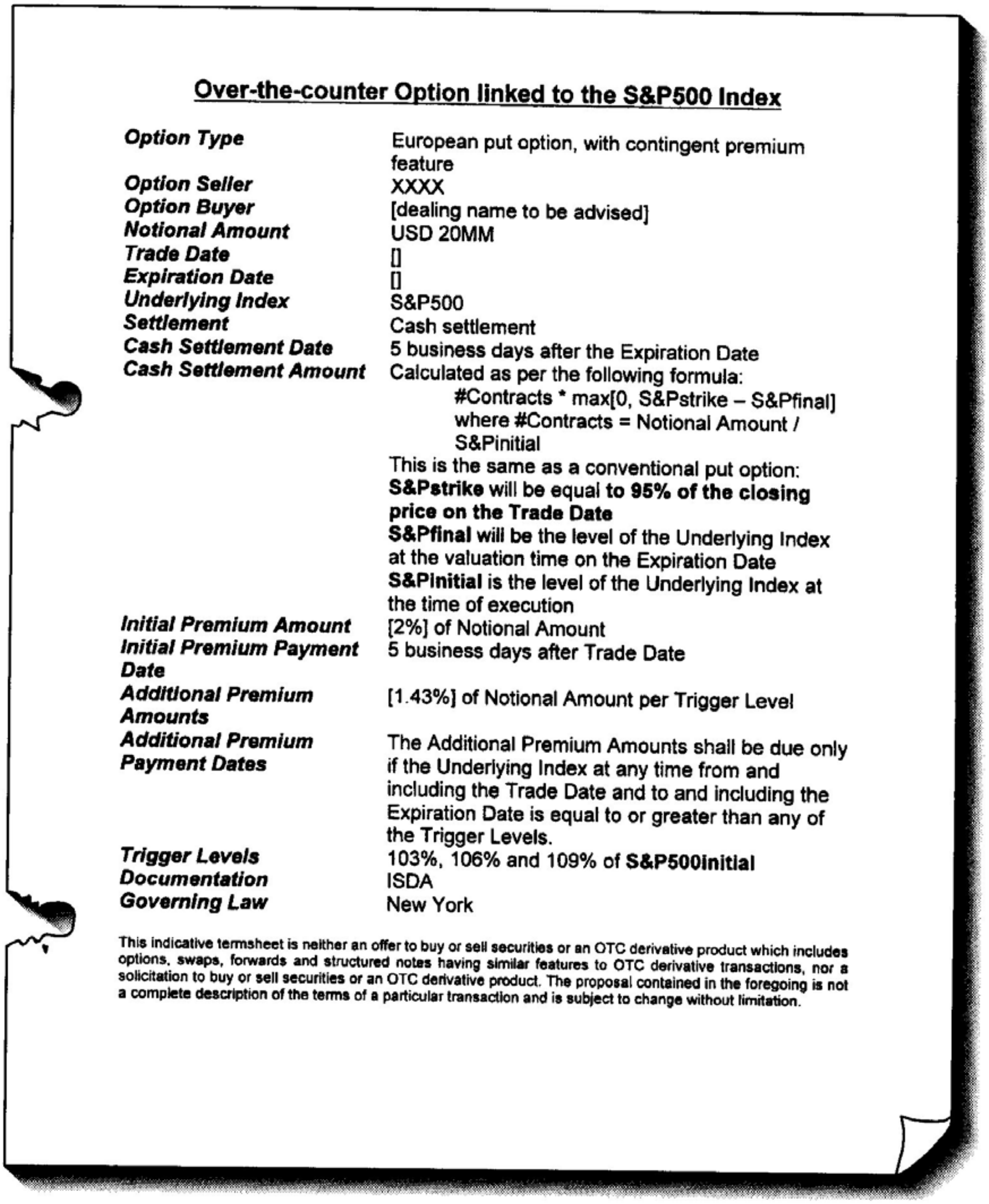
The typical lifespan of a warrant is five or more years. Occasionally **perpetual warrants** are issued, these have no maturity.

2.21 CONVERTIBLE BONDS

Convertible bonds or **CB**s have features of both bonds and warrants. They pay a stream of coupons with a final repayment of principal at maturity, but they can be converted into the underlying stock before expiry. On conversion rights to future coupons are lost. If the stock price is low then there is little incentive to convert to the stock, the coupon stream is more valuable. In this case the CB behaves like a bond. If the stock price is high then conversion is likely and the CB responds to the movement in the asset. Because the CB can be converted into the asset, its value has to be at least the value of the asset. This makes CBs similar to American options; early exercise and conversion are mathematically the same.

2.22 OVER THE COUNTER OPTIONS

Not all options are traded on an exchange. Some, known as over the counter or OTC options are sold privately from one counterparty to another. In Figure 2.27 is the term sheet for an OTC put option, having some special features. A **term sheet** specifies the precise details of an OTC contract. In this OTC put the holder gets a put option on S&P500, but more cheaply than a vanilla put option. This contract is cheap because part of the premium does not have to be paid until and unless the underlying index trades above a specified level. Each time that a new level is reached an extra payment is triggered. This feature means that the contract is not vanilla, and makes the pricing more complicated. We will be discussing special features like the ones in this contract in later chapters. Quantities in square brackets will be set at the time that the deal is struck.



Over-the-counter Option linked to the S&P500 Index

Option Type	European put option, with contingent premium feature
Option Seller	XXXX
Option Buyer	[dealing name to be advised]
Notional Amount	USD 20MM
Trade Date	[]
Expiration Date	[]
Underlying Index	S&P500
Settlement	Cash settlement
Cash Settlement Date	5 business days after the Expiration Date
Cash Settlement Amount	Calculated as per the following formula: #Contracts * max[0, S&Pstrike – S&Pfinal] where #Contracts = Notional Amount / S&Pinitial This is the same as a conventional put option: **S&Pstrike** will be equal to **95% of the closing price on the Trade Date** **S&Pfinal** will be the level of the Underlying Index at the valuation time on the Expiration Date **S&PInitial** is the level of the Underlying Index at the time of execution
Initial Premium Amount	[2%] of Notional Amount
Initial Premium Payment Date	5 business days after Trade Date
Additional Premium Amounts	[1.43%] of Notional Amount per Trigger Level
Additional Premium Payment Dates	The Additional Premium Amounts shall be due only if the Underlying Index at any time from and including the Trade Date and to and including the Expiration Date is equal to or greater than any of the Trigger Levels.
Trigger Levels	103%, 106% and 109% of **S&P500initial**
Documentation	ISDA
Governing Law	New York

This indicative termsheet is neither an offer to buy or sell securities or an OTC derivative product which includes options, swaps, forwards and structured notes having similar features to OTC derivative transactions, nor a solicitation to buy or sell securities or an OTC derivative product. The proposal contained in the foregoing is not a complete description of the terms of a particular transaction and is subject to change without limitation.

Figure 2.27 Term sheet for an OTC 'Put'.

2.23 SUMMARY

We now know the basics of options and markets, and a few of the simplest trading strategies. We know some of the jargon and the reasons why people might want to buy an option. We've also seen another example of no arbitrage in put-call parity. This is just the beginning. We don't know how much these instruments are worth, how they are affected by the price of the underlying, how much risk is involved in the buying or writing of options. And we have only seen the very simplest of contracts, there are many, many more complex products to examine. All of these issues are going to be addressed in later chapters.

FURTHER READING

- McMillan (1996) and Options Institute (1995) describe many option strategies used in practice.
- Most exchanges have websites. The London International Financial Futures Exchange website contains information about the money markets, bonds, equities, indices and commodities. See `www.liffe.com`. For information about options and derivatives generally, see `www.cboe.com`, the Chicago Board Options Exchange website. The American Stock Exchange is on `www.amex.com` and the New York Stock Exchange on `www.nyse.com`.
- Derivatives have often had bad press (and there's probably more to come). See Miller (1997) for a discussion of the pros and cons of derivatives.
- The best books on options are Hull (1999) and Cox & Rubinstein (1985), modesty forbids me mentioning others.

CHAPTER 3

predicting the markets? a small digression

The aim of this Chapter...

... is to explain ways in which people supposedly predict future movements in the financial markets. There is little scientific evidence that these methods work in practice but you, a future bond trader perhaps, must know about such matters and eventually decide for yourself.

In this Chapter...

- some of the commonly used technical methods for predicting market direction
- some modern approaches to modeling markets and their microstructure

3.1 INTRODUCTION

People have been making predictions about the future since the dawn of time. And predicting the future of the financial markets has been especially popular. Despite the claims of many 'legendary' investors it is not clear whether there is any validity in any of the methods they use, or whether the claims are examples of survivor bias. The big losers tend to keep quiet.

In this chapter we look at some of the traditional methods for determining trends, technical analysis, and also some of the more recent methods, often emanating from physics. I won't be describing some of the more dubious ideas, such as astrology, but then we Scorpios tend to be skeptical.

In the book generally, I'm taking the view that the markets are best modeled via probabilities. This chapter is very much a digression from the main thrust of the book.

3.2 TECHNICAL ANALYSIS

Technical analysis is a way of predicting future price movements based only on observing the past history of prices. This price history may also include other quantities such as volume of trade. These methods contrast with **fundamental analysis** in which prediction is made based on an examination of the factors underlying the stock or other instrument. This may include general economic or political analysis, or analysis of factors specific to the stock, such as the effect of global warming on snowfall in the Alps, if one is concerned with a travel company. In practice, most traders will use a combination of both technical and fundamental analysis.

Technical analysis is also called **charting** because the graphical representation of prices etc. plays an important part. Technical analysis is thought to be particularly good for timing market moves; fundamental analysis may get the direction right, but not necessarily when the move will happen.

3.2.1 Plotting

The simplest chart types just join together the prices from one day to the next, with time along the horizontal axis. These are the sort of plots we have seen throughout this book. Sometimes a logarithmic scale is used for the vertical price axis to represent return rather than absolute level. Later on we'll see some more complicated types of plotting. Sometimes you will see trading volume on the same graph, this is also used for prediction but I won't go into any details here, see Figure 3.1.

3.2.2 Support and resistance

Resistance is a price level which an asset seems to have difficulty rising above. This may be a previously realized highest value, or it may be a psychologically important (round) number. **Support** is a level below which an asset price seems to be reluctant to fall. There may be sufficient demand at this low price to stop it falling any further. Examples of support and resistance are shown in Figure 3.2.

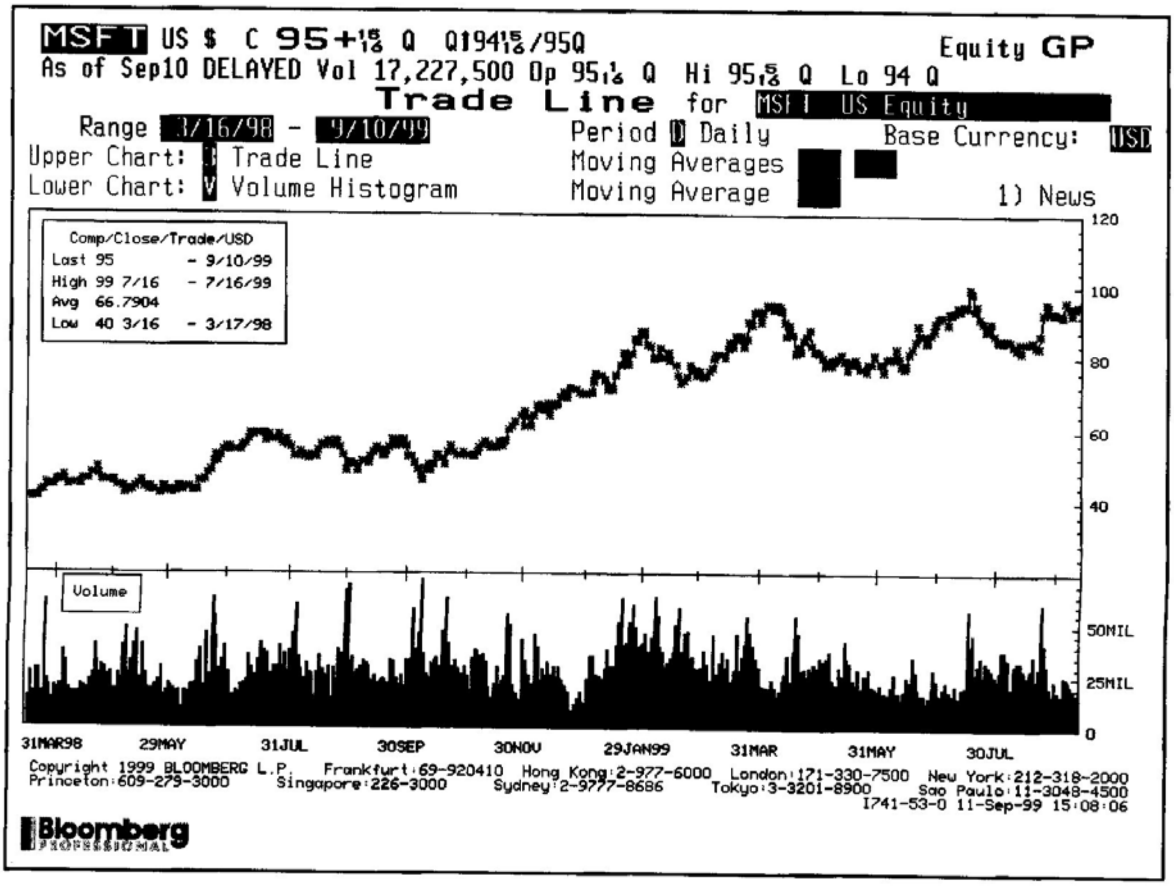


Figure 3.1 Price and volume. Source: Bloomberg L.P.

When a support or resistance level finally breaks it is said to do so quite dramatically.

3.2.3 Trendlines

Similar to support and resistance are **trendlines**. These are formed by joining together successive peaks and/or troughs in the price history to form a rising or falling support or resistance level. An example is shown in Figure 3.3.

3.2.4 Moving averages

Moving averages are calculated in many ways. Different time windows can be used, or even exponentially weighted averages can be calculated. Moving averages are supposed to distill out the basic trend in a price by smoothing the random noise.

Sometimes two moving averages are calculated, say a 10-day and a 250-day average. The crossing of these two would signify a change in the underlying trend and a time to buy or sell.

Although I'm not the greatest fan of technical analysis, there is some evidence that there may be predictive power in moving averages.

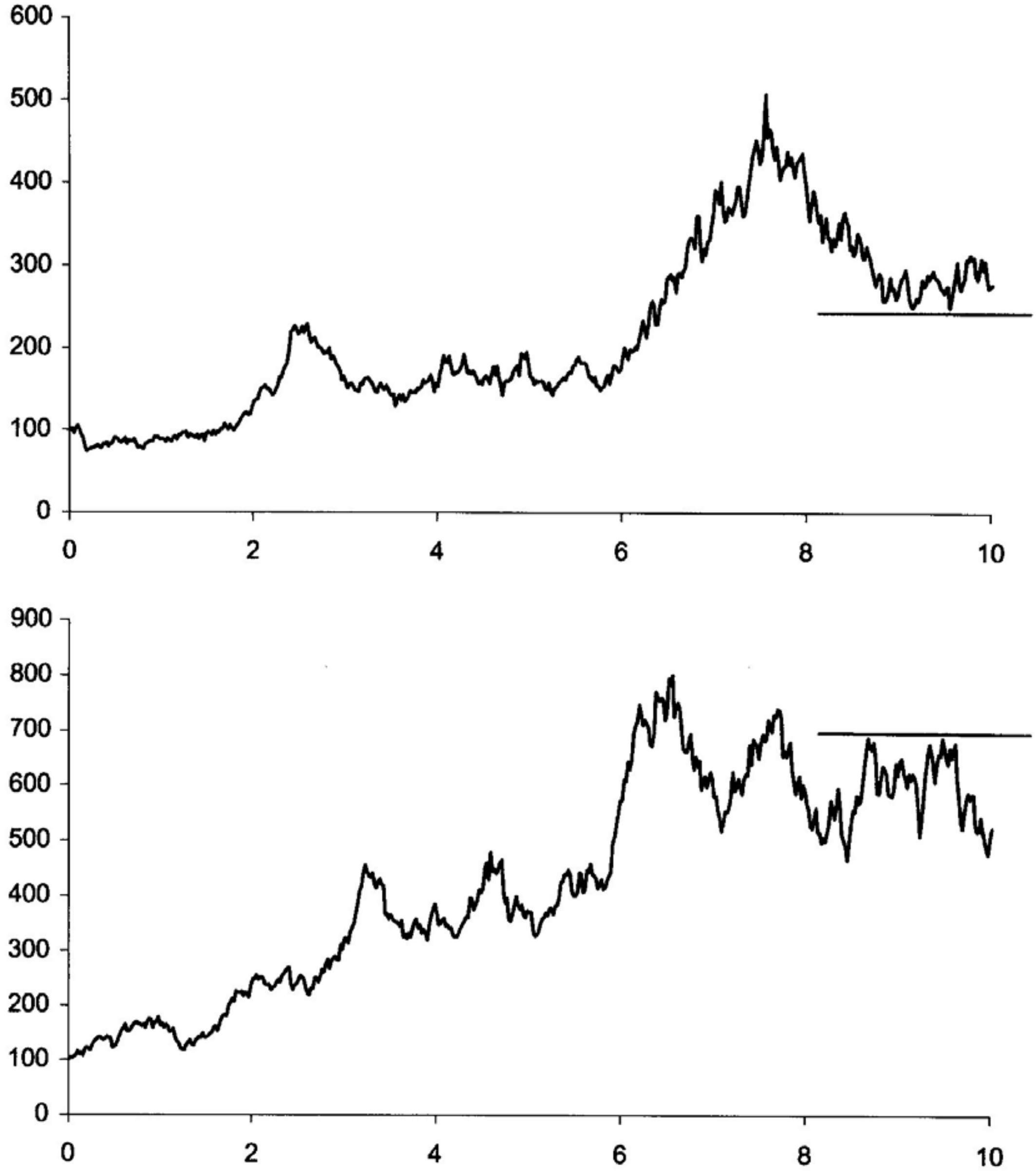


Figure 3.2 Support and resistance.

Figure 3.4 shows a Bloomberg screen with Microsoft share price, 5-day and 15-day moving averages.

3.2.5 Relative strength

The **relative strength index** is the percentage of up moves in the last *N* days. A number higher than 70% is said to be overbought and therefore likely to fall and below 30% is said to be oversold and should rise.

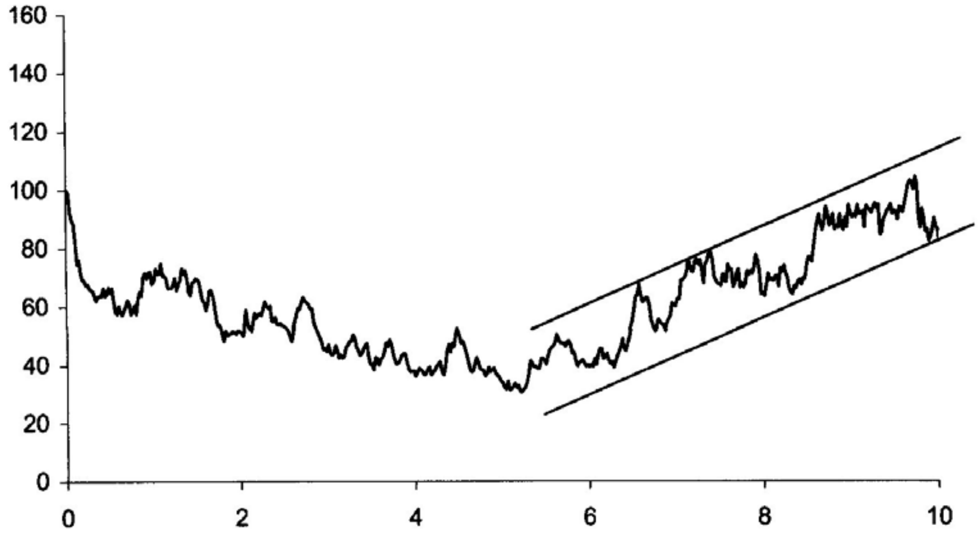


Figure 3.3 A trending stock.

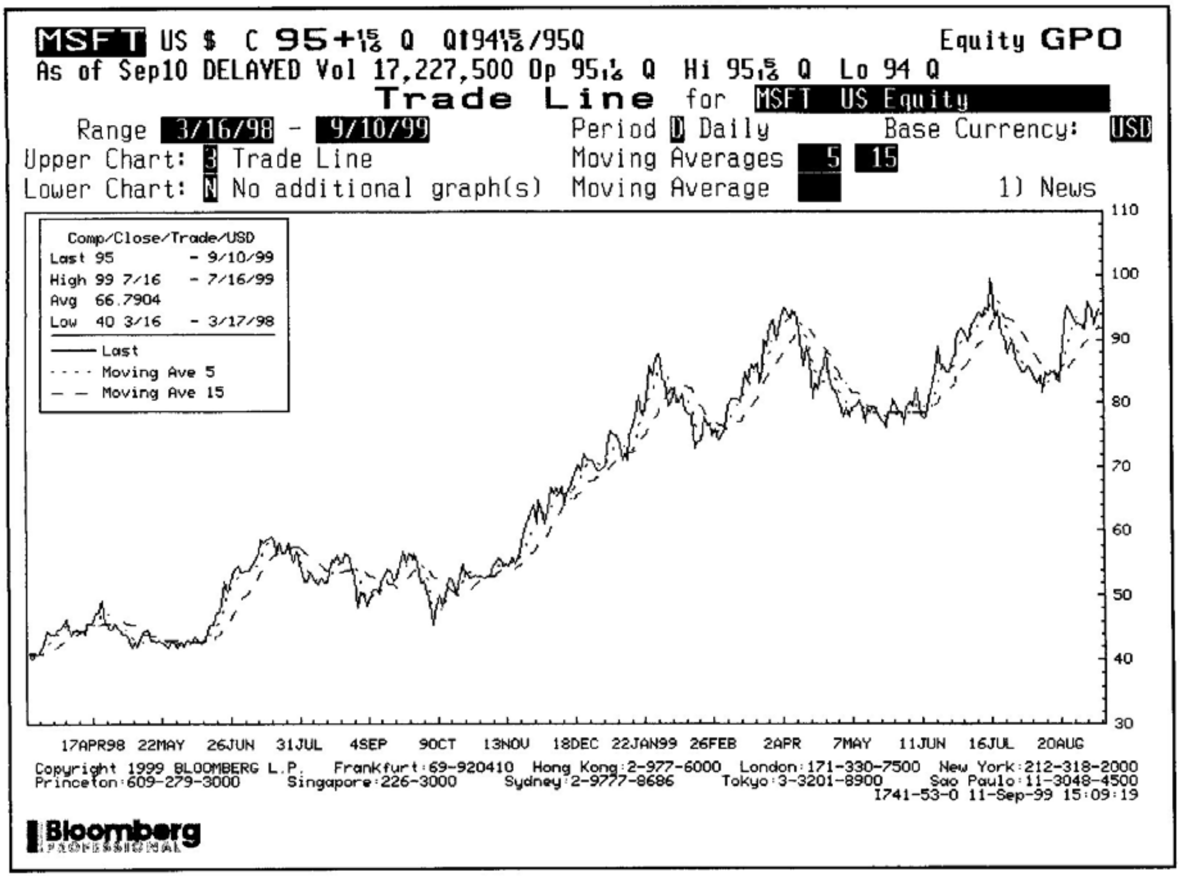


Figure 3.4 Two moving averages. Source: Bloomberg L.P.

3.2.6 Oscillators

An **oscillator** is another indicator of over/underbought conditions. One way of calculating it is as follows.

Define k by

$$100 \times \frac{\text{Current close} - \text{lowest over } n \text{ periods}}{\text{Highest over } n \text{ periods} - \text{lowest over } n \text{ periods}}.$$

Now take a moving average of the last three days, say. This average is plotted against time and any move outside the range 30–70% could be an indication of a move in the asset (Figure 3.5).

3.2.7 Bollinger bands

Bollinger bands are plots of a specified number of standard deviations above and below a specified moving average (Figure 3.6).

3.2.8 Miscellaneous patterns

As well as the 'quantitative' side of charting there is also the 'artistic' side. Practitioners say that certain patterns anticipate certain future moves. It's rather like your grandmother reading tea leaves.

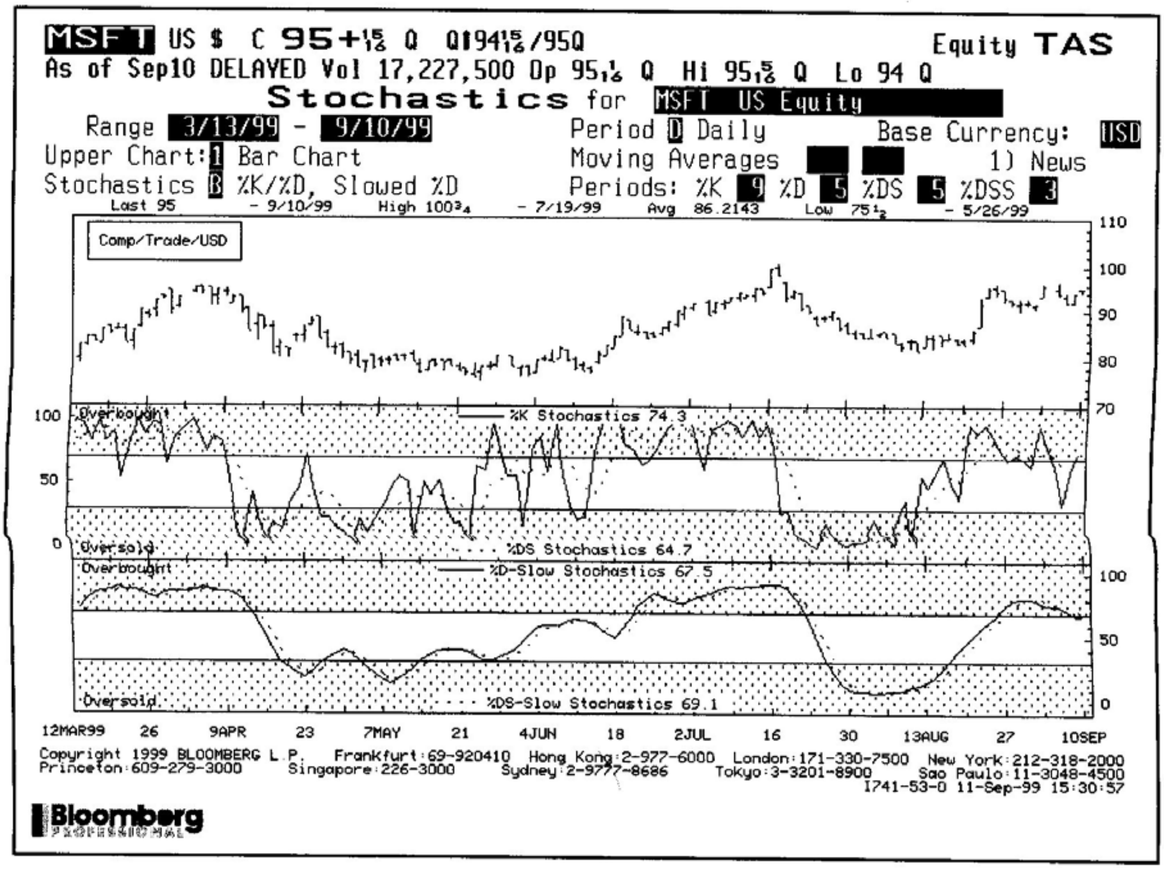


Figure 3.5 Oscillator. Source: Bloomberg L.P.

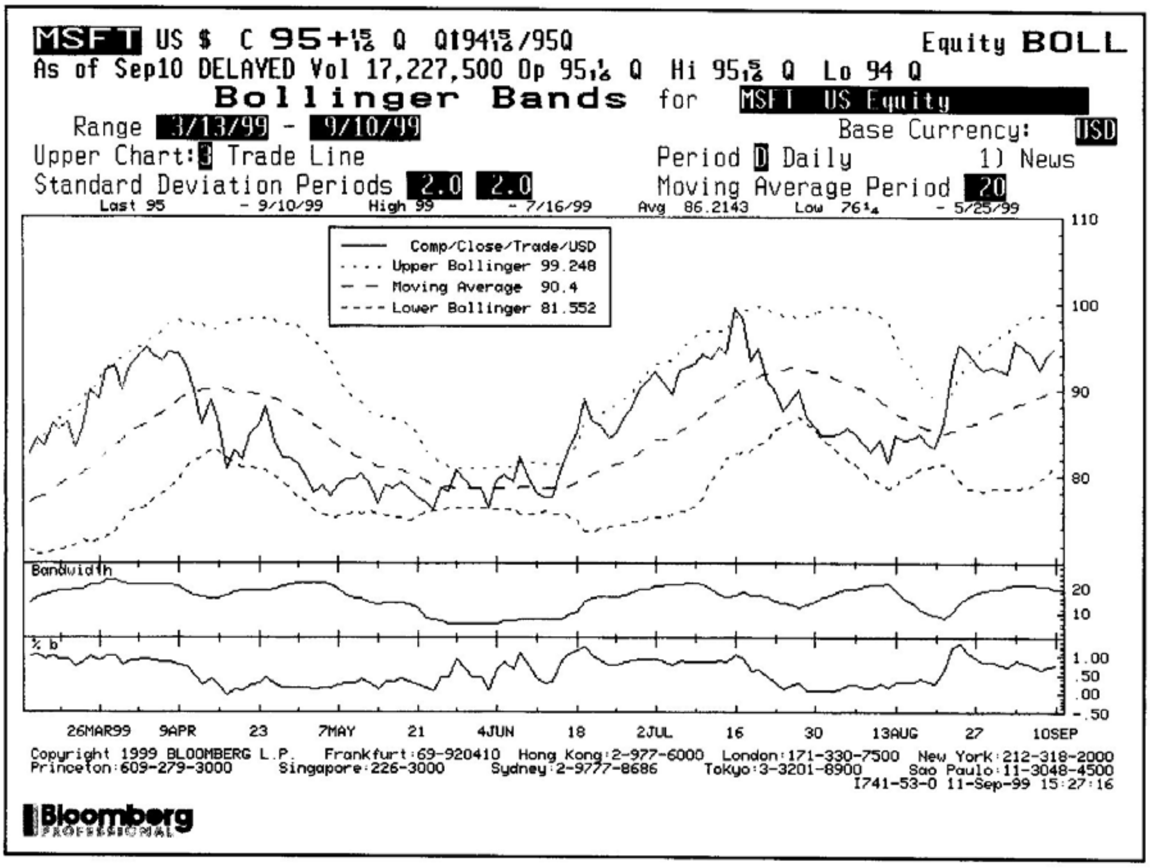


Figure 3.6 Bollinger bands. Source: Bloomberg L.P.

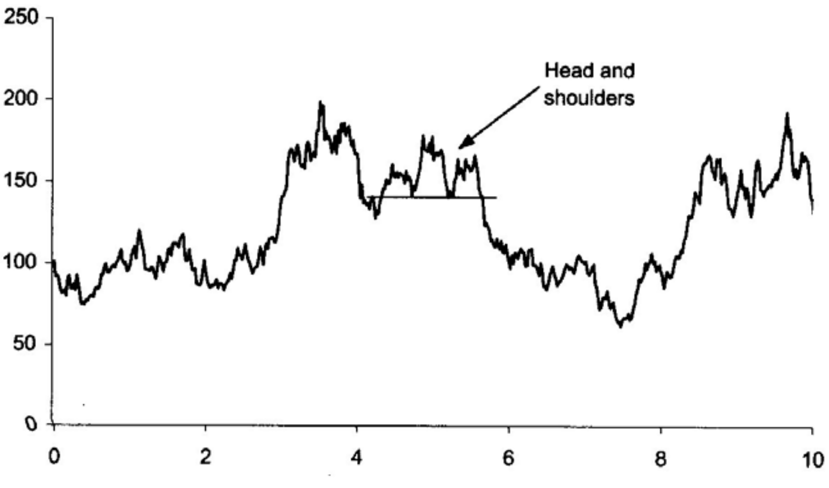


Figure 3.7 Head and shoulders.

Head and shoulders is a common pattern and is best described with reference to Figure 3.7. There are a left and a right shoulder with the head rising above. Following on from the right shoulder should be a dramatic decline in the asset price.

This pattern is supposed to be one of the most reliable predictors. It is also seen in an upside-down formation.

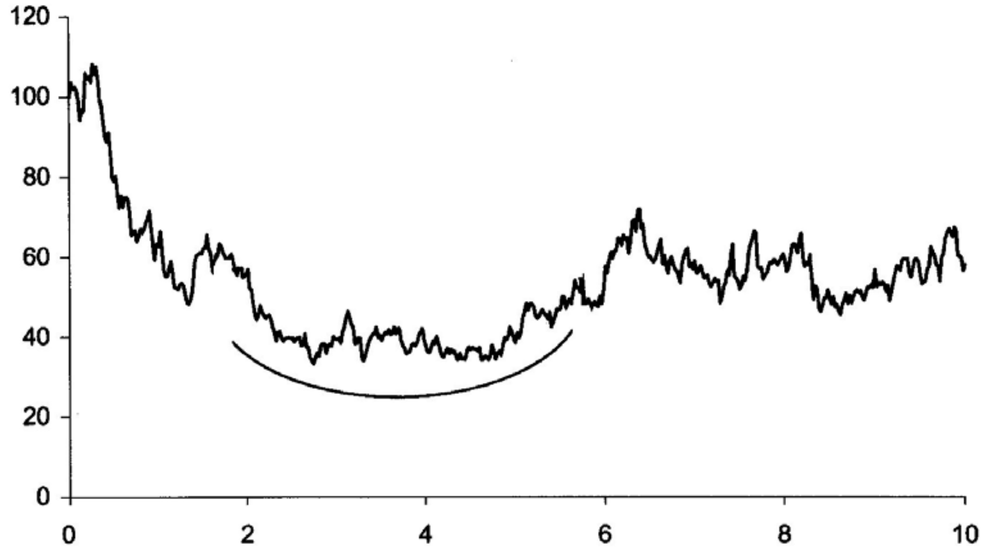


Figure 3.8 Saucer bottom.

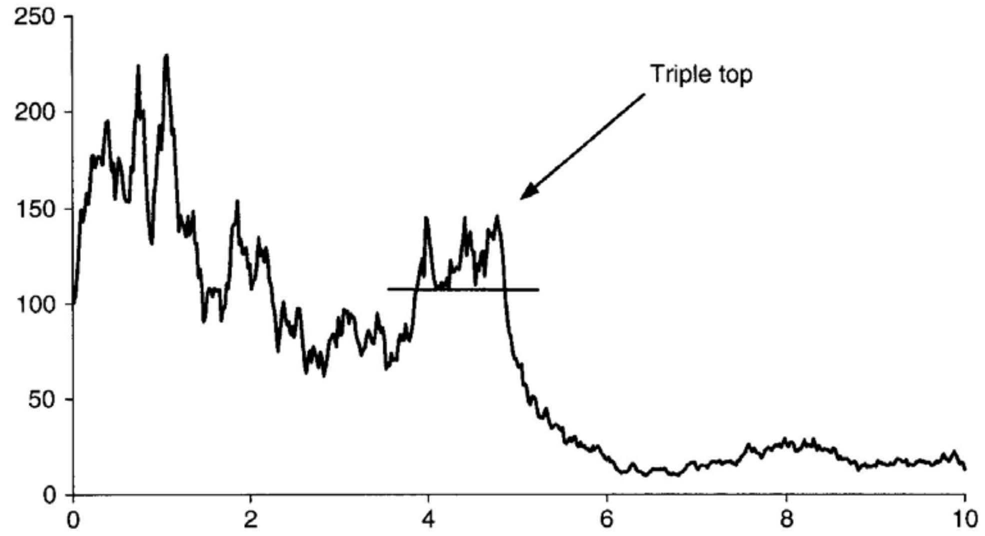


Figure 3.9 A triple top.

Saucer tops and bottoms are also known as **rounding tops** and **bottoms** (Figure 3.8). They are the result of a gradual change in supply and demand. The shape is generally fairly symmetrical as the price rises and falls. These patterns are quite rare. They contain no information about the strength of the new trend.

Double and triple tops and bottoms are quite rare patterns, the triple being even rarer than the double. The double top looks like an 'M' and a double bottom like a 'W.' The triple top is similar but with three peaks, as shown in Figure 3.9. The key point about the peaks and troughs is that they should all be at approximately the same level.

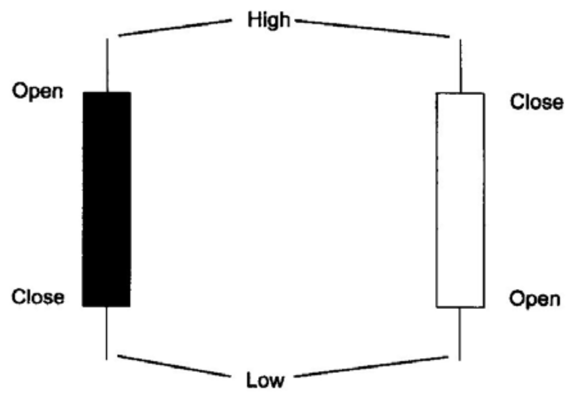


Figure 3.10 Japanese candlesticks.

3.2.9 Japanese candlesticks

Japanese candlesticks contain more information than the simple plots described so far. They record the opening and closing prices as well as the day's high and low. A rectangle is drawn extending from the close to the open, and is colored white if close is above open and black if close is below open. The high-low range is marked by a continuous line.

Certain combinations of candlesticks appearing consecutively have special meanings and names like 'Hanging Man' and 'Upside Gap Two Crows.' See Figure 3.10 for the two types of candlestick and see Figure 3.11 for candlesticks in action. On this chart are shown 'HR' = Bearish Harami, 'D' = Doji (representing indecision), 'BH' = Bullish Harami, 'EL' = Bearish Engulfing Line, and 'H' = Hanging Man (representing reversal after a trend).

Figure 3.12 shows some of the possible candlestick shapes and their interpretation.

3.2.10 Point and figure charts

Point and figure charts are different from the charts described above in that they do not have any explicit timescale on the horizontal axis. Figure 3.13 is an example of a point and figure chart. Each box on the chart represents a prespecified asset price move. The boxes are a way of discretizing asset price moves, instead of discretizing in time. For each consecutive asset price rise of the box size draw an 'X' in the box, in a rising column, one above the other. When this uptrend finishes, and the asset falls, start putting 'O' in a descending column, to the right of the previous rising Xs.

- A long column of Xs denotes demand exceeding supply.
- A long column of Os denotes supply exceeding demand.
- Short up and down columns denote a balance of supply and demand.

3.3 WAVE THEORY

As well as plotting and spotting trends in price movements there have been some theories for price prediction based on market cycles or waves. Below, I briefly mention a couple.

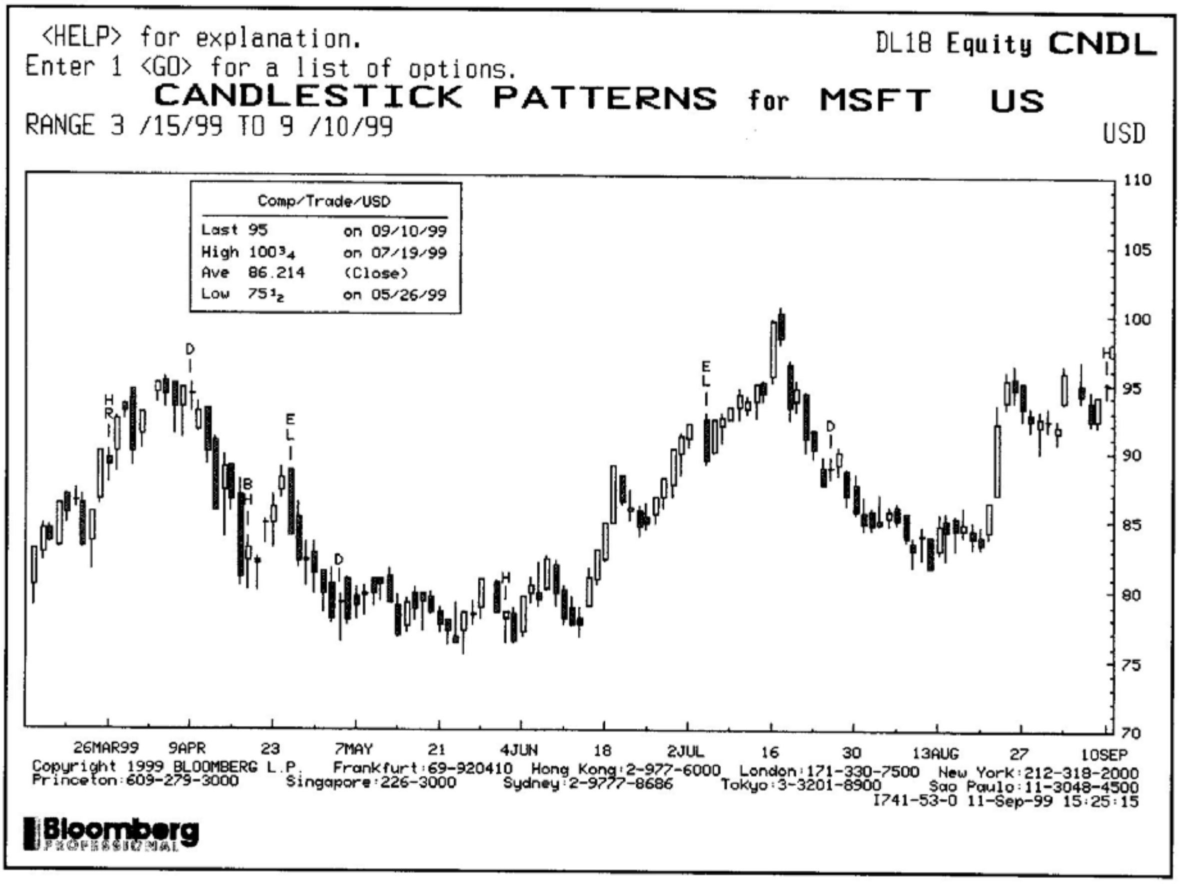
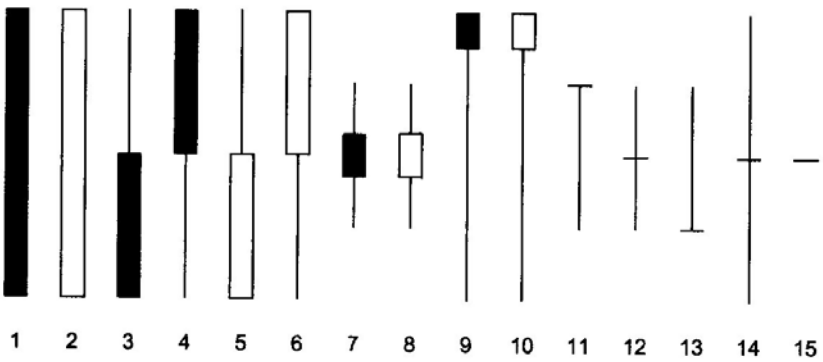


Figure 3.11 A candlestick chart. Source: Bloomberg L.P.



1 Extremely bearish
2 Extremely bullish
3 Bearish
4 Bearish
5 Bullish
6 Bullish
7 Neutral
8 Neutral
9 In downtrend, bullish; in uptrend, bearish
10 In downtrend, bullish; in uptrend, bearish
11 A turning period
12 A turning period
13 End of downtrend
14 A turning period
15 Possible turning period

Figure 3.12 The meanings of the various candlesticks.

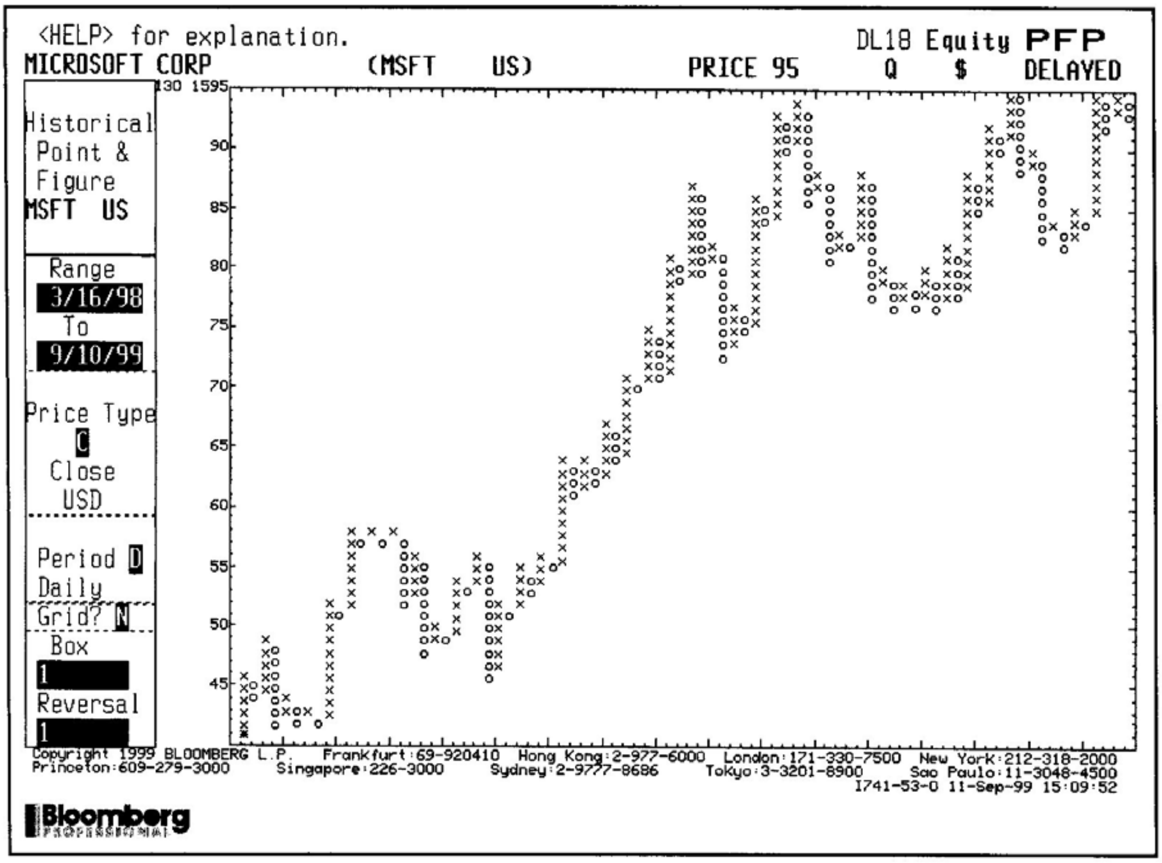


Figure 3.13 A point and figure chart of Microsoft. Source: Bloomberg L.P.

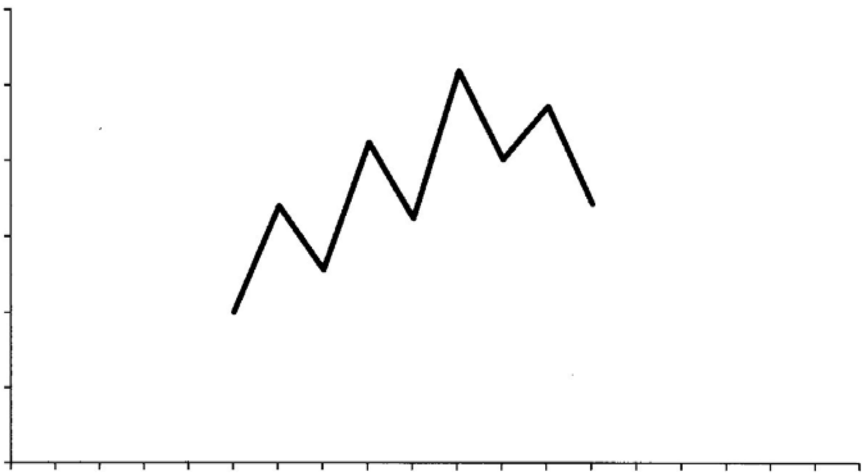


Figure 3.14 Elliot waves.

3.3.1 Elliott waves and Fibonacci numbers

Ralph N. Elliott observed repetitive patterns, waves or cycles in prices. Roughly speaking, there are supposed to be five points in a bullish wave and then three in a bearish one. See Figure 3.14. Within this **Elliott wave theory** there is also supposed to be some predictive

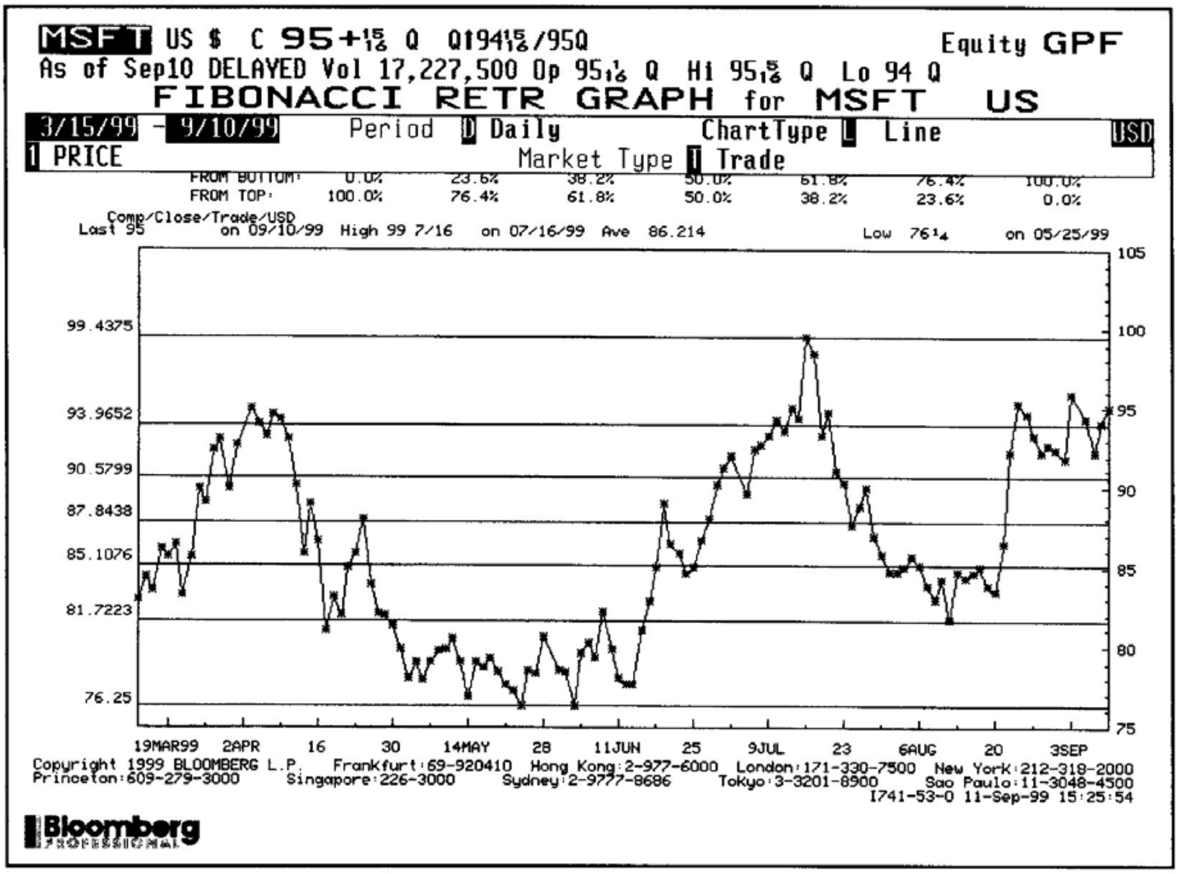


Figure 3.15 Fibonacci lines. Source: Bloomberg L.P.

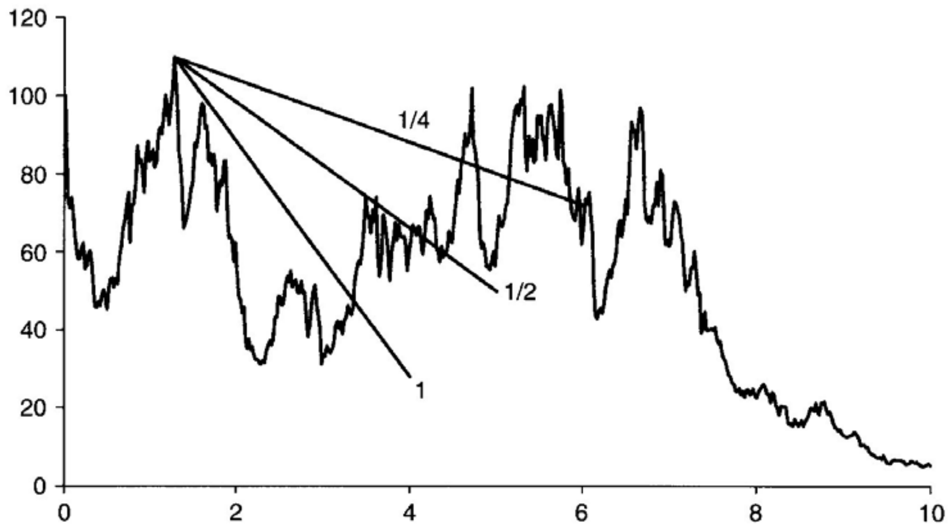


Figure 3.16 Gann charts.

ability in terms of the sizes of the peaks in each wave. For some reason, the ratios of peaks in a trend are supposed to be fairly constant; the ratio of second peak to first should be approximately 1.618 and of the third to the second 2.618. Unfortunately, the number 1.618 is approximately the **Golden ratio** of the ancient Greeks, $\frac{1}{2}\sqrt{5}$. It is also the ratio of successive numbers in the **Fibonacci series** given by $a_n = a_{n-1} + a_{n-2}$ for large n. I say, unfortunately, because people extrapolate wildly from this. And if it's a coincidence then... Figure 3.15 shows the key levels coming from the Fibonacci series.

3.3.2 Gann charts

Figure 3.16 shows a Gann chart. The lines all have slopes which are fractions of the slope of the lowest line. Need I say more?

3.4 OTHER ANALYTICS

There's an almost endless number of ways that chartists analyze data. I'll mention just a couple more before moving on.

Volume is simply the number of contracts traded in a given period. A rising price and high volume means a strong, upwardly trending market. But a rising price with low volume could be a sign that the market is about to turn.

Open interest is the number of still outstanding futures contracts, those which have not been closed out. Because there are equal numbers of buyers and sellers, open interest does not necessarily give any directional info, but an increase in open interest can mean that an existing trend is strong.

3.5 MARKET MICROSTRUCTURE MODELING

The financial markets are made up of many types of players. There are the 'producers' who manufacture or produce or sell various goods and who may be involved in the financial markets for hedging. There are the 'speculators' who try and spot trends in the market, to exploit them and make money. These speculators may be using technical analysis methods, such as those described above, or fundamental analysis, whereby they examine the records and future plans of firms to determine whether stocks are under- or overpriced. Almost all traders use technical analysis at some time. Then there are the market makers who buy and sell financial instruments, holding them for a very short time, often seconds, and profit on bid-offer spreads.

There have been many attempts to model the interaction of these agents, sometimes in a game theoretic way, to try and model the asset price movements that in this book we have taken for granted. For example, can the dynamics induced by the actions of a combination of these three types of agent result in Brownian motion and lognormal random walks?

Below are just a very few examples of work in this area.

3.5.1 Effect of demand on price

Buying and selling assets moves their prices. Market makers respond to demand by increasing price, and reduce prices when the market is selling. If one can model the relationship between demand and price then it should be possible to analyze the effect that various types of technical trading rule have on the evolution of prices. And eventually to model the dynamics of prices.

A common starting point is to assume that there are two types of trader and one market maker. One trader follows a technical trading rule such as watching a moving average and the other is a **noise trader** who randomly buys or sells.

Interesting results follow from such models. For example

- trend followers can induce patterns in asset price time series,
- these artificially induced patterns can only be exploited for gain by someone following a suitably different trend,
- the more people following the same trend as you, the more money you will lose.

There are good reasons for there being genuine trends in the market: There is a slow diffusion of information from the knowledgeable to the less knowledgeable. The piece-by-piece secret acquisition of a company will gradually move a stock price upwards.

On the other hand, if there is no genuine reason for a trend, if it is simply a case of trend followers begetting a trend, then it may be beneficial to be a contrarian.

3.5.2 Combining market microstructure and option theory

Arbitrage does exist, many people make money from its existence. Yet the action of arbitragers will, via a demand/price relationship, remove the arbitrage. But there will be a timescale associated with this removal. What is the optimal way to exploit the arbitrage opportunity while knowing that you actions will to some extent be self-defeating?

3.5.3 Imitation

Another approach to market microstructure modeling is based on the true observation that people copy each other. In these models there are a number of traders who act partly in response to private information about a stock, partly randomly as noise traders, and partly to imitate their nearest neighbors. These models can result in market bubbles or market crashes.

3.6 CRISIS PREDICTION

There has been some work on analyzing data over various timescales to determine the likelihood of a market crash. Some ideas from earthquake modeling have been used to derive a 'Richter'-like measure of market moves. Of course, an effective predictor of market crashes could either

- increase the chance or size of a crash as everyone panics or
- reduce the chance or size of the crash since everyone gets advance warning and can calmy and logically act accordingly.

3.7 SUMMARY

I started out in finance many years ago plotting all of the technical indicators. I was not very successful at it. I could only get directions right for those assets with obvious seasonality effects, such as some commodities.

There is only one technical indicator that I believe in. There is definitely a strong correlation between hemlines and the state of the economy. The shorter the skirts, the better the economy.

FURTHER READING

- The book on technical analysis written by the news agency Reuters (1999) is excellent, as is Meyers (1994).
- Farmer (2000) discusses and models trend following and the creation of trends. He also demonstrates properties of the relationship between demand and price that prevent arbitrage.
- Dewynne & Wilmott (1999) show how to optimally exploit an arbitrage opportunity while moving the market as little as possible.
- Bhamra (2000) has worked on imitation in financial markets.
- Olsen & Associates `www.olsen.ch` are currently working in the area of crisis modeling and prediction.
- Johnson *et al.* (1999) model self-organized segregation of traders, and conclude that cautious traders perform poorly.
- The above is only a brief description of a very few examples from an expanding field. See O'Hara (1995) for a wide-ranging discussion of market microstructure models.
- Bernstein (1998) has a whole chapter on the Golden ratio.
- Elton & Gruber (1995) describe the efficient market hypothesis and criticize technical analysis.
- Prast (2000a,b) discusses 'herding' in the financial markets.