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# FINANCIAL ECONOMETRIC MODELING

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## 1.1 WHAT IS FINANCIAL ECONOMETRICS?

There is no simple definition of financial econometrics. The subject is best described through its many different activities. These include the formulation of financial models intended for empirical implementation, methods of estimation and inference with these models, and their use for forecasting, for policy analysis, and for understanding financial phenomena.

As a subject, financial econometrics is interdisciplinary. It draws on ideas and methods from finance, economics, probability, statistics, and applied mathematics, while at the same time providing a rich source bed of new ideas for modeling, estimation, and inference. Partly because of this diversity, financial econometrics is a vast and growing discipline with applications that stretch across the social and business sciences. Its primary tasks stem from the particular nature of financial data and the body of financial theory that has been developed to explain the complex world of finance and financial instruments that surrounds us.

While the origins of financial econometrics may be traced back to early empirical studies of stock prices, bond yields, and interest rates, the subject began to take aspects of its modern form during the 1980s. At this time, the methods of time series econometrics evolved in ways that were especially beneficial to studying financial data, taking account of features such as the wandering nature of financial asset prices, the volatility of financial returns, and the availability of ultra-high-frequency observations. These new modeling and inferential tools drawn from time series econometrics and other constituent disciplines joined with a growing specialization among econometricians working with financial data to promote the development of a new discipline with the common goal of searching for a deeper understanding of the way in which financial markets work and financial asset prices are determined. Out of this understanding and sustained research, it is to be hoped, regulators and policymaker will be better equipped to assist in monitoring markets toward the lofty goal of financial stability and to guide the smooth functioning of financial markets in the face of crisis.

Central to the success of this scientific process is the initial step of establishing a reliable data set that is well-suited to the various tasks of econometric investigation. The financial data of primary interest in applications are the prices of financial assets and the yields or returns to investments from those assets. The first logical step in the study of financial econometrics, therefore, is to become familiar with the many different types of financial assets, how prices for these assets are quoted and reported, and how yields or returns to investment in such assets are constructed.

A distinguishing feature of financial econometrics that sets the subject apart from many other applications of econometrics, particularly macroeconomics, is the abundance of financial data. Table 1.1 gives a selective listing of commonly used data sources, some of which are free while others require institutional subscription. The vast global financial industry now creates terabytes of data daily covering a huge array of financial assets, producing high dimensional data sets that carry fine-grained transaction level details recording the continuous pulse of financial markets. These data are used in the

**TABLE 1.1 Common sources for finding data on financial variables.**

**Bloomberg**
bloomberg.com
Current and historical data on stocks, preferred stock, indices, bonds, commodities, futures, options, exchange rates, mortgages, and money market instruments.

**Datastream International**
solutions.refinitiv.com/datastream-macroeconomic-analysis
Comprehensive historical data on stocks, indices, bonds, commodities, futures, options, earning forecasts, economic conditions, interest rates, exchange rates, and economic forecasts.

**Federal Reserve Economic Data (FRED)**
fred.stlouisfed.org
FRED collects over 200,000 US and international economic time series. Data coverage includes growth, inflation, employment, interest rates, exchange rates, production and consumption, income and expenditure, savings and investment, and more.

**Kenneth French Data Library**
mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html
US equity returns and data on the Fama–French factors together with returns to sorted portfolios.

**Global Financial Data**
globalfinancialdata.com
Data on bonds, commodities, interest rates, stock markets and indices, futures, macroeconomic variables, stock market capitalization, dividend yields, price/earnings ratios, total return performance indices, and Global Financial Data's World Stock Market Indices. Historical data on selected macroeconomic variables dates to the 1700s and even earlier.

**Robert Shiller Data Library**
econ.yale.edu/ shiller/data.htm
An eclectic collection of historical data including stock, bond, interest rate, and consumption data together with stock market confidence and real estate indices.

**Thompson Reuters Tick History**
financial-risk-solutions.thomsonreuters.info/TickHistory
Based on the DataScope Select platform, TRTH provides access to historical high-frequency data across global asset classes dating to 1996.

**Wharton Research Data Service (WRDS)**
wrds-web.wharton.upenn.edu
Interface to many important financial and economic databases.

**Yahoo Finance**
finance.yahoo.com
Comprehensive data on stocks and currencies (including cryptocurrencies).

industry by financial firms searching for investment opportunities and they provide an extraordinary digitized resource for financial econometricians. Unlike macroeconomics, in finance there is no paucity of data for testing hypotheses of interest. But superabundance of observations is no testament to quality or the absence of measurement error, missing observations, data revisions, or subtleties associated with transaction-level data.

Much work is frequently needed to get financial data into the clean form that is necessary for meaningful empirical analysis. These problems go well beyond the superficial and they can involve deep questions associated with the very structure of trading in financial markets. Addressing the plethora of financial data, the risks associated with data mining, the subtleties involved in transaction-level observations, and the probabilistic foundations of modeling and inference with such data have galvanized the energies of the large and growing community of scholars in financial econometrics. This chapter does not attempt to cover all the interesting twists and turns of data creation in the financial world that applied researchers in financial econometrics have to face in their empirical work. But it will highlight some of these issues and stimulate a renewed awareness of the famous adage that empirical results are only as good as the data on which they are based.

## 1.2 FINANCIAL ASSETS

Although they may have no intrinsic physical worth, financial assets derive value from the contractual claims they place on a stream of services or cash flows. The major categories of financial assets that will be used in this book are cash, fixed-income securities, equity securities, and derivative securities.

### Cash

Cash represents a claim on the stream of services that it can secure by virtue of its role as a medium of exchange. One particularly important financial transaction that may be regarded as a cash investment is dealing in foreign exchange. The exchange rate is simply the price of one currency in terms of another. So trading in currencies may be regarded as investments in cash.

### Fixed-Income Securities

Fixed-income securities provide two sources of return. The first corresponds to a stream of interest payments (or coupons) that are made at fixed, regular intervals, and the second is to the eventual return of principal at maturity. Although the original distinguishing feature of this class of financial asset was that the periodic payment was known in advance, recent developments in financial markets link many of these payments to a particular short-term interest rate and some are even linked to the prevailing inflation rate.

*Money market* fixed-income securities are short-term assets whose markets are particularly active (or liquid). There is now a bewildering array of money market instruments available to study. But only two will feature in this book.

- *Treasury Bills* are the simplest form of government debt. The government sells Treasury Bills in the money market and redeems them at the maturity of the bill.

No interest is payable during the life of the bill and so they trade at discount to the face value of the bill that will be paid at maturity. The most common maturities are 3, 6, and 9 months.

- *Eurodollar Deposits* are the deposits of US banks that are denominated in US$ but held with banks outside the United States. Most of these deposits have a relatively short maturity (less than 6 months) and the Eurodollar deposit rate is commonly used as a representative short-term interest rate.

The *bond market* is the place where longer term borrowing of governments or corporations is conducted. A bond is a security which promises to pay the owner of the bond its face value at the time of the maturity of the bond and usually an ongoing coupon payment prior to maturity. There are also zero-coupon bonds that pay no regular interest and are therefore traded at prices that are below their face value. In recent times, this distinction has become less important because zero-coupon bonds may be created from coupon paying bonds by separating the coupons from the principal and trading each of these components independently. This process is known as stripping.

Another common way in which the fixed-income securities market is classified is by the issuer of the securities. For instance, a distinction is sometimes made between bonds issued by financial intermediates (FI bonds) and non-financial intermediaries (NFI bonds). Financial intermediaries are entities that facilitate financial transactions between two or more parties and include commercial banks, investment banks, and insurance companies.

### Equity Securities

Equities or common stocks give the owner an equity stake in a company and a corresponding claim on company assets and earnings. Equities can be bought and sold on stock markets. Stocks give the owner the right to a payment that represents the distribution of some of the company's earnings, which is known as a dividend. The dividend is usually expressed as the amount each share receives or as a percentage of the current market price, which is referred to as the dividend yield.

### Derivative Securities

Derivative securities provide a payoff based on the value(s) of other assets such as commodities, bonds, or stocks. Such securities therefore *derive* their own value from the market performance of the other underlying assets to which they are attached. Derivatives started out as over-the-counter (OTC) trades where interested parties made mutually beneficial trades. In recent years, as more standardized contracts have emerged, derivatives have been very actively traded on exchanges such as the Chicago Board of Exchange.

Two classes of derivative securities are emphasized in this book.

- *Options* contracts offer the buyer the right, but not the obligation, to buy (call option) or sell (put option) some designated financial asset (the underlying asset from which the option derives its value) at a particular price during a certain period of time or on a specific date.
- *Futures* contracts specify the delivery of either an asset or a cash value at a time known as the maturity for an agreed price, which is payable at maturity. The entity

who commits to purchase the asset on delivery takes a *long* position. The entity who commits to delivering the asset takes a *short* position.

One of the most significant developments in financial markets in recent years has been the growth of derivatives markets as illustrated in Figure 1.1. The problem with measuring the size of the derivatives market stems from the fact that there is a large volume of OTC trades which make it difficult to quantify the exact volume of derivative trading. What is clear from Figure 1.1, however, is that the combined outstanding value of derivatives is several orders larger than world gross domestic product, particularly in the latter part of the period.

## 1.3 EQUITY PRICES AND RETURNS

In this section, the prices of financial assets and the returns to holding these assets will be couched in terms of common stocks. Stocks represent an equity claim on the company and typically, although not always, receive a regular stream of dividend payments. Prices and returns associated with other financial assets are determined in a similar way.

### 1.3.1 Prices

The most basic data in financial econometrics are the prices of financial assets. The price of an equity security is defined in terms of the dollar (or other currency denomination) amount at which a transaction can occur (a quoted price) or has occurred (an historical transaction price). When dealing with high-frequency data the appropriate prices are usually quoted prices. An illustration is provided in Table 1.2 that gives quoted

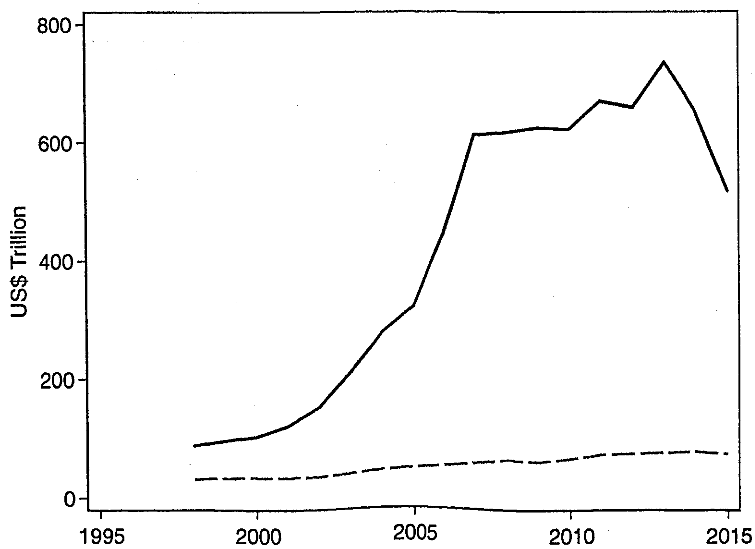


**FIGURE 1.1** Total outstanding value of derivatives contracts (solid line) plotted against gross world product (dashed line) from 1998 to 2015.

**TABLE 1.2 Quoted prices on Yahoo! Finance for The Boeing Company (BA) for 12 September 2014.**

| The Boeing Company (BA) - NYSE<br>127.64 ↓ 0.58(0.45%) | | | |
|---|---|---|---|
| Prev Close: | 128.22 | Day's Range: | 127.20 – 127.99 |
| Open | 127.82 | 52wk Range: | 109.14 – 144.57 |
| Bid: | 127.50 | Volume: | 1,988,616 |
| Ask: | 127.84 | Market Cap: | 91,98 bn. |

Source: https://finance.yahoo.com.

prices obtained from Yahoo Finance for common stock in the US company Boeing on September 2014.

Recording a price for the purpose of econometric analysis is not as straightforward as it might seem. A number of alternatives are available. In addition to the previous day closing price and the current day opening price, there are also prevailing bid and ask prices. The bid price is the maximum price that buyers are willing to pay for the stock, and the ask price is the minimum price that sellers are willing to accept for the stock. The differential between the bid and ask price is called the spread. Many studies that use intra-day data (popularly known as high-frequency data) compromise this complexity by using the midpoint of the bid and ask prices as the best summary estimate of the prevailing current price. This convention simplifies data analysis but circumvents important details of the transaction price determination process. In doing so it produces intriguing econometric problems arising from the impact of the neglected market microstructure in modeling prices, as we now explain.

The practice of using summary estimates of prices, like the midpoint of the bid-ask spread, points to an unusual feature of high-frequency data that affects econometric work: increasing the number of observations by using intra-day data need not always increase efficiency or improve understanding. More data often means that there is more to explain. Indeed, in the present case, adding more data by using more frequent observations changes the focus of attention toward a microscopic focus on the transaction process itself. This new focus in turn raises the dimensionality of the econometric problem by virtue of the complexity of the transaction process, which brings buyers and sellers together through a market determination process that involves multiple bid-ask order layers in which random elements may enter the price determination process in the microcosm of market forces.

When dealing with historical prices recorded at lower frequencies the situation is less complex. Table 1.3 reports the historical daily prices for the US stock Microsoft for the month of August 2014. The choice for the researcher is now simpler. We have the recorded opening price, closing price, daily highs and lows, and the adjusted closing price. In most cases it is convenient to choose the adjusted closing price (denoted by Close*), which is adjusted for stock splits and dividends.

The effect of a dividend payment is to lower the price by the amount of the dividend so that the closing price on 18 August is greater than the opening price on 19 August. In order to ensure that the effect of the dividend is smoothed out in historical prices, the correction is to subtract the dividend from the closing price on the previous day, compute the quotient $(P_{t-1} - D_t)/P_{t-1}$, and then multiply all previous prices by this factor. On 18 August the closing price and the adjustment factor are given by

**TABLE 1.3** Daily prices for the United States stock Microsoft (MSFT) for the month of August 2014. All prices are quoted in US$. The column Close* gives the closing price adjusted for dividends and stock splits. A dividend of US$ 0.28 per share was paid on 19 August 2014.

| Date | Open | High | Low | Close | Volume | Close* |
|---|---|---|---|---|---|---|
| 29 Aug 2014 | 45.09 | 45.44 | 44.86 | 45.43 | 21607600 | 45.43 |
| 28 Aug 2014 | 44.75 | 44.98 | 44.61 | 44.88 | 17657600 | 44.88 |
| 27 Aug 2014 | 44.90 | 45.00 | 44.76 | 44.87 | 20823000 | 44.87 |
| 26 Aug 2014 | 45.31 | 45.40 | 44.94 | 45.01 | 14873100 | 45.01 |
| 25 Aug 2014 | 45.40 | 45.44 | 45.04 | 45.17 | 16898100 | 45.17 |
| 22 Aug 2014 | 45.35 | 45.47 | 45.07 | 45.15 | 18294500 | 45.15 |
| 21 Aug 2014 | 44.84 | 45.25 | 44.83 | 45.22 | 22272000 | 45.22 |
| 20 Aug 2014 | 45.34 | 45.40 | 44.90 | 44.95 | 24750700 | 44.95 |
| 19 Aug 2014 | 44.97 | 45.34 | 44.83 | 45.33 | 28115600 | 45.33 |
| | | | Dividend US$ 0.28 | | | |
| 18 Aug 2014 | 44.94 | 45.11 | 44.68 | 45.11 | 26891100 | 44.83 |
| 15 Aug 2014 | 44.58 | 44.90 | 44.40 | 44.79 | 41611300 | 44.51 |
| 14 Aug 2014 | 44.08 | 44.42 | 44.01 | 44.27 | 19313200 | 44.00 |
| 13 Aug 2014 | 43.68 | 44.18 | 43.52 | 44.08 | 22889500 | 43.81 |
| 12 Aug 2014 | 43.04 | 43.59 | 43.00 | 43.52 | 21431100 | 43.25 |
| 11 Aug 2014 | 43.26 | 43.45 | 43.02 | 43.20 | 20351600 | 42.93 |
| 8 Aug 2014 | 43.23 | 43.32 | 42.91 | 43.20 | 28942700 | 42.93 |
| 7 Aug 2014 | 42.84 | 43.45 | 42.65 | 43.23 | 30314900 | 42.96 |
| 6 Aug 2014 | 42.74 | 43.17 | 42.21 | 42.74 | 24634000 | 42.47 |
| 5 Aug 2014 | 43.31 | 43.46 | 42.83 | 43.08 | 26266400 | 42.81 |
| 4 Aug 2014 | 42.97 | 43.47 | 42.81 | 43.37 | 34277400 | 43.10 |
| 1 Aug 2014 | 43.21 | 43.25 | 42.60 | 42.86 | 31170300 | 42.59 |

Source: https://finance.yahoo.com.

$$\$44.83 = 45.11 - 0.28 \quad \text{and} \quad \frac{45.11 - 0.28}{45.11} = 0.9938,$$

respectively. In consequence, the adjusted closing price on 15 August is

$$\$44.51 = 44.79 \times 0.9938.$$

Note that this process of adjustment means that the historical prices do not necessarily reflect the actual prices at which trades took place.

The adjustment process for a stock split is similar. Suppose, for instance, that a 2-for-1 stock split occurs in which a company replaces each existing share by two shares (or some other multiple). Then the price of an individual share is immediately halved (or scaled by the otherwise appropriate fraction). Such splits make shares appear more affordable even though the underlying market capitalization of the company has not changed. To avoid the artificially induced discontinuity in the share price at the time of the split, all historical prices need to be divided by 2 and the historical volume series correspondingly multiplied by 2 so that the price after the split and the price before the split are comparable.

A further issue of data comparability is the presence of non-trading days in the raw data. For instance, a close look at the calendar days in the first column of Table 1.3 reveals a number of missing days, each of which corresponds (in this instance) to weekends and public holidays. But there may be days other than public holidays and weekends when a stock does not trade. In addition, when comparing time series of stock prices from different countries, public holidays do not always fall on the same days. In preparing data for empirical work, all these details need attention.

### 1.3.2 Returns

The return to a financial asset probably receives more attention in financial econometrics than does the price of an asset, although the movement of stock prices over long historical periods is also of substantial interest to investors and is relevant in practical econometric work dealing with longer term trends. Broadly speaking, a financial return provides a measure of outcome of the decision to invest in a financial asset. This measure accounts not only for the capital gain or loss due to the price change over the holding period of the asset but also for the cumulative impact of the contractual stream of cash flows that take place over the course of the holding period.

In principle, a financial asset might be held for an indeterminate period. Historically, stock prices were usually measured at daily, weekly, and monthly frequencies. In that case, the holding period of the investment is limited to a multiple of this frequency. But with the advent of readily available high-frequency data, returns can be computed for most holding periods, even extremely short ones. The latter have become much more important with computerized trading practice.

#### Dollar Returns

The simplest measure of return on holding an asset for $k$ periods between time $t-k$ and $t$ is the dollar return, denoted $\$R_{kt}$, given by the price differential over this period,

$$\$R_{kt} = P_t - P_{t-k}.$$

Although this measure is a simple intuitive response to the problem of computing the return to an investment, its major drawback is that it is not scale-free and does not measure the return relative to the initial investment. Moreover, this measure depends on the unit in which prices (and dividends) are quoted. To make returns comparable across assets and across international financial markets, scale-free measures of returns are required.

#### Simple Returns

The simple return on an asset between time $t-1$ and $t$ is given by

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} = \frac{P_t}{P_{t-1}} - 1. \tag{1.1}$$

The relative price ratio $P_t/P_{t-1}$, also known as the price relative (or prel for short), is a useful quantity to compute. If the ratio is greater than 1 then returns are positive; and if it is less than 1 returns are negative. Equation (1.1) may be rearranged as

$$1 + R_t = \frac{P_t}{P_{t-1}},$$

in which $1 + R_t$ is known as the simple gross return. The usefulness of the simple gross return is that it represents the value at time $t$ of investing \$1 at time $t-1$.

The return to holding an asset for $k$ periods, $R_t(k)$, is given by

$$\begin{aligned}
R_t(k) &= \frac{P_t}{P_{t-k}} - 1 \\
&= \frac{P_t}{P_{t-1}} \times \frac{P_{t-1}}{P_{t-2}} \times \cdots \times \frac{P_{t-k+2}}{P_{t-k+1}} \times \frac{P_{t-k+1}}{P_{t-k}} - 1 \\
&= (1+R_t) \times (1+R_{t-1}) \times \cdots \times (1+R_{t-k+2}) \times (1+R_{t-k+1}) - 1 \\
&= \prod_{j=0}^{k-1} (1+R_{t-j}) - 1. \qquad (1.2)
\end{aligned}$$

The point to be emphasized in this calculation is that simple returns are not additive when computing multi-period returns because of the multiplicative effect of period-by-period returns.

If the data frequency is monthly, then the simple return for a holding period of 1 year is given by

$$R_t(12) = \left[\prod_{j=0}^{11} (1+R_{t-j})\right] - 1. \qquad (1.3)$$

The most common period over which a return is quoted is 1 year, and returns data are commonly presented in per annum terms. This means that the current monthly return needs to be appropriately scaled so that it is interpretable as an annual return and expressed on a per annum basis. In the case of monthly returns, the associated annualized simple return is computed as

$$\text{Annualized } R_t(12) = (1+R_t)^{12} - 1. \qquad (1.4)$$

Expression (1.4) is obtained from equation (1.3) by making the assumption that the best guess of the per annum return is that the current monthly return will persist for the next 12 months. In this case, all the terms in the product expansion (in square brackets) of equation (1.3) will be identical.

**Log Returns**

The log return of an asset is defined as

$$r_t = \log(1+R_t) = \log P_t - \log P_{t-1}. \qquad (1.5)$$

Log returns are also referred to as continuously compounded returns. To understand why this is so, it is convenient to use the exponential constant $e$. The Swiss mathematician Leonhard Euler (1707–1783) named this constant, introduced the letter $e$ to represent it, showed its now well-known exponential series representation, and proved its form in terms of the limiting operation

$$e \equiv \lim_{s\to\infty} \left(1 + \frac{1}{s}\right)^s \approx 2.71828.$$

Somewhat earlier in 1683, another Swiss mathematician Jacob Bernoulli (1655–1705) attempted to find this limit in studying the effect of continuously compounded interest. Its discovery is often attributed to him and links the mathematics of compound interest with the subjects of accounting, finance, and economics. The limit formula above represents the value of an account at the end of the year that started with \$1.00 and paid 100% interest per year but with the interest compounded continuously over time rather than at discrete intervals during the year.

If $m$ is the compounding period and $r_t$ the return, then it follows from above that

$$P_t = P_{t-1}\left(1+\frac{r_t}{m}\right)^m.$$

Continuous compounding is produced when $m \to \infty$ leading to

$$P_t = P_{t-1} \lim_{m\to\infty}\left(1+\frac{r_t}{m}\right)^m. \tag{1.6}$$

Let $s = m/r_t$ in this formula. Then the expression in (1.6) may be rewritten as

$$\begin{aligned} P_t &= P_{t-1} \lim_{s\to\infty}\left[\left(1+\frac{1}{s}\right)^{sr_t}\right] \\ &= P_{t-1}\left[\lim_{s\to\infty}\left(1+\frac{1}{s}\right)^{s}\right]^{r_t} \\ &= P_{t-1}e^{r_t}. \end{aligned} \tag{1.7}$$

Taking logarithms of expression (1.7) yields the definition of the log returns given in equation (1.5).

Log returns are particularly useful because of the simplification they allow in dealing with multiperiod returns. For example, the 2-period return is given by

$$\begin{aligned} r_t(2) &= \log P_t - \log P_{t-2} \\ &= (\log P_t - \log P_{t-1}) + (\log P_{t-1} - \log P_{t-2}) \\ &= r_t + r_{t-1}. \end{aligned} \tag{1.8}$$

By extension, the $k$-period return is

$$\begin{aligned} r_t(k) &= \log P_t - \log P_{t-k} \\ &= (\log P_t - \log P_{t-1}) + (\log P_{t-1} - \log P_{t-2}) + \cdots + (\log P_{t-k+1} - \log P_{t-k}) \\ &= r_t + r_{t-1} + \cdots + r_{t-(k-1)} \\ &= \sum_{j=0}^{k-1} r_{t-j}. \end{aligned} \tag{1.9}$$

In other words, the $k$-period log return is simply the sum of the single period log returns over the pertinent period.

For the case of data observed monthly, the annual log return is

$$r_t(12) = \log P_t - \log P_{t-12} = \sum_{j=0}^{11} r_{t-j}. \tag{1.10}$$

Once again, expression (1.9) may be used to obtain the returns expressed on a per annum basis by simply multiplying all monthly returns by 12, making the implicit assumption that the best guess of the per annum return is that the current monthly return will persist for the next 12 months.

By analogy, if prices are observed quarterly, then the individual quarterly returns can be annualized by multiplying the quarterly returns by 4. Similarly, if prices are observed daily, then the daily returns are annualized by multiplying the daily returns by the number of trading days 252. The choice of 252 for the number of trading days in a calendar year is an approximation because of the effect of public holidays, leap years, and additional days of trading interruption. Other choices are 250; and, very rarely, the number of calendar days, 365.

Table 1.4 provides calculations based on historical monthly prices for the US stock Microsoft showing the mechanics of return computations from the price of a stock. Note that no return figures are reported for January 2012. Their absence emphasizes that an observation is lost at the beginning of the sample when computing returns because the price of the stock before the start of the sample period is not available. The monthly dollar, simple, and log returns to Microsoft for February 2012 are, respectively,

$$\$R_t = 31.74 - 29.53 = \$2.210,$$
$$R_t = \frac{31.74 - 29.53}{29.53} = 0.075 = 7.5\%,$$
$$r_t = \log(1 + 0.075) = 0.072 = 7.2\%.$$

**TABLE 1.4 Monthly prices for the US stock Microsoft for the years 2012 and 2013. Also shown are alternative measures of the one-month return to holding Microsoft. Prices are month-end closing prices adjusted for splits and dividends quoted in US$.**

| Date | Price | Prel | Monthly Dollar Return | Monthly Simple Return | Monthly Log Return | Annual Simple Return | Annual Log Return |
|---|---|---|---|---|---|---|---|
| Jan 2012 | 29.530 | ... | ... | ... | ... | ... | ... |
| Feb 2012 | 31.740 | 1.075 | 2.210 | 0.075 | 0.072 | 1.378 | 0.866 |
| Mar 2012 | 32.250 | 1.016 | 0.510 | 0.016 | 0.016 | 0.211 | 0.191 |
| Apr 2012 | 32.020 | 0.993 | −0.230 | −0.007 | −0.007 | −0.082 | −0.086 |
| May 2012 | 29.190 | 0.912 | −2.830 | −0.088 | −0.093 | −0.671 | −1.110 |
| Jun 2012 | 30.590 | 1.048 | 1.400 | 0.048 | 0.047 | 0.754 | 0.562 |
| Jul 2012 | 29.470 | 0.963 | −1.120 | −0.037 | −0.037 | −0.361 | −0.448 |
| Aug 2012 | 30.820 | 1.046 | 1.350 | 0.046 | 0.045 | 0.712 | 0.537 |
| Sep 2012 | 29.780 | 0.966 | −1.040 | −0.034 | −0.034 | −0.338 | −0.412 |
| Oct 2012 | 28.530 | 0.958 | −1.245 | −0.042 | −0.043 | −0.401 | −0.512 |
| Nov 2012 | 26.620 | 0.933 | −1.915 | −0.067 | −0.069 | −0.566 | −0.834 |
| Dec 2012 | 26.730 | 1.004 | 0.110 | 0.004 | 0.004 | 0.051 | 0.049 |
| Jan 2013 | 27.470 | 1.028 | 0.740 | 0.028 | 0.027 | 0.388 | 0.328 |
| Feb 2013 | 27.800 | 1.012 | 0.330 | 0.012 | 0.012 | 0.154 | 0.143 |
| Mar 2013 | 28.610 | 1.029 | 0.810 | 0.029 | 0.029 | 0.411 | 0.345 |
| Apr 2013 | 33.100 | 1.157 | 4.490 | 0.157 | 0.146 | 4.751 | 1.749 |
| May 2013 | 34.880 | 1.054 | 1.780 | 0.054 | 0.052 | 0.875 | 0.629 |
| Jun 2013 | 34.530 | 0.990 | −0.350 | −0.010 | −0.010 | −0.114 | −0.121 |
| Jul 2013 | 31.830 | 0.922 | −2.700 | −0.078 | −0.081 | −0.624 | −0.977 |
| Aug 2013 | 33.400 | 1.049 | 1.570 | 0.049 | 0.048 | 0.782 | 0.578 |
| Sep 2013 | 33.310 | 1.097 | −0.090 | −0.003 | −0.003 | −0.032 | −0.032 |
| Oct 2013 | 35.350 | 1.061 | 2.040 | 0.061 | 0.059 | 1.041 | 0.713 |
| Nov 2013 | 38.130 | 1.079 | 2.780 | 0.079 | 0.076 | 1.480 | 0.908 |
| Dec 2013 | 37.430 | 0.982 | −0.700 | −0.018 | −0.019 | −0.199 | −0.222 |

Source: Bloomberg.

These calculations demonstrate that continuously compounded returns are very similar to simple returns as long as the return is relatively small, which it generally will be for monthly or daily returns. Indeed, it is only really at the third decimal place that the differences between the two definitions of returns become readily apparent.

Despite the similarities in the two measures of returns, appreciable differences emerge when the returns are annualized. For the simple return in February 2012 the calculation is

$$R_t(12) = (1 + 0.075)^{12} - 1 = 1.378 = 137.8\%.$$

By contrast, the annualized log return is

$$r_t(12) = 12 \times 0.072 = 0.866 = 86.6\%.$$

Note that the practice of quoting figures as annual rates is usually related to scaling the data. Returns, when computed over the time interval of a day or even shorter intervals, can be relatively small in value and this may lead to arithmetic errors when doing complex computations involving the returns. Annualizing the return scales can help to alleviate this problem.

### Dealing with Dividends

Adjusting the computation of returns for the payment of a dividend, $D_t$, between time $t-1$ and $t$, is relatively straightforward. The dollar return becomes

$$\$R_t = P_t + D_t - P_{t-1},$$

in which $P_t$ and $P_{t-1}$ are the unadjusted prices. The simple and gross returns are then given by

$$R_t = \frac{P_t + D_t - P_{t-1}}{P_{t-1}} = \frac{P_t}{P_{t-1}} + \frac{D_t}{P_{t-1}} - 1, \tag{1.11}$$

$$(1 + R_t) = \frac{P_t + D_t - P_{t-1}}{P_{t-1}} = \frac{P_t}{P_{t-1}} + \frac{D_t}{P_{t-1}}, \tag{1.12}$$

respectively. It is apparent from equations (1.11) and (1.12) that the simple and gross returns to a stock in the presence of a dividend payment are easily computed in terms of the price relative, $P_t/P_{t-1}$ and the dividend yield, $D_t/P_{t-1}$.

Adjusting log returns for a dividend payment simply requires using the correct definition of gross simple returns when taking logarithms

$$r_t = \log(1 + R_t) = \log\left(1 + \frac{P_t + D_t - P_{t-1}}{P_{t-1}}\right) = \log\left(\frac{P_t}{P_{t-1}} + \frac{D_t}{P_{t-1}}\right).$$

Much of the earlier discussion concerning the computation of returns has reflected common practice and ignored the issue of dividends. This practice stems from the reality that dividends are paid relatively infrequently and constitute a minor proportion of the overall return compared with price movements.

### Excess Returns

The difference between the return on a risky financial asset and a risk-free interest rate, denoted $r_{ft}$, is known as the excess return. The risk-free rate is often taken to be the interest rate on a government bond. The simple and log excess returns on an asset are therefore defined as $R_t - r_{ft}$ and $r_t - r_{ft}$, respectively. In computing the excess returns it is important to ensure that the risk-free interest rate is expressed in the same unit of time as the return on the risky financial asset. For example, interest rates are normally quoted as annual rates, so in the case of monthly log returns the quoted annual risk-free interest rate would need to be divided by 12.

### 1.3.3 Portfolio Returns

Financial econometric work is often concerned not with the return to a single asset as the prime object of the investigation but rather the return to a portfolio of financial assets. Attention to a portfolio of assets accords more closely with individual and firm investment decisions. In order to deal with this revised focus, it is necessary to address the aggregation of the returns of the assets in the portfolio.

Consider a portfolio with only two assets whose portfolio shares are $w_1$ and $w_2$, respectively. The portfolio shares represent the fraction of the total portfolio value allocated to each of the assets with the normalization condition

$$w_1 + w_2 = 1.$$

Using the definition of simple gross returns for each asset, the value of the portfolio between $t-1$ and $t$ may be calculated as

$$P_t = P_{t-1}w_1(1+R_{1t}) + P_{t-1}w_2(1+R_{2t}) = P_{t-1}\big(w_1(1+R_{1t}) + w_2(1+R_{2t})\big).$$

Rearranging slightly, this expression becomes

$$(1+R_{Pt}) \equiv \frac{P_t}{P_{t-1}} = w_1(1+R_{1t}) + w_2(1+R_{2t}). \tag{1.13}$$

In words, the one-period gross return to a portfolio, $1+R_{Pt}$, is given by the weighted sum of the gross returns to each of the assets using portfolio shares as weights. Expanding the right-hand side of equation (1.13) gives

$$1 + R_{Pt} = w_1 + w_1R_{1t} + w_2 + w_2R_{2t},$$

which yields the important result that for simple returns, the portfolio rate of return is equal to the weighted average of the returns to the assets

$$R_{Pt} = w_1R_{1t} + w_2R_{2t},$$

since $w_1 + w_2 = 1$. For $N$ assets, the simple portfolio return is given by

$$R_{Pt} = \sum_{i=1}^{N} w_iR_{it}, \qquad \sum_{i=1}^{N} w_i = 1. \tag{1.14}$$

This result does not extend to the case of log returns. From equation (1.5) and using the result in (1.14) it follows that the log return on a portfolio, $r_{Pt}$, is

$$r_{Pt} = \log(1+R_{Pt}) = \log\left(1 + \sum_{i=1}^{N} w_iR_{it}\right) \neq \sum_{i=1}^{N} w_ir_{it}. \tag{1.15}$$

In most practical situations, the fact that the log return to the portfolio is not the weighted sum of the log returns to the constituent assets is simply ignored. This is acceptable when the log returns are small, as is likely for short holding periods, in which case the log return on the portfolio is negligibly different to the weighted sum of the logarithm of the constituent asset returns because the approximation $r_{Pt} = \log(1 + R_{Pt}) \approx R_{Pt}$ is reasonably accurate when $R_{Pt}$ is small.

The result in equation (1.15) begs the question of how to combine log returns into the portfolio return. Consider again the case of two assets. Using the definition of log returns for each asset and expression (1.7), the value of the portfolio between $t-1$ and $t$ may be calculated as

$$P_t = P_{t-1}\, w_1\, e^{r_{1t}} + P_{t-1}\, w_2\, e^{r_{2t}},$$

so that

$$\log\left(\frac{P_t}{P_{t-1}}\right) \equiv r_{Pt} = \log\left(w_1\, e^{r_{1t}} + w_2\, e^{r_{2t}}\right).$$

For $N$ assets, the log portfolio return is then

$$r_{Pt} = \log\left(\sum_{i=1}^{N} w_i\, e^{r_{it}}\right). \tag{1.16}$$

More often than not, financial econometric work uses log returns and simply takes a weighted aggregate of these returns to find portfolio returns. Although not strictly correct, this approach will also be used in Chapter 3 where simple portfolios are constructed using linear regression.

Once returns, either simple returns or log returns, are available, then equations (1.2) and (1.9) may be used for temporal aggregation of the portfolio returns. The situation is summarized in Table 1.5.

## 1.4 STOCK MARKET INDICES

A problem of particular importance is the return to a portfolio that comprises all or at least a selection of prominent stocks on a stock exchange. An aggregate summary measure of the performance of the stock market as a whole is known as a stock market index. Indices combine a selection of (a large number of) stocks in a particular way to create a portfolio. The index then represents the value of the portfolio and is expressed in terms of an average price that has been normalized in some way. Because stock market indices are price indices, the computation of returns to the index can be performed in exactly the same way as if it were a single stock.

The major stock market indices are constructed in one of two ways. *Price-weighted indices* construct a portfolio of all the stocks in the index in which one share of each of

**TABLE 1.5 Summary of expressions for computing portfolio returns using simple and log returns and how to aggregate portfolio returns to obtain the *k*-period portfolio return.**

| Aggregation | Simple Returns | Log Returns |
|---|---|---|
| Portfolio Return | $R_{Pt} = \sum_{i=1}^{N} w_i R_{it}$ | $r_{Pt} = \log\left(\sum_{i=1}^{N} w_i\, e^{r_{it}}\right)$ |
| *k*-period Return | $R_{Pt}(k) = \prod_{i=0}^{k-1} (1 + R_{Pt-i}) - 1$ | $r_{Pt}(k) = \sum_{i=0}^{k-1} r_{Pt-i}$ |

the stocks appears and the weight given to the share is therefore simply the price of the share. In other words, the total monetary value invested in each share is only proportional to the price of that share. *Value-weighted indices* construct a portfolio of all the stocks in the index in which the weight given to each stock is proportional to the total market value of its outstanding equity.

The six indices commonly used in financial econometric work are plotted in Figure 1.2.

**(i)** *Deutscher Aktien Index* (DAX) comprises the 30 largest German companies that trade on the Frankfurt Stock Exchange. It is a value-weighted index although the weights are computed in a slightly more complex way than in a simple value weighting scheme.

**(ii)** *Dow Jones Industrial Average Index* (Dow Jones or DJIA) is computed using 30 prominent United States corporations. The DJIA is a price-weighted index.

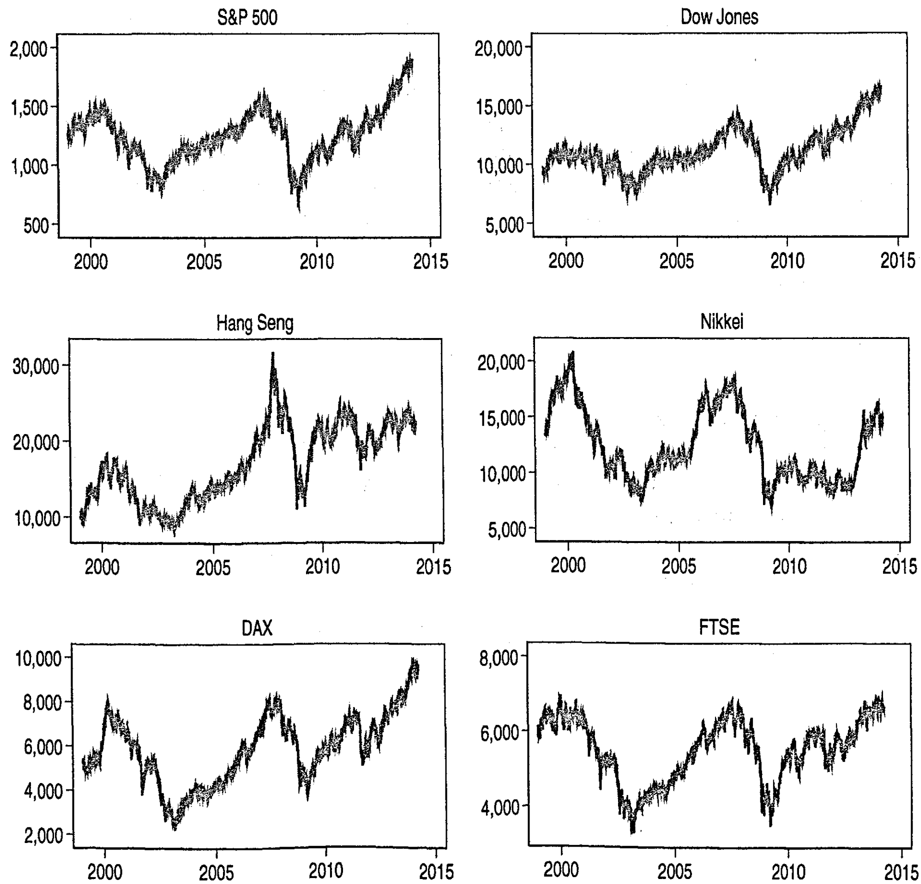


**FIGURE 1.2** Daily observations on six international stock market indices for the period 4 January 1999 to 2 April 2014.

(iii) *Financial Times Stock Exchange 100 Index* (FTSE) is a value-weighted index computed using the 100 largest companies listed on the London Stock Exchange.
(iv) *Hang Seng Index* (Hang Seng or HSX) comprises 40 of the largest companies that trade on the Hong Kong Exchange. It is a value-weighted index.
(v) *Nikkei 225 Index* (Nikkei or NKX) is a price-weighted index made up of 225 prominent companies listed on the Tokyo Stock Exchange.
(vi) *Standard and Poor's Composite 500* (S&P 500) is a value-weighted index. The index is computed by summing the market value of the outstanding equity in each firm in the index.

The falls in these market indices that occurred around the collapse of the dot-com bubble in the early 2000s and the global financial crisis of 2008–2009 are evident in each of the graphs plotted in Figure 1.2.

In addition to these six indices, another commonly encountered index is the NASDAQ Composite Index, which is a value-weighted index of all the stocks listed on the NASDAQ stock exchange. It is usually regarded as an index of the performance of technology companies and is particularly associated with the dot-com bubble of the late 1990s, which created and destroyed some $8 trillion dollars of shareholder wealth over a period of 5–6 years.

Table 1.6 lists the 30 component stocks of the Dow Jones obtained from Bloomberg in September 2014. The monthly closing price for December 2013 is also listed together with the market capitalization (US$ billion) of the component stocks (price of share × number of outstanding shares). Despite the fact that the DJIA is a price-weighted index, Table 1.6 also shows the notional share that each stock would have in a value-weighted index.

The DJIA is computed as

$$DJIA_t = \frac{1}{D}\sum_{j=1}^{30} P_{jt},$$

where the quantity $D$ that appears in the denominator is known as the Dow Jones divisor. The divisor started out as the number of stocks in the index so the DJIA was a simple average, but subsequent adjustment due to stock splits and structural changes required the divisor to be adjusted in order to preserve the continuity of the index. For example, the appropriate value of the divisor in December 2013 was 0.15571590501117.

Using the closing prices in Table 1.6, the DJIA for December 2013 is computed as

$$\begin{aligned}\mathrm{DJIA}_{\mathrm{Dec13}} &= \frac{140.25 + 90.73 + 35.15 + \cdots + 222.68 + 78.69 + 76.40}{0.15571590501117}\\ &= \frac{2581.25}{0.15571590501117}\\ &= 16576.662,\end{aligned}$$

which is identical to the value of the index, 16576.66, quoted by Bloomberg for December 2013. The DJIA is a price-weighted average. The main advantage of price weighting is its simplicity but its primary disadvantage is that stocks with the highest prices, like Visa ($222.68), IBM ($187.57), and Goldman Sachs ($177.26), have a greater relative impact on the index than perhaps they should have.

**TABLE 1.6 The 30 US stocks used in the construction of the Dow Jones. Month-end closing prices adjusted for splits and dividends and quoted in US$ are shown for the month of December 2013 together with total outstanding value of the company's shares ($ billion).**

| Company | Ticker | Closing Price (Dec. 2013) | Market Cap (Dec. 2013) | Market Share |
|---|---|---|---|---|
| 3M Co. | MMM | 140.250 | 93.300 | 0.020 |
| American Express Co. | AXP | 90.730 | 97.196 | 0.021 |
| AT&T Inc. | T | 35.150 | 97.196 | 0.021 |
| The Boeing Co. | BA | 136.490 | 102.566 | 0.022 |
| Caterpillar Inc. | CAT | 90.810 | 57.787 | 0.012 |
| Chevron Corp. | CVX | 124.910 | 240.224 | 0.051 |
| Cisco Systems Inc. | CSCO | 22.450 | 120.032 | 0.025 |
| The Coca-Cola Co. | KO | 41.310 | 182.422 | 0.039 |
| El du Pont de Nemours & Co. | DD | 64.970 | 60.169 | 0.013 |
| Exxon Mobil Corp. | XOM | 101.200 | 442.094 | 0.094 |
| General Electric Co. | GE | 28.030 | 283.590 | 0.060 |
| The Goldman Sachs Group Inc. | GS | 177.260 | 83.353 | 0.018 |
| The Home Depot Inc. | HD | 82.340 | 115.953 | 0.025 |
| Intel Corp. | INTC | 25.960 | 129.047 | 0.027 |
| International Business Machine | IBM | 187.570 | 203.674 | 0.043 |
| Johnson & Johnson | JNJ | 91.590 | 258.415 | 0.055 |
| JPMorgan Chase & Co. | JPM | 58.480 | 219.837 | 0.047 |
| McDonald's Corp. | MCD | 97.030 | 96.548 | 0.020 |
| Merck & Co. Inc. | MRK | 50.050 | 146.242 | 0.031 |
| Microsoft Corp. | MSFT | 37.430 | 312.464 | 0.066 |
| NIKE Inc. | NKE | 78.640 | 69.955 | 0.015 |
| Pfizer Inc. | PFE | 30.630 | 198.515 | 0.042 |
| The Procter & Gamble Co. | PG | 81.410 | 221.291 | 0.047 |
| The Travelers Companies Inc. | TRV | 90.540 | 32.963 | 0.007 |
| United Technologies Corp. | UTX | 113.800 | 104.421 | 0.022 |
| United Health Group Inc. | UNH | 75.300 | 75.809 | 0.016 |
| Verizon Communications Inc. | VZ | 49.140 | 140.626 | 0.030 |
| Visa Inc. | V | 222.680 | 141.756 | 0.030 |
| Wal-Mart Stores Inc. | WMT | 78.690 | 254.623 | 0.054 |
| The Walt Disney Co. | DIS | 76.400 | 134.256 | 0.028 |

Source: Bloomberg.

The other major type of weighting scheme is to weight stocks by market capitalization, giving a value-weighted average. In consequence, stocks like Exxon (0.094), Microsoft (0.066), and General Electric (0.060), would have the largest weights in the index if they were value weighted. The primary disadvantage of value weighting is that constituent securities whose prices have risen the most (or fallen the most) have a greater (or lower) weight in the index. This weighting method can potentially lead to overweighting stocks that have risen in price (and may be overvalued) and underweighting stocks that have declined in price (and may be undervalued).

The differences between price weighting and value weighting are illustrated in Figure 1.3 in which the 30 constituent stocks of the Dow Jones are combined to form two hypothetical indices, one based on simple price weighting and the other using shares

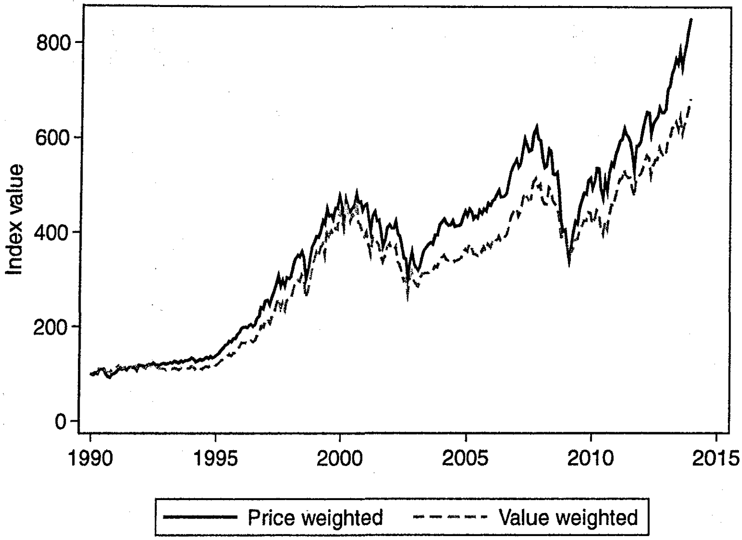


**FIGURE 1.3** The effect of price weighting and value weighting on an index comprising 30 stocks that make up the Dow Jones. The indices are computed using monthly data on prices and market capitalization for the period January 1990 to December 2013 with each index scaled to start from 100.

constructed from market capitalization as shown in Table 1.6. Both indices in Figure 1.3 are normalized to take the value 100 in January 1990. While the price-weighted and value-weighted indices track each other fairly closely over the period, the price-weighted index seems to overemphasize market movements during the period of the dot-com bubble during the latter half of the 1990s as well as the speed of the recovery from the 2008 global financial crisis.

## 1.5 BOND YIELDS

As noted in Section 1.2, zero-coupon bonds may be created from coupon paying bonds by separating the coupons from the principal and trading each of these components independently. Consequently, much of the econometric analysis of the bond market uses data based on zero-coupon bonds. The critical concept when dealing with bonds, which relates to the return on a stock, is the yield to maturity. If a zero-coupon bond has a face value of \$1 paid at maturity, $n$, the price of the bond purchased at time $t$ equals the discounted present value of the principal, which is given by

$$P_{nt} = 1 \times \exp\left(-n y_{nt}\right), \tag{1.17}$$

where $y_{nt}$ is the discount rate or yield and is commonly expressed in per annum terms. The yield on a bond is therefore the discount rate that equates the present value of the bond's face value to its price.

Taking natural logarithms and rearranging equation (1.17) gives

$$y_{nt} = -\frac{1}{n}\log P_{nt} = -\frac{1}{n}p_{nt},$$

where $P_{nt} = \text{lop}\, P_{nt}$. **(1.18)**

This expression shows that the yield is inversely proportional to the natural logarithm of the price of the bond, where the proportionality constant is $-1/n$. Moreover, as the price of the bond $P_{nt}$ is always less than \$1 then from the properties of logarithms, $p_{nt}$ is a negative number, and the yield in equation (1.18) will always be positive.

Governments issue bonds of differing lengths to maturity. Bonds at the shorter end of the maturity spectrum (maturity less than 12 months) are generally zero-coupon bonds (bonds that pay no coupon or interest), while the coupon bonds (for which the holder receives regular interest payments) can have a maturity as long as 30 years. The *term structure* of interest rates is the relationship between time to maturity and yield to maturity, and the *yield curve* is a plot of the term structure of yield to maturity against time to maturity at a specific time. Figure 1.4 presents scatter plots of observed US zero-coupon bond yield curves for the months of March, May, July, and August 1989, for yields ranging from 1 to 120 months. The yields are computed from the end-of-month price quotes taken from the CRSP government bonds files, the same data as that used in Diebold and Li (2006).

The plots of the yield curves in Figure 1.4 reveal a few well-known features.

(i) At any point in time when the yield curve is observed, all the maturities may not be represented. This is particularly true at longer maturities where the number of observed yields is much sparser than at the short end of the maturity spectrum.
(ii) The yields at longer maturities tend to be less volatile than the yields at the shorter end of the maturity spectrum.
(iii) On the assumption that longer term financing should carry a risk premium, a natural expectation would be for the yield curve to slope upward. However, the empirical plots in Figure 1.4 show that the yield curve can in practice assume a variety of shapes, including upward sloping, downward sloping, humped, and even inverted humped. These shapes are ultimately determined by the demand and supply of bonds of various maturities, market expectations, and risk assessments.

Modeling bond yields and the term structure are important and often challenging tasks in financial econometric work. Various aspects of these tasks in modeling bond yields and the tools designed to address them are examined in Chapters 6, 9, and 12.

## 1.6 EXERCISES

The data required for the exercises are available for download as `EViews` workfiles (*.wf1), `Stata` datafiles (*.dta), comma delimited text files (*.csv), and as `Excel` spreadsheets (*.xlsx).

1. **Equity Prices, Dividends, and Returns**

   (a) Access the Yahoo Finance website (https://finance.yahoo.com) and load the current quoted prices for The Boeing Company (BA). Compare the current situation with that reported in Table 1.2.
   (b) Observe the historical daily prices for Boeing. What do you notice about the order in which they are presented?

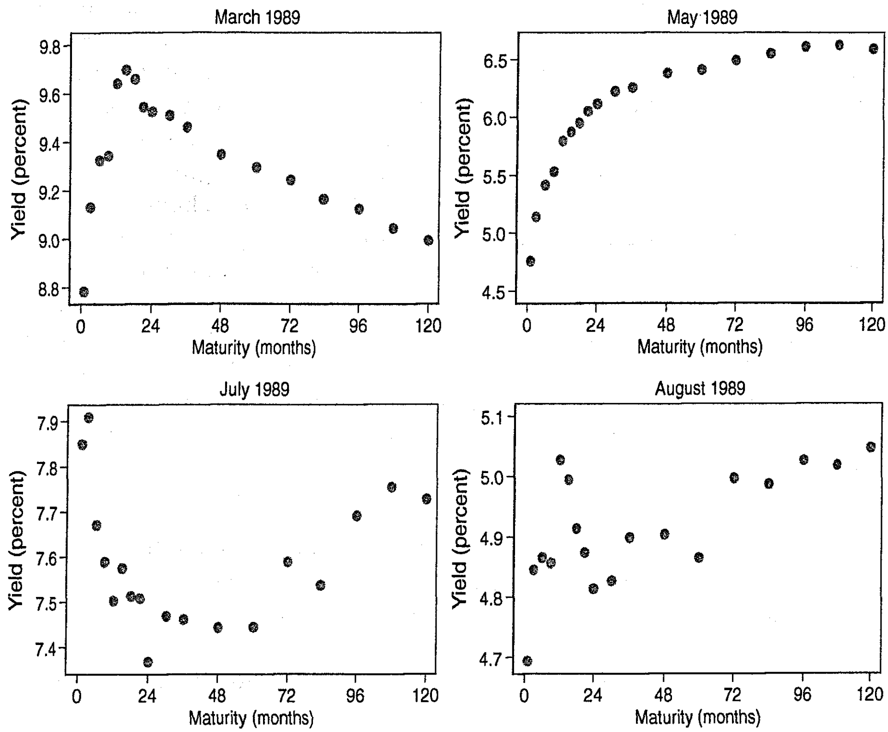


**FIGURE 1.4** Scatter plots of observed yields for the months of March, May, July, and August 1989 for US zero-coupon bonds.

(c) Examine the daily prices and scrutinize the days on which dividend payments are made. Verify that the dividend adjustments made to the historical price series are correct.

(d) Obtain monthly price data on Boeing. Are the quoted monthly prices beginning or end-of-month quotes?

## 2. US Stocks

| capm.* |
|---|

The data are monthly observations for the period April 1990 to July 2004 on the equity prices of Exxon, General Electric, IBM, and Microsoft and Walmart, together with the price of gold.

(a) Plot the price indices and comment on the results.

(b) Compute simple and logarithmic returns to each of the assets. For each asset plot the two returns series and comment on any differences.

(c) Assume that you hold each of the stocks in a portfolio. Compute the portfolio returns in both simple and logarithmic form for the first 7 months of 2004.

**3. Dow Jones Index**

| DJindexstocks.* |
|---|

The data are monthly observations for the period January 1990 to 31 December 2013 on the Dow Jones, the prices and market capitalization of the 30 constituent stocks of the index, and the risk-free interest rate.

(a) Consider the historical prices for Microsoft for the years 2012 and 2013. For these two years, compute the price relative, simple, and logarithmic monthly returns, and simple and logarithmic annualized returns. Compare your results with Table 1.4.

(b) Compute the logarithmic and simple returns to holding each of the 30 stocks in the Dow Jones for the month of December 2012.

(c) Assuming equal shares, compute the simple and logarithmic returns to holding a portfolio comprising each of the 30 Dow Jones stocks for the month of December 2012.

(d) Verify that your result is identical to THE quoted value of the Dow for that month

$$DJIA_t = \frac{1}{D}\sum_{j=1}^{30} P_{jt},$$

where the Dow Jones divisor, $D$, is taken to be 0.15571590501117. Verify that your result is identical to quoted value of the Dow for that month.

(e) Construct portfolio shares for each of the Dow Jones stocks based on market capitalization for the month of December 2013. Comment on which stocks that receive the most weight in the Dow under the price and market capitalization weighting schemes, respectively.

(f) Combine the 30 constituent stocks of the Dow Jones to form two indices, one based on simple price weighting and the other using shares constructed from market capitalization. Plot the indices over the sample period and comment on the differences.

**4. International Stock Indices**

| stockindices.* |
|---|

The data are daily observations on the Dow Jones, S&P 500, Hang Seng, Nikkei, Dax, and FTSE stock indices for the period 4 January 1999 to 2 April 2014.

(a) Plot the indices. Compare your results with Figure 1.2.

(b) Compute the daily logarithmic and simple returns of each of the indices and plot them. Comment on any differences.

(c) Express the daily logarithmic and simple returns in annualized form and plot the resultant series. Comment on your results.

(d) Compute the returns to holding each of the indices over the entire sample period in both logarithmic and simple form. Comment on the results.

### 5. Australian Stocks

| AusFirms.* |
|---|

The data are monthly observations on the prices of the largest 136 stocks in Australia from December 1999 to June 2014. Consider a portfolio constructed by holding one share in every stock in the data set that records a price, $P_{it}$, at every time $t$ in the sample period. In other words, drop those stocks that have any missing observations.

**(a)** Compute the simple and log returns to the portfolio over the full sample period using

$$R = \frac{P_T}{P_1} - 1, \qquad r = \log\left(\frac{P_T}{P_1}\right),$$

respectively, where $P_1$ is the first observation and

$$P_t = \sum_{i=1}^{N} P_{it}.$$

Note that P″ is the price of the portfolio in December 1999 and P′ is the price of the portfolio in June 2014. Comment on the results.

**(b)** Compute the portfolio weights of each stock in the portfolio for every time $t$ using the formula

$$w_{it} = \frac{P_{it}}{\sum_{i=1}^{N} P_{it}},$$

in which $N$ is the number of stocks in the portfolio.

**(c)** Compute simple and log returns to the portfolio in each time period, respectively,

$$R_{Pt} = \sum_{i=1}^{N} w_{it-1} R_{it}, \qquad r_{Pt} = \log\left(\sum_{i=1}^{N} w_{it-1}\, e^{r_{it}}\right),$$

remembering to use the weight at the beginning of the holding period.

**(d)** Compare the results obtained in (a) and (c).