THE MEASUREMENT AND MODELLING OF COMMERCIAL REAL ESTATE PERFORMANCE

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ABSTRACT

In this paper we discuss methods of developing real estate indices, the availability of real estate data, the problems of using published real estate data and how real estate data can be used for stochastic investment modelling for actuarial purposes. In recent years there have been many developments in the collection, presentation and analysis of real estate data that have not found their way into the actuarial literature. We review those developments and suggest and develop ways in which raw real estate investment data can be used for actuarial purposes. We then review the Wilkie real estate stochastic investment model and use the research of real estate finance academics to inform a critique and development of that model. In developing the models, different data sets are used, including data from valuation-based and de-smoothed indices in order to find appropriate parameter estimates. The significance (or otherwise) of the parameter estimates is tested for each of the fitted models and the differences between the fitted models are examined. By reviewing research in the real estate finance field, making use of the latest research and developing original work, the main aim of this paper is to ensure that actuaries have the means to collect, understand and manipulate real estate data for performance measurement and investment modelling purposes.

KEYWORDS

Commercial Property Indices; Stochastic Investment Modelling; Performance Measurement

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1. Introduction

1.1 Despite the prominence of actuaries in the areas of performance measurement and long-term investment modelling, there is little discussion in the actuarial literature of the subjects of real estate indices and modelling. For example, the only published stochastic real estate investment model for actuarial use is that by Wilkie (1995) — this was an update of that produced by Daykin & Hey (1990), itself based on advice from Wilkie. It is 18 years since a paper was published in the *British Actuarial Journal* or its predecessors on real estate performance measurement or since real estate investment was the subject of a sessional meeting at either the Faculty or the Institute of Actuaries (the last sessional meeting paper being Hager & Lord, 1985). Work in the real estate finance field has moved on since that time, and it is useful to present the relevant issues in the actuarial literature.

1.2 Before real estate investment data are used for actuarial purposes there has to be a thorough understanding of the sources and structure of the data. Valuation-based indices are beset with problems (although they are appropriate for some uses), but there have been considerable advances in the real estate finance literature, both in the United Kingdom and the United States of America, which have enhanced our understanding of real estate performance data in recent years. Thus, whilst it is true that data relating to the commercial real estate market are available at lower frequency and on a less timely basis than are available in securities markets, actuarial modelling should take account of research done in the finance field to understand better the structure of real estate returns. For long-term modelling purposes, immediacy of data provision is not normally a problem. Also, it is worth noting that real estate data are not significantly less satisfactory than data for other investment markets used for long-term modelling purposes — although they do require more interpretation. Much of the work on real estate returns has been notable for its attempts to relate the pattern of real estate returns to economic and financial theory, and to development and building cycles. The issue of the contribution of valuation smoothing to the pattern of real estate cycles has also received much attention. Relevant work includes that reported in Brown & Matysiak (2000). An understanding of these issues can enable actuaries to transform raw commercial real estate data, where that is necessary, so that it can be used for actuarial purposes.

1.3 Furthermore, where real estate return information is incomplete or difficult to apply for modelling purposes, information could be used from securities markets where this improves our understanding of the performance of the real estate market. Brown & Liow (2001) look at the relationship between property company returns and direct real estate returns. Lizieri & Satchell (1996) also look at the relationship between real estate markets, equity markets and other financial variables. We examine this issue in detail in Section 7.

1.4 Whilst it has been noted that little work has been published on stochastic modelling of real estate returns, except that by Wilkie (1995), there are, in fact, certain features of real estate data that may make the models of the style used by Wilkie more appropriate than they are for securities markets modelling. In particular, Wilkie used a mean reversion framework that has been criticised (see Huber, 1997). One criticism of the mean reversion framework is that it assumes market inefficiencies. However, there is clear mean reversion in real estate yields from valuation-based indices. Where it is helpful to model such indices, the Wilkie approach seems to be appropriate, given the behaviour of the data. The work on de-smoothing (e.g. Brown & Matysiak, 1998) is directly relevant to the preparation of the data for stochastic investment modelling. Indeed, de-smoothed real estate data have been used in an asset/liability modelling context by Booth & Matysiak (2004).

1.5 We begin by looking at the different forms of real estate index data. Whilst most of this paper is about commercial real estate indices, Section 5 looks at residential real estate data: this allows us to present a practical example of hedonic modelling, an approach that — along with repeat sales regression — is often suggested as an alternative to valuation-based commercial real estate indices. We then look at developments in the 'smoothing' literature that give us a better understanding of the problems of commercial real estate data and how to correct for those problems. This is followed by a brief analysis of real estate returns over a 60-year period. The purpose of Sections 1-6 is to present in the actuarial literature important issues about real estate indices that are already well understood in the finance literature. The main original contributions of this paper are in Sections 7 and 8. In Section 7 we consider how the information that is available in the real estate share market can be used to improve our understanding of the performance of the direct market. The methodology for this section is also discussed in Booth & Marcato (2003) but the work has been updated. In Section 8 we develop various stochastic real estate models for actuarial use, using different data sets. We have used the U.S. terminology 'real estate' rather than property throughout this paper, unless we are referring to a particular property. This is not only becoming the accepted usage in investment markets, it is also more descriptive. The concept of 'property' has a wider meaning than interests in land and buildings.

1.6 It is worth considering whether lessons can be learned from the U.S. literature or U.S. approaches to real estate index construction. It is reasonable to suggest that index construction in the U.S.A. is at roughly the same stage of development as in the U.K., but the theoretical literature has moved on further. Theoretical developments in the U.S.A. are relevant to the U.K. too, and relevant literature is cited in this paper. The U.S. Real Estate Research Institute website (www.reri.org.uk) is a useful source of the latest U.S. research on these issues. Commercial real estate performance in the U.S.A. is often measured by the N.C.R.E.I.F. (phonetically 'n-creef' or 'naycreef') Property Index (usually abbreviated to N.P.I. or N.C.R.E.I.F.) produced by the National Council of Real Estate Investment Fiduciaries. The index has been reported on a consistent basis since 1979. Relevant papers looking at the construction and performance of the index include Fisher *et al.* (1994), Geltner & Goetzmann (2000), Pagliari *et al.* (2001), Geltner (1997b) and Gatzlaff & Geltner (1998).

2. Methods of Producing Real Estate Indices

2.1 For most purposes, we would like an index of commercial real estate prices to represent movements in transaction prices in liquid markets; this is the purpose of published indices for most investment markets. However, real estate is infrequently traded and each property is unique. It is therefore not possible to obtain directly transaction-based indices for the commercial real estate market that are reliable in the sense that they accurately reflect transaction prices at a particular time. There are some exceptions to this general rule, but these are limited to a very small number of highly liquid markets in cities in which property is very uniform. There are a number of different approaches that can be taken in place of the ideal. Some of these are summarised below. It might be asked why indices that reflect transaction prices are necessary or desirable. If a real estate portfolio is not to be liquidated, it could be argued that the hypothetical transaction price is not relevant. However, to take this view would be to ignore the literature and very forceful arguments relating to the market-based valuation of assets and liabilities. Without reviewing the arguments in that literature, three general statements can be made:

- If indices are to be used for the construction of derivative products, the construction of funds designed to track market behaviour, or the assessment of market prices for asset allocation purposes, the index should reflect underlying transaction price behaviour.
- If indices are to be used for performance measurement, the index and the fund should both be assessed on a similar basis — in practice this is likely to involve the use of valuation-based indices (see below).
- If indices are to be used for long-term modelling and long-term market studies, transaction-based and valuation-based indices probably would give similar results over the long term.

2.2 *Different Forms of Real Estate Indices*

2.2.1 *Valuation-based indices*

The main commercial real estate indices in the U.K. (as well as in Europe and the U.S.A.) are valuation based. Different valuation-based indices are discussed in detail below. The data used to compile the indices are based on surveyors' infrequent and subjective valuations of the properties in the index. The valuation-based indices suffer from all the problems that are identified in Section 3 although there is now a substantial body of literature on how to deal with the problems of valuation-based real estate indices to create a series that behaves in a way that is more like the way in which we expect that the underlying transactions data behaved. In order to aid understanding of the remainder of this section, it is worth stating the basic problem of valuation-based indices, as identified by Hager & Lord (1985) and discussed further in the real estate finance literature. Because real estate is infrequently transacted, real estate indices are based on surveyors' subjective valuations. These are subject to random error, but these errors should cancel out on aggregation. However, the valuations may also be subject to bias, as there is a tendency for valuers to use historical comparables (see below) when forming an opinion of the value of a property. A particular value might therefore be too 'tied' to its previous valuation in a rapidly moving market. The methods described in the remainder of this section, some of which are expanded in detail below, are alternative methods of developing real estate indices to alleviate the problems described.

2.2.2 *Repeat sales indices*

2.2.2.1 Repeat sales indices rely on using the transaction data from properties that are actually sold. Securities market indices are repeat sales indices. With securities market indices, the same securities are sold normally several times within each index calculation period, so that the index can be based on a weighted average of the prices of the securities transacted at the time at which it is calculated. With real estate indices, the ideal would be a repeat sales index based on the same properties being transacted within the index calculation period (e.g. monthly, quarterly, or yearly). This rarely happens, although approximations to this ideal can be used. One approach is to construct indices based on a sampling procedure. Also, if the properties being considered are sufficiently homogeneous, an index can be constructed based on different properties being sold each time. For example, in an office market where offices fall very clearly into homogeneous groups, an index can, in effect, be constructed based on (for example) the price per square foot of freehold, air-conditioned office property; it would not have to be the same square feet sold each time to construct an accurate index. It is difficult to see this approach working in the U.K. office market, where homogeneity is not the norm. However, it is possible to create repeat sales indices, based on heterogeneous samples, even where properties are not sold within each data-collecting period, although such indices require the use of econometric techniques and subjective judgement. This approach, described in the paragraph below, looks the most promising method for the development of commercial real estate indices that are based on transactions data in the U.K. and the U.S.A.

2.2.2.2 Most databanks of real estate prices include a very low percentage of properties transacted at least twice between two index calculation dates. This means that any sample of properties used to compile a transaction price index directly would represent a very small proportion of all properties and would be a biased sample (e.g. more frequently transacted properties, would probably be prime properties). However, what is described as the 'repeat sales regression' (RSR) method can use a much larger sample of properties that have been transacted at least twice during the *overall* measurement period (i.e. from the beginning to the end of the index construction period, not necessarily between every two calculation dates). The information required is the periodical returns calculated from the difference of log-prices in time. If P_t represents the price at time t, then the capital growth rate β_t is found from a system of individual property equations as follows:

$$\log\left(\frac{P_{t+s}}{P_t}\right) = \log\left[\prod_{i=t}^{t+s}(1+\beta_i)\right] = \sum_{i=t}^{t+s}\log(1+\beta_i).$$

This can be expressed through the following regression equation:

$$Y = D\beta + \varepsilon$$

where Y represents a vector of relative log-price observations, β is the estimated vector of capital growth and D is a (N $\times$ M) dummy variable matrix with N and M indicating respectively the number of properties included in the sample and the number of periods (e.g. years) used to compute the index. The values 1 and 0 taken by the dummy variable respectively indicate that the Nth property has or has not been transacted in year M (i.e. for each line there could well be two 'ones' and [M – 2] 'zeros'). By regressing the dummy variables on the log ratio, the vector β can be estimated. The set of appreciation rates gives the repeat-sales index. This approach to real estate index construction is an evolving methodology. There are difficulties in applying the approach that need to be resolved. For example, it may be the case that the more liquid (prime) properties are sold in times of market downturn, and this might bias the regressions. Gatzlaff & Geltner (1998) apply a RSR estimation to U.S. commercial property, and find (perhaps surprisingly) that such an index conveys little more volatility than a valuation-based index. However, it also shows movements that a valuation-based measure is not able to capture. The RSR index appears to be a leading indicator of the NCREIF index, which may be confirmation of the problem of valuation smoothing to be discussed below.

2.2.2.3 A combination of the RSR and hedonic modelling (see ¶2.2.3 and Section 5) has been suggested for the future development of real estate indices. These can be described as hybrid indices. The combination of approaches allows a greater number of properties to be used in the sample, as the sample is not restricted simply to those properties that have been transacted. Such an approach was introduced to the literature by Case & Quigley (1991). The two authors demonstrate that their model conveys both theoretical and practical advantages (e.g. narrower confidence interval bands), and should then be preferred to pure RSR models when inferring the pattern of market prices of unsold properties.

2.2.3 *Hedonic modelling*

Hedonic modelling is currently the most common way to use real estate data to produce an index that mimics underlying transactions behaviour. Hedonic modelling is described in more detail in Sections 5.2 and 5.3. The principle is that a property is regarded as valuable for its characteristics and that the value of the characteristics can be combined in an additive fashion.

We can assess the characteristics of each property that is sold and model its price as a function of those characteristics. It is therefore possible to produce an index of the behaviour of the price of a representative property that has particular standard characteristics.

2.2.4 *Real estate equity performance*

Real estate shares are traded in liquid markets. They therefore provide information about investors' valuations of real estate reflected in transaction prices. Of course, this information is combined with information about a range of other issues. For example, real estate shares suffer from different tax treatment from the direct market and are normally geared. Nevertheless, it may be possible to adjust real estate share indices for these factors, and at least obtain an information set that is useful for the analysis of the direct market. See Booth & Marcato (2003) and Section 7 for a formal analysis of this issue.

2.3 *Real estate performance subjective, securities' performance objective?*

All real estate indices (whether based on hedonic modelling or not) will exhibit different performance because of the different methods of construction and the different ways in which a number of subjective issues are treated. However, it should not be thought that there is, on the one hand, a real estate market that can only be measured subjectively and, on the other hand, an equity market that can be measured using objective indices. Equity indices are also characterised by a number of problems that lead to the measurement of equity market performance being subjective too. These problems include the difficulty of defining market capitalisation (whether to use free float or full market capitalisation); the difficulties in defining nationality and sector and the difficulties in determining the appropriate coverage. There is lengthy discussion of these complex issues in the manuals of the major index providers at www.ftse.com and www.msci.com.

3. Valuation Inaccuracy, Real Estate Index Construction and Real Estate Performance

3.1 As valuation-based indices are the most common form of real estate index, we will now discuss in detail the problems of valuation-based indices and possible solutions to those problems in detail. The underlying theory has been discussed widely in the real estate literature, for example by Barkham & Geltner (1994), Clayton *et al.* (2001), Fisher *et al.* (1994), Geltner (1991, 1993a, 1993b, 1997a, 1998 and 1999), Quan & Quigley (1989, 1991), Bowles *et al.* (2001) and Brown & Matysiak (1998) and in the references contained therein. Hager & Lord (1985) also discussed the problems of using valuation-based indices for performance measurement.

3.1.2 The problem of valuation accuracy has been analysed at both an individual and a portfolio level. When valuing individual properties, random 'error' will occur because valuation is a subjective process. At a portfolio level, when an index is being constructed using the information from a range of valuers working for a range of institutions, such errors cancel each other out, given a large enough sample and no systematic bias, and do not have any impact on the overall portfolio value; but in the case of a portfolio, the problem of 'smoothing' arises. Smoothing refers to an inter-temporal link between values, and arises because valuations are based on the prices achieved by comparable sales (i.e. similar properties that have recently been sold). The valuer tends to use more than one comparable and includes historical comparables. This can create a bias in an index in certain market conditions. This bias may be particularly important when the market is moving quickly. It can be compounded by 'state appraisals' where valuations are not done at each index computation date.

3.1.3 The following sections analyse both the valuation accuracy issue for individual properties and also the problems of valuation smoothing when constructing valuation-based real estate indices.

3.2 *Transactions Price Error*

3.2.1 Consider the market for the most liquid gilt-edged securities on the day of an auction of an amount of stock that is small relative to the total amount in issue. The minimum price at which the stock is sold could reasonably be regarded as the value, at the margin, of one unit of stock to both buyer and seller. It is therefore the price that clears the market. The real estate market is marked by infrequent transactions and large lot size, relative to the total amount of property of a particular type available. At the time a transaction is observed, all we know for certain is that the price received is at least equal to the value placed on it by a potential seller who has the lowest use value for the property of all possible sellers, and is at most equal to the value placed on it by a potential buyer who has the highest use value for the property of all possible buyers. Within this range will fall the market clearing price that would pertain in a liquid market. We also know that buyers and sellers have some information regarding the underlying equilibrium price from observing other transactions. We can therefore be reasonably certain that the distribution of potential transaction prices is not as wide as the distribution implied by the lowest use value to potential sellers and the highest use value to potential buyers. Nevertheless, it is likely, except in the most liquid markets with homogeneous property, that the transaction price is an estimate, with error, of the underlying market clearing price.

3.2.2 The fact that we cannot assume that any transaction price for a property at a particular price is equal to a theoretical, underlying market clearing price leads to what Geltner (1997a) describes as valuation 'rule one'.

In valuing a property, if we ignore the impact of changing values with time, the valuer should make use of the information from the maximum number of comparables (prices of similar properties that have been transacted). If the mean of these is taken and if each of the transaction prices is an unbiased estimate of the market clearing price, then the law of large numbers suggests that the use of multiple comparables in the valuation process will lead to the closest estimate of the underlying market clearing price.

3.3 *Valuation Error*

3.3.1 Not all properties from which comparables are derived are the same. Thus, there will always be an element of 'valuation error', as a range of subjective factors should be taken into account in the valuation. One cannot simply translate the value of comparable properties into the value of the property under consideration. Bowles *et al.* (2001) usefully summarise the two problems that we have identified so far using equations of the following form:

$$\text{transaction price } = \text{true market clearing price} \pm e_1$$

$$\text{valuation} = \text{transaction price} \pm e_2$$

$$\text{true market clearing price} = \text{valuation} \pm e_1 \pm e_2.$$

3.3.2 Where real estate performance indices are derived from valuation data, in a world in which there are often small numbers of comparables, it is clear that a real estate index will only be an estimate of the underlying aggregate market clearing prices. One can therefore think in terms of a confidence interval that could be drawn round the value obtained from an index and a confidence interval that should be drawn round any performance measure derived from an index that is used to assess a fund manager. Furthermore, the fund manager's performance itself will be calculated with reference to valuations of properties within the portfolio. It would be necessary to draw a confidence interval around the fund manager's own performance measure when making comparisons with indices; see, in particular, Geltner (1997a) and also Bowles *et al.* (2001). Actuaries should note that this is an area to which they can make a theoretical and practical contribution.

3.4 *Time and Possible Bias*

3.4.1 The above discussion assumed that the transactions upon which comparables are based happen at a single moment in time. If that were the case, Geltner's 'rule one' would be optimal in all situations. Unfortunately, transactions occur at discrete times and infrequently. This means that, when using comparables, the valuer has to go back in time to find information relating to transacted properties. It would be sensible to use a declining weights function on recently transacted properties when determining the value of a given property. For example, we could propose the following as a 'rule of thumb' for surveyors:

$$V_t = \sum_{s=0}^{s=\infty} \theta_{t-s} P_{t-s}$$

where the value of the property is based on the prices of similar properties transacted at times $t, t-1, t-2$, etc., with $\theta_t > \theta_{t-1} > \theta_{t-2}$ etc. representing weights on past property prices, perhaps declining exponentially.

3.4.2 The surveyor valuing an individual property now has a trade off. The further back he goes in time, the more he may be introducing bias into the valuation (because the market values will have moved since the time the transactions on which the comparables are based took place). This may or may not lead to biases in the statistical sense, but it certainly adds an element of uncertainty to the valuation process. However, the further back in time the surveyor goes, the more comparables he has and therefore the more information he has on which to base the valuation. This leads to Geltner's 'rule two', which suggests that there is a trade off from using more comparables. This trade off involves trading the extra information gained from adding more comparables with the disadvantage of going further back in time. It is of course true that the valuer should use market information to adjust the yields from the comparables when making a new valuation. Nevertheless, the information content of the historic comparables still influences new valuations.

3.4.3 Published commercial real estate indices are based on individual properties valued using historical comparables for information. They will therefore exhibit serial correlation, as the values that are used in composing a previous value of the index will also be used in determining the current value of the index. The following features are likely to arise from the use of such index construction methods:

— As mentioned above, there may be serial correlation in the indices as valuation comparables are based on historical transactions.
— Troughs and peaks in the index are likely to be dampened because an index value at a given point in time (for example when the market is at a local peak) will depend on transaction values at earlier times; we might therefore expect to see reduced underlying index volatility. This problem is likely to be exacerbated when transaction levels are low — as they often are when the market is moving rapidly — because surveyors will have to go back further in time to accumulate comparables.
— If there are common factors underlying equity, bond and real estate market movements (for example changes in real interest rates or, in the

case of equity and real estate markets, changes in economic conditions leading to changes in anticipated dividend and rental growth), we would expect to see correlations between real estate and other investment markets below those that would pertain if actual transaction prices could be used for index construction.

3.4.4 It is of interest to note (and Geltner makes this point in Geltner, 1997a) that there is a sense in which the use of valuations, derived for the purposes of valuing an individual property are sub-optimal when an aggregate index is being compiled. The rationale for the valuer going back in time when valuing an individual property is that the information gained from using more comparables leads to a lower standard error for the computed value. Although it may introduce statistical bias, overall the expected deviation from the true value may be reduced. With regard to valuation for the purpose of aggregate index construction, the valuer should, in theory, use only the most recent comparables. The source of potential bias will be removed by the use of only recent comparables, and the standard error of the index value will be reduced due to aggregation of the individual value estimates of different properties into the aggregate index value. However, for nearly all purposes, the values used in index construction are not used for that purpose alone. As a result, historical comparables are used and Geltner's 'rule two' is followed.

3.5 *Some De-smoothing Techniques*

3.5.1 There are a number of ways in which one can adjust indices to alleviate or remove the problems that we have described. Alternative ways of constructing indices, such as repeat-sales, transaction-based indices and hedonic models do not rely on valuations, and therefore should not have the problem of 'valuation smoothing' (see Section 2). Also, we can use information from related investment markets to help us understand more about the process of price evolution in the commercial real estate market (see Section 7). In addition, valuation-based indices can be 'de-smoothed'. De-smoothing involves acceptance that the valuation process leads to serial correlation in the index and the use of a statistical process to remove the additional serial correlation. This process can be carried out by making assumptions about the statistical characteristics of the underlying transaction price process (for example that successive capital value movements are random) and removing any excess serial correlation from the capital value index that is regarded as arising from the valuation process. Alternatively, de-smoothing can be carried out by examining the characteristics of the valuation process (the use of historical comparables and so on) and imputing the index that would have been derived if the use of historical comparables had not distorted it.

3.5.2 In the U.K. the first approach to de-smoothing has tended to be taken. For example, if annual data are used, it is assumed that the valuation process gives rise to first order serial correlation between successive capital value returns that would not exist if the index were to reflect underlying transaction prices. In other words, it is assumed that capital value returns in any particular year are independent of capital value returns in the previous year. Thus, any first order serial correlation in the capital value return index is 'backed out'. The capital value index is then combined with the rental index to provide a total return index. There is still likely to be first-order serial correlation in the total return index because it is highly unlikely that income returns will not be serially correlated. There is no a priori reason to expect second-order and higher-order serial correlation to exist between capital value returns within valuation-based, annual commercial real estate indices. However, there is evidence of this in some data subsets and the issue will be discussed in more detail below. The approach to de-smoothing is a subjective matter, and should be derived from the interpretation of the valuation process that leads to smoothing in the first place. If valuers implicitly smooth capital values by basing capital values on historic comparables, then the approach that we have suggested above is appropriate. If valuers smooth yields and open market rents and then calculate the capital value from these two components, then an approach to de-smoothing that de-smooths a rent and yield index separately might be more appropriate. Alternatively, total returns themselves could be de-smoothed. In practice, it will make little difference which approach is used, and there will always be some uncertainty over precisely the extent of smoothing and the way in which it manifests itself.

3.5.3 Because reliable real estate data are important for actuarial applications (performance measurement, investment modelling, developing real estate derivative products, and so on) and because the statistical techniques used for de-smoothing are known to actuaries, the profession could make an important contribution to the development of more reliable real estate data sets using these techniques. Some of the technical details of this particular de-smoothing approach are therefore described below, with some additional references.

3.5.4 Quan & Quigley (1991) were the first authors to analyse the de-smoothing issue related to the functioning of real estate markets and transaction noise. They assume a random walk process for transaction prices, with valuers using an updating rule for their appraisals on the basis of a set of comparables and the last period's prediction error (weighted). If we let k, P_t^* and P_t^T indicate the weight assigned to new information, the appraiser's estimate of the market price (i.e. the appraiser's valuation) at time t, and its true estimate at time t respectively, the valuation process at a market level follows the following path: $P_t^* = k \times P_t^T + (1-k) \times P_{t-1}^*$. They apply the model to returns rather than levels of the index to extract underlying market returns from smoothed ones without strongly assuming true returns with no autocorrelation. This approach (known as first-order autoregressive reverse filter) allows for de-smoothing through 'judgmentally estimated parameters' at both aggregate and individual property level. The result obtained is a series of returns with double the standard deviation shown by appraisal-based indices and low positive autocorrelation. Other de-smoothing methods are shown in Fisher *et al.* (1994), Chaplin (1997) and Brown & Matysiak (1998). Brown & Matysiak propose a time-varying approach to estimate the smoothing parameter of a sample of 30 properties valued monthly between December 1986 and October 1995. By applying a maximum likelihood estimation and a Kalman filter, they find a time-dependent smoothing parameter (weight given new information) ranging from 50% to 62%, with an average of 57%. More discussion of de-smoothing techniques can be found in Brown & Matysiak (2000).

3.6 *De-Smoothing Real Estate Data for Historical Investigations*

3.6.1 The de-smoothing procedure used for all the statistical investigations in this paper is the one suggested by Fisher *et al.* (1994). It is a first-order autoregressive reverse filter. De-smoothed capital growth rates for direct real estate investment (i.e. ucg_t) are computed as follows:

$$ucg_t = \frac{[cg_t - \alpha_1 cg_{t-1}]}{(1 - \alpha_1)}$$

where cg_t is the capital growth for direct property at time t and α_1 is the parameter of the first order autoregressive process obtained from the same series. An income return recalibrated for the de-smoothed capital value index (i.e. uir_t) has been computed as follows:

$$uir_t = \frac{inc_t}{ucgi_t}$$

where inc_t is the income at time t and $ucgi_t$ represents the de-smoothed capital growth index at time t. The adjusted direct real estate return at time t ($udre_t$) is the sum at time t of the de-smoothed capital growth and the de-smoothed income return:

$$udre_t = ucg_t + uir_t.$$

It is assumed that there is no variation in the smoothing parameter over time. This may be unrealistic for two reasons. Valuation practice may evolve over time. Secondly, there may be variations in the degree of smoothing, depending on the speed with which market conditions are changing. As has been noted above, other researchers have used a time-varying smoothing parameter. A basic assumption behind the approach described above is that the income figure used in the index is the 'correct' figure — i.e. there is no smoothing or subjectivity surrounding the process of determining open market rents. As has been noted above, if it is felt that this assumption is unreasonable and an alternative approach would make an appreciable difference, the de-smoothing process could be applied to rents too. All the investigations in this paper use the simple approach to de-smoothing described above. The main purpose is to provide a 'window' through which the real estate data can be viewed. Academics and practitioners can then take these techniques further using, for example, more sophisticated de-smoothing techniques.

3.6.2 Data for the IPD valuation-based indices and the same indices de-smoothed using the approach described above are shown in Table 3.6.2.1.

Table 3.6.2.1. IPD returns and de-smoothed Real Estate Index data

	IPD Index return			IPD Index return: de-smoothed		
Year	Capital growth	Income return	Total return	Capital growth	Income return	Total return
				De-smoothing parameter = 0.5359		
1977	19.6	6.9	26.5	38.4	6.0	44.4
1978	19.5	6.2	25.7	19.5	5.4	24.8
1979	17.0	6.0	23.0	14.0	5.3	19.3
1980	11.5	6.0	17.5	5.2	5.6	10.8
1981	9.4	5.7	15.0	7.0	5.4	12.4
1982	1.9	5.6	7.5	−6.7	5.9	−0.8
1983	1.6	5.9	7.6	1.3	6.3	7.6
1984	2.4	6.2	8.6	3.3	6.5	9.8
1985	1.8	6.4	8.3	1.2	6.8	7.9
1986	4.5	6.6	11.1	7.5	6.7	14.3
1987	19.1	6.7	25.8	35.9	6.0	41.9
1988	23.5	6.2	29.7	28.6	5.3	34.0
1989	9.8	5.6	15.4	−6.1	5.7	−0.4
1990	−14.2	5.8	−8.4	−41.9	8.6	−33.3
1991	−10.5	7.3	−3.2	−6.2	10.3	4.1
1992	−10.0	8.3	−1.7	−9.4	11.7	2.2
1993	10.8	9.1	20.0	34.9	10.6	45.4
1994	4.0	8.1	12.0	−4.0	10.1	6.1
1995	−4.1	7.6	3.5	−13.4	10.6	−2.8
1996	2.0	8.0	10.0	9.0	10.3	19.3
1997	9.0	7.8	16.8	17.0	9.4	26.5
1998	4.6	7.3	11.8	−0.6	9.2	8.7
1999	7.4	7.1	14.5	10.8	8.7	19.4
2000	3.5	6.9	10.4	−1.0	8.9	7.9
2001	0.0	6.7	6.7	−4.1	9.0	4.9
2002	2.6	7.0	9.7	5.7	9.2	14.8
Mean return	5.6	6.8	12.5	5.6	7.8	13.4
Standard deviation of return	9.5	0.9	9.3	17.2	2.1	16.7

These data are used for our statistical investigations. However, slightly different data periods were used for different investigations (for example, because of the requirement for complementary data from other asset markets). It should be noted that when real estate data are de-smoothed, historical data points may change every time an extra year of data is added, because the smoothing parameter may change. It is likely that this change will be slight: if it is not, then serious consideration should be given to the use of a time-varying smoothing parameter.

3.6.3 The mean total return from the IPD annual index is 12.5% from 1977 to 2002. When the capital value returns are de-smoothed the mean return increases slightly to 13.4%. This does not represent a structural change in the mean, it simply arises as a result of the sample used. The standard deviation of returns from the raw index data is 9.3%. This increases to 16.7% as a result of the de-smoothing process. The partial auto-correlation coefficient (order one) falls from 0.41 to 0.17: this is a direct result of the de-smoothing process.

3.6.4 It is important to note that a data set on which the de-smoothing technique is applied must have particular characteristics for the technique not to give rise to changes in the mean level of real estate returns estimated from historical data (a small change in the mean is noted above). In particular, de-smoothing tends to accentuate peaks and troughs in the data. Therefore, if the yield on the real estate capital value index is substantially different at the beginning and end of the series, the mean return will be different in the de-smoothed and the original data. Significant changes in the mean value for returns is something that should be avoided.

3.6.5 The data below give a preliminary view of the effect of valuation smoothing on recorded real estate performance relative to other assets over a slightly different time period. Table 3.6.5.1 shows the standard deviation of returns from different asset classes, including real estate with the real estate return figures having been de-smoothed (the de-smoothed standard deviation figure is in brackets). The real estate returns are taken from the IPD index and the other asset returns from Barclays Capital (2003) and information

Table 3.6.5.1. Standard deviation of returns for different asset classes including 'de-smoothed' real estate

Asset class	Standard deviation of return % 1984-2002
U.K. equities	15.8
U.S. equities	21.9
Real estate	9.0 (17.1)
Index-linked gilts	7.2
Cash	3.2
Conventional gilts	9.4

from the Bank of England website (www.bankofengland.co.uk). It can be seen that the de-smoothing process considerably increases the standard deviation of real estate returns. We would argue that raw published data do not give a true picture of underlying real estate volatility. Whether the precise method of de-smoothing used gives a true picture is also open for debate; however, there are a range of de-smoothing techniques, many more sophisticated than that which we have used here.

3.6.6 The correlation coefficients between real estate data and other assets classes are shown in Table 3.6.6.1. The correlation coefficients where de-smoothed data is used are shown in brackets.

3.6.7 The changes in observed relationships when valuation-based data are de-smoothed are important. It is not the purpose of this paper to develop new methods of de-smoothing, and we do not claim that the methods that we have used adjust perfectly for the influence of valuation smoothing. However, it should be noted that the de-smoothing process is not intended either to increase the standard deviation of returns or to increase correlation coefficients with other asset classes. It is the intention of the de-smoothing process to remove what is believed to be unintended serial correlation to make the real estate return series look more like an underlying transaction series should look. If the adjusted series has stronger links with other investment markets, it is a preliminary indication that the de-smoothing process is achieving its objective (because we would expect there to be common economic and financial forces acting on real estate and securities markets that can be hidden by the process of valuation smoothing). It might be noted that the strong negative correlation between de-smoothed real estate and cash returns is also not surprising. The nature of the real estate markets and the financing of real estate investment is such that tight (loose) monetary policy, indicated by high (low) short-term real interest rates can have serious short-term negative (positive) effects on real estate returns. Depending on the purpose for which actuaries are using real estate data, the issue of de-smoothing may be an important one that deserves

Table 3.6.6.1. Correlation coefficients between different asset classes including 'de-smoothed' real estate

Correlation matrix (returns 1984-2002)	U.K. equities	U.S. equities	Real estate	IL gilts	Cash
U.S. equities	0.86				
Real estate	0.19 (0.31)	−0.01 (0.02)			
Index-linked gilts	0.47	0.46	0.23 (0.28)		
Cash	0.28	0.19	−0.24 (−0.49)	0.08	
Conventional gilts	0.36	0.29	0.05 (0.29)	0.78	0.06

further attention from actuaries. As is shown in Booth & Matysiak (2004), adjusting for valuation smoothing does make a difference to practical asset allocation decisions.

3.7 *Long-Term Performance of Real Estate and Other Asset Classes*

3.7.1 The sources of the real estate data discussed in this section are the Scott series up to 1971 and the IPD series thereafter. The source of the securities market data is Barclays Capital (2003). In Section 3.6, we considered the performance of real estate and a range of other asset classes in the period 1984 to 2002. This section considers performance over an 80-year period. As such the comparison is limited to U.K. equities and conventional bonds. Average total return statistics over 20-year periods are summarised in Table 3.7.1.1.

3.7.2 There is consistent out performance of real estate by U.K. equities in all periods. Unsurprisingly, real estate outperforms conventional bonds in the period during which unanticipated inflation was high (1961 to 1980).

3.7.3 Standard deviation of return statistics over the same periods, for the same investment categories, are shown in Table 3.7.3.1. Figures adjusted for valuation smoothing, using the technique discussed in Section 3.6, are shown in brackets. It might be noted that the quoted standard deviation of returns from de-smoothed data is higher in Section 3.6 than here. The reason for that is that a different smoothing parameter is derived from data sets derived from different periods. The analysis in this section uses a much longer data period than that in Section 3.6. This would seem to strengthen

Table 3.7.1.1. Total return (%) from real estate, U.K. government bonds and equities, 1921-2000

	Real estate	U.K. equities	U.K. government bonds
1921-1940	6.49	8.59	7.14
1941-1960	6.06	13.88	1.84
1961-1980	13.51	16.23	7.72
1981-2000	10.73	17.07	12.85

Table 3.7.3.1. Annual standard deviation of total return (%) from real estate, U.K. government bonds and equities, 1921-2000

	Real estate	U.K. equities	U.K. government bonds
1921-1940	9.93 (13.45)	13.87	11.21
1941-1960	5.74 (9.01)	18.74	8.94
1961-1980	11.27 (15.88)	37.81	14.23
1981-2000	9.07 (11.57)	12.21	11.66

Table 3.7.4.1. Correlation of Annual Returns (%) between real estate, U.K. government bonds and equities, 1921-2000

	U.K. equities	U.K. government bonds
Real estate	0.25 (0.34)	0.19 (0.28)
U.K. equities		0.51

the argument for the use of a time-varying smoothing parameter when de-smoothing real estate data. Clearly, the standard deviation of returns from equities is consistently higher than that from real estate (it should be noted that in the period, 1961-1980, there were some particularly sharp movements in equity market total returns, for example, in 1974, equity values fell by 55% and in 1975 rose by 136%). It might be more surprising that the standard deviation of real estate returns has been consistently less than that from bond returns. However, that result reverses when we make adjustments to the raw index values to allow for the influence of valuation smoothing.

3.7.4 The correlation between real estate total returns and total returns from other asset classes is shown in Table 3.7.4.1. Again, figures relating to de-smoothed real estate data are shown in brackets. All figures relate to the period 1921-2000. Closer analysis of the data suggests that the correlation coefficients calculated using the raw index data are remarkably stable over time. However, they seem to break down altogether in the period 1981-2000 (in that period real estate has a correlation coefficient close to zero with both U.K. equities and U.K. bonds: see also Section 3.6), although, de-smoothing the valuation-based data leads to stronger observed relationships between the asset categories. The weak relationship between conventional bond and real estate returns in the latter period may be because of the strong influence of changes in inflation expectations on conventional bond performance.

3.7.5 We do not present a full analysis of yield statistics. However, some basic facts are worth noting relating to yield statistics form real estate, equity and conventional bond indices:

— There is only one ten-year period since 1921 in which the average rental yield on property is less than the average dividend yield on equities (1971-1980).

— The average yield on property is greater than average U.K. government bond yields over all ten-year periods from 1921 to 1970, and then from 1991 to 2000, but not from 1971 to 1990. This suggests that property income is seen at least as a partial hedge against inflation (see Brown & Matysiak (2000) for a full review of the inflation hedging characteristics of real estate).

— The standard deviation of real estate yields is consistently less than that of both U.K. government bond yields and equity yields (the wartime decade is the only exception to this).

3.8 *Stale Appraisals and Monthly Indices*

So far we have looked at smoothing arising from the valuation process carried out in an active market, where comparables are available and appraisals are carried out thoroughly. There is an additional problem that is related both to the valuation process and to the index construction process. This problem — known as the 'stale appraisals' problem — is more apparent with monthly and quarterly indices than with annual indices. Stale appraisals in an index can arise for two reasons. The first reason is that, in the index construction process, not all appraisals will have been carried out on the date to which the index refers. Again, this causes index values to lag underlying changes in the market and induce serial correlation between successive changes in capital value indices and total return indices and a dampening of peaks and troughs in the index. A further problem is that valuers may not take full account of changes in market conditions when they calculate within-year values, if properties are valued more frequently than annually. The extent of this problem cannot be ascertained without looking at valuation data for individual properties. However, monthly real estate indices published in the U.K., do seem to have considerable first-order, second-order and twelfth-order serial correlation, which is indicative of a stale appraisals problem. Apart from some investigations in Section 7 and a brief description in Section 4, we do not consider monthly indices further. However, actuarial users of monthly real estate indices should note these problems and apply appropriate smoothing techniques to adjust for them.

4. U.K. Commercial Real Estate Indices

4.1 Various indices of U.K. commercial real estate prices, rents and yields are available. The main indices are discussed in Sections 4.2-4.4. In Section 4.5, we examine the relationship between the performance of the different current U.K. indices. For long-term performance analysis (that is before 1971), the most reliable series is the Scott series (see Scott, 1996). This series is mainly compiled using property data recorded by financial institutions and other sources. Between 1920 and 1948, in the absence of annual property valuations, a return index was derived for prime shops. Given the length of leases at that time, the income is kept constant and the capital growth index then varies as a result of yield movements (no figures are available during the war period — 1939-1945). During a second period (1949-1955) real estate returns have been obtained through analysing the performance of an insurance company's portfolio composed of 50 properties. Finally, between 1956 and 1970 two large financial institutions' portfolios — valued at £395m at the end of the period — were used to produce the return series. The total return formula that Scott uses is similar to that used by IPD (see below):

$$TR = \left(\frac{CV_t - CV_{t-1} - C + NI}{CV_{t-1} + \frac{1}{2}C} \right).$$

4.2 *Investment Property Databank (IPD)*

4.2.1 IPD is the most important provider of real estate indices throughout Europe and provides index data in respect of a number of other countries in addition: see www.ipdindex.co.uk. IPD produces indices measuring property returns to achieve two aims: firstly, to provide indicators of market performance for industry commentators and players; and secondly, to create benchmarks to be used by portfolio managers wishing to measure their investment performance. IPD indices are valuation-based indices, and include properties both directly and indirectly owned by clients (the coverage is around 75% of institutional holdings in the U.K.; see, for example, the IPD Annual Index Reports, available from www.ipdindex.co.uk). However, market measures (as opposed to portfolio measures) only include standing investments, and they exclude properties for which the main required data (e.g. rents, costs, etc.) are not available, those with an abnormal capital growth profile, or those with a non-standard valuation method. The impact of transactions and developments on portfolio returns is then separately provided by IPD (again see the Annual Index Report). The starting date of the IPD index is 1971, but figures referring to the first ten years come from a very low number of funds that gave recorded information to IPD in order to create a historical series for the 1970s. Consequently, 31 December 1981 should be considered the real base date of the IPD annual index. IPD performance measures have recently been re-computed to reflect a monthly time weighting (see IPD, 2001). Indices weight inflows/outflows of capital and rents during the year, by considering the month in which they happen. A total return is calculated for a given month and the monthly returns chain linked. The assumption is made that cash flows occur half way through the month. Assumptions also need to be made about the evolution of the value of a property during the year between two valuation dates, as values are needed each month. However, such assumptions, outlined in IPD (2001), are not critical in determining the annual return. In the past, historical index figures have been recalculated to reflect changes in computation methods. A different approach is normally used in securities markets where historical records tend to be ‘frozen’ (although may be recalculated for particular purposes). IPD has generally preferred to recalculate historical returns when the index is expanded or the methodology improved, in order to create the best possible historical record. However, it does make 'frozen' index figures available to clients. It was decided in 1999 that, from that date, 'freezing' of the historical record would be the norm for the total return index and main sector level indices when changes are made to the index composition or calculation methodology, unless there are major changes in the methodology. The change in methodology that took place at the end of 2001 was regarded as one such change.

4.2.2 The IPD sample composition by sectors and regions (as percentage of capital values) at the end of December 2002 can be found in publications on the IPD website www.ipdindex.co.uk. The retail and office sectors make up 81.8% of the total market, 15.1% is industrial estates and the remaining 3.0% a mix of farms, leisure and residential properties. The regional composition depends upon the sector, but Greater London constitutes one third of total standing investments. Central London is the predominant region for offices. At the end of December 2002 the IPD databank included 11,416 properties, belonging to 236 portfolios and worth £102.8 billion. Almost £73 billion of the property is owned by insurance funds (which could include insurance companies, unit linked funds and managed pension funds) and segregated pension funds, and £10 billion by property companies

4.2.3 The main performance measure is the total return, which reflects the return (including income return and capital growth) investors would have obtained if they had invested in the market throughout the measurement period. The following measure represents the total return:

$$TR_t = \frac{\sum_{i=1}^{n} \left(CV_{i,t} - CV_{i,(t-1)} - P_{i,t} + S_{i,t} - C_{i,t} + NI_{it} \right)}{\sum_{i=1}^{n} \left(CV_{i,(t-1)} + P_{i,t} + \frac{1}{2} C_{i,t} - \frac{1}{2} NI_{it} \right)}$$

where:

TR_t is the total return in month t;

CV_t represents the capital value at the end of month t;

P_t is the gross purchase cost of whole property purchases and any other capital expenditure greater than 20% of the start month value of the asset;

S_t is the net sale receipts from whole property sales during the month and any other capital receipts greater than 20% of the start month value of the asset;

C_t is the net value of all other capital expenditure less receipts during the month, after excluding in and out flows greater than 20% of the start month value of the asset; and

NI_t is the day-dated rent receivable during the month, net of asset management costs, ground rent and other irrecoverable expenditure.

This follows the principles outlined in ¶4.2.1. The total return is calculated from measuring the increase in capital value, plus income less capital expenditure relative to the capital value at the beginning of the period adjusted for half of the capital expenditure.

4.2.4 IPD returns are net of all non-recoverable operating costs and capital expenditures (i.e. capital improvements, transaction costs, maintenance expenses, property management fees, etc.), but they are gross of all costs incurred at a portfolio level (i.e. portfolio management fees, finance costs and fiscal costs). The total return can be attributed to two main components: capital growth and the income return (i.e. income net of expenditures as a percentage of the capital invested throughout the year):

$$CG_t = \frac{\sum_{i=1}^{n} \left(CV_{i,t} - CV_{i,(t-1)} - C_{i,t} \right)}{\sum_{i=1}^{n} \left(CV_{i,(t-1)} + \frac{1}{2} C_{i,t} - \frac{1}{2} NI_{it} \right)}$$

and

$$IR_t = \frac{\sum_{i=1}^{n} NI_{it}}{\sum_{i=1}^{n} \left(CV_{i,(t-1)} + \frac{1}{2} C_{i,t} - \frac{1}{2} NI_{it} \right)}.$$

If the capital value is expressed by the ratio of the open market rental value (OMRV) to the rental yield, the capital growth in year t can also be decomposed to discover whether the growth is due to rental growth within the year, i.e. $\left[\frac{OMRV_t - OMRV_{t-1}}{OMRV_{t-1}}\right]$ and/or a shift in the yield basis $\left[\frac{y_t - y_{t-1}}{y_{t-1}}\right]$. Similarly, the income return can be driven by a change in both/either gross income and/or the cost structure.

4.2.5 The IPD monthly index includes only the properties re-appraised monthly on a fee basis and covers 10% of the IPD annual index sample. Thus the monthly index gives approximately 8% market coverage.

4.3 *CB Hillier Parker (CBHP)*

4.3.1 CB Hillier Parker provides a rent index and an average yield index. The quarterly measures taken in February, May, August and November indicate respectively the open market rental value and the equivalent yield of rack rented properties of a standard specification, i.e. notional or hypothetical properties. Each quarter, CBHP collects rents and yields of hypothetical properties from its valuers spread all around the U.K. (i.e. each single rent and yield is given by a single valuer every quarter).

For example, for 'high street shops', rents and yields are based on a unit of:

— 7.6 m (frontage) by 24 m (depth);
— 46-93 sqm storage;
— located in the prime 100% trading pitch of the location; and
— let on full repairing and insuring terms;

whilst Central London Offices have the following characteristics:

— new or recently refurbished building of grade A;
— 930 sqm in best position; and
— let on full repairing and insuring terms.

This methodology, obviously, reveals two kinds of biases: firstly a 'company bias', as the index will reflect CBHP's view on the market; and secondly a 'valuer bias', due to the collection of the same information from the same valuer every quarter. The sample includes 1,129 locations, of which: 555 are shops, 239 offices, 187 industrials and 148 retail warehouses. The regions used are those defined by the Department of the Environment Transport and the Regions. Against these disadvantages, the index does allow the estimated value of a representative type of property to be tracked in a consistent way.

4.3.2 CBHP indices are capital-weighted indices measuring changes in rental values and yields. They are computed through a bottom-up approach, starting from single locations and subsequently building up (through a simple weighted summation) measures referring to regions, sectors and the overall market. The weights used to compute regional indices are capital values of the single hypothetical properties, whilst IPD regional and sector weights are respectively used to form sector indices and the All Property Index. CB Hillier Parker also computes a 'performance index', by using the above information and making some assumptions to obtain a capital growth and an income return index:

— the income on properties is assumed to be equal to the open market rental value;
— the rack rented equivalent yield is used as a discount factor to compute the capital value; and
— the income return is assumed to be equal to the rack rented equivalent yield.

The capital growth index is then computed as follows:

$$CV_t = \frac{Rent_t}{Yield_t}$$

from which the following quarterly capital growth can be obtained:

$$cg_t = \frac{CV_t}{CV_{t-1}} - 1.$$

The capital growth is finally added to the income return (i.e. yield) to obtain a total return measure:

$$tr_t = cg_t + yield_t.$$

4.3.3 In the literature (e.g. see Adams *et al.*, 2003) a number of different uses of investment indices are often proposed. These include performance measurement, historical analysis, investment decision making and so on. It is generally assumed that any equity market index can be used for any of these purposes as well as for constructing index funds and derivative products. In fact that is not true, and the major indices are normally constructed with these latter purposes and performance measurement in mind. For example, when measuring the general level of the equity market for historical analysis, total capitalisation, rather than free float indices, is probably better, although there are few commercial equity indices that are not now free float. Similarly with real estate indices, different indices might be useful for different purposes. The IPD and Jones Lang LaSalle (see below) indices might be better for using for performance measurement (because they are based on portfolio valuations), and the CBHP index for historical analysis (because it is based on the valuations of representative properties let at open market rent). The authors would argue that there is insufficient attention paid by actuaries in both the securities and real estate markets to the fundamentals (as opposed to the technical details) of index construction and the implications of the different methods of computation for the uses to which indices should be put.

4.4 *Jones Lang LaSalle*

4.4.1 Jones Lang LaSalle indices start in June 1977, are updated quarterly (i.e. March, June, September, December) and use an internal database. The sample is smaller than the one used by IPD because it only includes properties that are directly managed by Jones Lang Lasalle. The number of properties in 2001 Q4 was over 800. Nineteen funds are included in the performance measurement process (compared with 236 for the IPD indices). As with all U.K. property indices, no sampling methodology is applied and all properties within the valuation database are included if they represent standing investments (i.e. developments are excluded); are valued at both the beginning and the end of the quarter to which the performance refers (i.e. transactions are excluded); and do not represent owner occupied properties. The properties included belong to the three main functional sectors (office, retail and industrial). The geographical composition of the sample is the same as that used for the IPD index. The weightings for each sector and each region are kept within a +/ − 3% difference from the ones shown in the latest IPD Property Investor Digest. Consequently, by looking at the sector by region matrix, the weightings will match those of IPD +/ − 3%. For example, the weighting of south east industrial property in the Jones Lang LaSalle index is in the range [IPD South East Industrial −3%; IPD South East Industrial +3%]. If the index is not naturally weighted in this way properties are randomly deleted from the sample until the weights match up. However, a maximum of ten properties can be deleted in each sector by region sub-sample.

4.4.2 The total return for quarter q is simply computed as the sum of capital growth (first part of the equation) and income return (gross of management costs):

$$TR_q = \frac{\sum_{i=1}^{n} \left(CV_{i,q} - CV_{i,(q-1)} + NI_{iq} \right)}{\sum_{i=1}^{n} CV_{i,(q-1)}}$$

where:

$CV_{i,q} =$ Capital value of property i at the end of quarter q

$NI_{i,q} =$ Net income of property i at time t with $NI_{i,q} = \frac{ANI_{iq}}{4}$ (i.e. Annual net income at quarter q divided by 4).

This formula is simplified compared with that used by IPD and does not deal with management costs and voids. Moreover, it represents a holding period return formula (i.e. MWRR) and, consequently, it does not eliminate the distorting effects of cash inflows/outflows during the period.

4.4.3 The same methodology is applied to style indices that report the performance of properties showing similar characteristics. These measures, representing a new venture for the real estate market, can lead to better investment management decisions and asset allocation choices by allowing a more precise and efficacious style analysis to attribute portfolio performance and to create a benchmark index with which to compare portfolio returns. Style indices are based on 826 properties, but the number of properties used within the sample in any one quarter is restricted to the number of properties showing an income during the measurement period and valuations at both the end and the beginning of the period. The 'sample' is split (by equivalent yield) into two separate sub-samples to measure the performance of growth and value properties. In order to achieve a larger sample size, the two indices are not currently weighted by region or sector. The growth and value indices include respectively low and high yielding properties, and each sub-sample is composed of a mixture of properties belonging to office, retail and industrial sectors. Three main measures are computed: total returns, capital growth and net income growth.

4.4.4 De-smoothing monthly indices is difficult because the serial correlation tends to be very strong (normally 1st order, 2nd order and 12th order). The quarterly indices produced by Jones Lang LaSalle might therefore be a helpful compromise between annual and monthly indices. Also, the longer data period than exists for the IPD indices might be helpful for some purposes.

4.5 *Comparison of Performance from Different Real Estate Indices*

4.5.1 From the discussion above, we would expect the IPD indices and Jones Lang LaSalle indices to provide a broadly similar measure of performance of the real estate market. Although the Jones Lang LaSalle indices are smaller and may suffer from bias created by the use of valuers from the same house, they have the same basic objective as the IPD indices and the weights are calculated with reference to the weights from the IPD indices. The CBHP index, on the other hand, has a different objective and might well behave rather differently. The performance of the two indices is shown in Table 4.5.1.1. It is quite clear from these figures that the Jones Lang LaSalle index and the IPD index have very similar performance characteristics. The CBHP index has an average return that is quite different from that of the other two indices and a standard deviation of return that is much higher. The picture from disaggregated indices is very similar.

4.5.2 Two further comparisons of the index series are shown in Table 4.5.2.2 and Figure 4.5.2.1. Table 4.5.2.2 shows the correlation between the annual returns from the three indices. It is clear from both the figure and the table that there is a much closer relationship between the IPD and Jones Lang LaSalle indices (no difference can be noticed in Figure 4.5.2.1) than between either of these two indices and the CBHP index.

Table 4.5.1.1. Performance of three major U.K. all property indices

	Total return	Capital return	Income return
Average return 1978-2001			
JLL	12.1	4.8	7.3
IPD	12.0	5.1	6.9
CBHP	15.6	7.9	
Standard deviation of return 1978-2001			
JLL	9.1	9.4	6.1
IPD	9.3	9.1	1.0
CBHP	14.6	13.4	

Table 4.5.2.2. Correlation coefficients of three major U.K. indices

	JLL	CBHP
IPD	0.97	0.82
JLL		0.81

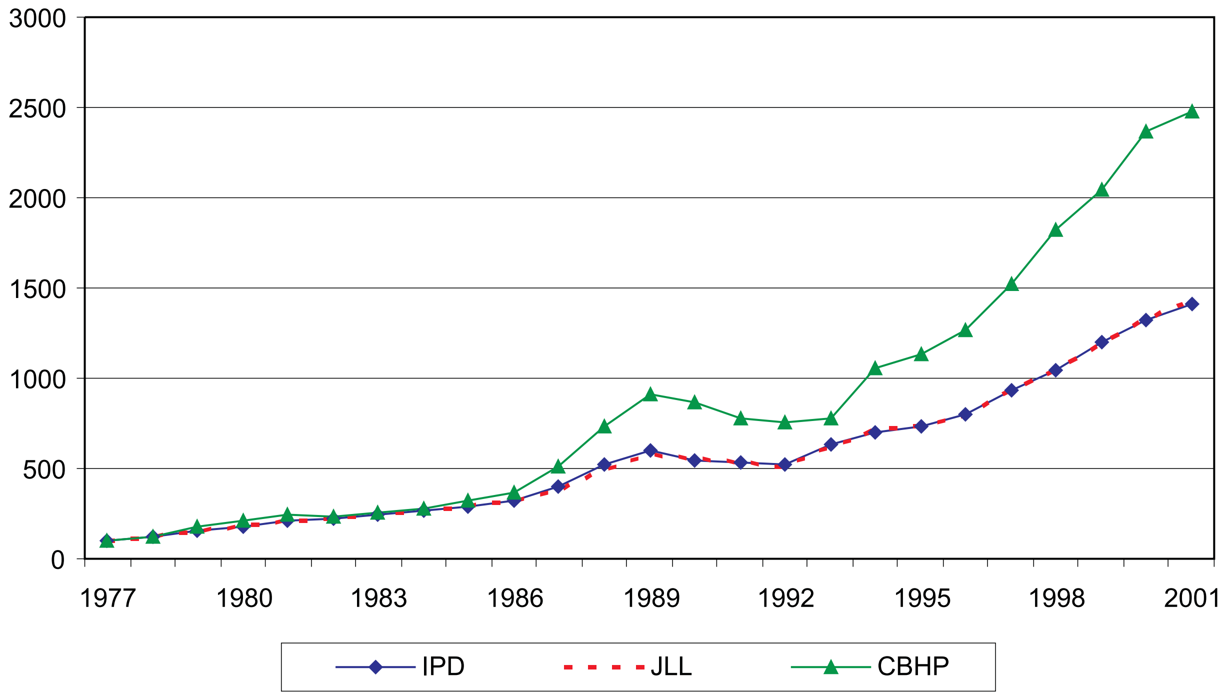

Figure 4.5.2.1. Performance of three major U.K. total return indices — all indices rebased at 100 in 1977

5. Residential Property Indices

5.1 There are a number of major sets of index data that are readily available for measuring the increase in the value of residential housing. Whilst these are not often used for investment purposes, they are used for other economic purposes. For example, they are part of the information set used by the Bank of England when taking monetary policy decisions. In this section we will concentrate on indices of capital value changes: to obtain a measure of the potential total return from housing, one would also have to take into account, potential rental income (less costs and depreciation). As with commercial real estate indices, house price index values can be subject to inaccuracy because house sales are insufficiently frequent and houses are too heterogeneous to develop repeat sales indices that measure the same representative sample of the market. Some residential indices use the practice of hedonic modelling to overcome these problems. Hedonic modelling is potentially a useful technique for the construction of commercial real estate indices, and this section can also be seen as an introduction to hedonic modelling. Further information on measuring house price movements can be found in the references contained within this section and also in Thwaites & Wood (2003).

5.2 *Halifax Bank House Price Index: an Example of Hedonic Modelling*

5.2.1 The Halifax Bank approach is described in Fleming & Nellis (1997). The basic data that form the index are the purchase prices of houses on which mortgages are agreed by the Halifax Bank in a particular month. Certain houses are excluded because they exhibit characteristics that would distort the data set (for example council houses that might be sold at a discount). Houses are included even if they do not proceed to completion. Whilst this could create some form of bias, this approach is regarded as preferable to basing the index only on values related to completed sales. The latter approach would mean that the values used in the index would be 'out of date', as sales complete some time after the agreement to sell.

5.2.2 Characteristics (locational and physical attributes) of all houses are recorded and a regression equation is fitted for the relationship between the price of houses and these characteristics. Some of the characteristics are linear variables (such as number of bathrooms) and others are represented using dummy variables (such as locational attributes). Thus we can write the price of house i as:

$$P_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + \ldots + b_j X_{ji} + e_i$$

where there are j characteristics and n houses, so that $i = (1, 2, \ldots, n)$. The house i is therefore said to derive its value from the set of j characteristics; such an approach is known as hedonic modelling. In this particular formulation the value of the house is a linear and additive function of the characteristics. Given the information about the j characteristics for each of the n houses, it is possible to estimate the parameters b_0 to b_j, therefore enabling us to determine the hypothetical value of a house with any combination of characteristics at any time. The parameters are calculated using ordinary least squares. The functional form that Fleming & Nellis decided was most appropriate was one in which the log of the dependent variable P_i was used. Thus, the final form of the estimated expression can be written as:

$$\ln P_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + \ldots + b_j X_{ji} + e_i.$$

5.2.3 There are several ways of considering the methodology used to calculate the index from the parameters. One way is to think about determining an index that measures the value of a representative house over time. Clearly, the representative house must have the same characteristics between two index dates. However, because many of the j characteristics are dummy variables, it is easier to think in terms of the index value tracking the value of a portfolio of houses. Information on the characteristics of houses bought in 1983 was used to set the weights for the index. Each of the X values is weighted to reflect the characteristics of the houses bought in 1983. The parameters are estimated from the data, and the index value reflects the change in the value of houses with 1983 characteristics between the base date and the date on which the index is calculated.

5.2.4 The weights are given the notation Q in Fleming & Nellis, and thus the value of the index would be:

$$I_t = \frac{\text{anti}\log \sum b_{jt} Q_{j1983}}{\text{anti}\log \sum b_{j1983} Q_{j1983}} \times 100.$$

The information gained from mortgage advances is then used to calculate a range of capital value indices based on regions and different types of houses and for all houses. The regional indices are calculated quarterly and the national indices monthly.

5.3 *Critique of the Halifax Approach*

5.3.1 The Halifax indices were an important step in real estate index construction in the U.K. The hedonic modelling approach may well have applications in the commercial real estate market in the U.K. However, there are difficulties with the approach. The following specific criticisms could be made:

— It would be better if the weights were regularly updated to produce a chain-weighted index based on characteristics that are closer to those of the average house at the time the index is calculated.
— The weights and the index data are derived from the mortgages advanced by one bank. In so far as the properties on which the mortgage portfolio of the bank is based are not typical of the housing stock of the country as a whole, the index will not reflect the increase in the value of the housing stock.
— The model can never capture all the subjective characteristics that determine value.
— The particular model described here considers the value of a house as being a linear and additive function of the characteristics with no interaction between the characteristics. For example a three-acre garden would make the same contribution to the value of a one-bedroom house as it would to the value of a five-bedroom house. Such a linear additive approach may well be unrealistic.

5.3.2 The second problem could be circumvented by basing the weights on the characteristics of the transacted housing stock as a whole, rather than on the characteristics of those houses transacted by one bank. The collection of data could be conducted through a trade body, independent company or an organisation related to a group of banks. Problem three could be regarded as being a greater problem for commercial property than for residential property as, in the former, the number of characteristics and variety of characteristics is likely to be greater. Hedonic modelling has, however, been applied in countries where commercial real estate tends to have more uniform characteristics (such as Singapore). Problem four could be overcome with more sophisticated modelling techniques.

5.4 *Nationwide House Price Index*

The Nationwide index is described in Nationwide (1999). The detailed statistical methodology is not considered here. As with the Halifax index, the Nationwide index attempts to track the value of an average house with representative characteristics. The weightings put on all the characteristics are determined from the Nationwide's own mortgage portfolio except for the regional weightings, which are derived from the Department of the Environment, Transport and the Regions' (DETR) figures: the Nationwide accepts that its mortgage portfolio is biased towards the south of England and that the index results would be biased if their own weightings were used. As noted above, there may be a case for using national average characteristics to compute the weights for all characteristics in both the Nationwide and Halifax indices.

5.5 *HM Land Registry Data*

5.5.1 HM Land Registry produces a monthly residential property price report based on transaction data in all areas of the country. The data they provide are described in HM Land Registry (2002), updated on www.landreg.gov.uk. The main advantage of the land registry data is that they are available on a highly disaggregated basis across England and Wales. The data show the rise in the transaction value of houses across the country, based on reports of sales to the Land Registry. From this a capital value index of house values could be created. As with the Halifax and Nationwide indices, certain sales are excluded where the transaction price is distorted (e.g. those transacted under 'right to buy' legislation). The Land Registry data simply show the average price of houses sold without any weighting. This means that, if the composition of houses sold changes and/or the prices of different types of house are rising at different rates, the index would be distorted. However, because disaggregated data are given relating to a range of characteristics (whether property is old or new, whether detached, semi-detached, terraced, or flat and by postcode), it would be possible to recreate a weighted index from the Land Registry figures. The weights could be based on DETR and other government figures for the numbers of different types of property and the numbers of properties in each region. Alternatively, a representative base year could be determined and Land Registry figures adjusted so that the average sale price would be based on consistent weights over time.

5.5.2 It is unlikely that an adjusted Land Registry approach would improve upon the data provided by the Halifax and Nationwide, unless there are further problems with those indices of which the authors are not aware. However, the sample size of the Land Registry figures might make them attractive if the Halifax or Nationwide coverage were to shrink. The Land Registry approach cannot provide more than a 'barometer' of the residential property market.

5.5.3 There are a number of differences between the three forms of housing market indices that could lead to differences in 'performance'. The main differences are as follows:

— potential dissimilarities in seasonal adjustment factors (the Land Registry figures have no seasonal adjustment), which may be important for short-term decision making;
— different weighting systems (Land Registry unweighted, Halifax weighted on the basis of 1983 advances, Nationwide weighted on the basis of DETR data for regional characteristics and Nationwide advances for other characteristics); and
— differences in statistical methodology.

5.6 *IPD Residential Property Index*

Investment Property Databank has recently developed a residential real estate index. This index is constructed in very much the same way as the IPD commercial real estate index series. It is based on valuations (rather than on hedonic modelling or transactions, as are the other main residential indices). The sample includes only let property, and there is therefore a strong bias towards flats and apartments (54% of the index at the end of 2001, see 2002 IPD Residential Property Index publication). A total return index is available as the use of let property allows an income return measure to be calculated. Further details of the IPD residential property index can be found in IPD (2002). Whilst this index could not be used reliably as a measure of the average level of the housing market, it could be used as a performance measure for investible residential real estate. Thus it may be useful for investing institutions, unlike the other residential indices that have been discussed that have more general economic uses.

6. Commercial Real Estate Performance Measurement and Modelling

6.1 Clearly the problems of valuation error, valuation smoothing and stale appraisals make real estate performance measurement and modelling more difficult than modelling securities markets' data, in the sense that the data need to be interpreted before use. The issues are different depending on the purposes for which real estate indices are used. If we are using indices for performance measurement purposes, even if there are sufficient properties in an index to remove the effect of valuation error through the law of large numbers, and there are no stale appraisals, we are still left with two problems. The first problem is that the index value is based on valuations derived from comparables, or past transaction prices. Of course, in performance measurement this will also be true of the value of the fund the performance of which is being measured. However, the impact of valuation smoothing on the index and on the fund may be different. If we assume that this effect is not significant (i.e. the properties in the fund have been valued, in aggregate, in a similar way to those in the index) there is still a further problem. Some funds will not be large enough to allow us to assume that the law of large numbers takes care of valuation error. Even if the index uses a sample that is large enough, individual funds may be insufficiently big for random errors to cancel out. Therefore, we have to assume that the performance figure, calculated from a particular fund, comes from a distribution of possible valuation-based performance figures. The best that we can do is to make appropriate assumptions about the possible distribution of valuations around the true mean, so that we can produce a confidence interval for the fund performance figure and measure whether the performance of the fund is significantly different from that of the index (see Bowles *et al.*, 2001). These problems are exacerbated where we measure the performance of a subsection of a particular fund — such a sub-sector, for example north of England offices, might be very small.

6.2 Similar problems exist when modelling real estate in an asset/liability context; which is, perhaps, the other major use of index data by actuaries. For some purposes the modelling of real estate may best be carried out using information collected from valuation-based indices. For other purposes, it may be best to adjust indices to remove the problem of valuation smoothing before models are developed. In any event, both the tools and the data exist to produce real estate models for asset/liability modelling purposes that stand alongside those that are used in other asset markets. This is particularly so if we bear in mind the points made in Section 8 about the nature of asset models and the stochastic asset/liability modelling process.

7. Using Information from the Real Estate Share Market to Understand the Performance of Commercial Real Estate

7.1 *Rationale for this Approach*

7.1.1 In general terms, there are at least three practical problems in using published real estate data for investment purposes. Data series that are published may suffer from valuation smoothing or valuation inaccuracy; in many countries, only relatively short histories of index data are available; and, in most countries, index values are only available with a relatively long time lag. It is possible that data obtained from the real estate share market (for example property investment companies) will provide a further source of data that can be used to both complement and supplement published indices. Barkham & Geltner (1995), Fisher & Geltner (2000) and Stevenson (2001) have examined the relationship between real estate shares and the direct market. White & Holman (2002) also look at the relationship between de-smoothed direct market indices and de-geared indirect market indices. Booth & Marcato (2003) also use the methods described below, but in this paper the results are extended to the end of 2002. There is a more extensive explanation of the methodology behind this work in Booth & Marcato (2003).

7.1.2 Consider the situation where an ungeared real estate investment company existed in a market where all transactions in real estate could be made immediately without frictional costs. Assume also that management of the company neither added nor destroyed value after allowing for its costs. In these circumstances we would expect real estate share prices to reflect exactly the value of the assets held by the company to marginal investors. However, issues such as gearing and the different tax positions of direct and indirect real estate investments will undermine this relationship. We will ignore tax in the analysis that follows. If we can adjust real estate share returns for the element of gearing in their capital structures, it should be possible to create an adjusted (de-geared) real estate share index, the performance of which should, at least, provide useful information about the performance that would be attained by direct real estate in a liquid market, based on transaction prices. We do not contend that the relationship would be perfect — merely that real estate share prices, appropriately adjusted for gearing, should provide some information about direct real estate transaction prices, and that this information can be useful for those analysing the real estate market, particularly in countries in which data are scarce. We also do not make any assumptions relating to the efficiency of the equity markets. However, transactions are continually taking place in the real estate equity market. The prices at which those transactions take place must have some information content.

7.1.3 If direct real estate returns are de-smoothed (to remove the effects of valuation smoothing) and indirect real estate returns are de-geared (to remove the impact of gearing on performance), real estate returns in the direct and indirect markets should have a closer relationship with each other than if those adjustments to raw data are not made. If this is confirmed to be the case in situations where we regard the data sources relating to the direct market to be reliable, it is an indication that it is possible to use the information in the indirect market to make inference about performance in the direct market in situations where performance information in the direct market is scarce, unreliable or not timely. This additional information should help index users in the functions of market analysis and could also be of some help in the construction of derivative products. The underlying theory behind the investigation is as follows. Consider two forms of valuation-based data: raw index data and data after a de-smoothing adjustment. Similarly, consider two forms of real estate share data: raw index data and data after adjusting for the gearing of real estate companies. We would expect that, if the impact of valuation smoothing were removed from valuation-based indices, the resulting data set would be more volatile and have a higher correlation with securities market indices (including real estate share indices). We would also expect that, if real estate share indices are de-geared (i.e. the impact of gearing removed), the adjusted index values would have a different volatility, but the correlation with valuation-based real estate indices would not change (the gearing, in effect, is just a scaling factor). If these changes in relationships are found, then the indices are behaving in accordance with prior theory, and it is reasonable to suppose that de-geared real estate share indices may provide a useful data source for investment analysis purposes in that they might help investors understand more about the pattern of underlying transaction prices. We cannot conclude more strongly than that!

7.2 *Data Description*

7.2.1 The indices used for the investigations of annual and monthly data respectively are:

— returns from the IPD Annual Index and the Datastream Real Estate Sector Index (from 1980 to 2002); and
— returns from the IPD Monthly Index and the FTSE 350 Real Estate Sector Index (from January 1995 to December 2002).

7.2.2 The gearing ratio for the Datastream Real Estate Index was obtained directly from the data source. The gearing ratio for the FTSE 350 Index for the monthly investigation was computed from original sources, using published accounting information and market equity values (see below). The rationale for using the Datastream Real Estate Index for the annual data investigation is that: firstly, it is the only index with a published gearing ratio; and secondly, it is the longest available time series. The published sources that were available to de-gear the FTSE 350 Index did not go back far enough to provide sufficient data points for the annual investigation. However, the Datastream Real Estate Index does contain some real estate companies that are not investment or development companies (e.g. agents), although these make up only a small proportion of the index. The FTSE 350 real estate sector only contains real estate investment and development companies. As this index does contain enough data points for the monthly investigation, it was used for that investigation. Preliminary investigations using annual data for the FTSE 350 Index combined with the best gearing information that is available for that index (Church, 2001) suggested that there was virtually no difference between the results using the FTSE All Share Index real estate sector and those using the FTSE 350 Index real estate sector. Like the Datastream index, the FTSE All Share Index contains real estate companies other than property investment and development companies. This 'cross check' suggests that the property companies that are not investment or development companies do not affect the performance greatly. Given the limitations, even of primary data sources, it is difficult to verify results more thoroughly. The data from the direct market were de-smoothed using the techniques introduced in Section 3.

7.3 *De-gearing*

7.3.1 In the investigation using annual data, an implicit assumption when calculating de-geared equity returns from the market value return data is that any new debt issues or redemptions take place at the beginning of the year. Published sources for the gearing ratios were used in the process of de-gearing annual data. However, these published sources calculated gearing using book values rather than market values of equity.

7.3.2 With regard to the monthly investigation, there is no published information that allows us to derive an average gearing ratio for the FTSE 350 Index real estate sector directly on a monthly basis. We therefore computed the gearing ratio by examining the individual constituents of the monthly index and their debt issues on a monthly basis. The average gearing ratio of the indirect property index for each month is then computed by taking the weighted average gearing ratio of the constituents at the beginning of the same month (where the weights are the market values of the companies). The gearing ratio for company i at time t (i.e. G_{it}) is given by:

$$G_{it} = \frac{Debt_{it}}{MV_{it}}$$

where $Debt_{it}$ is the book value of the debt of company i at time t and MV_{it} is the market value of company i at time t. For simplicity, it is assumed that repayments of debt only occur at the end of the year, leaving only new issues as a variable in the numerator (debt) each month. The new issues are assumed to take place at the beginning of each month. These assumptions are made necessary by the limitations of the publicly available data. We have used disaggregated company-level, monthly data to determine the gearing ratios and debt issues. The value of debt is collected from primary sources through company balance sheets, which indicate the date and amount of new debt issued during the year.

7.3.3 The market evaluation of the underlying real estate assets of the quoted real estate sector can be measured as a function of the gearing ratio and the return on the market value of the equity of the company. As is shown in Barkham & Geltner (1995) and Stevenson (2001), the underlying property return ($R_{p,t}$) is given by the following equation:

$$R_{p,t} = [R_{e,t} - g_t^* R_{d,t}]/(1 + g_t)$$

where $R_{p,t}$ is the rate of return on the property assets from $t-1$ to t, $R_{e,t}$ is the rate of return on the company's shares over the period $t-1$ to t, g_t is the gearing ratio (measured as the debt to equity ratio at the beginning of the tth year) and $R_{d,t}$ is the rate of return on debt. If $R_{d,t}$ is zero, it can be shown by simple algebra that this expression measures the absolute increase in the market value of the equity (which is the same as the absolute increase in the market value of the underlying property during the period, given our assumption of no debt issues during the period), expressed as a proportion of the total asset holdings. The $g_t^* R_{d,t}$ adjustment factor arises as it is necessary to service the debt using the returns from the property, and the interest rate at which this is assumed to be serviced is $R_{d,t}$. The debt capital is contributing to the performance of the real estate in the company. However, it has a cost, as measured by the $g_t^* R_{d,t}$ factor. The term is of second order of magnitude, and therefore the precise choice of interest rate is not important. We used the benchmark yield for five year gilts with a 0.125% per month spread.

7.3.4 Figure 7.3.4.1 shows the performance of the geared and de-geared

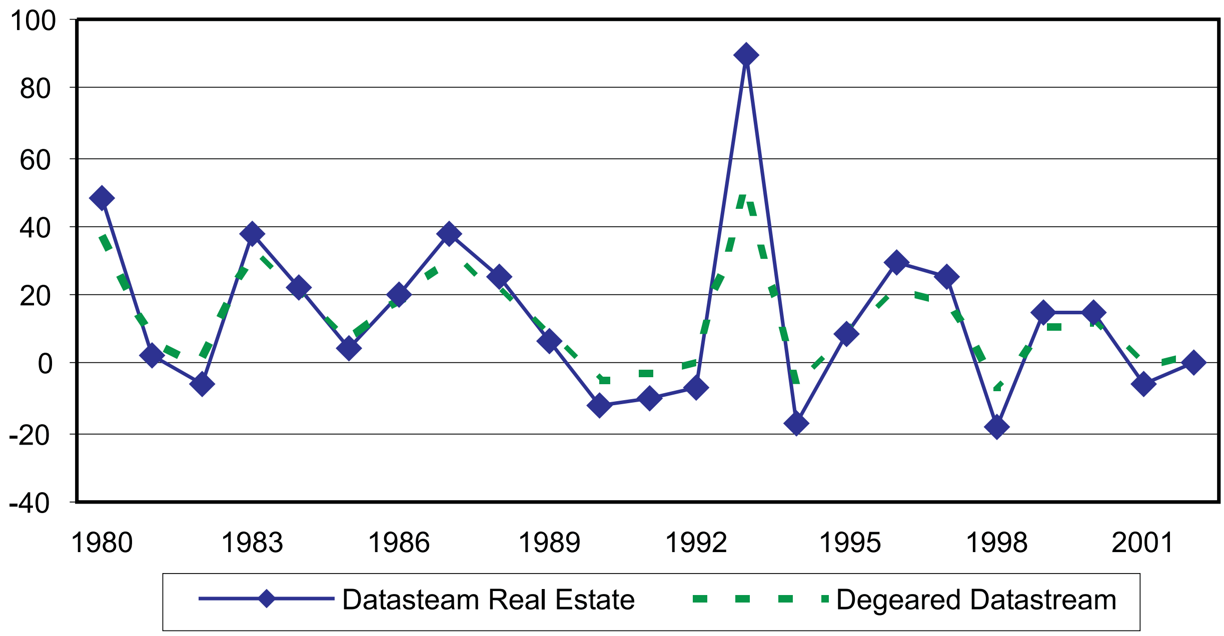

Figure 7.3.4.1. Datastream real estate and de-geared returns (annual data) 1980 to end 2002.

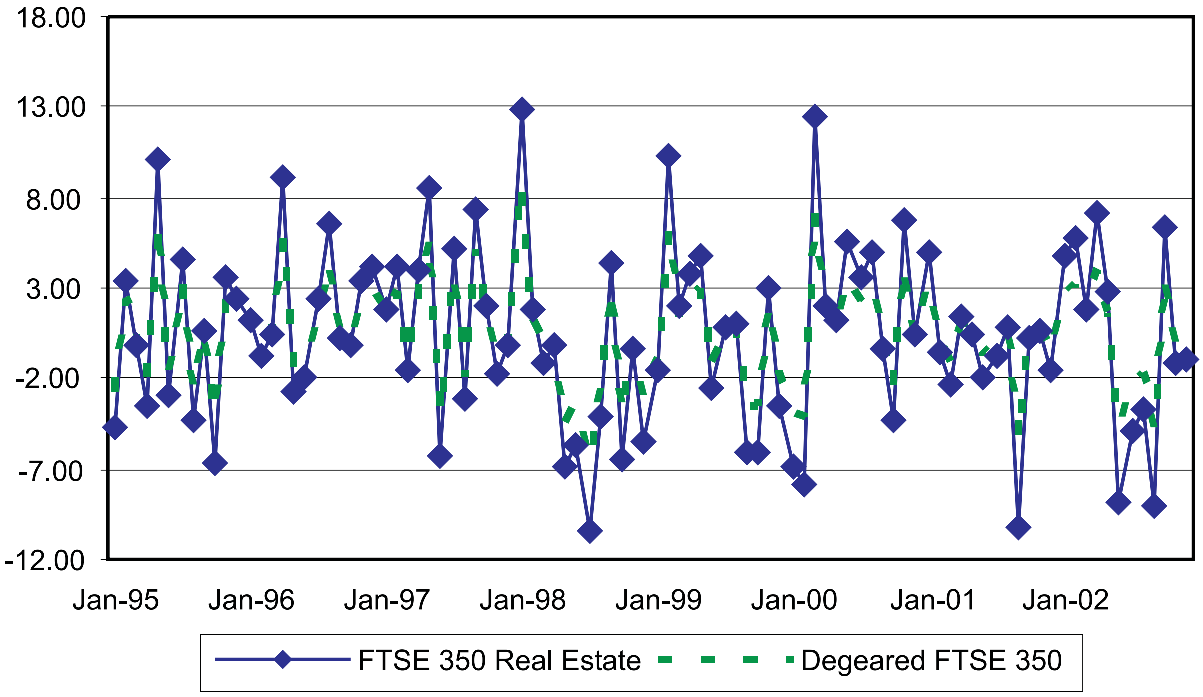

Figure 7.3.4.2. FTSE 350 real estate and de-geared returns (monthly data)

indices for the annual data and Figure 7.3.4.2 shows the same information for the monthly data. In both cases the data are from 1980 to end 2002. The monthly real estate share index data, both geared and de-geared, together with related descriptive statistics for the period 1980 to end 2001, are published in Booth & Marcato (2003). The de-geared monthly returns should be an important primary source for further investigations of the relationships between the direct and indirect markets. The mean return from the annual real estate index from 1980 to 2002 was 13.57% p.a. When the index was de-geared, the mean return fell slightly to 12.39% p.a. The closeness of these two figures is indicative of the fact that the rate of return from real estate, over the data period, is very similar to the cost of debt capital. The standard deviation of return decreases when the index is de-geared from 24.94% to 15.30%; this is exactly the result that we would expect. The mean return from the monthly real estate index was 0.40% per month. When the index was de-geared the mean return increased slightly to 0.47% per month. The standard deviation of return decreases when the index is de-geared from 4.91% to 2.97%.

7.4 *Dependency between the Direct and Indirect Markets: Monthly Data*

7.4.1 The measures of dependency between the various monthly data series are shown in Table 7.4.1.1. The correlation coefficient is a parametric measure of correlation that takes into account all observations. The robust correlation coefficient removes those data points that form the 10% most outlying observations. Thus, for example, if the de-gearing process had led to some extreme observations at particular points in the cycle, the robust correlation measure would ignore these observations. The conclusions that we would draw would then only hold for the less extreme part of the cycle (i.e. not for the tails of the distributions). The Kendall's Tau $k_{x,y}$ measures the difference between the probability of association and the probability of disassociation:

$$k_{x,y} = P[(x_1 - x_2)(y_1 - y_2) > 0] - P[(x_1 - x_2)(y_1 - y_2) < 0].$$

The product of the two differences in values is greater than zero if both $(x_1 - x_2)$ and $(y_1 - y_2)$ are either positive or negative (i.e. concordance). Vice versa, the product of the two differences in values is lower than zero if the two terms show opposite signs (i.e. discordance). Finally, the Spearman rank correlation coefficient measure is non-parametric. It relates the order of the data points in the series rather than their absolute values:

$$s_{x,y} = \frac{\sum_{i=1}^{n} \left(A_i - \overline{A}\right)\left(B_i - \overline{B}\right)}{\sqrt{\sum_{i=1}^{n} \left(A_i - \overline{A}\right)^2} \sqrt{\sum_{i=1}^{n} \left(B_i - \overline{B}\right)^2}}$$

where A_i and B_i are respectively the ranks of x_i and y_i.

7.4.2 The measures of dependency between different monthly indices are shown in Table 7.4.2.1. All measures suggest a lack of dependency between different indices (i.e. they are not significantly different from zero). De-smoothing and degearing do not improve these measures. Total dependency would be indicated by a dependency measure of 1.

Table 7.4.2.1. Dependency measures between real estate indices (monthly data).

Measures of dependency	Pearson's correlation coefficient	Robust correlation coefficient	Kendall's Tau	Spearman's correlation coefficient
IPD index vs. real estate shares	–0.10	–0.15	–0.04	–0.08
Unsmoothed IPD index vs. degeared real estate shares	–0.13	–0.04	–0.05	–0.08
IPD index vs. degeared real estate shares	–0.10	–0.14	–0.05	–0.09
Unsmoothed IPD index vs. real estate shares	–0.11	–0.04	–0.05	–0.08

7.4.3 The result that there is no change in the relationship between the direct and indirect market as a consequence of de-smoothing and de-gearing, in the case of the monthly data, is important. We can draw one of two conclusions from this. Either the monthly index for the direct market does not properly represent the underlying transactions performance of the direct market, even when the index is de-smoothed, or the de-geared monthly index for the indirect market does not provide useful information about the direct market. Thus, in a sense we have a joint hypothesis problem. The result of there being no change in the relationship between the direct market and the indirect market can be explained by one (or both) of two factors. The first is that there is fundamentally no relationship between the direct market and the indirect market, even where the direct market indices are adjusted to allow for the impact of valuation smoothing and indirect market indices are adjusted for the effect of gearing. The second is that monthly direct market indices, even where de-smoothed, do not represent the underlying transactions value of the market. There ought to be some relationship between the direct and indirect markets once we have adjusted direct market indices for the impact of smoothing, because, fundamentally, both forms of index are measuring the price at which people are willing to transact interests in property.

7.4.4 The problems of stale appraisals and valuation smoothing are much more acute at the monthly index level than they are at the annual index level. It therefore seems likely that it is not possible to properly represent the underlying transactions process using monthly indices, even when they are de-smoothed, using standard techniques. Thus, it may be possible to shed more light on this joint hypothesis problem by considering the relationships between annual indices. There is an a priori reason why we might expect de-smoothed annual direct real estate indices to more closely reflect the performance of transaction prices than a de-smoothed monthly index. For the reasons discussed above, we would expect the problems caused by valuation smoothing to decrease the longer the computation period of the index (in the limit for an index which had so few computation points that all comparables were derived from properties transacted since the last computation date, there would be no valuation smoothing). There is, in turn, no a priori reason to assume that the annual index of the indirect market should more closely reflect the underlying transactions process than the monthly index of the indirect market, given that the real estate share market is more liquid than the direct market.

7.5 *Dependency between Direct and Indirect Markets: Annual Data*

7.5.1 Table 7.5.1.1 shows — when the frequency is annual — the dependency measures defined in Section 7.4 for relationships between valuation-based indices, de-smoothed valuation-based indices, real estate share indices and de-geared real estate share indices.

Table 7.5.1.1. Dependency measures between real estate indices (annual data).

Measures of dependency	Pearson's correlation coefficient	Robust correlation coefficient	Kendall's Tau	Spearman's correlation coefficient
IPD index vs. real estate shares	0.56	0.47	0.42	0.56
Unsmoothed IPD index vs. degeared real estate shares	0.67	0.56	0.42	0.62
IPD index vs. degeared real estate shares	0.58	0.49	0.42	0.55
Unsmoothed IPD index vs. real estate shares	0.68	0.58	0.45	0.65

7.5.2 All measures of dependency (except Kendall's Tau) suggest the same pattern. De-smoothing direct real estate indices leads to a substantially closer relationship with the real estate share market indices. As is suggested above, de-gearing the real estate equity index makes little difference to the relationship with either the original or the de-smoothed direct index. The correlation coefficient increases, as a result of de-smoothing, from a level broadly similar to that which exists between two closely connected equity markets (for example the U.K. and German markets) to a rather higher level. It is worth noting that the results in Booth & Marcato (2003) are slightly stronger, but broadly the same, using a slightly shorter data period. Assuming that the technique of de-smoothing leads to the creation of a direct real estate index that is closer to the underlying transactions pattern, the result would suggest that there is significant information content in the indirect real estate indices about the direct market. That information is best provided by the de-geared indirect index rather than by the raw data, and can be used to help us understand direct market movements at higher frequencies (e.g. monthly) and with a shorter time lag than published direct market indices allow in many countries. Even in the U.K., where direct real estate indices are available monthly, users may wish to use information from the de-geared indirect market in the interpretation of that information. Tests of cointegration were carried out to find whether the long-run equilibrium relationship between the indices changed as a result of de-smoothing. These tests were inconclusive as a result of the lack of data leading to insufficient power. It is possible, using published sources, to develop a monthly index of de-geared real estate share returns, and, as has been noted, we have compiled such an index and presented the results in Booth & Marcato (2003). With slightly stronger assumptions (or better information sources), this index could be produced at daily or shorter intervals. Such an index could be used to provide information about short-term movements in transaction prices in the direct real estate market.

7.5.3 In some senses, readers might regard the conclusions of this section as being weak or, indeed, inconclusive. However, the context must be understood. We have a direct real estate market and we would like to understand the performance of equilibrium transaction prices. There are at least two sources of information from that market: valuation-based indices relating to the direct market (which we can de-smooth); and real estate share price indices (which we can de-gear). With regard to the monthly data at least, we do not know which of the two adjusted indices best reflects transaction prices. However, we do know that the process of de-smoothing is much more reliable for annual than it is for monthly indices. The fact that there is a closer relationship between annual de-smoothed direct real estate returns and de-geared real estate share returns does suggest that de-geared real estate share returns provide us with some information about short-term movements in the direct market, when we can get no better source of information. The conclusion is 'weak' because of the nature of the problem. It is no less important for that.

8. Modelling Real Estate Returns

8.1 *Introduction*

8.1.1 It is helpful for a number of actuarial purposes to be able to develop models appropriate for simulating future real estate returns. In this section we use the results of earlier sections relating to de-smoothing and so on to develop stochastic models for real estate returns. There has been debate about stochastic asset model forms in the actuarial literature. Smith (1996), Harris (1997), Whitten & Thomas (1999) and Yakoubov *et al.* (1999), for example, have published and justified different model forms, in addition to those published by Wilkie (1995). Huber (1997) critiques different approaches to modelling in detail. After taking into consideration the various critiques and approaches to modelling, in this section we have used the model forms suggested by Wilkie (although with some adjustment). The data suggest that such a model form happens to be appropriate in the case of real estate, regardless of its adequacies or otherwise for modelling other asset classes.

8.1.2 When modelling for some purposes, actuaries may wish to carry out projections using valuation-based data. For other purposes they may wish to use data that appear closer to underlying transaction prices. Models are developed in the sections below using both types of data and also using property company data. The sources of all the real estate data discussed in this section are the Scott series up to 1971 and the IPD series thereafter. The source of the securities market data is Barclays Capital (2003).

8.2 *Modelling Real Estate Yields*

8.2.1 *The Wilkie real estate yield model*

8.2.1.1 The Wilkie model is described in detail in Wilkie (1995). It models real estate yields and rents separately. The data used are the Jones Lang Wootton Indices from 1967 to 1994.

8.2.1.2 The yield model can be described as follows:

$$P(t) = \exp\{PI.I(t) + PN(t)\}$$

or

$$\ln P(t) = PI.I(t) + PN(t)$$

with:

$$PN(t) = AR1(\ln PMU, PA, PSD)$$

where:
$P(t)$ is the rental yield on the real estate index; and
$I(t)$ is the rate of inflation at time t.

8.2.1.3 Thus, the property yield is described as a function of a mean value (PMU), a first-order auto-regressive parameter (PA) and a random term, PSD.N(0, 1). More explicitly, we could write the model as:

$$\ln P(t) = PI.I(t) + \ln PMU + PA.(\ln P(t-1) - \ln PMU) + PSD.\mathrm{N}(0, 1).$$

There are various possible explanations for including the parameter representing the relationship between inflation and property yields. If there were no money illusion or lags in the economy, a rise in the general price level would feed straight through into rents and capital values, and inflation should not affect yields. However, if, for example, inflation leads to long-run increases in rents, but not in the rents receivable from a real estate portfolio (because of the periodic nature of rent reviews), capital values may increase to anticipate future increases in rents, but yields fall because rents respond with a lag. There are also aspects of money illusion that could lead to a relationship between rental yields and inflation. Nevertheless, in fitting the general model Wilkie found the inflation parameter insignificant, and therefore proposed a simple AR(1) model.

8.2.1.4 Wilkie found the following parameter values for that AR(1) model:
$PMU = 7.41\%$
$PA = 0.9115$
$PSD = 0.1177$.

8.2.3 *Further development of a stochastic real estate yield model*

8.2.3.1 Prior theory would suggest that a relationship between real estate yields and equity and bond yields might exist. It would normally be thought that such a relationship would be a positive one. There are a number of reasons for supposing that such a relationship might exist. The most obvious reason is that equity, bond and real estate values can be determined in a discounted income model. If there were an increase in risk free rates of return with all other variables remaining the same, we would expect to see an increase in yields in all markets. The problem of valuation smoothing may, however, complicate any such relationship. Indeed, if there were cyclical patterns in bond and equity yields, valuation smoothing may produce a negative relationship between bond and/or equity yields and real estate yields. There is a prior case for testing the relationship between short-term interest rates and real estate yields. It is feasible that increases in short-term interest rates, signalling a tightening of monetary policy, may take effect through investment and credit channels, adversely affecting real estate capital values (see, for example, Pepper, 1994): we might therefore expect a positive relationship between short-term interest rates and real estate yields.

8.2.3.2 We therefore generalise Wilkie's model to add the following additional parameters:
$D(t)$ = dividend yield from equities;
$C(t)$ = redemption/running yield from consols; and
$T(t)$ = return from Treasury Bills (as a proxy for short-term interest rates).

The generalised model therefore becomes:

$$\begin{aligned}\ln P(t) = {} & PI.I(t) + PD.\ln D(t) + PC.\ln C(t) + \ln PMU + PA.(\ln P(t-1) \\ & - \ln PMU) + PT.T(t) + PSD.\mathrm{N}(0,1).\end{aligned}$$

There is no clear economic rationale for expressing the model in log form rather than using untransformed variables, although the former does give better diagnostic statistics. It can also be said that there is no clear economic case for not using log variables, so it seems reasonable to be guided by the data in this case. After fitting the model using this basic structure, we then investigated whether there were further auto-regressive relationships that had not been captured. In the next section, we re-estimate a generalised form of the Wilkie model using different forms of real estate data.

8.2.4 *Results of fitting the stochastic model using the IPD indices*

8.2.4.1 The same approach as that used by Wilkie was used. The yield data series from the IPD annual index from 1971-2000 (inclusive) was used to estimate the models. It should be noted that this is different from the data set used by Wilkie. There were no model forms in which any relationship between yields and inflation were found. Thus, we focused on the relationship between real estate yields, bond yields, equity yields and Treasury Bill returns, together with the auto-regressive parameters. The absence of the significance of inflation was not of great concern: a prior case can be made for including inflation in such models (see above); however, the case is not an overwhelming one.

8.2.4.2 Auto-regressive parameters of order one were significant, as were bond yield, equity yield and Treasury Bill parameters. The coefficient on the bond yield parameter was negative. This should not be of great concern. Whilst prior theory might indicate some relationship between bond yields and real estate yields (through the risk-free rate of return), it should be noted that most studies find a very low, zero or negative correlation between U.K. bond returns and U.K. real estate returns from valuation-based indices; the correlation between returns is higher when de-smoothed real estate returns are used (see Booth & Matysiak, 2004). Nevertheless, whilst these findings from modelling real estate yields do not contradict other studies, the result is counter-intuitive, and further research into the various relationships between securities markets and the real estate market would be worthwhile. The coefficient on equity returns is positive; there is generally a positive correlation between U.K. equity returns and real estate returns, even where the latter are computed from valuation-based indices, so this result is not surprising. We therefore suggest one of the following models for real-estate yields, as computed from valuation-based indices:

Simple model 1

$$\ln P(t) = \ln PMU + PA.(\ln P(t-1) - \ln PMU) + PSD.\mathrm{N}(0, 1)$$

where:
$PMU = 6.1\%$ ($s.e. = 1.23$)
$PA = 0.83$ ($s.e. = 0.10$)
$PSD = 0.10$
$\bar{R}^2 = 0.72$.

The Lagrange multiplier (LM) statistic was used to test for serial correlation in the residuals for all the models. In this case the LM statistic was 1.17, so there is no evidence of serial correlation in the residuals. The results are very close to those found by Wilkie. The fact that different data providers and different data sets were used for both investigations gives some confidence in the results.

Simple model 2

In simple model 2, a second order auto-regressive parameter was included. The following results were found:

$PMU = 6.1\%$ (1.23)
$PA = 1.1$ ($s.e. = 0.18$)
$PA(2) = -0.30$ ($s.e. = 0.18$)
$PSD = 0.10$
$\bar{R}^2 = 0.72$

where $PA(2)$ is the second order auto-regressive parameter. Again there was no evidence of serial correlation in the residuals.

Complex model 1

In the complex model, we include parameters for bond and equity yields and Treasury Bill returns, but not for inflation. The parameter values are then:
$PMU = 6.1\%$ (1.23)
$PA = 0.90$ ($s.e. = 0.08$)
$PD = 0.35$ ($s.e. = 0.10$)
$PC = -0.33$ ($s.e. = 0.09$)
$PT = 0.11$ ($s.e. = 0.06$)
$PSD = 0.08$
$\bar{R}^2 = 0.82$.

There was some evidence of serial correlation in the residuals, although the hypothesis of 'no serial correlation' would not be rejected at the 95% level. It should be noted that the sign on the bond yield parameter is negative. The implications of this are discussed above.

Complex model 2

Significantly better diagnostic statistics were achieved by including a second order auto-regressive parameter. When this is included, all the parameters that are significant in complex model 1 remain significant. The results when a second order auto-correlation term is included in the complex model are:
$PMU = 6.1\%$ ($s.e. = 1.23$)
$PA = 1.19$ ($s.e. = 0.15$)
$PA(2) = -0.31$ ($s.e. = 0.14$)
$PD = 0.40$ ($s.e. = 0.10$)
$PC = -0.40$ ($s.e. = 0.10$)
$PT = 0.14$ ($s.e. = 0.06$)
$PSD = 0.07$
$\bar{R}^2 = 0.83$.

There is no evidence of serial correlation in the residuals.

8.2.4.3 For practical simulation purposes the simple model is clearly significantly easier to use (particularly if real estate is the only category being modelled). However, it will miss any relationships between equity, bond and real estate yields. A positive auto-regressive parameter order one, as has been used above, can be explained by the process of valuation smoothing; in theory the same could be said for positive auto-regressive parameters with greater lags. However, using all data forms and analysing the raw data, there is extremely strong evidence of *negative* second-order serial-correlation. Furthermore, including a second-order, serial-correlation parameter improved the diagnostic statistics of the models. The authors can find no obvious economic or financial reason for a negative second order auto-regressive relationship, either in the literature on efficient markets or in the literature on the influence of valuation smoothing on real estate indices. However, the evidence for negative second-order serial-correlation is so strong that its inclusion should be considered in long-term forecasting models (but see also Section 8.2.7). It should be added that there is also strong evidence of second-order serial-correlation in the capital return indices; it is not just a function of the yield data. It is possible that the combination of both smoothing and some form of cycle in the yield could create complex auto-regressive structures with alternating positive and negative signs of the kind that we have found. We feel that this is an important area for further research in the valuation smoothing literature, which hitherto has concentrated on the positive first-order correlation between returns. It is worth noting that the second order serial correlation does not exist in all U.K. commercial real estate data sets (see below), but, in many respects, this feature is the great 'uninvestigated feature' of real estate data in the U.K. real estate finance literature.

8.2.5 *Model results using property company data*

8.2.5.1 Further models were fitted using data from real estate companies. Such a model, estimated from real estate share prices, provides a further tool for those involved in asset/liability modelling, as many institutional investors obtain their exposure to real estate through the purchase of real estate shares. The yield modelled in this case was the dividend yield. Monthly data were used from the FTSE 350 Real Estate Index from 1987 to 2000 inclusive (180 observations in all). Because reliable monthly data were available, this was used. The most useful model form appeared to be similar to complex model 1, estimated above for the IPD data for direct real estate yields, but without the inclusion of Treasury Bill returns as a variable. There were no significant auto-regressive parameters higher than first order. Whilst the first order auto-regressive parameter is similar to that found from direct real estate, it should be noted that monthly data is used. One would expect less strong relationships between successive yields when quoted real estate company data are used, as compared with those between successive yields from direct real estate investment, where the time interval between data points is the same. This is certainly apparent from the limited further investigations that we made.

8.2.5.2 The model which we propose for the quoted real estate sector would have the following parameters:
$PMU = 3.85\%$ ($s.e. = 1.36$)
$PA = 0.94$ ($s.e. = 0.03$)
$PC = -0.04$ ($s.e. = 0.02$)
$PD = 0.07$ ($s.e. = 0.04$)
$PSD = 0.08$
$\bar{R}^2 = 0.94$.

There is no evidence of serial correlation in the residuals.

8.2.6 *Model results using de-smoothed, valuation-based data*

8.2.6.1 There are circumstances in which it is appropriate to use 'de-smoothed' valuation-based data in actuarial modelling. De-smoothing attempts to remove those aspects of the serial correlation between returns that arise from the process of using comparables for valuations. The Wilkie construction allows all yield models to follow an auto-regressive, stationary process. The auto-regressive parameters that we have estimated for direct real estate are very high compared with those that Wilkie (1995) finds for equity markets, for example. Real estate finance specialists would argue that some of this serial correlation is, in effect, artificial and arises from 'valuation smoothing'. There may be some actuarial purposes for which the use of the 'smooth' data may be appropriate (for example, where liability valuation assumptions are also smoothed). However, certainly where market-based liability valuations are used and asset values are adjusted for the impact of smoothing, it would be appropriate to use a real estate stochastic model derived from de-smoothed data.

8.2.6.2 We investigated the same kind of model forms, incorporating auto-regressive parameters as well as parameters for the relationship between real estate yields, bond yields, equity yields and Treasury Bill returns. It should be noted that the process of de-smoothing removes serial correlation between successive capital value returns and not between successive values of the rental yield. Therefore, we would not necessarily expect that process to remove serial correlation between successive yield values, although one would expect to see any serial correlation reduced.

8.2.6.3 It is necessary to limit the data period when de-smoothed data are used. The de-smoothing technique will give rise to unintended changes in the mean of the data if the starting and finishing yields are not approximately the same. We have used data from 1976 to 2000 for fitting the model to de-smoothed data. The yield is 6.1% at the beginning of the period and 6.4% at the end of the period. Using the de-smooth data, a simple AR(1) model has very serious serial correlation in the residuals. An AR(2) format removes much of this. An AR(3) model removes the serial correlation further. None of the financial variables (equity yields, bond yields, inflation or Treasury Bill returns) are significant in any circumstances. We therefore propose two models:

Simple model 1
$PMU = 7.35$ ($s.e. = 2.56$)
$PA = 1.29$ ($s.e = 0.17$)
$PA(2) = -0.55$ ($s.e. = 0.17$)
$PSD = 0.14$
$\bar{R}^2 = 0.82$

where $PA(2)$ is the second-order auto-regressive parameter.

Simple model 2
$PMU = 7.35$ ($s.e. = 2.56$)
$PA = 1.57$ ($s.e. = 0.21$)
$PA(2) = -1.16$ ($s.e. = 0.31$)
$PA(3) = 0.45$ ($s.e. = 0.19$)
$PSD = 0.13$
$\bar{R}^2 = 0.85$.

8.2.6.4 It is useful to compare the model fitted using the original data with the new data period with models fitted using the original data over the original data period, and then compare with the models fitted using de-smoothed data. The dividend yield parameter is not significant over the shorter time period. The significance of the dividend yield parameter where the full data period was used may have arisen as a result of the extreme market movements found in 1973-1975, which coincided with extreme movements in the real estate market. This strengthens the case for using the simple model. It is also notable that bond yields (negative parameter) and Treasury Bill returns (positive parameter) are not significant where the de-smoothed data are used, but just significant (at the 10% level) where the original data are used over the shorter data period. There is no obvious reason for this. In general, we expect stronger correlation between de-smoothed returns and other financial variables (see, for example, Booth & Matysiak, 2004). One would also expect these stronger correlations to be reflected in yields, and thus exhibited through the yield model (although it should be noted that small changes in correlations would not necessarily translate through the model structure into significant parameters). There is some reduction in the first-order auto-regressive parameter where the de-smoothed data are used. We would expect to see this. The reduction is relatively small, despite the fact that all the first-order serial correlation is removed from the capital value returns. This result may seem surprising at first sight. However, it arises from the fact that the absolute value of (rather than the change in) the yield is being modelled. The mean yield also increases in the de-smoothed model. This is a direct function of the de-smoothing process. The de-smoothing leaves the arithmetic average return in each year the same as in the original data set. However, the data are more volatile. This means that the geometric average return is reduced in the de-smoothed series and the average yield is increased.

8.2.7 *Model results using the Scott series*

8.2.7.1 Many stochastic investment models are fitted using data from much longer data periods than the periods that have been used for real estate models. The desire to use a longer data period is compatible with the desire to model over long time periods and emphasise long-term relationships. We have therefore created additional models using the Scott (1996) data series from 1921 to 1992 followed by the IPD data series from 1993 to 2000. Clearly this involves the use of two data series combined together. This is not unusual in actuarial stochastic modelling where there is an emphasis on modelling long-term relationships. Two particular features of the data should be noted. First, the war period was 'switched off' using a dummy variable. This addresses a criticism made by Booth in the discussion of the Wilkie (1995) model. Secondly, instead of the passing rental yield, the income return in a given year per unit capital value index at the beginning of the year was used as a proxy for yield in the Scott series.

8.2.7.2 Using the same notation as above, the following two models are evident from the Scott/IPD data:

Simple model
$PMU = 6.0\%$ ($s.e. = 0.89$)
$PA = 0.74$ ($s.e. = 0.08$)
$PSD = 0.10$
$\bar{R}^2 = 0.55$

Complex model
$PMU = 6.0\%$ ($s.e. = 0.89$)
$PA = 0.55$ ($s.e. = 0.10$)
$PD = -0.06$ ($s.e. = 0.03$)
$PC = 0.07$ ($s.e. = 0.03$)
$PI = -0.007$ ($s.e. = 0.002$)
$PSD = 0.09$
$\bar{R}^2 = 0.57$.

There are no problems with serial correlation in the residuals and the other diagnostic statistics are satisfactory.

8.2.7.3 In this form of actuarial modelling details of relationships do change over time. Those involved in modelling are then left with a dilemma. In short-term econometric forecasting and, for example, in value-at-risk modelling, more weight is often put on the immediate past observations in forming a view about the immediate future. When modelling over time periods as long as 60 years or so, it is arguable that this should not be the case. Once again, these issues need to be approached pragmatically. A comparison of the models fitted using the IPD index data and those fitted using the Scott data is therefore worthwhile. Simple model 1 from the IPD data is remarkably similar to the simple model using the Scott data. This should give us some confidence about its use for long-term modelling. One difference is interesting though. With the shorter, IPD, series there is a very strong case for including a second order auto-regressive parameter (see simple model 2). However, the second order auto-regressive parameter for the longer series is barely significant and very small (0.2). We have already noted that there is no clear economic rationale nor rationale based on valuation methodologies for the second order auto-regressive relationship. Once again, given the strength of this parameter in the IPD valuation-based indices (and in the smoothed indices and capital return indices), there is a clear case for conducting further theoretical and empirical work to ascertain the underlying cause of this second-order auto-regressive process. However, it may be a 'random' feature arising during a particular time period.

8.2.7.4 There is less consistency across the complex models than across the simple models, as might be expected. The Treasury Bill parameter is not significant in the Scott data, but the inflation parameter is (and has the expected sign). Dividend yields and bond yields are both significant in the Scott data, but the signs are reversed. It can be said that both complex model 1 estimated from the IPD valuation-based data and the complex model estimated from the Scott model have a basic economic rationale (except for the negative sign on either the dividend yield or bond yield parameter).

8.3 *The Wilkie Real Estate Income Model*

8.3.1 *Form of the Wilkie rent model*

8.3.1.1 The Wilkie real estate income model is based on the Wilkie equity income model. Adapting his notation, Wilkie's model is as follows:

$$R(t) = R(t-1).\exp\{RW.RM(t) + RX.I(t) + RMU + RSD.\mathrm{N}(0, 1)\}$$

where:

$R(t)$ is the level of rents in year t;
$RM(t)$ is a term (defined in more detail below) that captures the impact of past values of inflation on current rental growth;
$I(t)$ is inflation;
RMU is the mean level of real rental growth; and
RSD is the standard deviation of the residuals.

Simplifying, this becomes:

$$\ln[R(t)/R(t-1)] = RW.RM(t) + RX.I(t) + RMU + RSD.\mathrm{N}(0, 1).$$

8.3.1.2 This provides the equation for the force of rental growth (i.e. the annualised rental growth expressed in continuous time). The force of rental growth therefore depends on the impact of earlier inflation and current inflation (both also expressed in continuous time), a mean growth term, and a random term. A key issue for modelling rents is whether and how quickly inflation feeds through into rents. Because the model is being developed for use in asset/liability modelling and therefore relates to a group of standing properties, the rental index used is the rent that would be expected to be received from a portfolio, not the rents that would be received from properties that have just been reviewed. Therefore passing and not market rents are modelled.

8.3.2 *Unit gain from inflation to rents*

8.3.2.1 The empirical evidence on the relationship between increases in the general price level and commercial property returns is mixed. Prior theory would suggest that a rise in the general price level would lead to a rise in rents. Almost certainly there would be leads and lags, depending on the transmission mechanism of monetary policy and inflation through the economic system and also depending on rent review periods. As is noted above, one of the problems of long-term actuarial modelling is how to make judgements about whether to include parameters for which there is an economic logic, even if the data set from which parameters are estimated does not provide evidence of an empirical link. This problem is exacerbated by the fact that modelling has to be undertaken over a long time horizon, even where the data period used for estimation of the model is short.

8.3.2.2 In modelling investment returns, we should make the distinction between expected and unexpected inflation. Some assets (for example long-term bonds) should reflect expected, but not unexpected inflation in returns. Index-linked bonds, on the other hand, should reflect expected inflation in current prices, but also, in their long-run returns, should reflect unexpected inflation. The situation is more complex for real investments such as real estate and equities. One would expect these to reflect both expected and unexpected inflation in their returns; however, their returns also depend on a number of other factors in the real economy. For example, the transmission mechanism of inflation may lead to costs to businesses that impair real performance. As has been mentioned, the rent review structure of real estate leases may lead to a lag before unexpected inflation is reflected in rents.

8.3.2.3 Brown & Matysiak (2000) review the evidence for whether expected and unexpected inflation are reflected in real estate returns across a number of countries. There is considerable evidence that both are reflected to some extent and some evidence that both are fully reflected. It seems reasonable, as an a priori assumption, to assume unit gain from inflation to real estate rents, but with a lag. There are institutional factors (the rent review structure) that would prevent unexpected inflation being reflected in rental growth immediately, even in an economy with no friction and no money illusion.

8.3.2.4 We began, as Wilkie did, by making an assumption of unit gain from the general price level to the level of rents, but where the increase in rents occurs with a lag structure. We then tested the significance of the parameters and investigated alternatives where necessary. We estimated the model assuming unit gain and then with the parameters RW and RX unconstrained. A result that $RW + RX > 1$, as Wilkie found, would not seem consistent with prior theory. However, a result that $RW + RX < 1$ or that the parameters were not significant might be of interest, as it would confirm earlier work that the empirical relationship between inflation and rents was, at best, ambiguous.

8.3.2.5 In terms of the notation, the inflation feed-through mechanism in the Wilkie structure can be explained as follows. The parameter on current inflation (RX) and the parameter on lagged inflation (RW) sum to one (if we wish to require long-run unit gain). The influence of lagged inflation (through RW) on real estate rents is assumed to arise through the following process:

$$RM(t) = RD.I(t) + (1 - RD).RM(t-1)$$

that is that the lagged inflation feed-through for year t is equal to a parameter (RD) times inflation in year t plus $(1 - RD)$ times the lagged inflation input in the previous year. The lagged inflation input in the previous year depends on the lagged inflation input the year before, and so on, so that all previous values of inflation are included with declining weights. For example, if RD is 0.2, $(1 - RD)$ is 0.8. As $RM(t-1)$ would have been equal to $0.2.I(t-1) + 0.8.RM(t-2)$, then $RM(t) = 0.2.I(t) + (0.8 \times 0.2.I(t-1) + 0.8 \times 0.8 \times RM(t-1))$. Continuing this process, the parameters on all previous values of inflation can be found and the weights on current and all previous values of inflation from this aspect of the process will sum to unity. This is then multiplied by the parameter RW that distributes the influence of inflation between current inflation and past values. The influence of current inflation is $RW.RD + RX$. So, if RX is 0.4, then the influence of a 1% increase in the price level on rents in the same year would be $100^*(0.6^*0.2 + 0.4)\%$. The total influence of inflation is $RX + RW$. Wilkie found that $RD + RX$ was greater than unity, so he constrained $RX = 0$.

8.3.2.6 Wilkie found the following parameter values:

$RW = 1$

$RD = 0.11$ ($s.e. = 0.07$)

$RMU = 0.0006$ ($s.e. = 0.0152$)

$RSD = 0.0661$ ($s.e. = 0.009$).

Thus mean real rental growth was negligible and the influence of inflation was mainly through lagged inflation.

8.3.3 *Estimation of the rent model*

We re-estimated this form of the Wilkie model for real estate rents using the IPD rental series from 1973 to 2000. It was notable that no significant coefficients could be found of the form RW or RX, despite a correlation coefficient of 0.64 between current inflation and current rents. In order to investigate the lag structure of inflation further, we used a slightly more generalised form of the model of the impact of lagged inflation. However, to avoid over-parameterisation, we only used four years lagged inflation. The model form looked as follows:

$$\begin{aligned}\ln[R(t)/R(t-1)] = {} & RX(0).I(t) + RX(1).I(t-1) + RX(2).I(t-2) \\ & + RX(3).I(t-3) + RX(4).I(t-4) + RMU + RSD.\mathrm{N}(0,1).\end{aligned}$$

Only $RX(0)$ was significant, although the other inflation parameters were all positive. As these forms were unsatisfactory, the following model form was then fitted:

$$\ln[R(t)/R(t-1)] = RX.I(t) + RY.RI(t-1) + RMU + RSD.\mathrm{N}(0,1)$$

where RI is the force of rental growth in period t. The rationale for this model is that the upward only rent review structure should lead to the deferral of the impact of market rental growth on passing rents, whether this increase in rents arises from inflation or is a 'real' change in rents arising from another source. We would not necessarily expect long-run unit gain in this model, as the auto-regressive parameter will capture, in part, the impact of past values of inflation on current rents, parameters for which have been excluded as insignificant. The RMU parameter represents long-term mean real rental growth. This is -0.8%, so that long-term rental growth is slightly less than the rate of inflation.

The parameters we estimated for this model are:

$RMU = -0.0083$ (*s.e.* $= 0.06$)
$RX = 0.31$ (*s.e.* $= 0.13$)
$RY = 0.67$ (*s.e.* $= 0.14$)
$RSD = 2.94$
$\bar{R}^2 = 0.66$.

There was no evidence of serial correlation in the residuals and other diagnostic statistics were satisfactory. We believe that this is an appropriate model form for long-term actuarial modelling.

8.4 *Conclusions on Stochastic Modelling of Real Estate Yields and Rents*

Actuarial stochastic modelling always involves a mix of data and theory driven approaches. The length of time over which data need to be collected in order to forecast over the long term of institutional actuarial liabilities means that the forms of rigorous back testing and other statistical testing used for short-term econometric models are not appropriate. Actuarial models tend to be developed pragmatically. Appropriately, they should also be used pragmatically in order to obtain a better understanding of the risks faced by financial institutions from their long-term investment policy. We believe that the models developed in this paper are as soundly based as those developed in the actuarial literature for modelling equity and gilt markets, and that real estate can therefore take its place alongside those asset classes in the modelling process. We have proposed different models, some simpler, others more complex; some based on de-smoothed or real estate company data, others based on valuation-based index data. Different models could be used for different purposes, and it would be appropriate to use data from alternative ways of de-smoothing in the models. There are few surprises regarding the types of economic and financial variables that are significant in the models, given what we already know about real estate data.

9. Conclusion

Since the publication of the last actuarial paper in *B.A.J.* or its predecessors on real estate performance measurement and modelling, there have been a number of developments in real estate data provision. It is still the case that real estate data suffers from publication lags and is not available at high frequencies. Nevertheless, professional indices are available and are reliable — particularly at annual frequencies. Valuation-based indices do suffer from a number of problems — particularly valuation smoothing. However, with appropriate adjustments and interpretation these problems can be alleviated. Alternative methods of construction are being developed, although it is unlikely that these will be viable in the commercial real estate sector in the next few years. Information regarding the performance of the direct market can be found from the indirect market. This may be particularly useful in countries where direct real estate data are very scarce or unreliable. Rental and yield data can be modelled for actuarial purposes as reliably as data for securities markets. Different model forms might be appropriate for different uses. For some purposes it might be appropriate to use de-smoothed data; for other purposes, valuation-based data might be appropriate.

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