The Investment Risk of
Institutional-grade Commercial Real Estate in Australia

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A thesis submitted in partial fulfilment of the
requirements for the degree of Doctor of Philosophy in Property,
The University of Auckland, 2003.

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ABSTRACT

Knowledge of the investment risk of investment-grade commercial real estate ('ICRE') is important because it determines the approaches which should be taken to portfolio management. However, relatively little is known about this risk.

This research expands the body of knowledge of ICRE investment risk by producing conclusions about the information content of prices and the distribution of returns in the ICRE context. It is broken into three main parts.

First, the ICRE returns-generating process is characterised to form a basis for deducing theoretical conclusions about the information content of prices and the stochastic attributes of returns. The rationale for this approach lies in capital markets literature, which demonstrates that the characteristics of the information structure of markets, the decision-making processes of investors and the market trading mechanism determine the main attributes of the process of price evolution (which is assumed to be the main driver of returns). The analysis concludes that ICRE prices are partially informed, and changes in prices are described by a 'jump' process.

Second, analysis of a database of 'large' price changes supplied by the Property Council of Australia is undertaken to empirically test the jump process hypothesis. This analysis provides evidence that natural events associated with changes in the leasing structure of properties are a primary driver of relatively large, infrequent dislocations in valuation-based prices.

With parts one and two as a backdrop, the third part of this research empirically tests a discrete mixture of normals ('DMON') model of investment risk. Capital markets research shows that a DMON model flows naturally from jump price processes. DMON models fitted to cross-sectional returns on individual properties supplied by the

PCA are found to be superior to the normal and stable Paretian models previously proposed by other researchers.

In aggregate these conclusions have serious implications for the management of ICRE portfolios, and suggest a need for additional research. Some implications include:

- Mean-lower partial variance is superior to mean-variance optimisation.
- Forecasting the distribution of ICRE returns forms a new tool for active management.
- Passive portfolio management is inappropriate.
- Comparables-based valuations may be unreliable for investment decisions.

This work is dedicated to my supervisor, Professor Gerald R. Brown.
Without his support and patience, it may never have been completed.

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Chapter I INTRODUCTION

The goal of this research is to make a contribution to the body of knowledge on the investment risk of individual investment-grade commercial real estate ('ICRE') assets. To make this contribution, this research shows primarily that:

i. The distribution of individual ICRE investment risk is described by a discrete mixture of normals ('DMON') probability law; and

ii. The prices of individual ICRE assets are poorly informed.

A conclusion that risk is distributed according to a DMON probability law is important because investors are concerned about assets' investment risk functions, and generally assume ICRE returns are normally distributed. It thus has serious implications for the ways in which investors should manage their portfolios of ICRE assets.

This conclusion is also important because it builds on previous research which found that ICRE investment risk is described by a stable Paretian probability law. Stable laws pose very serious complications for the use of popular quantitative portfolio construction tools; in a stable Paretian world, these tools are virtually unusable. Building on previous work which is mostly empirical in nature, the current research shows that theoretical and empirical analyses in tandem suggest that ICRE investment risk is described by a DMON probability law.

A conclusion that the prices of ICRE assets are poorly informed is important to investors for several reasons, though most importantly because of the implications it has for the suitability of alternative portfolio management strategies in the ICRE context. When prices are poorly informed, it is inappropriate for naïve investors to pursue a passive management strategy (i.e. the strategy that is consistent with their skills) because they cannot assume that the prices at which assets may be traded are 'fair'. For a similar reason, pursuit of an active management strategy is attractive to informed investors (i.e. those with competitive advantages in the gathering and interpretation of information) because trading in markets where prices are poorly informed can yield abnormal returns.

Theoretical analysis undertaken whilst conducting this research produced the ancillary conclusion that returns on individual ICRE assets are generated by a 'jump' process. This conclusion is valuable because little is known about the returns-generating process in the individual ICRE context, yet knowledge of this process is useful to active investors because it serves as a basis for the formulation of models of *ex ante* returns.

The balance of this chapter describes the justification for the research and outlines the thesis structure. It begins in the next section with a definition of investment risk. The motivations for conducting research on the investment risk of assets in general is then discussed. This is followed by the presentation of a rationale for researching the risk of ICRE assets in particular, that has regard to the results of the literature review conducted in Chapter 2. In the last section, the structure of the research program is described.

1.1 The definition of investment risk

The simple return from holding any investment over time period t+1 is composed of two components: CF_{t+1}, being the net cash flow in period t+1, and $P_{t+1} - P_t$, being the difference between the market prices of the investment at the ends of periods t+1 and t.[1] Expressed as proportions of P_t, these two quantities constitute *income return* and *capital return*, respectively. Their sum is denoted by R_{t+1}.

It is frequently the case that investors are unable to forecast the return that an investment will produce over a typical portfolio revision period or *investment horizon*. It may be that the net cash flows that an investment generates in a particular time period are not fixed, or the change in market price it experiences in that time period cannot be forecasted with certainty by investors. The unpredictability of an investment's future return is termed its *investment risk*.

However, it is also the case with many investments that almost all of the risk in their *ex ante* return is attributable to the unpredictable effects of natural processes on market prices. For example, in the case of publicly traded equities, dividend yields are quite predictable in the short term. The substantial unpredictability in *ex ante* returns on equities is thus associated mainly with capital returns that are uncertain because investors cannot forecast future market prices.

It has been established in the financial economics literature (see Samuelson (1960)) that changes in the market prices of assets in an *informationally efficient* market are unpredictable because events that are relevant to assets' prices occur unpredictably through the passage of time, and these are all quickly and fully incorporated in prices. When data on the outcomes of these events are observed by economic agents, they become *information*, and thus form part of the global information set I_t. *News* is the portion of this information that gives rise to revisions in investors' expectations of the

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[1] For the time being, the market price of an asset at time t , P_t, is defined as the most likely price at which a buyer and seller would agree unconditionally at time t to trade the asset after a reasonable period of exposure in the market in which such assets are traded.

returns to holding assets. In other words, news is the 'surprise' or unpredicted component of information. The unexpected changes in the market prices of assets that are precipitated by news constitute *innovations*.[2]

This reasoning suggests that, at any particular time t, the return that an asset might produce over the period $t+1$ is a random variable that can be partitioned into two components: an expected return and an unexpected return. If it can be assumed that income returns are quite predictable, then unexpected return represents the cumulative effect of innovations that occur during the period and has an expectation conditional on I_t equal to zero. Together, expected and unexpected returns form a probability distribution conditional on I_t that constitutes an asset's *investment risk function*. This can differ from the unconditional distribution of return to the extent that the conditional distribution of returns is dependent on I_t.

1.2 The information content of prices

As used in the previous section, the term 'informationally efficient' denotes a market in which all information is immediately and accurately impounded into the prices of assets. In this ideal market, when information enters I_t, market prices adjust instantaneously and correctly. Prices are thus *fully* informed with respect to the information set I_t.

In practice, prices may be *partially* informed because a market or its supporting information structure possess imperfections. For example, the channels through which investors observe I_t may possess imperfections that give rise to delayed, incomplete or flawed transmission of information for some or all participants. Alternatively, trading

[2] Innovations are also attributable to other factors. This is discussed further in Chapter 3.

mechanisms may possess imperfections that 'corrupt' the processes by which investors formulate, place and execute trading orders. The prices of assets in such markets may, at times, be poor reflections of the information on which investors formulate their expectations of assets' returns. Both sets of imperfections serve to reduce the informedness of prices.

The discussion in the previous section suggests that the degree to which prices are informed is also determined by the completeness of the information in I_t. This is true irrespective of how efficient a market may be in its processing of the information in I_t; the degree to which prices are a full, timely and accurate reflection of the outcomes of all (relevant) events that have occurred through time t is also a function of the extent to which such events have actually been observed (and thus become part of I_t). The latter depends on the ease with which economic agents can observe the outcomes of relevant events.

Markets in which prices are partially informed may nonetheless be efficient in a practical sense (Fama (1970)). In the 'real' world, the presence of imperfections means that investors must incur a cost to observe parts of I_t. A more realistic definition of efficiency in this context provides for prices to reflect information until the marginal costs of observing information and trading exceed the marginal benefit (in terms of additional return) that investors can obtain by procuring the information.

The degree to which prices are informed is of concern to investors for several reasons. First, the informedness of prices is a key determinant of an investor's choice of portfolio strategy and analysis techniques. The two main choices of portfolio strategy are *passive* and *active*. Under a passive strategy, the forecasting of assets' returns does not play a role in investment decisions. The prices at which assets may be traded are assumed to be timely, accurate and complete reflections of all information, given the costs of such information.[3] An implication of the capital asset pricing model ('CAPM') is that passive portfolios of assets should be constructed such that investment in each asset is in proportion to the role it plays in the universe of assets or *market portfolio*.

Under an active strategy, investors aim to exploit the partial informedness of prices. They use research and analysis to forecast assets' returns, thereby creating a basis for bets to be placed on specific assets in the hope of earning abnormal returns. ('Abnormal returns' are risk-adjusted returns in excess of the market price of risk.) The investment made in each asset is a function of the confidence an investor places in their forecast, and the excess return per unit of undiversifiable risk that is associated with each asset.

It will be evident from this description of the two main strategies that investors would be well advised to select strategies consistent with their skills and information, and the efficiency of the market. A passive strategy is always appropriate for uninformed or *naïve* investors in an efficient market. However, the optimal course for naïve investors in an inefficient market is to avoid participation completely. An active strategy is appropriate for an informed investor only if they possess special information or research and analysis skills which can yield abnormal returns on a net of costs basis. Opportunities for such returns exist in efficient and inefficient markets, but the number and value of these are much smaller in an efficient market. Success at capturing these

[3] The presumption here is that the costs of information are not so great as to cause a significant proportion of the information set I_t to be excluded from investors' private information sets.

opportunities will be determined by the information and forecasting skills possessed by an investor in comparison to those of others.

It will also be evident that the informedness of an asset market's prices clearly influences the research and analysis technique(s) that a speculator might seek to apply in support of active management. This is because the informedness of prices is tied to the speed, accuracy and completeness with which new information is reflected in them. An understanding of the information content of prices in a market is therefore valuable to speculators, as it enables them to assess the value of their skills, or identify the skills they should seek to develop.

Second, the informedness of prices determines the extent to which an asset's transaction price at time t-1, or the prices at which similar assets trade at time t, can be used to infer the market price of an asset at time t. This has important implications for investors' trading decisions, and the willingness of lenders to finance equity investors' activities.

Third, the information content of prices affects the willingness of some investors to participate in asset markets. The ability to measure the performance of portfolios and have confidence in the fairness of the prices at which assets may be bought and sold are more important to some investors than others. For example, investors such as institutions with boards of trustees who face stringent prudential obligations place great emphasis on these abilities.

Fourth, the information content of prices is of indirect interest to investors because of the effect it has on the allocational efficiency of a market. Because prices serve as the basis for individuals' investment decisions, the informedness of prices affects the optimality of the allocation of funds and scarce resources to their most productive uses in an economy. Sub-optimality is to the detriment of all economic agents.

In summary, the degree to which prices in an asset market are informed is of keen interest to investor. It is mainly determined by two things: the informational structure of the market, and the degree to which I_t is a complete, accurate and timely reflection of all events relevant to the prices of assets which have occurred prior to time *t*.

1.3 The risk functions of investments

It is well established that investors, in constructing their portfolios, choose between investments with uncertain future prospects on the basis of their risk functions. Economic theory assumes that this is the case, and the tools and techniques used by investors to construct their portfolios provide explicit evidence of the role that information about assets' risks play in investment decision-making.

For many years it has been generally accepted that investors make investment decisions with the objective of maximising the expected utility of their future wealth at the end of some investment horizon.[4] The utility of future wealth rather than future wealth itself is the appropriate measure of investor satisfaction due its subjectivity. *Expected* utility is the quantity that is maximised because future utility is a random variable.

By definition, however, the future utility of an investment portfolio is a function of the return on that portfolio. This is because future utility is a function of future

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[4] See von Neumann and Morgenstern (1944). This analysis can be extended into the multi-period context but is constrained to the simple single-period case for exposition purposes.

wealth, which is itself a random variable that is a function of current wealth and an uncertain portfolio return.

The expected utility maximisation theorem thus implies that the risk functions of the assets available to investors affect portfolio construction decisions. This is because the shapes of assets' risk distributions have direct implications for the distribution of an investor's future wealth, and thus expected utility.

For utility functions to be reflective of the ways in which rational investors act, they must be specified such that 'rational' relationships exist between expected utility and the moments of the portfolio risk function. For example, expected utility should be an increasing function of expected portfolio return because rational investors' satisfaction increases with greater wealth. However, expected utility should be a decreasing function of the dispersion in returns because rational investors are assumed to be averse to uncertainty. (Given a choice between a certain future return of $*X* or a range of outcomes with an expected return of $*X*, rational investors tend to prefer the former, though the degree of preference varies due to subjectivity.)

In a world where investors comprise individuals and institutions, it is convenient to assume that the objective of both types of investor is to maximise expected end-of-period utility. Due to the fiduciary nature of their activities, managers of institutions are supposed to make investment decisions consistent with the objectives of the stakeholders for whom they are agents. It has been asserted that managers make investment decisions with their personal objectives in mind also (see Jensen and Meckling (1976)). Incorporation of managers' personal aims thus makes institutional utility functions more complicated than those of investors. However, it does not lead to rejection of the expected utility maxim as a model of investor decision objectives.

The role played by investments' risk functions in investment decisions is exemplified by the portfolio construction tools used by investors. The great majority of such tools require information on the risk distributions of available assets. The reason for this is that these tools are constructed on the basis of models of investor behaviour that assume fundamentally that investors seek to maximise expected utility. Thus, information on assets' risk distributions plays an important role in portfolio optimisation and individual asset selection.

A model of investor behaviour that underlies widely used portfolio construction tools was proposed by Markowitz (1952). Modern portfolio theory, or 'MPT' as it is commonly known, hypothesises that investors choose between assets based on the means and variances of assets' returns distributions, and the correlations between them.

Tobin (1958) shows that in order for MPT-based portfolio optimisation procedures to maximise expected utility, and thus yield economically defensible results, it must be assumed that investors possess quadratic utility functions, or assets' returns are normally distributed.

The first assumption implies that investors exhibit irrational behaviour under certain conditions. A quadratic utility function implies that expected utility may be expressed solely in terms of the means and variances of returns; higher order moments such as skewness, if they exist, are not relevant. This conflicts with rational behaviour, as it has been convincingly argued that investors would normally be expected to exhibit a preference for positive skewness, all other things being equal.[5] Furthermore, a quadratic utility function assumes that, beyond a certain level of expected return,

[5] See Scott and Horvath (1980), Kane (1982) and Francis (1975).

investors exhibit *increasing* aversion to risk as wealth increases. This is also unreasonable.[6]

Alternatively, the restriction on the form of investors' utility functions may be relaxed if it can be assumed that assets' discrete returns are normally distributed. In this case, moments of higher order than two do not exist, and investors' preferences can thus be cast in two-dimensional mean-variance space. Interestingly, though Tobin (1958) demonstrated that an assumption of normally distributed returns is critical to the validity of MPT, Markowitz (1959) assumed multivariate normality more as a matter of convenience. The computational tractability of MPT is simplified by the fact that normal distributions are stable under addition, in which case the returns on portfolios of normally distributed assets are also normally distributed.

In summary, the investment risk functions of assets play an important role in the investment decisions made by investors. Furthermore, the widespread usage of quantitative portfolio construction techniques based on MPT implies that many investors assume that assets' risk functions are described by a normal probability law.

1.4 ICRE assets in the universe of risk assets

ICRE investments are commercial properties that have been leased to tenants whose financial obligations are rated as 'investment grade'. Commercial real estate investments differ from owner-occupied properties in that occupancy rights in the former case have been conveyed to tenants in exchange for financial leases. ICRE investments are differentiated from other commercial real estate investments due to

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[6] See Francis and Archer (1979) for a concise discussion of utility functions within an MPT framework.

their ability to attract tenants with high quality credit ratings. This makes ICRE assets suitable for pension, statutory life and managed funds.

ICRE investments are similar to other risky assets in that investors cannot predict returns over typical investment horizons with certainty. Just as in the case of financial assets, the returns on ICRE assets are composed of incomes and changes in market prices. The income produced by leases over the typical investor's investment horizon is generally predictable. This is because the cash flows are generated by lease contracts, and the effects of the main factors governing incomes may be anticipated. Indeed, some researchers have been lead to draw similarities between ICRE assets and fixed income securities.[7]

In contrast, changes in the market prices of ICRE assets are difficult to forecast. Rational valuation models suggest that a property's market price should be equal to the net rents it is expected to produce in future, capitalised at an opportunity cost of capital, plus an embedded conversion option. The cyclical nature of commercial real estate markets, coupled with the inelasticity and lumpiness of the supply of space, suggests that expectations of a property's future cash flows have a propensity to change substantially in the short term. This implies that the returns on ICRE investments are risky, in large part due to unpredictable changes in prices.

Even though they are risky, ICRE investments comprise an important asset class. For example, Roulac and Eachempati (2000) report that the total value of ICRE equity in the US alone is approximately USD 600 billion. Miles et al (1994) calculated that ICRE equity constituted over 10% of the total investable universe in the mid-1990s.

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[7] See Chapter 4.

Furthermore, ICRE equity forms a significant part of institutional portfolios. Sowden (1997) asserts that 38% of all U.S. commercial real estate is owned by listed and unlisted institutions for investment purposes. Surveys conducted by McCadden and McNally (1997) suggested that institutional ownership of commercial real estate would likely grow in absolute terms and as a proportion of their total investment in all asset classes. They attributed this sentiment of future growth to a general trend toward securitisation, which facilitates institutional ownership, and a growth in institutional preference for real estate in mixed asset portfolios.

In summary, the large size of the ICRE asset class and uncertainty in future returns indicates that knowledge of the price content of ICRE assets and the distribution of ICRE investment risk must be at least as important to investors as similar knowledge in the case of other asset classes.

1.5 The information content of individual ICRE prices

It has been established earlier in this chapter that the degree to which the prices of assets are informed is a key factor affecting investors' selection of portfolio strategy.

Informal evidence suggests that investors in ICRE markets, as in other asset classes, are concerned about the information content of the prices of individual assets. Articles in industry serials and journals, public presentations by ICRE market participants and anecdotal evidence all strongly indicate that most investors believe ICRE markets are quite inefficient, and adopt active portfolio management strategies accordingly. However, these sources also indicate that some investors believe prices are sufficiently efficient to permit a passive approach to portfolio management. [8]

[8] See, for example, Hartzell, Hekman and Miles (1986), Baum and MacGregor (1992) and Hutchison and Nanthakumaran (2000).

Interestingly, a survey of the published literature in the ICRE context indicates that little is known about the information content of prices. As discussed in Chapter 2, the main reason for this is that little research has been conducted on the information content of prices, being limited in the main to tests of serial linear independence in time series of individual ICRE returns (indicating weak form efficiency). While studies of this kind draw valuable conclusions about the extent to which prices at time *t* reflect the information contained in previous prices, they offer little insight into the information content of prices overall.

It is worth noting that the small volume of research in this area is very likely attributable for the most part to the serious shortage of individual asset return data in the ICRE context. Such data is considered to be of a very commercially sensitive nature by the owners of ICRE assets, to the extent that even commercial and industry-based providers of aggregate ICRE performance indices are severely restricted in their ability to share individual property data with researchers, academic or private.

Another likely reason for the small volume of research is that the number of researchers active in the field of ICRE investment risk is comparatively small. While this may be partly attributable to the scarcity of empirical data with which to conduct research, it may also simply be due to the fact that, whereas a large number of topics remain unresearched in the ICRE context, the resources devoted to researching them are limited (in terms of people and funding).

In summary, it appears that investors in ICRE assets are concerned with the extent to which the prices of individual ICRE assets are informed, but little research has formally addressed this question.

1.6 The distribution of individual ICRE investment risk

It has also been established earlier in this chapter that investors in general have regard to the distributions of assets' risk functions when making investment decisions.

Several factors suggest that investors are concerned with the distribution of individual ICRE assets' risk functions, and assume that these possess a normal or Gaussian distribution. First, quantitative portfolio construction tools based on modern portfolio theory ('MPT') are in prevalent use in the ICRE industry internationally. Second, researchers customarily apply analysis tools to ICRE returns data which implicitly assume that returns are normally distributed. Third, the frequency with which the statistical characteristics of ICRE returns are presented within the ICRE industry in the form of means and variances also implies an assumption of normality.

The emergence of corporate and public pension plans in the U.S. and U.K. as major real estate equity investors in the 1980s (earlier in the U.K.) precipitated attempts to apply quantitative portfolio management techniques to optimise direct real estate portfolios and the role of real estate in mixed-asset portfolios. These early attempts were primarily undertaken by academics. Several of these studies, which used simple MPT-type techniques and historical data, raised issues about the number and characteristics of properties required to maximise diversification in property portfolios.[9] Over time, MPT-type optimisation techniques became widely accepted and applied in the ICRE industry internationally, facilitated by the availability of increasing long time series of aggregate property returns available from commercial providers and industry organisations.

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[9] E.g. Miles and McCue (1984b), Hartzell et al (1986), and Mueller and Ziering (1992).

In addition to the prevalent use of MPT-type portfolio construction tools, published research indicates that ICRE investors believe ICRE investment risk is normally distributed. For example, the numerous studies and reports which characterise the statistical properties of ICRE returns by reporting the means and variances of historic time series implicitly assume that investment risk is normally distributed. A similar assumption is made by studies which examine the covariance structure of sectoral real estate returns using regression models, as this is a necessary condition for the results of such models to be valid.

Though the available evidence suggests that ICRE investors are concerned with investment risk and generally assume it is described by a normal distribution, a survey of published literature indicates that the body of knowledge on ICRE investment risk is limited.

Some studies have sought to verify or refute the normality hypothesis at the individual property level. Internationally, this body of research is limited to studies by Brown (1988), King and Young (1994), Young and Graff (1995), Graff, Harrington and Young (1997) and Brown and Matysiak (2000). Again, the dearth of research in this area is likely attributable for the most part to the critical shortage of empirical data that exists in the ICRE context.

These investigations tend to agree that individual ICRE investment risk is not normally distributed, at least over time horizons consistent with those over which investors revise their portfolios. As covered in detail in Chapter II, existing research generally concludes that returns measured over period of one year or less are statistically significantly non-normal.

Just one of these studies goes on to propose and test an alternative distributional model of individual commercial real estate returns. In that study, Young and Graff (1995) seek to explain the leptokurtosis in cross-sectional samples of returns. They use arguments similar to those put forward by Fama (1965) with respect to common stocks to hypothesise that a stable probability law (of which the normal law is the only finite variance case) is the most economically defensible model of the risk of individual ICRE assets.

To test this hypothesis, Young and Graff (1995) fit stable distributions to individual valuation-based property returns underlying the National Council of Real Estate Investment Fiduciaries ('NCREIF') Classic Property Index, formerly known as the Russell-NCREIF Property Index. Their analysis indicates that the unsystematic portion of annual real estate risk is not normally distributed in most time periods, being better described by stable Paretian (i.e. non-Gaussian) distributions with a common shape parameter for which variance is undefined. A similar exercise using Australian data (Graff et al. (1997)) produces similar results.

The critical review conducted in Chapter II indicates that the research conducted by Young and Graff provides only partial grounds for accepting their hypothesis that individual ICRE investment risk is distributed according to a stable Paretian probability law. The primary reason for this is that their research, while having taken an important first step in explaining the non-normality of the distribution of ICRE risk, is somewhat limited in that its results are based mainly on empirical analysis using valuation-based returns.

In general, empirical studies undertaken for the purpose of developing models of economic activity make use of inductive reasoning. Under an inductive approach, a researcher observes the outcomes of economic processes in order to infer theories or models that are positive descriptions of reality. This contrasts with deductive reasoning, in which a researcher uses imagination and hints from the surrounding environment to create generalisations to be tested empirically (where possible) through experiment.

Deductive and inductive reasoning are complementary approaches because they are two sides of the same iterative process in which the output of experiments (e.g. economic processes) are used to formulate or revise theories that can be subjected to further experiment.[10]

Therefore, in order for research that proposes and tests distributional models to be fully defensible, it should encompass both theoretical and empirical analysis. Otherwise, in the absence of theoretical analysis, it is possible that an hypothesised model could be accepted or rejected erroneously simply on the basis of its ability to fit the data. The mainly empirical basis for research of Young and Graff calls into question the validity of their conclusions.

This discussion strongly suggests that additional research of individual ICRE investment risk is warranted in order to either verify or build on the results of research already in hand.

As an aside, it is worth noting that there is another factor which militates in favour of questioning the stable Paretian hypothesis: a conclusion that ICRE investment is described by a stable Paretian law has severe implications for the ways that ICRE portfolios should be managed, and the tools appropriate for doing so. In a world of non-normal risk, all MPT-based portfolio construction tools and equilibrium asset pricing

[10] See Feynman et al (1966) and Clapp et al (1994).

theory is inapplicable, and analytical techniques such as linear econometric models are invalidated. Furthermore, in a world of stable Paretian risk, the effectiveness of diversification is mitigated (relative to a 'normal' world) and statistical measures such as variance are undefined.

In order to address the concerns which have been raised about the validity of existing research results, it is evident that additional research should specifically seek to ascertain whether a stable Paretian probability law is indicated by analysis as being applicable to ICRE investment risk in a theoretical sense. If this does not prove to be the case, then the law(s) which arise from theoretical analysis should be tested for their empirical validity. To the extent possible, such testing should take account of the valuation basis of empirical returns.

1.7 Research methodology, data and summary of results

So far, the discussion in this chapter has indicated that, while knowledge of the information content of prices and the distribution of investment risk is valuable to investors in the ICRE context, the published research in each of these areas is quite limited. Review of this research indicates that two questions require more attention:

i. To what extent are the prices of individual ICRE assets informed?
ii. Does theoretical analysis lead to a conclusion that ICRE risk is described by a stable Paretian probability law? If not, what law does such analysis imply? Does this law provide a superior description of empirical ICRE investment risk?

The analysis which can be undertaken to answer the first question must be entirely theoretical in nature. This is due to the serious shortage of publicly available data on the performance of ICRE assets. Unlike some other asset classes, time series of individual property returns with associated descriptive information is unavailable. As noted earlier, the main reason for this is owners consider ICRE performance data to be highly commercially sensitive. Moreover, since they generally hold properties for no more than a few years, even private databases of returns are quite rare.

Theoretical analysis of the information content of ICRE prices is facilitated by the volume of relevant literature that exists in the capital markets context. This pertains to the linkage between *natural events* and the unexpected changes in prices which are effected through the information structures and trading mechanisms of markets.[11]

Capital markets literature in this area postulates that the price-generating process in the case of financial assets can be modelled as an information processing system in which inputs (i.e. information on natural events) are converted into outputs (i.e. changes in the market prices of assets). The two main components of the system are the information structure and trading mechanism of a financial asset market:

i. The information structure of a market comprises the channels through which data of a fundamental nature is transmitted to market participants.

ii. The trading mechanism enables market participants with differing expectations of assets' future returns to adjust their holdings of these assets.

Under this model, the characteristics of the information structure and trading mechanism of a market combine to determine the speed and degree with which information is translated into changes in prices. Thus, analysis of these two components can be used to yield observations about the price-generating process which can be used as a basis for drawing conclusions about the information content of prices.

In addition, other capital market literature which explores the extent to which prices reveal the private information of investors suggests that attention must also be paid to the frequency, integrity and observability of prices in the ICRE context in order to fully characterise the information content of prices overall.

[11] The term 'natural events' will be defined fully in Chapter III.

In order to address the second research question, it is again possible to make use of capital markets research to conduct analysis, this time leading to the identification of the theoretical distribution of ICRE investment risk.

A substantial volume of research has considered the distributions of returns on financial assets. Early studies, as in the case of ICRE investment risk, were primarily concerned with testing a hypothesis of normality. Subsequent studies tested other candidate distributions that arise from theoretical hypotheses about the price evolution processes.

An important conclusion of these latter studies is that the qualities of the process generating changes in the price of a financial asset have direct implications for the distributional law governing the resulting investment risk function. In essence, continuous or discrete mixtures of distributions arise as descriptions of investment risk according to whether the stochastic processes generating price changes can be characterised as being of the 'continuous' or 'jump' variety (respectively). Characterisation of a process as falling into one of these categories points clearly to an associated class of candidate distributions to describe risk.

The question that arises, of course, is how to characterise a price-generating process as being of the continuous or jump variety. The distributional literature essentially differentiates between these according to whether there is (respectively) a single information source, or multiple information sources from which bits of information emanate at differing rates. Thus, categorisation of the ICRE price process as being of one of these types requires examination and characterisation of price impetuses in the ICRE context.

Following the literature review presented in Chapter II, the capital market research which is relevant to the theoretical analysis of the information content of prices and the distribution of individual ICRE investment risk is discussed in Chapter III. As part of this discussion, it is noted that two assumptions must be made in order to make use of capital market literature to analyse the process generating prices on individual ICRE assets.

First, ICRE assets must be assumed to be *common value* goods (see Quan (1994)). Such goods have a single objective market price that is unknown to all investors prior to rounds of trading. This contrasts with *private value* goods which are desired purely for their consumption value. In the capital markets literature, financial assets are often modelled as common value goods. The main consequence of such an assumption is that heterogeneity in market participants' estimates of assets' prices are thus attributable solely to diverse information. An assumption that ICRE assets are common value goods facilitates the application of capital market literature to the study of these assets.

The second assumption that must be made is that virtually all of the uncertainty in the future returns of ICRE assets over typical investment horizons is attributable to innovations in market prices. In other words, the income returns on individual ICRE assets over an investment horizon of, say, one year are forecastable with a relatively high degree of accuracy. By implication, then, the great majority of ICRE investment risk is attributable to innovations in market prices.

The capital markets literature discussed in Chapter III suggests that the characteristics of ICRE assets, investors and the information and micro structures of

ICRE markets should be analysed in order to draw conclusions about the returns-generating process.

Thus, Chapter IV draws on generally available information as well as investment content provided by Frank Russell Company Pty, a major institutional investment consulting house, to develop an overall view of the workings of the ICRE market in Australia, the jurisdiction on which this thesis focuses. (Australia was chosen as the thesis focus because of the author's access to data, and personal familiarity.)

Chapter V then uses the insights that can be gained from capital markets research to analyse the ICRE asset class in Australia. There are two main conclusions of this analysis. First, prices of individual ICRE assets in Australia reflect partial information and are poorly informed. This conclusion arises as a result of the hidden nature of many natural events which affect prices, the poor availability of information on natural events, and the poor information revelation of price vectors in ICRE markets.

Second, price changes of ICRE assets in Australia follow a jump process. This conclusion arises as a result of the theoretical observation that major changes in ICRE asset prices are attributable to asset-specific events that occur with comparatively low frequency. Asset-specific events are occurrences which give rise to major changes in the tenancy structure and cash flows of an ICRE asset.

As one of the two main objectives of this research is to theoretically verify the stable Paretian hypothesis, the chapter further concludes that the jump process which describes ICRE returns causes the stable Paretian hypothesis to be rejected. A discrete mixture of distributions is indicated on theoretical grounds to be the more defensible class of probability laws for describing individual ICRE investment risk.

Due to the general lack of publicly available data on the returns generated by individual ICRE assets, empirical testing of any of the theoretical observations or conclusions of Chapter V is problematic. However, the author's access to the meeting notes of the Index Committee and individual returns data underlying indices produced by the Property Council of Australia ('PCA') affords an opportunity for limited empirical testing.

In Chapter VI the results are presented of an analysis of a database of explanations for 'large' individual ICRE asset returns supplied to the PCA by valuers on behalf of subscribers to the series of PCA Investment Property Indices ('IPI'). These results provide general support for the theoretical conclusion that ICRE prices follow a jump process because outlying returns in the distribution of investment risk are attributable to infrequent asset-specific events.

The analysis in Chapter VI also raises some questions about the potential bias that may exist in valuations that are conducted immediately before or after these asset-specific events.

Empirical verification that ICRE returns are generated by a jump process provides strong justification for proceeding with empirical tests of the theoretical hypothesis that ICRE investment risk is described by discrete mixture of distributions model. Thus, Chapter VII considers the range of candidate probability laws within the class of discrete mixture models, concluding that Kon's (1984) version of the discrete mixture of normals ('DMON') model is an ideal candidate for empirical testing against the stable Paretian hypothesis. Also presented in Chapter VII are the sampling theory associated with the DMON and stable Paretian laws, and empirical data consisting of cross-sections of returns on individual properties underlying the PCA IPI, the same dataset studied by Graff, Harrington and Young (1997) in their reproduction of Young and Graff (1995).

In Chapter VIII, a DMON model is tested empirically against the stable Paretian alternative proposed by Young and Graff (1995) for its ability to explain the shape of unsystematic ICRE investment risk. Empirical tests relate to unsystematic rather than total risk because the data available consists of cross-sections of returns. The data is first examined graphically and statistically to assess its general compatibility with the DMON and alternative models, then fitted DMON and stable Paretian models are compared for their goodness-of-fit.

The main result of the empirical analysis conducted in Chapter VIII is that a DMON probability model is clearly superior to a stable Paretian model in its ability to explain the shape of empirical unsystematic risk. This result lends empirical support to the theoretical arguments in favour of a DMON model developed in Chapter V.

Because the conclusions of this research both supplement and supersede those of previous research in the area of ICRE investment risk, there is a clear need to assess their implications for the management of ICRE portfolios. An appropriate course for doing this is to ascertain how DMON-distributed risk and poorly informed prices affect the investment decisions made by investors.

In Chapter IX, therefore, the conclusions of this research are summarised, and their implications for the specification of portfolio optimisation tools, the selection of portfolio management strategies and ancillary aspects of portfolio management and regulatory policy are identified. The chapter concludes by identifying areas for further research.

Chapter II LITERATURE REVIEW

As established in the previous chapter, the information content of prices and the probability distribution of individual ICRE investment risk are of interest to investors because of the important role they play in decisions concerning portfolio strategy and construction.

The purpose of this chapter is to present the results of a critical review of literature which was undertaken in order to ascertain the extent to which these issues have been addressed by researchers. The aim of this review is to identify the current body of knowledge.

2.1 The information content of ICRE prices

Within the ICRE context, very few studies have considered the information content of prices. Of the studies that have been undertaken, all are concerned with testing whether ICRE markets possess weak informational efficiency (i.e. returns are serially independent). The data sources for these studies are time series of returns at the aggregate or individual property level.

For the purpose of this review, attention has been focussed on studies of individual property returns, as studies using aggregate data offer insight only about the speed with which systematic factors are reflected in prices. The question at hand, however, is concerned with ascertaining the speed, accuracy and completeness with which all types of information (systematic or otherwise) is reflected in prices.

A review of the informational efficiency literature conducted by Gatzlaff and Tirtiroğlu (1995) mentions two studies of individual ICRE asset returns. These studies, as well as one other conducted since then, are listed in Table 1 (next page).

Table 1
Studies of the informational efficiency of individual real estate assets.

Study	Test Market (Period)	Data Source Index or Model Type	Major Findings
Gau (1984) "Weak form tests of the efficiency of real estate investment markets" *Financial Review.*	Office investments in Vancouver, B.C. (1971-1981)	Local transaction data (120 obs.). Price and return per square foot indices constructed using one transaction per month.	Insufficient statistically significant autocorrelation in returns to develop an exploitable forecasting model.
Brown (1985a) "The information content of property valuations" *Journal of Valuation.*	Retail, office and industrial properties in the U.K. (1979-1982)	Monthly time series of individual returns created using valuations and cash flows.	Rejects the hypothesis that serial correlations for all lags and holding periods are significantly non-zero.
Dokko, Edelstein, Pomer and Urdang (1991) "Determinants of the rate of return for non-residential real estate: inflation expectations and market adjustment lags" *AREUEA Journal.*	U.S. income property markets (1976-1984)	Annual returns on 102 properties in six large commingled real estate funds.	Properties within the same US state and of the same type exhibit no first order serial correlation. Unanticipated inflation appears to be incorporated quickly and fully in returns.
Brown & Matysiak (2000) "The efficiency of the property market" Chapter 13	Retail, office and industrial properties in the U.K. (1987-1997)	Monthly times series of individual returns.	Average serial correlations for individual properties do not differ significantly from zero.

All of these studies test the hypothesis that a particular market is informationally efficient with respect to an information set containing past prices. To do this, they seek to ascertain whether prices or returns are serially independent. This implies that the underlying stochastic process can be classified as a weak random walk. (A pure random walk also requires that prices or returns are identically distributed.) If a random walk hypothesis holds, then a market is informationally efficient with respect to past prices. In the taxonomy proposed by Fama (1970) on the basis of ideas contained in Roberts (1967), such markets are deemed to be *weak form* efficient.

To test for serial independence, these studies investigate the autocorrelation structure of time series of returns. Autocorrelation tests determine whether price or return at any time t is linearly dependent on price or return at time $t-i$ for $i > 0$. Only Gau (1984) is able to identify significant autocorrelation in prices and returns across various lags; the remaining three studies support the hypothesis that prices are weak form efficient.

To put the results of these studies into context, it is worth noting that autocorrelation tests can be influenced by the basis on which empirical data has been produced. For example, studies which examine returns calculated on the basis of valuations may exhibit spurious autocorrelation as a result of intertemporal aggregation of information that may occur in the valuation process.

Similarly, shortcomings in time series construction methods call into question the validity of the conclusions that can be drawn. For example, the study by Gau (1984) which uses a time series constructed on the basis of just one transaction per month may not exhibit significant autocorrelation simply because the assets underlying transactions are different in each time period. As a consequence, the resultant time series are not calculated on the basis of prices which reflect a constant bundle of asset characteristics. Prices or returns at time t will be thus be statistically independent of prices or returns in earlier time periods. However, this would in no way imply informational inefficiency.

While these studies are groundbreaking in the sense that they represent the first attempts in the ICRE context to ascertain the information content of prices, it is fair to say that they offer only partial insight in this regard. A lack of serial correlation in monthly or quarterly time series implies that new information is being impounded into prices in a timely fashion (at least within each time period). However, this result enables no conclusions to be drawn about the quality of the global information set I_t, what proportion of I_t is impounded in prices at any point in time, or the degree to which price changes are accurate reflections of new information.

2.2 The investment risk of individual ICRE assets

While the body of literature pertaining to ICRE investment risk includes studies which have examined returns at both the individual and aggregate levels, the literature review undertaken herein intentionally excludes studies of aggregate returns. The main reason for excluding such studies is that they yield observations only on the components of total risk that are systematic to all properties in particular markets, or within sub-classes partitioned according to type, economic region or geographic location.

The body of literature composed of studies of the distributions of returns on public real estate securities is also excluded from this review. It is well known that the ICRE asset class is unique in that exposure can be secured both directly and indirectly. Moreover, data on the returns produced by publicly traded securities is voluminous and readily available, and numerous empirical studies of their investment risk have been done. However, while it can be argued that these studies should be reviewed on the grounds of completeness, there are three reasons to believe that indirect ICRE returns are not reflective of those on direct assets:

i. The returns on indirect ICRE equity in many jurisdictions are affected by leverage, as publicly listed vehicles investing in ICRE assets commonly make use of debt. It is well known that leverage acts to increase the volatility and expected returns on equity, thereby corrupting the validity of indirect ICRE returns as indicators of those on direct property.

ii. The correspondence is at best loose between the prices of unleveraged ICRE equity securities and the proportionate share they represent of underlying portfolios of assets. This is because there are reasons to believe that the prices at which small lots of shares trade frequently deviate from their net asset backing per share (being equal to the total market value of an underlying portfolio divided by the number of shares outstanding).

   For example, the fractional nature and large free float of many ICRE securities, coupled with public listing, make them a relatively much more liquid form of exposure to ICRE returns. Arbitrage forces cannot be counted on, however, to ensure that security prices closely match proportionate asset backing. The transaction costs and time frames associated with trading in direct and indirect equity differ considerably.

   Furthermore, securities represent claims on pools of underlying assets bundled with management contracts, and any investor intent on acquiring sufficient shares for a controlling interest will almost certainly pay a premium for the privilege.

As a consequence, the loose connection between marginal security pricing and the value of underlying assets means that security prices will rarely equate to their 'true' prices. The factors discussed above indicate that public ICRE equity should exhibit higher volatility than its direct counterparts (at least in the short term), *ceteris paribus*.

iii. Publicly listed equity securities represent claims against pools of properties which change in composition over time.

These facts suggest that examination of time series of real estate security returns is likely to yield little information about the distribution of individual ICRE investment risk, as such returns do not measure the performance of individual assets of particular types and locations.

Also excluded from this literature review are the many studies that have reported the means and variances of historic time series of ICRE returns. Such studies do not contribute directly to the body of knowledge pertaining to the distributional characteristics of unconditional returns, as they simply report statistics that investors may find of interest in forecasting returns.

2.2.1 Studies of individual investment risk

Research which has been conducted with the express purpose of identifying the probability law(s) governing individual ICRE returns is composed of relatively few studies that have examined cross-sectional and longitudinal data. The number of published studies is small due to the general shortage of data, particularly at the individual property level. This shortage is attributable to the commercial sensitivity that owners of ICRE assets attach to individual returns data, which results in restrictions on the form in which this data is disseminated for purposes of research. In the case of the PCA, for example, returns on individual properties may be released only as randomised panel data without the benefit of descriptive information so that time series cannot be constructed for individual assets. Furthermore, this data has been available to academic researchers only since 1992. Similarly, the Investment Property Databank releases time series of individual properties' returns, though without the benefit of any identifiers.

In view of the general lack of publicly available performance data in the real estate context, it is not surprising that the number of published studies that have investigated the distributional characteristics of individual real estate returns is quite small. These studies include Brown (1988), King and Young (1994), Young and Graff (1995), Graff, Harrington and Young (1997) and Brown and Matysiak (2000).

In the course of investigating the benefits to diversification within U.K. real estate, Brown (1988) concludes that individual ICRE returns are non-normally distributed across short time periods. He analyses the distributional characteristics of continuously compounded monthly returns on 135 individual properties over the period January 1979 to December 1982. On average, the time series exhibit positive (non-normal) skewness and leptokurtosis.

A critical assumption underlying this conclusion is that returns based on monthly valuations are a good proxy for those based on unobservable market prices. The validity of this assumption in view of the difficulties associated with the production of frequent valuations is subsequently questioned by Brown and Matysiak (1997).

Based on an examination of a large dataset of individual ICRE assets in the U.S., King and Young (1994) conclude that annual returns are also non-normal. Their analysis examines time series of valuation-based returns over the period 1980-1992 on all of the unleveraged properties underlying the Russell-NCREIF Property Index and deleveraged returns on debt-financed properties owned by members of NCREIF. Sample subsets of returns grouped by property type exhibit skewness and kurtosis that are significantly non-normal at the 1% level. Interestingly, these conclusions also apply to the distributional characteristics of cross sections of returns on properties grouped by sector and calendar year.

In a groundbreaking study, Young and Graff (1995) set out to identify an alternative distributional model that better explains the leptokurtosis exhibited by histograms of ICRE returns drawn from the Russell-NCREIF database. [12] They begin with a simplified real estate market model which assumes that differences in the expected returns of individual properties are attributable entirely to differences in property type (e.g. office, retail, industrial). In other words, sectoral subindices explain all of the covariance between properties within a sector. Deviations of individual properties' returns from the cross-sectional mean within a sector and time period are thus attributable entirely to property-specific factors. The resulting model of covariance is:

$$R_t(p) = \mu_t(h(p)) + \varepsilon_t(p)$$

Equation 1

Where $R_t(p)$ is the return on property p in year t, $h(\,)$ is the property type, $\mu_t(\,)$ is the expected total return during year t as a function of property type, and the $\varepsilon_t(p)$ are assumed to be independent identically distributed random variables with zero mean, corresponding to the asset specific risk of property p during year t. Systematic and real estate market risk is captured by the function $\mu_t(h(\,))$. Each property type possesses a specific risk function that is independent across properties within and between types as well as independent of $\mu_t(h(\,))$.

[12] Young and Graff (1995) shall be hereinafter denoted by 'Y&G'.

Primarily on the basis of graphical analysis, Y&G hypothesise that asset specific risk (as defined earlier) in individual ICRE returns might be better described by a stable Paretian probability law. This hypothesis arises from their observations that the deviations in individual properties' returns about sectoral means in each year during the period 1980-1992 (inclusive) appear to possess excess kurtosis relative to the normal distribution, and stable Paretian distributions are the only fat-tailed distributions that are stable under addition.

By way of background, stable distributions have four parameters: (1) a location parameter δ, (2) a scale parameter c, (3) an index of skewness β taking on values in the interval $-1 \leq \beta \leq 1$ with positive numbers indicating skewness to the right, and (4) a shape parameter α that can take on any value in the range $0 < \alpha \leq 2$. Otherwise known as the characteristic exponent (for its role in the characteristic function of stable laws), α determines the total probability contained in the extreme tail areas of the distribution and, thus, the overall shape of the distribution.

Alternative values of α gives rise to distributions which are well known. For example, the normal or Gaussian distribution is a special finite-variance case of the stable laws when $\alpha = 2$. Such other probability laws as the Cauchy ($\alpha = 1$) and binomial ($\alpha = ½$) are also stable laws; the moments of all stable laws of order greater than α are infinite, thus all stable laws with characteristic exponent less than two possess infinite variance.

By definition, a stable distribution is any distribution that is invariant in shape under addition. Fama (1965) shows that stability means that the sums of independent, identically distributed (i.i.d.) stable variables are themselves stable with the values of the parameters α and β constant under addition.[13] Such distributions thus have strong theoretical appeal as models of price changes which are attributable to an accumulation of continuous price changes across much shorter periods. If these shorter term price changes are i.i.d. random variables possessing finite variance, then the Central Limit Theorem asserts that their limiting sum is normally distributed. Furthermore, it has been shown (see Mandelbrot (1963)) that even if these price changes are asymptotically Paretian with $0 < \alpha < 2$, but not stable, the limiting distribution will nonetheless be stable Paretian with the same value of α.[14]

Using tabulated parameter estimation techniques prepared by McCulloch (1986), Y&G find that they are unable to reject the hypothesis that all properties regardless of type or time period possess a common specific risk function that is best described by a stable Paretian model with a characteristic exponent of approximately 1.5. Their data also provides clear evidence of heteroscedasticity while exhibiting a smooth decline in skewness (β) from +1 to -1 during the period 1980-1992 inclusive. A repetition of the stable parameter estimation exercise using Australian data appears to support the results of the U.S. study, producing a characteristic exponent less than two (1.58), heteroscedasticity and time-varying skewness (Graff et al (1997)).

A conclusion that risk is described by stable infinite variance probability laws has consequences for the effectiveness of diversification (relative to the normal or finite variance case) and the specification of portfolio management tools and techniques. As

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[13] In addition, Fama (1965) shows that β need not be constant, as the skewness parameter of a sum of stable variables is a complex weighted sum of the individual β of each variable.

[14] A random variable is asymptotically Paretian when the tails of its probability density function follow an asymptotic form of the law of Pareto in terms of the way they decrease as the distance from the peak of the density function increases.

shown by Fama (1965), as the departure from normality increases, so does the proportion of total dispersion that cannot be diversified away (*ceteris paribus*). Furthermore, because statistics such as variance and Pearson's coefficient of correlation are infinite or undefined in an infinite variance context, the generally accepted specification of MPT in terms of these variables is inappropriate in a context of stable Paretian returns.

Y&G assert that their findings have two main implications. First, versions of MPT commonly used in stock market analysis should not be applied without modification in the real estate environment. While it is possible to re-specify MPT in terms of the parameter c as a measure of the scale of returns, there is no equivalent for Pearson's correlation in an infinite variance environment (see Fama and Miller (1972)). Second, equally weighted property portfolios of a size equivalent to that underlying the NCREIF Classic Property Index are required to reduce specific risk to proportions readily achievable in the stock and bond markets.

The severity of the practical and theoretical implications of a stable Paretian model of risk for portfolio construction and management suggests that rigorous analysis should be undertaken prior to adopting it as a model of real estate specific risk. However, review of Y&G indicates several areas where their analysis is not as rigorous as it could be.

By far the most important shortcoming of the analysis undertaken by Y&G is their lack of consideration of the ICRE returns-generating process as a basis for their stable Paretian hypothesis. To arrive at this hypothesis, Y&G simply note that the empirical distribution of ICRE specific risk is fat-tailed, and stable Paretian distributional laws are the sole known class of distributions which possess fat-tails and are infinitely divisible. However, for the infinite divisibility characteristic of stable Paretian laws to be supportive of their adoption as a distributional model of ICRE risk, it must be assumed that the returns-generating process is continuous. Unfortunately, Y&G do not provide any arguments in favour of such an assumption. Their conclusion that ICRE risk is described by a stable Paretian law thus rests solely on its superior ability to fit empirical data (relative to a normal law).

It is possible that Y&G's inconsideration of the returns-generating process in the course of proposing a stable Paretian law of ICRE investment risk may be attributable to an incomplete review of the capital markets literature pertaining to distributional models of returns. A very wide range of alternatives have been shown in the financial markets literature to be able to explain leptokurtosis in returns distributions. Some of these are finite-variance models that fit empirical distributions at least as well as stable Paretian alternatives but with the benefit of far better developed sampling theory. A key point also made by this literature is that classes of distributional models are implied by alternative models of the returns-generating process, and there are alternative models for explaining fat-tailed empirical data. However, much of this literature was published after 1983, the year through which Y&G's literature review extends.

An example of the incompatibility of a stable Paretian law with the ICRE returns-generating process that arises in Y&G is the conflict between the stability characteristic of such distributions and the variable degree of non-normality exhibited by ICRE returns in other studies. A characteristic of stability is that the shape parameter α should not vary with the length of the return measurement period. However, the reduction in non-normality associated with lengthening the measurement period, as shown by Brown (1988) and Myer and Webb (1994b), is inconsistent with a stable Paretian returns-generating process unless α is time varying. This conflicts with Y&G's conclusion that α is time invariant.

Y&G appear to ignore the ICRE returns-generating process elsewhere in their research, as evidenced by their inability to satisfactorily explain the substantial time variation in the scale and skewness of empirical returns. Curiously, Y&G attribute negative skewness in the cross section of empirical returns to the fixed income component of the return produced by ICRE assets, and positive skewness to the enactment of tax legislation favourable to real estate. As both of these factors would be expected to affect all properties fairly similarly, it is difficult to comprehend how they would give rise to skewness in the distribution of *unsystematic* risk.

Graff and Webb (1997) hypothesise that cross sections of individual real estate returns possess fat tails due to biases present in the valuation-based returns on some fraction of all properties of a particular type. Graff and Webb assert that such biases arise as a result of valuers having excessive regard to the prices at which properties have transacted, which themselves are biased due to the presence of agency costs.

The validity of this hypothesis is highly questionable for several reasons. First, it is constructed entirely on the basis of conjecture and anecdotal evidence. Second, in order for it to hold, quite restrictive assumptions must be made about the behaviour of investors and their agents. Finally, contradicting the growing body of research pertaining to the correspondence between valuations and prices, it suggests that valuations are irrationally biased estimates of market prices.

The most recent study to have explored the distributional characteristics of ICRE returns, and how these characteristics vary with the length of the return measurement period, is Brown and Matysiak (2000). The empirical basis for this study consists of two valuation-based datasets: time series of monthly returns on 100 individual properties across three sectors in the Investment Property Databank (‘IPD’) over the period December 1987 to November 1997, and annual returns on 250 individual properties in each sector in the IPD over the period 1987-1996. The main finding of this study is that the probability that individual property returns are drawn from a normal distribution increases as the return measurement period lengthens.

While the findings of this study tend to reinforce those of earlier, similar studies of time series of returns, they are subject to two main criticisms. First, as pointed out by the authors, there is reason to believe that valuers have difficulty detecting changes in the prices of ICRE assets across short periods, e.g. monthly. It will thus be the case that returns will tend toward normality as measurement periods are lengthened even though returns across short periods are non-normal (but drawn from a finite variance distribution). This is a consequence of the effects of the Central Limit Theorem.

Second, reliance on the Bera-Jarque statistic to test the hypothesis that sample time series are drawings from a normal population may be inappropriate in the context of this study. As noted by Bera and Jarque (1981), their test for the normality of a sample of observations is constructed on an assumption that the sample is from a distribution that is a member of the Pearson family. Furthermore, the efficiency of the Bera-Jarque statistic is limited for small sample sizes. As Bera and Jarque show by example for sample sizes of 20 observations, the Shapiro-Wilk statistic is superior to the Bera Jarque statistic for testing normality.

These two criticisms call into question the validity of Brown and Matysiak’s main finding because it is based on ten year samples of annual returns. However, the weight of these criticisms is mitigated by the large number of samples used by these authors in their study.

2.3 Summary and conclusions

The literature review presented in this chapter shows that few studies have investigated the information content of individual ICRE asset prices, with all of these being concerned with testing whether markets are informationally efficient with respect to historic prices.

While the few studies which have been conducted support the hypothesis that ICRE market are efficient with respect to past prices, this conclusion sheds only partial light on the information content of prices. A conclusion that ICRE markets are weak form efficient suggests that new information is incorporated in prices as it appears. As noted in Chapter 1, however, the intention of the current research is to ascertain the extent to which prices are accurate and complete (as well as timely) reflections of the information set I_t, and to which I_t contains timely, accurate and complete data on all natural events which have occurred through time t.

This literature review also shows few studies have investigated the distribution of individual ICRE investment risk, with most being concerned with testing for normality. This is likely attributable to the acute shortage of data for the use of researchers in the ICRE context.

The results of these studies tend to support the hypothesis that individual ICRE investment risk is not normally distributed, though the degree of normality tends to increase as the returns measurement period increases. However, the latter may arise simply as a result of the decline in sample size that results from increasing the length of the return measurement period.

Furthermore, just one study has sought to explain non-normality. Young and Graff (1995) conclude that ICRE risk is described by a stable Paretian law with a shape parameter α that does not vary over time.

All of the research that has investigated the distribution of ICRE risk suffers the shortcoming that it is primarily empirical in nature. This is a shortcoming because the results of such research are not as defensible as they could be were they also supported by rigorous theoretical analysis.

Thus, while the research of Young and Graff is groundbreaking in its proposition of an alternative stable Paretian model of ICRE investment risk and the testing of this model using individual ICRE returns, the fact that it does not develop a theoretical rationale for proposing a stable Paretian model over other candidate models call the validity of its results into question.

Furthermore, the motivation to question the validity of the stable Paretian model is heightened by the severity of the implications of such a model for the strategy and construction techniques that should be pursued or applied in the management of ICRE portfolios.

In conclusion, there appears to be a strong case for conducting further research into the information content of prices and the distribution of individual ICRE investment risk, with the specific aim in the latter case of confirming the theoretical defensibility of the stable Paretian hypothesis or identifying an alternative model that is defensible in both theoretical and empirical terms (and thus applicable to true ICRE investment risk).

Chapter III THEORETICAL RESEARCH METHODOLOGY

The discussion presented in Chapter I indicated that knowledge of the information content of prices and the distribution of investment risk is valuable to investors in the ICRE context. However, review of published research conducted in Chapter II indicates that the body of knowledge in both of these areas is quite limited. In tandem, Chapters I and II suggest that two questions require further research attention:

i. To what extent are the prices of individual ICRE assets informed?

ii. Does theoretical analysis lead to a conclusion that ICRE risk is described by a stable Paretian probability law? If not, what law does such analysis imply? Does this law provide a superior description of empirical ICRE investment risk?

The purpose of this chapter is to identify and present methodologies for conducting the research required to address these questions.

3.1 Capital markets research

A natural starting point for developing methodologies with which to address these research questions is the research that has considered similar issues in the capital markets context. The volume of this research is large because a great deal of attention has been devoted to assessing the information content of the prices of financial assets, and postulating distributional laws which describe the investment risk functions of these assets. Thus, capital markets research has the potential to form a rich source of analytical insights in these areas.

In order to apply capital markets research in the ICRE context, it must be assumed that ICRE assets are similar to financial assets in that they are common value goods (see Quan and Quigley (1991) and Quan (1994)). This assumption is necessary because the economic validity of applying capital markets research to the ICRE asset class is contingent on there being a commonality in the economic natures of financial and ICRE assets.

3.1.1 ICRE assets: Common or private value goods?

As outlined by Quan (1994), the main differences between private and common value goods derive from the nature of the good and the motives for ownership. Private value goods are desired purely for their consumption value, such that differences between individuals' estimates of worth arise due to varying tastes. Investors' valuations are known only to themselves and are independent. Resale is not a motive for owning private value goods.

In contrast, a common value good has a common objective value that is determined by the equilibration of aggregate demand and supply for the good at any point in time. Differences in the valuations of the good by potential buyers and sellers are due to diverse information. Private valuations are not influenced by differences in tastes, and future resale is a motive for owning common value goods.

There is reason to believe that ICRE assets may be classified as common value goods. By definition, ICRE is a category of property assets for which the rights to service flows have been separated from ownership through leases. As a result, the market prices of investment properties are determined by capitalised lease payments. Potential bidders' estimate of properties' prices differ because of their diverse private information about the quantum and uncertainty of future cash flow streams. Furthermore, an important motive for owning ICRE investments is the possibility of future resale.

Though it is a feature of ICRE assets that their future net cash flows are influenced to some extent by its management, this does not violate their classification as a common value asset. Because physical real estate is a non-passive investment, it is possible for landlords or professional managers to develop competitive advantages in management based on geographic knowledge, property type, or scale of operation. This does not suggest that there is a subjective element to its value. This does imply, however, that the market price of an ICRE asset varies to some extent according to its management. This situation is no different from the case of any other capital asset that is used in the production of a good or service. The market price of any productive asset is determined by the highest and best use to which it can be put.

While some authors have asserted that a link exists between the prices of ICRE assets and the prices of owner-occupied commercial real estate assets, it can be argued that this link is generally tenuous. Fully or partially leased commercial buildings are not substitutes in the eyes of potential owner-occupiers unless it is possible for them to secure vacant possession at the time they are needed. By definition, however, the properties in institutional portfolios tend to be fully or mostly leased because their owners are strongly motivated to keep them that way.

It is therefore assumed for the purpose of this study that marginal pricing is determined by activity in the ICRE investment market, and that ICRE assets are common value goods.

3.2 The information content of prices

As noted in Chapter I, the first of the two research questions stated at the beginning of this chapter can be expressed in more specific terms as follows: to what extent are the prices of individual ICRE assets at time *t* a timely, accurate and full reflection of all elements of I_t, the set of all information which is relevant to prices and exists at time *t*.

In order to develop a research methodology for answering this question, it is first necessary to define the terms 'relevant' and 'information'.

To define the term 'relevant', it is necessary to refer to a theory of the manner in which investors form opinions of assets' prices. Of the several theories which have been put forward, one has clearly ascended to a level of acceptance within the capital markets literature that is far above the rest. This theory is the *rational expectations hypothesis*, which predicts that price opinions are formed on the basis of expectations concerning the future pay-outs of assets, including their resale value to third parties. Under this theory, any information that affects investors' expectations of assets' future pay-outs is relevant.

What is meant by the term 'information'? Groth (1979) defines information as data which is relevant to the pricing of assets. Damodaran (1985) asserts that the outcomes of *natural events* constitute relevant data. He defines natural events as being "events, decisions or occurrences that change the true value" of an asset. Though Damodaran does not explain what he means by the term 'true value', it is assumed for the purpose of this research that an asset's true value is its market value at time t, conditional on the global information set I_t.

Given these definitions, it thus appears to be the case that, in order to assess the extent to which individual ICRE prices are informed at any time t, it is necessary to analyse the efficiency and effectiveness of the process through which data on natural events (being those events which affect investors' expectations of assets' future pay-outs) is reflected in the prices of those assets.

In an ideal world, this analysis would have theoretical and empirical components. Unfortunately, this is not possible in the ICRE context. Due to the shortage of publicly available data on the performance of ICRE assets, empirical analysis cannot be undertaken. In contrast to other asset classes, time series of individual property returns with associated descriptive information are not in the public domain. Furthermore, even it were possible to obtain private data, the vast majority covers limited time periods.

In order to proceed with a theoretical analysis, it is necessary to have a model of the price-generating process in hand. A basic model presented in the capital markets context that has been widely cited in subsequent research was presented by Groth (1979). The graphic depiction of this model which originally appeared as Exhibit 1 in Groth (op. cit.) is shown on the next page as Figure 1.

Figure 1

In this model, the price-generating process is described as a signal processing system in which natural events affect prices through an information market and a price mechanism. The process operates as follows:

- Natural events occur with the passage of time.
- When data on the outcome of a natural event is observed by an economic agent, it becomes information, thereby becoming part of the global information set I_t.
- The content of I_t is transmitted to receivers (i.e. investors) through the information market.
- Investors use their private information sets, which are by definition subsets of I_t, to formulate trades for placement and execution through the price mechanism.

Analysis of this basic model of the price-generation process and review of the research which has investigated its components in the capital markets context suggest that four aspects of the ICRE price process must be analysed (once the natural events relevant to asset pricing are identified) to assess the information content of prices:

i. *The observation of natural events by economic agents.*

   The characteristics of the process by which economic agents observe the outcomes of natural events (and thus create information) determine the extent to which I_t is a timely, accurate and complete reflection of the natural events which have occurred up to time *t*.

ii. *The structure through which economic agents transmit information to investors.*

   Damodaran (1985) observes that the characteristics of the information structure through which the contents of I_t are transmitted to investors can have a substantial effect on the quality of investors' private information sets. The main concerns here are the frequency, accuracy and completeness of the disclosures by economic agents who first observe natural events, and the characteristics of the channels through which information is transmitted to investors.

iii. *Investors' evaluation of the information in their private information sets.*

   Research on the micro-structure of markets shows that the manner in which investors review and evaluate their private information sets for the purpose of making trading decisions directly affects the adjustment of prices to new information. For example, Goldman and Sosin (1975) and Beja and Hakansson (1977) both note that an assumption that investors review their information sets continuously is unrealistic. Thus, a gap in time likely exists between the receipt of information and its analysis.

iv. *The mechanism through which orders are placed and executed.*

The market micro-structure literature also asserts that the attributes of the mechanism through which investors who wish to trade can place and execute their orders also directly affect the adjustment of prices to new information. For example, various authors have asserted that frictions in the trading mechanism (such as transaction costs or limitations on market access) give rise to delays in the adjustment of prices.

Around the same time as the appearance of the information processing model of Groth (1979), other researchers proposed the existence of another element in the price-generating process. This element is the 'feedback loop' which enables data on the prices at which assets transact to enter investors' private information sets (see Grossman (1976), Grossman and Stiglitz (1976) and Strong and Walker (1987)).

In essence, the ability of all investors to observe the vector of prices at which assets trade works to mitigate the effects of any asymmetries that may exist in the fundamental information sets of individual investors. Asymmetries may come about because some investors' private information may be better reflections of I_t than others'. By observing prices, less informed investors can infer the private information of better informed investors, and revise their expectations accordingly. This suggests that one more aspect of the price-generating process in the ICRE context must be examined in order to assess the information content of prices:

v. *The ability of transaction prices to reveal traders' private information to the market.*

Several characteristics of the price vector at time *t* determine the information-revelation powers of prices: the size of the vector, its observability by investors, and the integrity of the price data itself (i.e. its age and noise content). The ability to infer fundamental information from prices also depends on the availability of asset-specific data.

To analyse these five aspects of the price-generating process in the ICRE context, the analysis proceeds in two parts. In Chapter IV, the ICRE asset class and natural events are characterised in a factual sense, while having regard to the five questions which have been identified in this section. This factual characterisation is then analysed in Chapter V in order to produce observations about the price-generating process which can serve as the basis for a conclusion to be drawn about the theoretical information content of ICRE prices.

3.3 *The distribution of ICRE investment risk*

As noted earlier in this chapter, the large existing body of knowledge on the distribution of investment risk in the case of financial assets offers a potentially very useful basis for (a) ascertaining whether a stable Paretian probability law provides a theoretically defensible description of the investment risk of ICRE assets, and (b) identifying a preferred alternative if this is not the case.

The economic validity of applying this knowledge in the ICRE context is contingent on two assumptions. One of these, that ICRE assets are similar in economic nature to financial assets in that they are both common value goods, has already been established.

A second assumption that must be made is that virtually all of the uncertainty in *ex ante* returns on ICRE assets over investors' typical investment horizons is attributable to innovations in prices. There are two reasons for this assumption. First, it simplifies the analysis by permitting attention to be limited to the capital component of return. Second, it is consistent with a similar assumption which has been made in research which has explored the distribution of investment risk in the context of financial assets.

3.3.1 *Uncertainty: Innovations in market prices*

To establish a basis for assuming that all of the *ex ante* uncertainty in ICRE returns is attributable to the capital component of return, it is appropriate to begin with a definition of the term ‘return’. Due to the potential for ICRE assets to generate multiple cash flows over a holding period, investment return is commonly measured by investors through the use of internal rate of return (‘IRR’). In order to avoid the problems associated with the need to use iterative techniques to solve for an investment’s IRR, a Taylor series expansion can be used to develop a closed-form expression that approximates the true IRR quite accurately (see Giliberto (1994)).

As the main body of empirical data that will be used later in this research consists of returns on individual properties underlying the indices produced by the Property Council of Australia (‘PCA’), reference is made to the IRR approximation equation used by PCA to calculate return:

$$R_t = \frac{(MV_t - MV_{t-1}) - CI_t + PS_t + CF_t}{MV_{t-1} + 0.5(CI_t - PS_t) - 0.5CF_t}$$

Equation 2

where:	R_t	=	Return during period *t*
	MV_t	=	Market value at end of period *t*
	CI_t	=	Capital improvements during period *t*
	CF_t	=	Net income received during period *t*
	PS_t	=	Partial sales income received during period *t*

This expression, which is similar in form to that currently used in the calculation of the NCREIF Classic Property Index, implicitly assumes that *all* cash flows occur at the mid-point of the holding period, e.g. all capital expenditures, partial sales and net income cash flows occur in lump sums at the end of the sixth month in any given one year holding period.

It is evident from Equation 2 that the uncertainty surrounding forecasts of R_t over some investment horizon is a function of the accuracy with which investors are able to forecast the amounts and timing of partial sales and capital expenditures, holding period net cash flows, and the market price at the end of the holding period.

There are good arguments to suggest that partial sales and capital expenditures play a small part in the uncertainty of forecast return. Anecdotal evidence and the notes of the Property Index Committee of the PCA indicate that partial sales are a rare occurrence. Furthermore, according to the Property Council of Australia (2000), capital expenditure as a proportion of capital value has remained fairly constant for all major asset classes since PCA began gathering data. The planning required for capital expenditure suggests that it is known with a fair degree of certainty months in advance of its actual occurrence.

In relative terms, it is arguable that uncertainty surrounding CF_t has far less of an effect on the uncertainty in forecast returns than uncertainty surrounding MV_t, particularly for investment horizons of one year or less. This is true because periodic cash flows are far more predictable than future market prices in this time frame. Since operating expenses are generally borne by tenants and are highly predictable in any case, variation in net cash flows is largely driven by changes in revenues. All or most of the revenue streams of all major property types are fixed in advance under leases, subject to rent reviews, lease renewals and terminations, and new leases. Since the occurrence of many of these lease events are generally forecastable months in advance, uncertainty in forecasting net holding period cash flows arises only to the extent that there is uncertainty as to the outcomes of these events. Given the information available about existing leases at time t–1, the uncertain holding period return due to uncertainty in forecasts of CF_t is small for forecast periods of approximately one year.

Empirical support for the assertion that income returns are highly predictable is provided by the low dispersion of income returns on individual properties in the database underlying the Investment Performance Indices produced by the PCA, as well as on properties elsewhere. For example, in the PCA database, the vast majority of income returns in any particular year fall within a range which is no wider than approximately 300 basis points. In addition, King and Young (1994) show that the distribution of income returns for all types of property over the period 1978-1992 had standard deviations of no more than 4.4%. The fact that unconditional income returns exhibit low dispersion suggests that conditional income returns are predictable.

Moreover, it is likely that market prices are much more uncertain than net cash flows because there are many more sources of uncertainty relevant to future market prices, in relative terms. This is because rational expectations theory suggests that MV_t is related to investors' required rates of return and beliefs about net cash flows and market prices subsequent to time t. The information contained in leases at time t–1 is likely to be of far less value for predicting MV_t than for predicting CF_t.

These arguments combine to support an assumption that the uncertainty in forecast returns on ICRE assets is primarily associated with innovations in market prices.

3.3.2 Distributional models and the price process

A review of distributional research in the capital markets context indicates that numerous probability laws have been proposed to describe the unconditional distributions of financial assets' investment risk. (Appendix A contains a summary of this review, as well as analysis supporting the discussion presented in this section.)

All of these laws arise as solutions to one of the differential equations which describe the two main types of stochastic processes that have been proposed to describe the evolution of prices over time. These two types are *continuous* and *jump* processes.

Under a continuous process, prices are assumed to evolve continuously over time (either physical time, or a "local" time scale measured for example in terms of the volume or number of transactions). Incremental price changes (either absolute or relative) over very short periods of the time scale in question are assumed to possess a continuous distribution. When the flow of time is not measured in physical time units, it is assumed that the price process in local time is *directed* by another continuously distributed random variable which relates the 'price change dimension' to physical time. In the latter case, the evolution of prices in physical time is thus said to follow a *subordinated* stochastic process.

Under a jump process, it is assumed that prices are driven by a combination of a continuous process (as above, measured in physical time) and a discrete but random number of continuously distributed price impetuses, or 'jumps'. The price path of a jump process can thus exhibit discontinuities, with the number of discontinuities in any period being a function of the frequency with which jumps occur.

Depending on whether a price process is of the continuous or jump variety, the probability laws which arise as descriptions of unconditional returns can be partitioned into one of two main categories: *continuous* and *discrete* mixture models.

i. A continuous mixture model of unconditional risk arises as a result of conditioning continuously-distributed price changes on another continuous random variable.

ii. A discrete mixture model of unconditional risk arises as a result of conditioning continuously-distributed price change on another discrete random variable.

Continuous and jump processes are essentially differentiated by the number of distinct 'information distributions' that exist as sources of price impetuses.

Under a continuous process, it is essentially assumed that all prices impetuses are continuous drawings from a single continuously-distributed information distribution, e.g. a normal or stable Paretian distribution.

The subordinated stochastic process is an embellished version of the continuous process which alternatively assumes that information arrives continuously across "local" time periods measured by the number or volume of trades. Researchers have proposed several distributions for the relationship between local and physical time (e.g. stable Paretian, lognormal and inverted Gamma) taking their cue from empirical distributions of the number or volume of transactions per unit time, or other measures of activity. The unconditional distributions which arise as a result of researchers' assumptions about the directing and directed processes include the stable Paretian, the Student's *t* and the lognormal-normal.

Under a jump process, it is assumed that price impetuses are produced by more than one information distribution, and that at least one of these produces potentially large continuously-distributed impetuses (relative to other information distributions) at discrete points in time. In the basic case (see Press (1967)), a single information distribution described by a normal probability law produces price impetuses continuously over time, while another information distribution also described by a normal law produces a discrete number of more important price impetuses in any given time period, as determined by a probability law such as the Poisson or Bernoulli. These assumptions result in unconditional distributions which are *n*-component mixtures of normals with parameters that may be linearly related.

In describing his rationale for assuming that stock prices follow a jump process, Merton (1976) highlights how it differs from a continuous process:

> (1) The 'normal' vibrations in price, for examples, (are) due to a temporary imbalance between supply and demand, changes in capitalisation, changes in the economic outlook, or other new information that causes marginal changes in the stock's value. This component is modelled by a standard geometric Brownian motion with a constant variance per unit time and it has a continuous sample path. In general, any continuous diffusion process would work equally well.
>
> (2) The 'abnormal' vibrations in price are due to the arrival of important new information about the stock that has more than a marginal effect on price. Typically such information will be specific to the firm or possibly its industry although occasionally general economic information could be the source. It is assumed that this important information arrives only at discrete points in time, and it is reasonable to expect that (*ex post*) there will be 'active' periods for the stock when such information arrives and 'quiet' periods when it does not although (*ex ante*) the 'active' and 'quiet' periods are random. This component is modelled by a 'jump' process with an inherently non-continuous sample path reflecting the non-marginal impact of information. The prototype for the jump component is a 'Poisson-driven' process.

In view of the objective of this research and the great differences that are well known to exist between the characteristics of the information structures and trading markets in the financial and ICRE asset contexts, this discussion suggests that a test of the theoretical defensibility of the stable Paretian model of individual ICRE investment risk can be conducted by simply ascertaining whether prices evolve according to a continuous or jump process. This would point to one of the two categories of unconditional risk models as being more theoretically defensible in the ICRE context.

If the ICRE price-generation process is classified as continuous, then the stable Paretian hypothesis is supported by theoretical analysis and no further investigation is required. Otherwise, if the process is classified as having jump properties, then a discrete mixture model can be selected from the range that has been proposed in the capital markets context for empirical testing. This selection would be based on the underlying assumptions and availability of sampling theory in each case.

3.3.3 The ICRE price process: Continuous or jump?

The discussion in the previous section indicates that the ICRE price-generation process would be classified as a jump process if it is possible to identify an information distribution which produces price impetuses with a low frequency but large potential effects on prices (relative to other information distributions).

The question arises as to what is meant by the term ‘low’? In the case of annual time periods, if it can be assumed that drawings from the information distribution are governed by a Poisson or similar law, then an average drawing frequency of no more than about three events per year would classify the distribution as a jump process. At any greater frequency, the effect of the Central Limit Theorem will be such that any single drawing from the distribution would no longer appear to give rise to an “abnormal vibration in price” in the year in which it occurs.

In order to identify whether an information source exists in the ICRE context with ‘jump’ characteristics, analysis should proceed with the following questions:

i. Can the natural events which are relevant to ICRE prices be grouped and identified as sources of information?

   An ability to group important natural events due to homogeneity across an economic dimension suggests that they could belong to a single information distribution.

ii. Of the groups of events, which has the greatest potential to affect prices?

   Because a jump process is associated with “abnormal vibrations” in prices, attention should be focussed on identifying the events which are of potentially greatest import.

iii. Do the events in this ‘important’ group tend to occur with a low frequency?

A final criterion for a group of potentially important natural events to be classified as an information distribution giving rise to jumps is a low frequency of occurrence.

These three questions can be posed in Chapter V in tandem with the analysis that will be undertaken for the purpose of establishing the information content of prices.

Chapter IV THE ANATOMY OF THE ICRE MARKET

4.1 Introduction

As discussed in the previous chapter, theoretical conclusions about the information content of prices and the distribution of investment risk in the ICRE context can be drawn from analysis of the price generating process. It is proposed to conduct this analysis in two stages. In this chapter, the system through which natural events give rise to innovations in the market prices of ICRE assets is characterised. This characterisation serves as the basis for analysis which is conducted in the next chapter with the aim of producing observations about the price generating process. From these observations, conclusions about the informedness of prices and the distribution of investment risk may be drawn.

In this chapter, characterisation of the price-generating process in the ICRE context is undertaken in two steps:

i. Identification of the natural events relevant to the market's pricing of assets.
ii. Description of the elements of the price-generating system.

In step (i), which is covered in Sections 4.2 and 4.3, the focus of attention is on identifying the inputs to the ICRE price-generating system. To do this, the ICRE asset class is first described. Then the factors or 'state variables' which are known to affect investors' opinions of the prices are identified. The natural events which are relevant to prices are thus those which give rise to changes in these state variables.

In step (ii), which is covered in Section 4.4, attention focuses on the information structure of the ICRE market, the decision-making processes of investors, and the mechanism within which trading is effected. These are the elements of the price-generating system which the discussion in Chapter III suggested should be scrutinised in order to draw conclusions about the information content of prices and the distribution of investment risk.

Much of the factual data presented in this chapter on the decision-making processes of investors is derived from a manager information database maintained by Frank Russell Company PTY Ltd (‘Russell’). This database contains information on the investment management processes of the four largest managers (the ‘Managers’) of ICRE assets in Australia. As at June 2000, these managers (denoted by the letters ‘A’ through ‘D’ for the purpose of confidentiality) had total ICRE assets under management of AUD30.6bn, which comprised approximately 67% (by value) of the properties tracked by the PCA Australian Composite Property Index, and 56% by value of the estimated stock of ICRE assets in Australia (as estimated by the PCA Institutional Weighting Survey, December 1999).

The information contained in Russell’s manager database was obtained by the author through interviews and written questionnaires. Interviews were conducted between June and October 2000 in Sydney, Australia with the Heads of Wholesale Investment, Portfolio Manager(s) and Research Managers or their equivalents in each firm. Written submissions were prepared by these firms in response to a Manager Review Questionnaire formulated on the basis of questionnaires normally supplied by Russell analysts to managers of other asset classes.

Though the Russell manager information database on ICRE investment managers was not created to serve as a basis for scholarly research, it is worth referencing for the purpose of describing the decision-making processes of investors in Australia. The database forms a rich and valuable source of information that is unique in the Australian market. It is arguable that no other investment consulting firm has a database of similar quality and breadth. Furthermore, because the contents of the database are highly proprietary, the author's access is privileged. It is thus worth exploiting this database in order to enhance the description presented in this chapter of investors' decision-making processes.

As an aside, it is worth noting that two factors motivate managers to provide information to Russell. First, managers are motivated to provide extensive detail on their procedures, human resources and management skills because they are aware of the considerable influence that Russell has on the investment decisions of its clients. Managers know that their information will be used to assess their capabilities as managers of ICRE assets. [15] Second, managers provide this information on the express understanding that Russell will strictly protect its confidentiality.

4.2 The ICRE asset class

Graaskamp (1976) describes buildings as physical structures that provide occupants with space through time. Land and buildings provide storage and shelter for the plant, equipment, labourers, inventories and customers of enterprises engaged in the production, distribution and consumption of goods and services. The attributes of buildings that occupiers find of interest are their physical configuration and geographic location because these determine the kinds of activities that can be conducted within it.[16] These attributes include the quality, appearance, condition, age, type of plant, or environmental status of a particular building, the regulations governing its use, and its

[15] Frank Russell Company recognises that managers may exhibit a bias in the information they make available for the purpose of their assessment. Interviews and questionnaires are structured in order to validate the information provided by firms, and this is cross-checked where possible.

[16] A useful synthesis that draws on several different theories of asset pricing appears in Miles et al (1990).

proximity to infrastructure, the sources and uses of other goods and services (e.g. other buildings), and labour.

An important implication of this premise is that no two buildings can offer identical bundles of attributes if for no other reason than it is impossible for two objects to occupy the same space. This suggests that, while it may be convenient to be able to class buildings as being of a particular type (e.g. office, retail or industrial), buildings within a type class can nonetheless be quite heterogeneous in terms of their specific physical and locational attributes.

Though it has been assumed for the purpose of this analysis that ICRE assets are common value goods, their characteristics stand in stark contrast to those of financial assets. One of the most important of these is the heterogeneity of ICRE assets. As discussed above, all properties differ because no two can occupy the same space, and they are physically immobile.

ICRE assets are also lumpy, and of relatively large value. They are lumpy because the equity interests in ICRE assets are generally not fractionalised. Amongst institutional investors in Australia, it is very rare for ownership of individual properties to be divided across more than two parties because of the difficulties this poses for achieving a consensus with respect to management strategy. Furthermore, the ownership interests in ICRE assets are large in value compared to the minimum lot sizes prevalent in portfolios of financial securities. The average value of the smallest individual assets in the Managers' portfolios as at June 2000 was approximately AUD10m.

Another key characteristic of ICRE assets is that their ownership carries a burden of management. In other words, ownership of ICRE assets is a commercial enterprise. It is well known that the cash flows generated by ICRE assets, and thus their values, are directly related to the quality of management. The Managers tend to differentiate between three levels of management: the portfolio, the asset, and the physical facility. Responsibility for major decisions is retained at the portfolio level, whereas such things as lease and rent review negotiations, and capital expenditure decisions are delegated to asset managers. Physical managers deal with the day-to-day requirements of tenants and buildings.

As is to be expected, in the business of owning and operating ICRE assets, it is possible to develop competitive advantages. For example, amongst the Managers there are quite large differences of opinion as to whether the physical management of their assets should be out-sourced or kept in-house. Manager C out-sources all physical management because it is not a core competence, and the awarding of management contracts acts as an inducement to broker-managers to present their investment opportunities preferentially. In contrast, Manager A runs all physical management in-house because of a belief that this is a key means of adding value. The firm believes keeping management in-house affords greater control, aligns the interests of ownership and management, and reduces 'information leakage'.

4.3 Natural events relevant to the pricing of ICRE assets

Assuming that rational expectations theory applies equally to the market's pricing of ICRE assets, it is possible to make use of the present value model in Equation 3 to identify the factors relevant to the pricing of ICRE assets. In this model, present value is a function of expected future cash flows and opportunity costs of capital, with these expectations being conditional on the global information set I_t.

$$PV_t \big| I_t = \sum_{j=0}^{\infty} \frac{CF_j}{\left(1 + r_j\right)^j}$$

Equation 3

where:	PV_t	=	the present value at time t of all future cash flows
	CF_j	=	expected net cash flow in period j
	r_j	=	opportunity cost of capital across time period of maturity j

In the case of ICRE assets, value derives from the leases under which tenants occupy space. Leases delineate the spaces that tenants may occupy while specifying the rights, obligations and term of those occupancies and the consideration that must be paid. In most cases, leases are created by customising a standard form of agreement. Rents normally comprise a combination of a lump sum at the outset of a lease, and fixed periodic payments that may be subject to adjustment. As a debt-like form of financing, real estate leases rank as secured indebtedness of tenants.

Rental revenues are offset by the cash outflows associated with operating expenses and capital expenditure. Depending on the terms and conditions of leases, landlords may bear operating expenses that are not reimbursed by tenants. To the extent they are borne by the landlord, variations in operating costs affect the net cash flows to owners. Furthermore, it is usually the case that the capital expenditure associated with maintaining the physical integrity of a building, plant and equipment, and other improvements are obligations of ownership.

The net cash flows produced by a property over time are therefore similar to those of a portfolio of fixed and variable income securities of which the principals are recaptured and reinvested at maturity, or on the default of the borrower.[17] Because

[17] See Lusht (1988), Gyourko and Linneman (1990), Geltner (1990) and Graff (1992).

most properties have economic lives that are longer than the maturity of the leases which encumber them (i.e. they are operating leases), owners possess forward rights to re-lease space when leases terminate. However, re-leasing is sometimes delayed due to unavoidable vacancy periods between leases, and intentional vacancies for the purposes of renovation or conversion.

An important element of the value of an ICRE asset that is not captured by a present value model is the continuous option to increase an asset's value by changing its use. Due to its physical nature, property tends to be useable in several ways. The use to which a property is actually put by tenants will be a function of the characteristics of their requirements, the regulations imposed by authorities, and a property's physical characteristics. Over time, these factors can change, and the highest and best use to which a property can be put may change as a consequence. The option that landlords possess to modify a property's physical form or its permitted uses has value.[18]

This discussion suggests that the market price of an ICRE asset is equal to the sum of the present values of (a) leases in place, (b) operating expenses and capital expenditure, (c) new leases in the future, and (d) a continuous option to convert or rehabilitate.

In Appendix B, a discussion of these four components is undertaken in order to identify the factors which have an effect on the market's pricing of an ICRE asset, and the natural events which would give rise to changes in rational investors' expectations concerning the values of these factors over the economic life of a particular property (and beyond). In Table 2 below, examples of the natural events that could affect the future status of each factor are summarised.

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[18] See Titman (1985) and Williams (1991), (1997).

Table 2
Pricing Factors and their Associated Natural Events

Pricing Factor	Example Natural Events
i. The property's tenancy structure, i.e. terms and conditions of existing leases.	Deeds of amendment agreed between landlord and tenant; a court decision that leads to an interpretation of a lease clause that is different from that originally intended, new leases, and lease terminations.
ii. The scale and composition of commercial activity in general, and tenants' businesses in particular.	The development of a new production technology, a shift in consumer preferences or tastes, the creation of a new product, a change in the level or burden of taxes, new competition, or acquisition and divestment activity.
iii. The efficiency of tenants' general utilisation of space.	The development of a new information, communication or production technology, a change in work practices, the creation of new building construction techniques or design concepts.
iv. The property's physical and locational characteristics.	The development of a highway interchange, the discovery of a structural geotechnical fault, an upgrade in a building's 'telecommunications backbone', the installation of sewage treatment capacity or new electricity generation capacity, or the discovery of oil reserves.
v. The stock of substitute space, and the terms and conditions of encumbering leases.	Changes in planning regulations, tenant defaults and new lease executions, the commencement of a new economic development programme, or the granting of approvals to a development company for a new project.
vi. Regulations governing the use of the property and its substitutes.	New laws and building codes, an election or appointment of new planning authority staff, a shift in public opinion, or the discovery of an environmental problem.
vii. The economic demography of the region in which the property is situated.	The discovery of natural resources, the expansion of a major employer, a change in taxation policy, a shift in weather patterns or the installation of new transportation capacity (e.g. highway, mass transit routes and hubs).
viii. Spot rates of return on riskless investments.	A shift in future inflation expectations, a change in current real rates of return, a shift in economic productivity (e.g. due to a technological change), changes in fiscal or tax policy, or a change in the regime by which a central bank adjust inter-bank lending rates.
ix. The risk premia demanded by investors in ICRE assets.	A collective shift in the risk aversion or liquidity preference of investors, or the term structure of returns available on alternative investments.
x. The costs of operating properties.	Changes in the character of tenants' businesses, tax regimes, weather patterns, the characteristics of a building's physical fabric and plant, and the required level of maintenance.
xi. The capital expenditure associated with repairs and upgrades.	A revision of the standard form of lease, discovery of a geological fault, an improvement in HVAC technology or a decision to perform a higher level of preventative maintenance.
xii. The operational efficiency of leasing markets.	A change in the leasing market mechanism, or the technology which supports this.

Table 2 (cont'd)
Pricing Factors and their Associated Natural Events

Pricing Factor	Example Natural Events
xiii. The credit ratings of tenants.	Increases in consumer spending, changes in consumers' tastes, a shift in firms' productivity or wage rates, or any event that affects the physical supply of raw materials or the quality of a firm's management.
xiv. The time profile of market rents associated with alternative uses.	Examples of the natural events which can give rise to changes in expectations concerning these factors have already been discussed.
xv. The hard and soft costs of development (e.g. construction, approvals).	Shifts in the prices of raw materials and labour, the appearance of new building technologies and codes, shifts in tenants' tastes and requirements, and alterations to planning procedures.
xvi. Transaction costs associated with lease originations and terminations.	The imposition or modification of stamp duty, a change in the form of standard lease documentation, and new legislation governing the environmental or maintenance obligations of landlords and tenants.

4.4 Elements of the price-generating system

In this section, attention focuses on the three main elements of the price-generating system: the information structure of the ICRE market, the decision-making processes of investors and the mechanism through which trading between investors is conducted.

4.4.1 The information structure of ICRE markets

The degree to which the global information set I_t reflects the outcomes of natural events is a critical factor in the link between natural events and the market prices of ICRE assets. Since it is necessary for an economic agent to observe the outcome of a natural event in order for it to become information a characterisation of this element of the price generating process must be concerned with the observability of natural events. One specific interest thus lies in identifying the parties that first observe natural events, and the means with which they do so.

Given a global information set I_t that is available in theory to all investors, the degree to which the information sets of individual investors coincide with each other and I_t determines the degree to which prices are informed. A characterisation of this element of the price-generating system must be concerned with the disclosure of information by economic agents who first observe natural events, and the transmission of this information to investors. A second specific interest of this section thus lies in answering the following questions: What is the propensity of the economic agents who first observe natural events to disclose their information truthfully to the market? What are the characteristics of the information diffusion channels? What roles do intermediaries play?

In this section, attention is restricted to the natural events that are relevant to investors' forecasting of properties' net cash flows; the information structure as it pertains to the events which affect investors' required rates of return is ignored. The main reason for this is that analysis of the observability of the natural events which affect discount rates is unwarranted. The term structure of interest rates, as well as all of the equilibrium risk premia on factors not related to real estate, are observable in other capital markets easily and accurately. These fully incorporate the market's expectations about future spot rates and risk premia based on the relevant natural events which have occurred to date. There is thus no need for ICRE investors to concern themselves with observing directly the natural events which underlie these expectations.

Furthermore, to the extent that there is a separate priced real estate risk factor, it is not unreasonable to assume that the expected risk premium associated with this factor is fairly time invariant, or the sensitivities of individual properties to this factor are fairly homogeneous.[19]

An idiosyncrasy of the information structure of ICRE markets is that it exists in three main components. The first component, discussed in Part A (below), involves the information about individual ICRE assets that is customarily available to investors outside the negotiations in which the trading of assets occurs. The second component, discussed in Part B, involves the information flows that occur as a specific part of trading negotiations. Part C discusses the role of information intermediaries.

A. Observing the flow of natural events

As presented earlier, a wide range of natural events have the potential to affect investors' expectations concerning the cash flows that a property will produce in future. They do this by affecting investors' forecasts of the factors that determine the cash flows a property might produce in future. The observability of the natural events which affect these factors (excluding factors (viii) and (ix) which affect discount rate expectations) is discussed in general detail in Appendix C and summarised in Table 3 (next page).

[19] Sirmans (1997) postulates similarly that discount rates for institutional grade real estate are not localised.

Table 3 – Pricing Factors and the Characteristics of their Associated Natural Events

Pricing Factor	Events First Observed by:	Integrity of Observation	Disclosure Characteristics
i. The property's tenancy structure, i.e. terms and conditions of existing leases.	Parties to leases and their professional advisors.	Complete, accurate details observed in a timely fashion.	Specific details do not generally become public record.
ii. The scale and composition of commercial activity in general, and tenants' businesses in particular.	Individuals within firms.	Complete, accurate details observed in a timely fashion.	Only data at a general level reported in public statements of accounts.
iii. The efficiency of tenants' general utilisation of space.	Parties who develop systems by which firms conduct business.	Because of their role, parties observe complete accurate details.	Full details enter public domain quickly and accurately.
iv. The property's physical and locational characteristics.	Tenants, landlords and their agents.	Generally high, but some events observed with a substantial lag.	Information generally private; parties face no obligations to disclose.
v. The stock of substitute space, and the terms and conditions of encumbering leases.	Tenants, landlords and their agents.	See other entries.	See other entries.
vi. Regulations governing the use of the property and its substitutes.	Public officials.	Complete, accurate details observed in a timely fashion.	A significant time lag can exist between decisions and public disclosure.
vii. The economic demography of the region in which the property is situated.	Individuals within firms, public authorities, the public.	Varies considerably, but generally high (subject to lags).	Also varies considerably, from complete non-disclosure to non-issue.
x. The costs of operating properties. *xi. The capital expenditure associated with repairs and upgrades.*	Landlords and tenants.	Complete and timely observation due to procuring role of parties in relevant natural events.	Information transmitted primarily via data intermediaries.
xii. The operational efficiency of leasing markets.	All ICRE market participants.	Details observable fully/quickly.	Full dissemination occurs quickly.
xiii. The credit ratings of tenants.	Tenants and competing businesses.	Quickly/fully by tenants themselves.	Third party information disclosure poor.
xiv. The time profile of market rents associated with alternative uses.	See *i*, *v* and *vi*.	See other entries.	See other entries.
xv. The hard and soft costs of development (e.g. construction, approvals).	Public authorities and/or ICRE market participants.	Details observable fully/quickly.	Commercial pressures and disclosure obligations ensure quick dissemination.
xvi. Transaction costs associated with lease originations and terminations.	ICRE market participants (though landlords may have an advantage).	Details observable fully/quickly.	Poor disclosure due to private nature of information.

In addition to direct observation, an indirect means available to market participants to observe the outcomes of the natural events which affect the time profile of a property's market rent is observation of the details of new lease contracts and rent reviews. The prices at which new leases and rent reviews are agreed reflect the views of a single landlord and tenant pair of the market rents they expect to prevail over an upcoming rent review period. If it can be presumed that these prices were agreed on the basis of analysis by both parties of the information available to them, then it may be concluded that these same prices are indirect signals of more fundamental information.

Observation of these prices by third parties is difficult. Leases and rent reviews are negotiated and effected privately, and (as noted earlier) there is generally no obligation to disclose full details of these transactions to the public.

B. Information flows during trading

As noted earlier, an idiosyncrasy of the ICRE asset class is the flow of information that occurs between owners and potential purchasers about the assets that are the subject of negotiation. It is evident that owners and non-owners possess asymmetric information on the outcomes of natural events that affect assets. In order for trading negotiations to proceed in ICRE markets, owners must therefore supply asset-specific information to potential purchasers. This is necessary in order to enable bidders to form their initial estimates of prices.

In this environment, owners face an issue of moral hazard. Because potential bidders must rely on information provided by an owner, motivations exist for owners to falsify or omit elements of the information they make available to bidders.

To mitigate the risks of misinterpretation or misinformation (intentional or otherwise), use is made in ICRE markets of conditional purchase agreements. Real estate purchase and sale agreements are, in essence, call option contracts. These afford purchasers a period of time after a contract is signed to perform a ‘due diligence’ investigation prior to declaring the contract unconditional. The terms and conditions of contracts generally provide purchasers the right to renegotiate or abandon a purchase and sale agreement on specific grounds.

While due diligence investigations can be as exhaustive as a purchaser is prepared to undertake, there may be limitations on what a seller is prepared to permit. For example, in order to maintain the confidentiality of a prospective sale, an owner may prevent a purchaser from communicating directly with tenants. Tenants may also be unwilling to provide a purchaser with the information needed to verify or assess their credit strength. A contract purchaser may therefore be unable to verify all owner-supplied information through a due diligence process.

It is worth noting that due diligence processes frequently uncover issues or deficiencies that an owner did not disclose, or of which an owner was not aware. Examples include environmental contamination, hidden liens and other legal encumbrances, and shortcomings in the quality of plant and equipment.

C. Information intermediaries

The high proportion of private information on natural events in ICRE markets gives rise to opportunities for third parties to engage in the business of information intermediation. These parties develop a competitive advantage in information gathering and interpretation, or capitalise on information to which they gain access through other commercial activities. As in other countries, the main parties which engage in information intermediation in Australia are real estate agents that are active in leasing and trading markets, and valuers.

Real estate agents are able to engage in the role of information intermediation due to the access they have to information gained through participation in leasing and transaction markets. Leasing agents gain access to two sets of information: the full details of transactions which they facilitate, and the characteristics of the supply and demand for space in the markets in which they operate. Similarly, investment brokers also gain access to two sets of information: the full details of deals which they facilitate (which will be considered later), and the characteristics of vacant and improved assets which they (or other agents) have offered for sale, or about which they have consulted to a potential purchaser. To some extent, both of these agents gain access to the same sorts of information held by competitors through informal information sharing arrangements.

As previously noted, there may be some restrictions on the information pertaining to completed leases that agents are able to share with third parties. It is not uncommon for the parties to leases in Australia to impose obligations of confidentiality on the agents involved due to the commercial sensitivity of a transaction. For example, it is in an owner's interest to limit the availability of information on leases to which he/she is a party, as this puts other current and potential tenants of the same owner at an information disadvantage in rental negotiations. The same applies for tenants who occupy leased premises in multiple properties, as information on the rent they are paying at one location can be used against them in rent negotiations on others.

There are two main ways in which agents package and sell their information. One way is by bundling it together with the agency services they provide to customers and clients. This information is used by the parties to potential sale or lease transactions to estimate the market prices of assets or rents of premises, or set their reservation prices. Agents are compensated for the information delivered in this way by a consulting fee or commission.

The second way that agents sell their information is by packaging it as a free-standing product. Many real estate agents in Australia, as elsewhere, are multi-disciplinary firms that have separate research divisions. These divisions combine internally-sourced information with additional data procured by active market research into products that are provided on either a subscription or one-off basis to clients. Onward distribution of such products is prohibited.

In contrast to agents, the main competitive advantage possessed by valuers lies in their information gathering and interpretation skills. Valuers obtain information in three ways. First, they are able to make use of the information to which they become privy through participation in lease and rent review negotiations. This source is somewhat limited to the extent that confidentiality restrictions are imposed on valuers by the parties to these negotiations. Second, valuers have informal networks with other valuers and owners of ICRE assets through which information on new leases and rent review outcomes is shared. Third, some valuers are able to draw on the information to which they have internal access because they form part of a larger organisation that is also engaged in leasing agency activities.

Valuers sell their information, with or without the benefit of analysis, to parties engaged in lease and rent review negotiations.[20] The primary way in which this is done is by means of a consulting arrangement in which the valuer provides a written report and/or acts as an advocate for one of the parties to a negotiation. Recipients of the

[20] Another service area is the estimation of the market prices of assets. This is considered further in a subsequent section concerned with price information in ICRE transaction markets.

information provided by a valuer are typically prohibited from onward distribution. Furthermore, while valuers are keenly interested in capturing information on the outcomes of negotiations in which they are involved (as well as the information provided by other parties), such opportunities to add to the proprietary database are frequently frustrated by the confidentiality restrictions imposed on, or by the parties.

In contrast to the information activities undertaken by agents, those performed by valuers are covered by a body of regulations which set quality standards and impose an ethical code of practice. The quality standards to which registered valuers must adhere require them to act diligently and defensibly in order to ensure that the information with which they work is accurate and complete, and the analysis procedures they apply are consistent with industry standards. The code of practice further requires that valuers act independently and professionally in order to ensure that the products of their efforts do not exhibit a bias toward the interests of one party over another, and the confidentiality requirements of clients and data suppliers are protected.

Interestingly, most of the valuation firms used by large investors in Australia are divisions of the real estate consultancies listed earlier as the main sources of agency data.

In closing this section, it is worth noting that, while valuers and real estate agents are the main actors in the business of information intermediation in Australian ICRE markets, other parties engage in the collection and interpretation of data on the outcomes of natural events relevant to ICRE asset prices. These include BIS Shrapnel for property sector reports, PCA for market reports and shopping centre directories (in addition to indices), the Australian Bureau of Statistics, CPM Research for its Commercial Property Sales & Leasing Monitor, and Cityscope.

4.4.2 The decision-making of institutional investors

While the ownership of ICRE assets in Australia is spread across a range of parties in terms of numbers and types, managerial control is concentrated. Owners of ICRE assets include corporate and public superannuation plans, insurance companies, retail (listed) property trusts, wholesale property trusts, charitable organisations and syndicates. While some of these parties manage their own ICRE assets, many employ a professional manager. In some cases this is by design, as in the case where a firm is a promoter and manager of retail (listed) and wholesale property vehicles. In other cases, management is effected by means of a separate account relationship in which a manager takes over control of an owner's discrete portfolio.

The fees charged by managers for services have at most two components. In all cases, a component of the fee is tied to the value of assets under management. For example, in the case of Managers C and D, the fees associated with some of their management contracts have a performance-related component tied to the growth in portfolio value experienced over the life of a fund. No account is taken of the risk of the portfolio in calculating performance-based fees.

Investors also pursue differing portfolio strategies. For example, Manager C takes the view that ICRE markets are inefficient and that good stock selection is able to add value over the benchmark. In contrast, Managers A and B both take the view that their wholesale pools provide diversified exposure to the ICRE sector, though Manager B also believes that value can be added through active trading, within the constraints imposed by the Australian tax rules' asymmetric treatment of capital gains to passive and active management. Manager A strongly believes that it is the large scale and diversification of its wholesale product that make it attractive to investors.

By necessity, managers tend to manage similarly the assets in separate accounts and captive pools. For example, all of the Managers prepare budgets and forecasts for each property formally once a year, subject to quarterly or half-yearly review. While in-house research departments contribute to the planning process in all cases, the quantity and quality of resources in these departments vary considerably. For example, while each firm has several experienced and qualified members of staff undertaking ICRE research, Manager B's team is particularly large, but the Manager C team takes the most sophisticated approach. In all of the Managers, the process of formulating and updating plans for individual properties is jointly undertaken by the portfolio manager, asset manager and research staff. Portfolio managers are viewed as "champions" of their portfolios and thus possess a considerable degree of authority over acquisition and disposal decisions.

As part of the regular planning cycle, professional managers measure the *ex post* performance of the portfolios they manage against a benchmark index, and regularly assess the desirability of continuing to hold individual assets. These activities require valuations which are generally sourced externally at least once a year with a proportion of the portfolio being valued every quarter or half-year, supplemented by more frequent internal valuations. The 'desirability assessment' typically entails a ranking of the total returns that individual assets have produced, as well as a comparison of the total returns they are expected to produce over a forecast period with hurdle or threshold rates set for properties according to their type. Discounted cash flow ('DCF') techniques are used by all firms for this purpose. The performance benchmark is invariably a version of the PCA Australian Property Composite Index, customised to take account of non-standard geographic or sector weightings.

All of the Managers rely to some extent on real estate agencies for investment opportunities and three of them have separate in-house teams of varying sizes that manage acquisitions and disposals, and seek out opportunities to buy or sell investments without the use of an agent. However, most transactions are brought about at the instigation of an agent, and are initiated by an owner placing an asset "on the market." Interestingly, all four Managers profess that they generally receive "first look" at investment opportunities presented by the brokerage community, though it is likely that these statements relate to individual brokerage firms.

Because all of the Managers act on behalf of several owners including, in some cases, themselves, all have mechanisms in place to resolve conflicts that arise as a result of competition for new investments or tenants. When leasing opportunities arise for which more than one property is suitable, or purchase opportunities arise that are consistent with the objectives and cash resources of more than one portfolio, formal procedures are followed to resolve conflicts. In all cases, an investment committee decides which asset or portfolio manager should receive priority to negotiate. Though a decision to joint venture a purchase is possible in any of the four firms, this is usually a last resort.

4.4.3 The ICRE market trading mechanism

In Australia (as in most Western economies), the market in which ICRE assets are traded is not centralised, such that trading tends to be conducted by private pairwise negotiation. This is explained partly by the regional nature of leasing markets, institutional inertia, and the lack of facilitating technology historically. Auctions in which one or more assets are offered for sale through closed or open bidding are a secondary form of trading.

An important aspect of the non-centralised nature of ICRE markets is the significant role played by intermediaries in the operation of ICRE markets in Australia. This is to be expected: the high fixed costs of search in non-centralised markets give rise to economies of scale, thereby creating opportunities for third parties, i.e. real estate agents, to facilitate trades.

In order to create a picture of the manner in which the ICRE investment market in Australia operates, it is instructive to examine how a stylised 'sell order' is processed. For this purpose, it is initially assumed that all parties are motivated by the prospect of speculative gain. The seller is not in need of cash, and buyers are not pursuing assets in order to complete their exposure to the ICRE asset class.

Assume that an owner has decided to offer an ICRE asset for sale. This decision is based on a belief that a speculative opportunity exists to dispose of the asset at a price which is in excess of its market valuation. The asset's market valuation is the price at which it would be expected to exchange if the market possessed knowledge of the objective distribution of the asset's future returns (being its income and future market price) conditional on I_t and the property management skills available. The decision must take account of the high direct and indirect costs of disposal, the effort that must be expended to replace the asset with another that is (at least) fairly priced, the abnormal return being produced by the worst performing asset in the seller's portfolio, and the value being added by seller management.

In addition to these items, the spread between the market valuation and potential sale price must also be large enough to account for the substantial noise that exists in the seller's estimates of these quantities. The noise in a seller's valuation arises primarily due to the general shortage of fundamental information. The analysis conducted in the previous section showed that a substantial portion of the information in the global set I_t is private, or otherwise difficult to observe. As will be shown in the next section, the seller's estimate of the asset's transaction price will possess noise depending on the size of the price vector, the infrequency with which the asset itself has traded, and the non-observability of the bid/ask prices in contemporaneous transactions and in the order books of agents facilitating transactions in the market.

In order to instruct an agent to sell the asset, the owner must establish a reservation price and an asking price. The reservation price is the lowest possible price at which the seller could sell and still ensure that an excess return is being earned. The spread between a seller's reservation price and market valuation of the asset under his management is a function of the factors identified in the previous two paragraphs. The asking price is set at a point above the estimated transaction price based on observation of the level of activity in the trading market and the advice of the agent. The setting of an asking price is a strategic issue that is tied to the perception that is to be created in the minds of potential buyers as to the willingness of the seller to negotiate. The offering package must be structured in such a way as to generate interest from potential purchasers.

Once an offering package is prepared, it is submitted by the agent to potential buyers in his/her order book with the aim of precipitating physical inspections, preliminary due diligence studies and offers to purchase from as many parties as possible.

An agent's order book contains formal and informal orders to buy and sell assets. Agents have informal orders in their books because potential buyers and sellers who are otherwise disinterested in buying and selling assets at market prices are nonetheless interested in trading at prices which they believe are below or above market (respectively). By regularly canvassing potential buyers and sellers, agents accumulate a book of informal limit orders that generally pertain to specific assets on one side, and non-specific assets on the other.

Depending on the responses received from potential buyers and the characteristics of the fee arrangement between the owner and agent, the offering package may be circulated to other agents or advertised publicly. To communicate orders, print advertising is the primary medium. However, applications of the Internet have begun to filter into Australian markets for ICRE assets, as evidenced by the recent announcement of a decision by the four largest agency firms to post the assets they are marketing on a communal web page.

Alternatively, the asking price of the asset may be adjusted downward (and the offering package recirculated to potential purchasers in the agent's order book), or the asset may be taken off the market.

It is frequently the case that the number of potential buyers that might be prepared to consider the acquisition of an ICRE asset in Australia is small. There are several reasons for this. First, the ICRE market in Australia is not populated with a large number of investors because large sums of money are required to invest in property directly. Second, due to the localised nature of markets, an information barrier stands in the way of 'cross-border' trading. The highly irrecoverable nature of the costs that 'external' purchasers must incur to consider an acquisition increases their selectivity in terms of the trades they will consider.

Another reason is that it is quite possible in this scenario for some parties with an interest in trading to be excluded from considering the asset. In non-centralised markets such as ICRE, multiple negotiations are conducted simultaneously. Because ICRE markets lack a formal mechanism for announcing the opening of a round of trading on a particular property, not all potentially interested parties will be aware of the negotiations that are being held at any point in time. Some potential buyers will therefore be excluded from each negotiating group.

The number and types of responses of potential purchasers to the sale proposal will be a function of their willingness and capacity to consider the asset for acquisition, the outcome of their own analysis of the difference between their market valuation (i.e. their estimate of the asset's market price under their management and conditional on I_t), and the price at which they believe it may be acquired. For those parties who undertake an analysis and find that this difference is sufficiently positive (i.e. the anticipated purchase price is lower than their reservation price), it may be appropriate to initiate negotiations. In this way, potential purchasers become market participants through a process of self-selection.

It is worth noting, however, that potential purchasers' market valuations will be rendered on the basis of fundamental information sets that are different from, and smaller than that of the seller. Furthermore, their estimates of the price at which the asset may be acquired will be a function of the seller's asking price, their impression of the seller's negotiability, their evaluation of the vector of contemporaneous prices on similar assets, and the bid/ask information they are able to glean from other negotiations on similar assets in which they are involved. However, there are physical limitations on the number of negotiations in which any single buyer can participate.

The process from this stage depends on the number of potential purchasers that seek to initiate negotiations. If none wish to do so, then the seller must revisit the disposal decision or the offering terms. If one party comes forward, then the seller will likely engage in negotiations in the hope that another potential purchaser will come along (real or fictional) and thereby create competition between bidders.

If several parties initiate negotiations, the situation has the potential to become complicated for the seller. The reason for this is that it is likely that these negotiations will commence at different times, proceed at different rates, and thereby produce a range of possible scenarios. For example, a stage may be reached where all potential purchasers have submitted their top bid, but none of these are above the seller's reservation price. Alternatively, one purchaser's top bid may exceed the reservation price and carry an explicit or implicit time limit for response, even though negotiations are proceeding with other purchasers. In yet another scenario, multiple purchasers may produce offers in excess of the reservation price, and the seller may find him/herself in the situation of having to manage a private pairwise auction.

This stylised example of the manner in which a sell order is processed in the ICRE market in Australia places into context a number of observations about this market that differentiate it substantially from, for example, public equity markets.

A. Transaction price dispersion

The price at which an asset transacts has the potential to fall anywhere between the reservation prices of the seller and the potential purchaser who places the highest reservation price on the asset (the presumption being that the latter must be greater than the former for a trade to occur). The precise point at which the asset transacts will be a function of many things, including the number of potential purchasers with reservation prices in excess of the seller's, the effectiveness of the marketing programme, the motivations, decision systems and negotiating skills of the seller and potential purchasers, and the composition of the set of assets on which negotiations are proceeding contemporaneously.

B. Transaction costs

Brokerage fees are comparatively high in ICRE markets. One reason is the contingency basis of fees. The complexity of the negotiation and contracting processes and the frequency with which negotiations end in failure mean that many assignments are fruitless efforts. Another reason is the high fixed cost of operating as an agent. The time and expenditure involved in maintaining information databases, both technology-based or otherwise, are substantial.

A third reason lies in the difficulty that agents can experience in establishing a claim for a brokerage fee. It is frequently the case that the party from whom a commission is due enjoys substantial market or financial strength, and may attempt to capitalise on that strength by negotiating the amount of a commission even after the associated transaction has completed. It is therefore imperative for an agent to secure a commitment from one of the parties to pay a commission prior to introducing the parties in order to establish a formal claim to a fee. [21]

A fourth reason is credit risk in the commission receivables due agents. The collection of fees from one or both of the parties to a transaction can be difficult. For example, a seller can be suffering financial distress and the proceeds from a sale may be earmarked for another party with a prior charge over the asset that has been sold.

[21] In the case of formal instructions, agents establish the commission fee at the time of taking the instruction. When seeking the co-operation of other agents, a commission sharing arrangement is typically advertised, though this is negotiable.

High brokerage fees contribute to the high total costs of trading that are a consequence of the non-centralised nature of ICRE markets in Australia. The combination of high brokerage costs, the costs of the due diligence process that must be undertaken and the stamp duties that must be paid on certain transactions result in high direct trading costs. It is estimated that these total approximately 5.5% of the price of an asset, not including the indirect costs arising from the lost opportunity in terms of the time invested by the parties who negotiate trades.

It is interesting to note that the presence of high total costs of trading in ICRE markets offers an explanation for the persistence of non-centralised trading in a modern world where technology that clearly facilitates centralisation is available cheaply. High contingency-based commissions motivate intermediaries and consultants to adopt protectionist policies. Furthermore, in this environment, some agents are much better than others, and the financial rewards are commensurate.

C. Non-standardised contracts

The predominance of private pairwise trading also has several important consequences for the characteristics of trading in ICRE markets. As has been discussed earlier, purchase and sale agreements in Australia, as elsewhere, are contingent contracts that afford the purchaser an opportunity to verify and supplement through physical inspection the information supplied by a seller. Purchasers also undertake some of the more costly aspects of the due diligence process during the conditional period rather than incur the expense beforehand, when the risk of an abortive outcome is greater.

In contrast to the contracts used to trade financial securities, purchase and sale agreements in ICRE markets are highly idiosyncratic. Trades are typically contracted through the use of the industry standard agreement that has been customised to embody changes to the standard terms, and additional terms and conditions of the sale. It is not uncommon for contracts to be supplemented by side agreements or deeds with related parties. It is also not uncommon for the ownership of ICRE assets to be transferred by selling the shares in a shell company whose sole asset is a single ICRE asset.

Together, the idiosyncratic and contingent elements of purchase and sale agreements lead to long transaction times in ICRE markets. As noted earlier, because a great deal of the information that is pertinent to buyers' valuations of ICRE assets is privately held by the seller, conditional contracts are usually required. The heterogeneity of the terms and conditions of individual transactions precipitates additional negotiation time. As a consequence, typical transaction times (i.e. the time period that transpires between execution and settlement of trades) in ICRE markets are measured in weeks, or months.

D. Unobservable negotiations

Another important consequence of private pairwise trading in ICRE markets is the asymmetric abilities of negotiating parties to observe the bidding activity of other negotiating pairs. In general, a pair of negotiating parties is unable to observe the negotiations of another pair, even if the same agent is the facilitator in each case. However, a seller that is negotiating with multiple potential buyers has an informational advantage because he/she can observe the activities of multiple negotiating pairs, and has an opportunity to exploit that advantage.

E. Poor transaction price observability

A similar and particularly important consequence of private pairwise trading in ICRE markets is that observation of details on trading outcomes is difficult. This is because the full details of trades (i.e. prices, terms and conditions of sales) are not reported into the public domain. Transacting parties are required to report only prices and sales dates to the Department of Land and Property Information. However, reported data may be distorted by the omission of side agreements and inconsistencies in the classification of component assets (e.g. chattels).

There are three main ways in which the details of transaction can make their way into the public domain. First, basic information on completed transactions 'leaks' via word of mouth, principally emanating from the professionals involved (e.g. lawyers, agents and property consultants). This information varies widely in terms of its quality, and generally reaches a small clientele over a period of days.

Second, the transacting parties themselves may issue releases to the press or wire services. Newspapers such as The Australian, Financial Review, Sydney Morning Herald and Australian Property Review report details of transactions, though the detail they report is frequently inaccurate (though timely) because of the informality of the source. In the case of listed property trusts, the level of detail and accuracy is greater due to the disclosure obligations they face as part of their listing agreement with the Australian Stock Exchange.

Third, as in the case of leasing markets, information on transactions is available from commercial intermediaries which are primarily agents and valuers. Their information is obtained through the roles they play in negotiations, or proactive research on transactions which come to their attention. The latter involves the use of informal networks with owners and other professionals, frequently on an 'information sharing' basis.

While the information available from intermediaries is usually the most detailed, it is generally the least timely. This is consistent with what would be expected in a world where transacting parties tend to view the specific terms and conditions of sales as being commercially sensitive. The concern of institutional buyers and sellers, of which they are relatively few, is that this information can be used against them in other negotiations. Thus, the longer the time period since a sale, the greater the level of detail they are prepared to share with others.

Intermediaries deliver transaction data to consumers in two main forms. Valuers prepare summary sheets which are available to their clients within about one month of sales. They also refer to transactions in detail in valuation reports prepared for clients on specific assets. Real estate agents circulate free research publications either quarterly or semi-annually, and sell reports (e.g. JLL Subscriber Service) quarterly.

F. No short selling

Private pairwise trading and the poor availability of transaction data combine to yield one more important consequence, which is that short selling of ICRE assets, while theoretically possible, is problematic. Because ICRE assets are heterogeneous, they are poor substitutes. Thus to cover a short position on a particular asset, a short seller has only one option: negotiate with the asset's current owner. The privacy of trading and slow reporting of transactions facilitates this, as public information on the existence of a short sale would harm the short seller's negotiation position. However, the presence of informal information networks puts this position in jeopardy. Should the owner be unwilling to sell for the price which the short seller is prepared to pay, then a default situation arises.

4.5 Conclusion

In this chapter, the natural events which can give rise to changes in the prices of ICRE assets were identified, and the observability of categories of these events was assessed. In addition, the system by which natural events act on prices through the information structure and trading mechanism of ICRE markets was characterised.

In the next chapter, this factual characterisation of the ICRE price-generating process is analysed with the aim of producing theoretical conclusions about the informedness of prices and the distribution of investment risk in the ICRE context.

Chapter V THE INVESTMENT RISK OF ICRE ASSETS

5.1 Introduction

This chapter draws on the findings of Chapter IV in order to produce theoretical conclusions about the information content of ICRE prices and the defensibility of a stable Paretian law as a model of the investment risk of ICRE returns.

In Section 5.2, the information content of prices is assessed. This is done by analysing the system through which natural events give rise to changes in the information set I_t and are translated into changes in prices. This analysis yields observations about the sensitivity of the market to the occurrence of natural events, and the effectiveness with which information is transmitted. Taken together, these observations produce conclusions about the degree to which prices in ICRE markets are timely, accurate and full reflections of I_t.

Having developed a theoretical view of the linkage between natural events and prices, it is then possible to assess the defensibility of the stable Paretian model. This is done in Section 5.3 by analysing the characteristics of the natural events which affect ICRE prices in order to ascertain in theory whether price evolution follows a continuous or jump process. Characterisation of ICRE price-generation as one of these processes provides a strong theoretical indication of the type of probability model which governs the distribution of investment risk.

5.2 The information content of prices

In Chapter III, it was determined that five aspects of the ICRE price-generating system must be analysed in order to draw a conclusion about the extent to which prices are a timely, full and accurate reflection of all natural events. These aspects are:

i. The observation of natural events by economic agents.
ii. The structure through which economic agents transmit information to investors.
iii. Investors' evaluation of the information in their private information sets.
iv. The mechanism through which orders are placed and executed.
v. The feedback loop through which investors gain access to others' private information by observing transaction prices.

This section proceeds by analysing the role that each of these aspects of the ICRE price-generating process plays in translating information into prices. The aim of this analysis is to produce observations about the effectiveness with which each aspect plays its role. In aggregate, these observations create a basis for conclusions about the content of I_t, and the degree to which prices are a reflection of I_t at any point in time.

5.2.1 The observability of natural events

As established in Chapter III, the quality of the global information set I_t as a source of information on the outcomes of natural events depends on the extent to which it contains accurate, complete and timely information on these outcomes. These characteristics are a function of the observability of natural events.

The discussion in Chapter IV indicates that an appreciable proportion of events relevant to the market's pricing of individual ICRE assets are not observed immediately by economic agents. The events in question are primarily those which come about as the result of natural processes rather than decisions or intentional actions. Examples include contamination, subsidence, sick building syndrome and flaws in construction. These events tend to affect the physical fabric of an ICRE asset, or the physical environment in which it exists. As a consequence, they have the potential to affect the prices of assets substantially, but it can be weeks, months or even years before they are first observed by an economic agent.

This suggests that the global information set I_t which is hypothetically available for all investors to observe is an incomplete reflection of the outcomes of all natural events which have occurred up to time *t*. Furthermore, this shortcoming is significant because the events in question have important effects on the ability of a property to provide services to tenants.

5.2.2 The information structure of ICRE markets

Given the global information set I_t, the degree to which the individual information sets of ICRE investors at time *t* fully and accurately reflect the outcomes of all natural events contained in I_t is a function of the characteristics of the channels through which they may be observed.

It is evident from the discussion in Chapter IV that an appreciable portion of the information in I_t is unobservable by investors. Many of the events that affect the physical characteristics or tenancy structures of ICRE assets, or future demand and supply conditions in space markets, are observed initially only by owners and tenants individually, and their agents. These parties, for the most part, do not face disclosure obligations, and some are constrained from voluntary disclosure.

Another substantial portion of the information in I_t is observable only by indirect means. Some of the private information of tenants and landlords is distributed to small clienteles through informal networks, or gathered and sold by intermediaries possessing the networks and economies of scale in the gathering of information that market participants generally lack. However, the information gathered by intermediaries can suffer from a lack of integrity.

Furthermore, of the events that occur in the public or semi-public domain, it is apparent that some parties possess advantages over others in terms of the speed with which they gain information. This is again due to the operation of informal networks, and the choice of methods used by public bodies to disseminate information.

These observations have three main implications for the characteristics of the information sets possessed by ICRE investors. First, asymmetries exist among these sets across several dimensions:

i. Property owners have an information advantage over non-owners with respect to many of the natural events affecting the market prices of competing properties. This is due to the *privilege of proximity* they enjoy. For example, the physical attributes of buildings and the experiences of existing tenants are observable in general only by owners. Similarly, the information benefits that accrue to participants in lease negotiations and transactions suggest that investors with large portfolios possess an information advantage over smaller investors. This conclusion confirms the observation made by Gau (1987).

ii. Asymmetries also exist between the information sets of investors within and across real estate sub-markets. The local nature of the determinants of rents suggests that market participants who possess local expertise or portfolios have an information advantage over those who do not.

iii. In the same vein, investors who specialise in properties of a particular type, in a particular geographic area, or that are occupied by particular tenants will possess more information in these specialist areas than more generalist investors. By definition, specialist investors capitalise on their special skills, training and experience to develop comparative advantages in the areas of information gathering and interpretation.

Second, a significant proportion of investors' fundamental information is out-of-date due to the relatively slow speed with which data on the outcomes of particular types of natural events diffuses through ICRE markets. The size of this proportion will vary across investors according to the scale of their investment operations, access to formal and informal information networks, willingness to purchase information, and skill at information gathering skill.

Third, it is likely that the fundamental information sets of ICRE investors contains significant noise. This is due in part to the generally informal nature of information networks in real estate markets. Data transmitted through informal channels is corrupted more easily than if transmitted through formal channels. Furthermore, because it is difficult to verify the accuracy of information that is transmitted informally, economic agents may intentionally report inaccurate information if there is sufficient incentive. The opportunity to 'insider trade' may be just such an incentive. Not only is insider trading permitted in ICRE markets, but the generally poor level of public information suggests that it can also be profitable.

In summary, analysis of the information structure of ICRE markets suggests that investors' information sets are poor quality subsets of the global information set I_t. This state of affairs is attributable not only to the slow speed and accuracy with which fundamental information is transmitted in ICRE markets; the very high proportion of private information and informality of transmission leads individuals' information sets to be small subsets (and thus highly heterogeneous parts) of the global set I_t.

5.2.3 Translating information into transaction prices

So far, analysis has suggested that individual ICRE investors' information sets at any point in time are poor quality subsets of the global information set I_t because of the high proportion of private information and poor quality information transmission in ICRE markets.

Given this state of affairs, and setting aside (for the moment) the information that investors can glean indirectly from observation of transaction prices, it is evident that the information content of prices will further be a function of the manner in which information is incorporated by individual investors in trades, and the extent to which the trading process aggregates the contents of individual investors' information sets.

To assess these, it is necessary to consider how investors evaluate their individual information in order to formulate trading orders, and the mechanism by which orders are placed and executed. Examination of these elements of the price-generating process, which were described in Chapter IV in the context of the Australian ICRE market, yields several observations:

- *There is a substantial time delay between information receipt and evaluation.*

Because the investment strategies of individual assets tend to be formally revisited with relatively low frequency, it is possible for several months to pass between the time of information arrival and its incorporation in trading decisions. Furthermore, this delay can be exacerbated by the time it can take for information to flow within management organisations from the initial recipients (e.g. asset managers) to analysts.

- *Barriers to trading exacerbate the delay in incorporating information in prices.*

In order to participate in trading negotiations, investors in ICRE markets must incur information gathering costs that are much higher than those in a world of public information and centralised markets. Furthermore, as pointed out by Clapp et al (1994), much of the total cost that potential traders must bear (in terms of time and money) to participate in negotiations on specific assets are sunk, in that they are generally unrecoverable (at least in a direct sense).

As suggested by Goldman and Sosin (1979) in the capital markets context, increasing costs curtail the trading activities of speculators. Applying Goldman and Sosin's argument in the ICRE context suggests that high information and trading costs force real estate speculators to identify a wider mispricing gap before a speculative trade can be justified. As a consequence, such trades are bound to occur less frequently, ceteris paribus.

An important consequence of curtailed trading is further delay in the impounding of fundamental information in transaction prices.

The immobility of ICRE assets is a factor which aggravates this situation. Because of the immobility of properties, a high proportion of the factors which govern their prices are location specific. As noted earlier, this gives rise to an environment in which local investors are likely to enjoy information advantages over external investors. This suggests that the information costs of undertaking 'cross-border' trades are even greater than those faced within local markets, and a greater proportion of these are sunk.

Other factors which reduce the propensity of investors to trade ICRE assets are their motivation for investing and the long time required for two-way trades. Many ICRE assets in Australia are managed by organisations acting on behalf of institutional owners for whom an allocation to ICRE is part of a strategic investment plan. The Managers are excellent examples of such organisations. Because the management of separate accounts is compensated by fees that are tied to the gross market value of the ICRE assets under management, managers face strong incentives to be fully invested. Similarly, because the commingled funds under their management are expected to produce returns that meet or exceed the performance of benchmark real estate indices, there are also incentives to keep these funds fully invested.

These incentives act to reduce the motivation of managers to trade in ICRE markets where it can take months to liquidate and re-invest. During a round-trip trade, exposure to the asset class is reduced, thereby reducing asset-based fees or performance against benchmark.

- *There is a time delay between the placement and execution of orders.*

Once a decision to trade is made, a period of time measured in months can transpire while a purchase or sale order is being placed and executed. In either case, the process of instructing one or more real estate agent(s) requires considerable information sharing and contracting which can take days or weeks to complete (particularly in the case of a sale). Furthermore, once an agent has been instructed, it can take weeks or months for potential buyers or sellers to be identified, negotiations to be completed, and contracts drafted, agreed and signed.

- *The trading process is a poor aggregator of the private information of investors.*

In the Australian ICRE market, the number of investors who are ready and able to participate in a round of trading at any point in time is small. There are several reasons for this.

First, as already noted, managers are not motivated to trade. Asset-based compensation creates an incentive to remain as fully invested as possible at all times.

Second, investors are limited in the number of negotiations in which they can participate simultaneously. Participation in the negotiations surrounding individual assets is expensive in terms of management time, professional resources and other information gathering costs. However, the resources that individual investors can devote to acquisitions and disposals are limited such that active participation in several sets of simultaneous negotiations is rare.

Third, investors that might have an interest in negotiating to purchase an ICRE asset can be left out of the trading process. This is due to the ineffectiveness of the market mechanism in the ICRE context, which frequently leads to purchase opportunities being announced initially to a narrow audience of potential bidders. The relatively high frequency with which completed sales are met with surprise in ICRE markets suggests that potential purchasers are being left out of rounds of trading.

Low investor participation in trading negotiations in ICRE markets suggests that the outcomes of these negotiations reflect the private information of few investors.

In combination, these observations suggest that there is, on average, a substantial lag between the arrival of information in investors' individual information sets, and its impounding in transaction prices. By accumulating information over time for processing, investors introduce an additional delay in the time required for fundamental information to appear in prices, and the effects of information tend to be temporally bundled.

Furthermore, these observations also suggest that the trading of assets is relatively ineffective at incorporating into prices the heterogeneous information possessed by investors. Low investor participation in markets means that individual transaction prices reflect a consensus of the views of small numbers of investors. However, individual investors in ICRE markets tend to possess some information monopolistically. Thus, the forces which customarily work to fully incorporate the effects of private information in prices do not operate in ICRE markets because competition between investors with at least some degree of common information is required for this to occur.

5.2.4 Information revelation of prices

As discussed in Chapter III, an indirect means by which investors can observe the private information of other investors is through observation of the prices at which assets transact. This is because prices (to some extent) reflect a consensus of the expectations of market participants, which have been formed on the basis of their fundamental information sets.

Information may be assumed to be extractable in two ways from ICRE prices, depending on the model of valuation to which investors are assumed to adhere. If a rational expectations model is assumed, then prices can be used to infer traders' expectations of the net cash flows that will be produced by assets. For example, this could be achieved by using a simple capitalisation rate heuristic. Since risk-adjusted discount rates appropriate to a class of similar properties are readily observable, they can be combined with estimates of assets' first year incomes to infer expected rates of growth in net cash flows.

Alternatively, it may be assumed that investors take a hedonic approach to the pricing of properties. In this case, the prices of assets' characteristics may be inferred from the prices at which comparable properties have traded, and the characteristics of those properties.

In ICRE markets, investors use the information inferred from transaction prices to forecast the prices of other assets, as they do not possess perfect *ex ante* knowledge of these prices prior to trading. The heterogeneity of ICRE assets and long transaction times in ICRE markets mean that potential buyers and sellers cannot refer to the price at which an asset very recently traded for an indication of its current price. Also, the decentralised nature of the market means that investors cannot forecast prices by examining the contents of real estate agents' order books.

The conclusions reached at the end of the previous section indicate that transaction prices are, at best, poor signals of investors' private information. The fundamental information content of prices in ICRE markets are not only old, but quite incomplete and prone to inaccuracy. However, the question must still be asked: to what extent do prices reveal the private information of investors who have been market participants?

Because of the special characteristics of ICRE markets, the degree to which transaction prices reveal private information is a function of the observability of transaction prices in these markets, the size of the price vector, the integrity of price data, and the availability of information on the characteristics of the assets that trade. Some general observations follow:

- *The observability of transaction price data is poor.*

In Australian ICRE markets, the transaction price data that is available for observation by investors is generally incomplete, inaccurate and out of date. There are several reasons for this.

First, it has frequently been the case that properties change hands by means of a transfer of shares in a shell company. Thus, the prices at which some properties trade do not become a matter of public record.

Second, it is not uncommon for errors to be made in the process of reporting prices into the public domain. This is attributable to the informality of the means by which some price data is transmitted (e.g. via word of mouth or unaudited data collection methods of consultants).

Third, the process of reporting transaction prices to local authorities in Australia can take weeks to complete, depending on the motivation and diligence of the trading parties.

- *The quantity of price data is small.*

In the previous section, several factors were identified as posing a barrier to trading in ICRE markets. In addition to delaying the incorporation of fundamental information in prices, these barriers serve to reduce the frequency of trading.

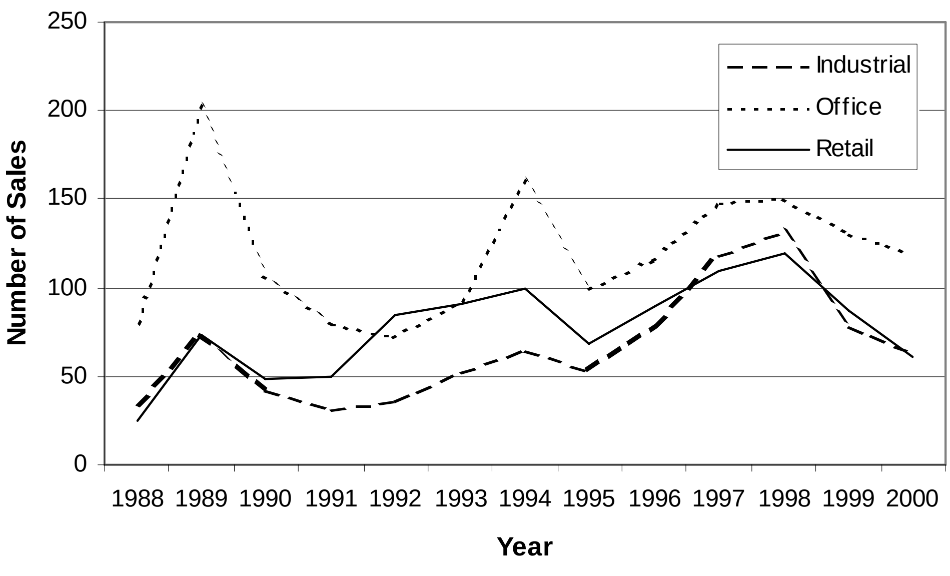
The general non-availability of relevant information is another factor which serves to mitigate trading in ICRE markets. Klein and Bawa (1977) have shown that the volume of funds that investors are prepared to commit to an asset market is inversely proportional to the availability of information, as this has implications for size of the error in participants' estimates of assets' market prices. They reasonably argue that, in a market characterised by heterogeneous information, investors skew their investment toward markets with better information.

In comparison to public capital markets, the market for ICRE assets is short on information. This suggests that the participation of investors in the Australian ICRE market is less than it might otherwise be, and this is supported by anecdotal evidence. The main consequence of this is a reduced volume of trading.

The participation of investors in ICRE markets is also influenced by the lumpiness of ICRE assets, which dictates that large sums are required to construct portfolios. This serves to reduce the number of potential participants in ICRE markets by limiting access to investors with sufficient resources. While the relatively low cost with which property may be securitised suggests that no parties are excluded from real estate markets, it is nonetheless the case that some investors cannot gain access to controlling interests in institutional-grade real estate because of their size. The information provided by the Managers confirms the concentration of ownership in the Australian context.

While anecdotal evidence certainly confirms the hypothesis that the Australian ICRE market has low trading velocity, some empirical evidence is provided by data collected by Jones Lang LaSalle Advisory (Australia) Pty Limited. Jones Lang reports that total transactions across Australia of value greater than A$5,000,000 over the period 1988 – 2000 were 1,556 (office), 1,006 (retail) and 855 (industrial). Annual transaction activity for each sector over this period is shown in Figure 2. The data verifies that the size of the price vector for all of Australia in any given month was quite small even in peak months during this period.

Figure 2
Jones Lang LaSalle
Australian Commercial Real Estate Sales over A$5,000,000



- <u>*The extraction of information from prices in ICRE markets is difficult.*</u>

The non-availability of information on the characteristics of the assets to which transaction prices relate makes the extraction of information from prices difficult in ICRE markets. The characterisation of ICRE markets contained in Chapter IV indicates that, while transaction price data eventually appears in the public domain after a contract is settled, it is not normally accompanied by supporting details of the asset in question. In some cases, no detail ever emerges, and there is little that investors can do to circumvent this shortage. In other cases, full details eventually emerge, but this can be subject to a substantial time delay.

- *Transaction prices are noisy, potentially biased signals of private information.*

Numerous factors combine to cause transaction prices in the ICRE market to be poor, and potentially biased signals of private information.

One problem is the unrepresentativeness of reported prices. The price which is reported by trading parties frequently includes a component that is attributable to items which are not part of the property itself, i.e. a rental guarantee issued by the seller, or chattels. Reported prices can thus be unreflective of the value that trading parties have agreed for an asset itself.

Another problem is the non-uniqueness of prices in ICRE markets, which is attributable to its non-centralised nature. Non-centralisation does away with the notion that all trades take place at a single market clearing price for each asset in the ICRE context, in favour of a cross-sectional distribution of potential transaction prices for any given asset in time period *t*. (This fact leads to a new definition of the term *market price* in ICRE markets. An ICRE asset's market price is the most likely price at which it would be expected to trade in time period *t*, given the factors cited in the previous paragraph.)

Yet another factor which can contribute to the noise in individual transaction prices is the information advantage that sellers have over potential buyers in a market characterised by private pairwise trading, heterogeneous assets and low trading velocity. In such a market, bidders cannot observe the actions of other bidders on the same property. While an individual seller is privy to the bids of all prospective buyers, individual buyers are privy to their own bids only. Furthermore, the heterogeneity of assets means that observation of the bidding activity on other assets is of limited use in offsetting this disadvantage, as will be observation of the vector of contemporaneous transaction prices.

This state of affairs creates an opportunity for a seller to influence bids in his/her favour by transferring distorted information between bidders. The degree of influence that a seller will be able to exert will be a function of the experiences and negotiating skills of the trading parties, which will vary across transactions. At the very least, the control that sellers have over the information content of transaction prices will serve to corrupt the usefulness of price data.

At a higher level, the absence of opportunities to short sell ICRE assets can cause the entire price vector at any point in time to be a biased indicator of the private information held by investors. Diamond and Verrecchia (1987) have shown that constraints on short-selling in stock markets reduce speculative trading activity and, therefore, the speed with which private information (bad news in particular) diffuses through a market. Moreover, in periods when no trading activity takes place, the most recent transaction price is thus an upward biased measure of the market value of a stock. It is not unreasonable to assume that these same effects prevail in the ICRE asset market.

In summary, the analysis conducted in this section produces four main observations about the powers of ICRE transaction prices to reveal private information. First, the observability of transaction prices is poor. The price data available to investors generally appears with a time lag, suffers inaccuracies, and does not cover all properties which trade.

Second, the number of price signals that appear in any given time period is small when compared, for example, to financial assets. Transaction activity is low in the ICRE market due to the high direct and indirect costs of trading, reduced investor participation, and the obligation faced by many investors to be invested in the ICRE asset class fully and continuously.

Third, extraction of private information from prices is difficult. This difficulty is associated with the inability of market participants to observe the details of transactions, based on the rationale that such details are needed in order to extract information from a vector of prices that can be used in the pricing of another asset.

Fourth, transaction prices are noisy, possibly biased signals of private information. The noise in transaction prices is mainly attributable to the non-centralised nature of the ICRE market. This permits a large number of factors specific to individual negotiations to affect the outcome of trades, thereby corrupting the integrity of prices as signals of private information. Furthermore, the prices at which ICRE assets transact may be upward or downward biased signals of assets' market values depending on the extent to which the lack of a short sale opportunity has prevented trading, or the powers of sellers to influence information flows has actually caused individual prices to be biased in favour of sellers.

5.2.5 Theoretical conclusions about the information content of prices

This analysis produces two primary conclusions about the information content of prices in the ICRE market in Australia. First, prices reflect partial information, in that they differ from those which would prevail if all natural events affecting the prices of properties were reported into I_t timely and accurately. The incompleteness of I_t is attributable to inefficiencies in the initial observation of the outcomes of natural events by economic agents.

Second, prices are partially informed, in that they differ from those which would prevail if all investors could observe (and act on) all changes in I_t accurately, cheaply and quickly. Specifically, there is a long time lag in the incorporation of new information in prices, and prices may not be full reflections of the information incorporated in them. It also appears to be the case that some classes of information suffer serious inaccuracies.

Moreover, analysis suggests that transaction prices do little to alleviate the shortcomings of investors' private information sets through their revelation of traders' expectations. This is because the characteristics of the market, assets and investors give rise to difficulties in extracting information from prices, a low level of trading activity, a substantial proportion of old information in the prices of transactions that do occur (particularly when the market is declining) and only a loose correspondence between transaction prices and market prices.

5.3 The theoretical basis for a stable Paretian model of ICRE investment risk

Having now (in essence) developed a theoretical model of the price-generating process in the ICRE context, an appropriate stage has been reached at which the findings of Chapter IV can be analysed further in order to ascertain whether there is a theoretical case for the assertion that individual ICRE investment risk is described by a stable Paretian probability law.

The discussion in Chapter III suggests that a broad test of the theoretical defensibility of the stable Paretian model of individual ICRE investment risk can be conducted by ascertaining whether prices evolve according to a continuous or jump process. Classification of the process in this way points to either a continuous or discrete mixture model of unconditional risk as being more theoretically defensible in the ICRE context. A theoretical finding that the process is continuous would support a continuous mixture model of risk. Of the candidate continuous mixture models which have been considered in the capital markets literature, the stable Paretian model is one of the most attractive on theoretical economic grounds.

Examination of the capital markets literature relevant to this issue indicates that a jump process is differentiated from a continuous process by the existence of an information distribution (i.e. a source of price impetuses associated with a group of natural events that are similar in economic nature) which produces price impetuses with a low frequency but large potential effects on prices (relative to other information distributions).

Therefore, in order to ascertain in a theoretical sense whether such a source exists in the context of the process driving changes in the prices of individual ICRE assets, the analysis proceeds in three steps:

i. Identify and group the natural events that are relevant to the prices of ICRE assets according to their similarity of economic nature.

ii. Ascertain which of these groups of events has the greatest potential to affect prices, i.e. which is the most ‘important’.

iii. Ascertain whether the events in this most important group occur with a ‘low’ frequency.

5.3.1 The generation of ICRE prices: Continuous or jump process?

Step (i) of this analysis has already been completed as part of the characterisation of the overall price-generating process in the ICRE context undertaken in the previous chapter. Having regard to the present value model described by

Equation 3, the factors which determine the quantum and uncertainty of the cash flows produced by ICRE assets were identified. This enabled the natural events which could be expected to affect investors' expectations concerning the values of these factors over the economic life of a property to be identified. These are listed in Table 2. Fortunately, these natural events fall into economic groups because they are associated with specific pricing factors.

In order to determine which of these groups has the greatest potential to affect ICRE prices, it is possible to narrow the field considerably by making two broad generalisations.

- *The natural events which affect expected future cash flows are more important than those which affect the term structure of discount rates.*

A natural result of the use of Equation 3 to identify the natural events that are relevant to ICRE prices is an ability to partition all groups of natural events into those which affect expected future cash flows, and those which affect discount rates.

Geltner (1990) has established that 'cash flow risk' is more important than 'expected return risk' in explaining the time series volatility in the capital returns on individual ICRE assets. He reached this conclusion by applying a present value model to a stylised investment property, using empirical data on the innovations which occur in expectations concerning future rental growth, and in discount rates.

Geltner's results are consistent with intuitive reasoning. Anecdotal evidence suggests that, over a return measurement period of one year, the discount rates that investors use to appraise the attractiveness of individual ICRE investments tend to change little. This is related to the stability of risk premia over time (e.g. see Brown (1991) and Geltner and Mei (1995)), and the approach taken by central banks in most developed countries to managing inflation by setting bank borrowing rates. In contrast, a wide range of unpredictable natural events can precipitate substantial revision in the expectations of investors concerning a property's future cash flows, particularly those in the short term. Moreover, these events can occur coincidently (e.g. discovery of environmental contamination after a tenant unexpectedly vacates a property).

- *The natural events which affect the cash flows being produced by a property are more important than those which affect its potential future cash flows.*

The natural events which affect a property's expected future cash flows can be partitioned into those which affect the rents that tenants are contractually obligated to pay through the foreseeable future, and those which affect the rents that tenants could be obligated to pay thereafter. This partitioning arises due to the character of the lease contracts that are typically put in place across all property types in Australia (and elsewhere). In essence, rents tend to be fixed for periods of three to five years at initial lease execution and by periodic rent reviews over the life of a lease contract. Thus, once a lease is signed or a rent review is agreed, a building's net operating income ('NOI') is generally fixed for some time, i.e. until the next rent review or the lease terminates. Similarly, when a building is vacant, its NOI is reduced until such time as new lease(s) are executed.

Of these two classes of natural events which affect expected future cash flows, the class of events which affects the contractually determined rents payable over the foreseeable future ('passing rents') is likely to have a greater effect on prices than the class of events which have the potential to affect the rents that may be paid in future. There are two reasons for this.

First, whereas passing rents are debt-like in nature and thus discounted through time at (relatively low) borrowing rates, future rents (i.e. subsequent to the next rent review or lease termination) are quite uncertain and therefore attract discount rates inclusive of risk premia.

Second, passing rents occur by definition earlier in time than the rents which will be payable in future.

Thus, all other things being equal, events which affect current cash flows have a greater influence on prices than those which affect the cash flows that a property might produce when they are reset in future.

On the basis of these two broad generalisations alone, it is clear that *lease events* constitute the group of natural events that have the greatest potential (of all natural events) to affect the prices of ICRE assets. In this context, the term lease events is defined to include all natural events which affect a property's passing rents. Such events include new leases, rent reviews, lease terminations and tenant defaults.

The question that now arises is whether it is the case that individual ICRE assets experience a discrete (i.e. low) number of lease events in any given year, being the time period across which returns are calculated for performance measurement purposes (and which support the empirical tests conducted in subsequent chapters). From Chapter III, it will be evident that the frequency of lease events will be a function of the number of leases affecting individual assets, the length of these leases, the time period that transpires between subsequent leases, and the periodicity of rent reviews.

In general, the cash flows produced by properties held by institutional investors in Australia tend to be generated by between one and five major tenants in each property. To some extent, this is a direct result of the bias that institutional investors have in selecting properties for acquisition. Investment grade properties are generally characterised by a low number of major leases. For example, high quality industrial properties are generally occupied by a single tenant. Similarly, the cash flows of CBD office buildings are normally attributable to no more than four or five major tenants.

It is also the case, in general, that leases across all three main property types extend for periods of between three and 10 years, with rent reviews occurring once every three to five years. While there is a degree of variation in the typical new lease term and rent review cycle across property types, this is not large.

The vacancy period between leases will vary substantially across individual assets due to market conditions and the amount of notice that a landlord has received of a sitting tenant's intention to vacate. It is thus not uncommon for landlords to experience vacancy periods between leases of up to one year.

Taken together, these observations about the lease structures of ICRE assets in Australia suggest that individual properties typically experience at most about one lease event per year. This conclusion arises by assuming that leases in multi-tenant buildings are asynchronous with a similar proportion of total NOI being affected by lease events in any given year.

5.3.2 Theoretical conclusion about a stable Paretian model of risk

In summary, this discussion strongly suggests that lease events form a group of natural events that is a low frequency source of price impetuses which have the greatest potential (amongst all natural events) to affect individual ICRE prices.

The weight of this theoretical analysis favours a conclusion that price evolution in the context of individual ICRE assets can be characterised as a jump process. In such a process, prices follow a continuous path that is punctuated by discontinuities which arise as a result of the infrequent occurrence of lease events.

There thus appears to be no theoretical case for a stable Paretian model of investment risk. As noted in Chapter III, characterisation of a price process as being of the ‘jump’ variety suggests that a discrete mixture model is likely to be superior to a continuous probability law in the ability to describe investment risk.

The question of whether a discrete mixture model also possesses an empirical justification in the context of individual ICRE investment risk is pursued in the next three chapters. In Chapter VI, a basic empirical test of the ‘jump process’ hypothesis is conducted prior to proposing and empirically testing a discrete mixture model in Chapters VII and VIII using individual ICRE returns data supplied by the Property Council of Australia.

Chapter VI EMPIRICAL TEST OF THE JUMP PROCESS HYPOTHESIS

6.1 Introduction

The theoretical analysis conducted in Chapter V yields several conclusions about the information set embodied in prices and the process through which prices evolve in the ICRE context in Australia.

However, the severe shortage of ICRE data limits the range of empirical tests that can be conducted of these conclusions. For example, in order to test a hypothesis that prices are slow to incorporate the effects of natural events, a dataset consisting of high frequency prices and the characteristics of individual assets in particular time periods is required. Not only does such a dataset not exist, but due to the commercial sensitivity with which property-specific data is viewed by subscribers, PCA would not be able to make it available to external researchers even if it did exist. Like other equivalent organisations elsewhere, the data that PCA is permitted to make available to researchers is limited to the income, capital and total returns on anonymous properties.

The author's participation on the Index Committee of the PCA offers special access to a dataset that has the potential to yield insights into the relationship between information and empirical price change. This dataset consists of short explanations of 'large' changes in the valuations of properties underlying the index series prepared by the PCA. The Index Committee reviews these explanations in order to identify outliers that might best be filtered out of the data underlying a particular time period's index calculation.

Because access to this dataset of explanations is limited to members of the Index Committee, it is not customarily released for the purpose of academic (much less commercial) research. These explanations thus form a unique dataset. To the best of the author's knowledge, neither this dataset nor any other of a similar type has served as the basis for empirical testing of the price evolution process in the ICRE context.

Specifically, the PCA explanations database provides a source of data for a simple empirical test of the hypothesis that prices evolve according to a jump process in which jumps are attributable to the occurrence of lease events. If this hypothesis is true, then the occurrence of lease events should be cited with appreciable frequency by subscribers to explain large changes in property valuations. The frequency with which lease events are actually cited will be governed to some extent by the definition of the term 'large'.

This chapter proceeds by first describing the database of explanations maintained by the PCA and explaining the methodology used to analyse the data. The results of this analysis are then presented and discussed. Following this, attention focusses on one particular explanation which suggests that property prices react to the impending uncertainty associated with lease events during the immediately preceding period. Discussion centres on whether this is consistent with rational expectations.

6.2 The PCA explanations database

As noted earlier, the PCA database consists of short explanations submitted by index subscribers or their valuers in response to a request from the PCA Index Committee. Explanations are requested by the Committee when outlying returns are detected as part of the index production process which occurs at the end of each quarterly index period. At this time, the valuation-based returns on the properties in each index are calculated for the quarter and year ended on that date, and for each of the three previous quarters. The cross-sectional means and standard deviations of the annual returns are then calculated. Outliers in the cross-section of returns underlying each index are identified by whether their annual return, or any of their quarterly returns, fall outside a range that is arbitrarily set at ±1.5 standard deviations around the mean annual return.

The PCA dataset comprises an electronic database of explanations covering the CBD office, retail and industrial properties that were valued in the six month periods ended 30 June and 31 December of each year over the time period January 1996 to June 2000. The database is incomplete in the period between the inception of the indices and December 1995 because the database was constructed retrospectively from paper records (which have since been destroyed) and records of explanations were not kept in the early years of the PCA Indices.

It is apparent that the PCA explanations database possesses at least two shortcomings in terms of serving as a basis for drawing conclusions about the events which cause ‘large’ returns. These are the relatively short time period it covers, and the non-standardised nature of explanations. The 4.5 year period covered by the database is not long enough to encompass one full ‘property cycle’ in Australia. Therefore, the database is not a complete aggregation of the reasons that could be offered to explain large value changes. In addition, due to the lack of restrictions on the form of explanation that subscribers can submit, it is rarely the case that any two explanations are exactly the same.

Nonetheless, the PCA explanations dataset should be exploited for the empirical testing of hypotheses about the price evolution process in the ICRE context because it is unique, generally unavailable to researchers, and has the potential to shed light on the extent to which otherwise purely theoretical hypotheses are consistent with reality.

An implicit assumption made for the purpose of the empirical analyses conducted in this and the next two chapters is that professionally-prepared valuations are unbiased estimates of the market prices of ICRE assets. A substantial and growing body of research has considered this issue. This research is mostly theoretical in nature because the market prices of ICRE assets are not observable.[22] In general, this research concludes that individual valuations may contain biases depending on the circumstances under which they have been commissioned, and the market environment prevailing at the time in which they are conducted. For example, valuations can exhibit stickiness in their adjustment because of their frequency (e.g. valuers may find it difficult to detect market movements) or the influences of clients on valuers (e.g. to secure a desired outcome depending on the purpose to which a valuation is being put).

However, the PCA returns data used in the current research is based on valuations over periods of six months or one year which have been supplied by a multitude of subscribers of all types on properties in numerous locations around Australia. Thus, for the purpose of this research, it is assumed that PCA returns are unbiased estimates of the 'true' returns experienced by properties over the periods in question (i.e. any biases present are unsystematic and small).

6.3 Empirical testing

To ascertain how this dataset could be used to produce empirical insights with respect to the theoretical conclusions drawn in Chapter V, it was noted that the information contained in the dataset – 'large' capital returns and short explanations –

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[22] Empirical research has made use primarily of transaction prices, which (as discussed earlier) are samples from distributions of possible prices that are theoretically centred on market prices. A comprehensive overview of the valuations versus prices issue is presented in Brown and Matysiak (2000).

has a parallel in the event studies used in the capital markets literature to test informational efficiency. In these studies, a particular type of event is identified, and then the rates of return produced by affected securities over the period surrounding the event are analysed. The aim is to ascertain whether the market incorporates the effects of the news associated with the event quickly and fully in prices.

It will be evident that the PCA database of explanations enables the conduct of something along the lines of a 'reverse' event study in that it permits empirical evaluation of the events associated with large returns.

In what ways might a study of this kind be useful in the current context? One way is by providing insights about the extent to which the returns falling in the tails of the empirical returns distribution in any period are associated with lease events.

An important conclusion of the theoretical analysis undertaken in Chapter V is that lease events are the source of a jump process in the ICRE context. This conclusion arose as a result of two observations: lease events occur with low frequency, and they are the most 'important' amongst all events in the ICRE context.

Lease events are important because their outcomes are unpredictable, and they affect the cash flows that a property's bundle of leases is producing. Their unpredictability is a key characteristic, as lease events would not precipitate price changes if their outcomes are predictable. It has been observed that investors face a general shortage of the information they require to forecast supply and demand conditions for space in particular buildings. This makes it difficult to forecast the time profiles of market rents and the future tenancy structures of these buildings, even in the short term. As a consequence, while it may be known in advance that certain lease events are due to occur, it will be difficult for investors to predict what the outcome of those events will be. This, in conjunction with the immediacy of their effect on cash flows, suggests that they have the potential to precipitate large price changes.

The PCA explanations thus offer an opportunity to ascertain whether empirical returns are produced by a jump process. If this hypothesis is true, then ‘the occurrence of a lease event’ should be a frequently cited explanation for large returns. It is not possible to develop an *a priori* expectation as to the precise frequency with which lease events should arise as explanations of large returns, as this will be an empirical issue linked closely with the filtering rule used to identify outliers.

For the purpose of this study, an outlier identification rule different from that used by the PCA Index Committee is applied. In this study, properties with true six monthly returns only are examined (i.e. they were actually valued at the beginning and end of the index period in question). This avoids contaminating the population of outliers by including properties which are tested on the basis of their annual return, being the approach taken by PCA. To capture the returns which lie in the tails of the cross-sectional distributions of returns, a six month return is deemed to be an outlier if it falls outside a range of ±1.0 standard deviation around the mean.

6.4 Results

Applying the outlier filtration rule described in the previous section to the PCA explanations database yielded a sample of 591 outlying returns. Of these, 272 possessed associated explanations. The difference between these two figures is entirely attributable to differences between the identification rules used in this study, and by the PCA Index Committee.

Categorisation of the 272 explanations was a straightforward exercise. Examination indicated that many occurred frequently in essentially similar form (i.e. the differences are minor due to the shortness of each explanation). Identifying each explanation as belonging to one of 19 general categories (plus one miscellaneous category) required the exercise of subjective judgement in only three cases. Eight categories account for 78% of all explanations, and one miscellaneous category holds three explanations. All 20 categories and the number of explanations in each are shown in Table 4.

Table 4
Explanations of 'Large' Valuation Changes – 1996 to 2000
Index Committee – Property Council of Australia

Frequency (#)	Frequency (%)	Explanation Category
41	15.1%	Revised beliefs about current market rents
31	11.4%	Approaching lease expiry/rent review
29	10.7%	New lease signed on vacant space
28	10.3%	Property sold out of index
25	9.2%	Lease terminated
23	8.5%	Redevelopment / major capital expenditure
19	7.0%	Lease renewed or renegotiated – existing tenant
17	6.3%	Cap rate shift – undeterminable reason
13	4.8%	Rent review completed
8	2.9%	Change in valuation firm
8	2.9%	Change in valuation technique
7	2.6%	Shift in retail turnover rent
6	2.2%	"Special" neighbourhood factor
5	1.8%	Property is vacant
3	1.1%	Previous valuation was incorrect
3	1.1%	Property is being sold; valuation is reaction to market sentiment
1	0.4%	Change in operating expenses
1	0.4%	Property brought into index
1	0.4%	Head/ground lease bought out by tenant / owner
3	1.1%	Miscellaneous

The PCA data appears to support the hypothesis that lease events are a frequent source of outlying returns. According to Table 4, about one-third of all large valuation changes are attributable to new or renewal leases, lease terminations or the completion of rent reviews. The market appears to experience some difficulty in forecasting the outcome of lease events, even though it knows with certainty that they are about to occur. The resolution of this uncertainty by observing the outcome of events *ex post* gives rise to valuation changes which are amongst the largest in any particular time period.

The assertion made earlier that *ex ante* uncertainty in forecasting the outcome of lease events is attributable to a shortage of information is further supported by the fact that the most frequently cited explanation is “market rents have shifted.” This explanation says that the appearance of current leasing evidence seems (at times) to substantially alter the expectations that investors developed at the time of the previous valuation. This clearly indicates that investors have a thirst for information that can be used to forecast future demand and supply, and they place great weight on current leases’ rentals and vacancy rates as indicators of future conditions, at least in the short term.

An interesting outcome of this analysis is the frequency with which outliers are associated with properties being sold out of an index. This means that, in approximately 10% of all cases, the prices at which assets were sold are sufficiently different from their most recent valuation to cause the implied capital returns to constitute an outlier. This result is consistent with the assertion that the price at which a property trades is a drawing from a distribution of possible prices, and that this distribution can, at times, be quite wide. An important implication of this for the construction of the PCA indexes is that there may be an argument for dropping sold properties out of indexes at their market valuation at the time of sale (if one exists), rather than their noisy transaction price.

It is also interesting to note that 31 outliers in the PCA dataset were explained by the approach of a lease expiry or rent review. The appearance of this explanation for large value changes is odd because the explanation itself does not refer to the occurrence of an event. It is generally known from the time a lease is executed when rent reviews will occur and the lease will terminate. The suggestion of this explanation is that prices 'wake up' to the uncertain potential effect on cash flows of an impending lease expiry or rent review during the period of 12 months or less that precedes their occurrence. This phenomenon should be examined further.

6.5 Price changes around lease events

The appearance of the explanation "approaching lease expiry/rent review" is odd because it suggests (at first look) that prices are not rationally incorporating the uncertainly that lease events introduce in investors' forecasts of properties' future cash flows. Rational expectations theory suggests that prices should take account of the uncertainty surrounding all future lease events. Therefore, the "approach" of a lease expiry or rent review should not, in and of itself, give rise to a large price change. To what are such price changes thus attributable?

One explanation might be that more information appears about the possible outcomes of a lease expiry within a short period prior to its occurrence. For example, leases generally contain clauses providing for tenants to give notice to landlords about their intentions to renew or vacate on expiration of their lease. Notice periods can extend for up to one year or more. Commencement of negotiations between a landlord and tenant prior to a lease expiry has the potential to yield information about the likely outcome of the lease expiry, thereby rationally affecting prices.

However, it is to be expected that the effects of information produced during these negotiations would be more likely to appear in value changes associated with other explanation categories: "lease terminated" or "lease renewed." If formal information about a tenant's intention to renew or terminate was received and precipitated a change in value, then it is to be expected that this information would be cited in explanation.

Alternatively, it may be the case that the market is myopic when it comes to taking account of future rent reviews and lease expiries in pricing. Support for this view comes from comments made by the senior valuers interviewed as part of the empirical study reported by Levy and Schuck (1999), and by portfolio managers ('clients') in a follow-up to that study. These comments indicate that it is common practice for valuers to reduce the valuation of a property immediately prior to a rent review or major lease expiry in order to account for impending "rent review / vacancy risk." Assuming that open market valuations are proxies for prices, then it must be inferred that the market believes a reduction in value is appropriate.

Why would the market customarily reduce the value of some ICRE assets *immediately* prior to a lease expiry or rent review? It is easy to show that a progressive reduction in the market value of a property as it approaches a rent review or lease is consistent with rational expectations, *ceteris paribus*. Such a reduction reflects a decline in the number of contractually fixed cashflows until the next lease event, and a difference between the rates of return used to discount fixed cash flows in the short term, and uncertain cash flows in the medium and longer term. However, a substantial reduction in value of the period immediately preceding a lease expiry or rent review appears to be indicative of irrational behaviour.

It is possible that a reduction in value immediately prior to a lease expiry or rent review is a valuation issue. For example, it may behove institutional owners who are managers of ICRE assets to intentionally mark down the value of properties immediately prior to major lease events as insurance against the possibility that the outcomes of such events go against them. Value reductions, which institutional clients can achieve by exerting influences on valuers, can then be attributed to 'industry practice' rather than poor management skill.

Alternatively, it may be that institutional clients are unwilling to accept valuations that show the progressive reduction in value that can be rationally expected to occur as time passes between rent reviews. Under this scenario, valuers succumb to client demands until they are eventually forced to adjust their valuations as the disparity between reported and 'true' value becomes large – immediately prior to the occurrence of a rent review or lease expiry.

In either case, valuers are influenced by institutional clients to exhibit myopia in their forecasts so that value reductions that should otherwise occur progressively are compacted into the period immediately preceding a rent review or lease expiry.[23]

These observations make a case for examining the PCA dataset of large price changes more closely. A simple way of doing this involves examination of the signs of the outliers associated with lease events. For example, if large price changes occur before lease expiries because of the appearance of tenants' renewal notices, then these changes should be distributed roughly symmetrically, and there should be no price reversals post-event.

Alternatively, if prices are customarily marked down prior to rent reviews and lease expiries to reflect cash flow risk, then empirical price changes should be skewed to the left. Furthermore, properties which have their prices marked down should also exhibit price reversals once the outcomes of rent reviews and lease expiries are

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[23] This nearsightedness is confirmed by Parker (1997) on the basis of his empirical examination of the approaches that valuers take to assessing the economic situation for the purpose of constructing capitalisation rates.

resolved. Once the uncertainty surrounding a property's cash flow is resolved by the completion of a rent review or the signing of a new or renewal lease, a valuer can revert to a 'normal' capitalisation rate to reflect the fact that the property's cash flows are now fixed by contract for the foreseeable future. Large positive capital value changes should result.

The price changes associated with each of the 117 explanations involving lease events or the approach of a rent review or lease expiry were examined for their sign. The results of this simple exercise are shown in Table 5 below.

Table 5
Explanations of 'Large' Valuation Changes – 1996 to 2000
Index Committee – Property Council of Australia

Frequency (#)	# Positive	% Positive	Explanation Category
31	0	0%	Approaching lease expiry/rent review
29	27	93.1%	New lease signed on vacant space
25	0	0%	Lease terminated
19	19	100%	Lease renewed or renegotiated – existing tenant
13	12	92.3%	Rent review completed

The figures in Table 5 appear to confirm the hypothesis that the market is somewhat myopic in its pricing of cash flow risk, for rational or irrational reasons. The figures show that the approach of a lease expiry or rent review (through the passage of time) customarily precipitates a value reduction. Furthermore, if an impending lease expiry results in a lease renewal or a rent review is completed, a large increase in value results.

The figures in Table 5 also indicate that the events "lease terminated' and "new lease signed on vacant space" uniformly produce value changes consistent with expectations. A decision by a tenant to not renew a lease uniformly produces a value reduction, while the execution of a new lease on vacant space precipitates a large positive valuation change that presumably reverses the large negative changes that arose when previous tenants vacated (in the case of existing buildings).

Further empirical verification of these observations is provided by the explanations associated with large value changes on properties underlying the indices produced by the Property Council of New Zealand ('PCNZ'). Within the dataset of 178 explanations pertaining to CBD office, retail and industrial properties over the period August 1994 to December 1997 (which are produced by the PCA for PCNZ using exactly the same procedures), the statistics shown in Table 6 arose. These results confirm the conclusions reached on the basis of examination of the PCA dataset.

Table 6
Explanations of 'Large' Valuation Changes – 1994 to 1997
Research Committee – Property Council of New Zealand

Frequency (#)	# Positive	% Positive	Explanation Category
23	1	4.3%	Approaching lease expiry/rent review
40	40	100%	New lease signed on vacant space
5	0	0%	Lease terminated
15	14	93.3%	Lease renewed or renegotiated – existing tenant
35	30	85.7%	Rent review completed

6.6 Conclusion

Empirical analysis in this chapter suggests that price evolution follows a jump process in the ICRE context. The basis for this conclusion is that lease events appear to be an important factor in driving large changes in prices experienced by ICRE assets. Furthermore, the proportional role of lease events is even greater when the population of large returns is adjusted downward by removing those associated with valuation error ("property sold out of index") or seemingly irrational valuation movements ("approaching lease expiry/rent review").

However, in identifying the approach of a rent review or lease expiration as an important explanation for large value changes, this simple analysis also raised a concern about the way that the market or valuers account for cash flow risk. The idea that valuations (and assuming by proxy, prices) ‘wake up’ to impending lease events immediately before they occur is irrational and suggests that other factors may be at work. This is an area for further research.

Chapter VII EMPIRICAL TEST OF THE DISCRETE MIXTURE MODEL PART 1: DATA AND METHODOLOGY

7.1 Introduction

Theoretical analysis presented in Chapter V indicates that price evolution in the ICRE context can be characterised as a jump process, and empirical analysis of the PCA explanations database supports this conclusion.

An important implication of this is that, of the two main types of distributional models that have been proposed in the capital markets context to describe investment risk, a discrete mixture model should theoretically provide a better description of the investment risk of individual ICRE assets than a continuous mixture model.

An appropriate next step in this research process is to test empirically the hypothesis that ICRE investment risk is described by a discrete mixture model, and whether the ability of such a model to describe risk is superior to that of the stable Paretian model that has been proposed to explain the non-normality of ICRE risk.

For this purpose, use is made of a database of individual property returns maintained by the Property Council of Australia ('PCA'). This database is the same as that utilised by Graff, Harrington and Young (1997) to test their stable Paretian model of ICRE investment risk.

Empirical testing of the distribution of ICRE investment risk is reported in this and the next chapter. In this chapter, the PCA database of individual property returns is presented and methodological issues are addressed. In the next chapter, the results of empirical testing are presented and evaluated. This comprises preliminary testing of the two distributional hypotheses against the statistical characteristics of the PCA data, presentation of the results of curve-fitting and goodness-of-fit tests, and evaluation of these results.

7.2 Research approach

An ideal empirical test of the discrete mixture model would make use of time series of returns on individual ICRE assets partitioned according to their type, economic and geographic location, physical characteristics and tenancy structures. On the assumption that the returns in each time series represent independent drawings from a stationary distribution, then empirical histograms would yield information on the parameters of models associated with specific sets of asset characteristics

Unfortunately, the PCA database of rolling annual returns on individual properties contains no identifying information other than property type (since data is grouped in this way). The motivation for providing data in this form is to protect subscribers' confidentiality by preventing individual properties' returns from being tied together over time.

Therefore, after the description of the PCA dataset presented in the next section, a discussion concerned with ascertaining what information about risk can be gleaned from cross-sectional data is undertaken. This discussion recognises that sample distributional parameters can be estimated from such data only if it is the case that cross-sectional samples of returns are groups of independent drawings from the same distribution.

Following this, a discussion is presented which argues that the discrete mixture model to be fitted to the cross-sectional PCA data should be constrained *a priori* to a two component discrete mixture of normals ('DMON'). All of the models presented in the capital markets literature are mixtures of normal distributions which differ only according to the number of components, and the relationship between the parameters of each component. Ideally, the specification of the appropriate number of distributions in the fitted mixture model should be ‘driven’ by the data. However, as will be shown later, the number of observations required in order to arrive at sample parameter estimates with reasonably small asymptotic variances grows geometrically with the number of components. It is thus necessary to ascertain whether the *a priori* imposition of a constraint on the number of components in the DMON model is reasonable given the underlying stochastic process.

As part of this discussion, *a priori* expectations about the relationships between the parameters of the two components of the specified DMON model are developed. The purpose of this is not to further constrain the specification of the DMON model to be fitted to the data, but to form a basis for evaluating the consistency of the fitted model parameters with our theoretical view of the underlying stochastic process.

Finally, in the last section of this chapter, the sampling theories pertaining to DMON and stable Paretian probability laws are presented as a basis for the curve-fitting exercises to be conducted in the next chapter.

7.3 The PCA dataset

The PCA prepares sectoral Investment Performance Indices using valuations of individual ICRE assets. To protect the confidentiality of subscribers, the datasets of returns made available to researchers are randomised sets within each time period so that time series of individual properties’ returns cannot be constructed. The dataset utilised in this research contains rolling annual returns as at June and December over the period January 1984 to June 2000. As at June 2000, it contained information on 208 CBD office, 149 retail and 136 industrial buildings located in major demographic centers across Australia including Sydney, Brisbane, Melbourne, Adelaide, Perth and Canberra. With a total value of AUD 35.7 billion, the first two indices are believed to each cover approximately 35% of the total institutionally-held office and retail stocks, respectively. Since June 1995 the indices have appeared on a quarterly basis; prior to that time they appeared semi-annually.

As the PCA indices were developed with the assistance of the Frank Russell Company, Equation 4 is used to calculate the holding period return in period *t*.

$$R_t = \frac{(MV_t - MV_{t-1}) - CI_t + PS_t + CF_t}{MV_{t-1} + 0.5(CI_t - PS_t) - 0.5CF_t}$$

Equation 4

This expression, which is similar in form to that currently used in the calculation of the NCREIF Classic Property Index, is slightly different in that it assumes that *all* cash flows occur at the mid-point of the holding period, whereas NCREIF-CPI assumes that net operating income is paid in equal monthly instalments.

The rationale behind PCA's choice of approximation to holding period return is unclear, but it is an area of potential concern given that 10 years of the PCA indices appear semi-annually. Applying Giliberto (1994) and assuming a) equal monthly net operating income, and b) partial sales and capital expenditures at the end of month six, yields an expression similar in form to Equation 4 with the coefficient of I_t in the denominator being –0.417 rather than –0.5. As this difference is quite small, it shall be given no further consideration.

An issue of greater import is the match between the frequencies of the index and the valuations of the underlying properties. Table 7 reproduces information provided by PCA concerning the proportions of the sectoral datasets that are revalued in each time period. Several observations may be made on the basis of this data. First, the proportions revalued in early years of the indices show that some properties were not valued as frequently as annually, as evidenced by sums of six-monthly pairs being less than 100%. A restriction was imposed in 1990 requiring properties to be valued at least annually in order for them to qualify for inclusion in their respective sectoral index.

Table 7
Proportion of Index Revalued in Each Period and Sector
Property Council of Australia Sectoral Indices

PERIOD	CBD Office	Retail	Industrial
Jun-85	28.9%	34.6%	46.6%
Dec-85	61.4%	28.5%	48.4%
Jun-86	27.5%	39.4%	46.4%
Dec-86	65.3%	40.7%	45.2%
Jun-87	39.9%	40.9%	41.8%
Dec-87	56.8%	49.4%	53.8%
Jun-88	49.2%	36.3%	53.4%
Dec-88	55.7%	58.8%	42.8%
Jun-89	50.7%	38.0%	53.0%
Dec-89	53.4%	45.8%	43.0%
Jun-90	56.2%	50.6%	33.8%
Dec-90	57.3%	63.4%	62.8%
Jun-91	67.0%	58.7%	41.5%
Dec-91	61.8%	62.8%	69.9%
Jun-92	70.7%	69.0%	50.7%
Dec-92	61.1%	68.2%	57.9%
Jun-93	72.1%	56.9%	46.6%
Dec-93	62.9%	79.4%	42.0%
Jun-94	81.3%	72.6%	75.3%
Dec-94	70.0%	67.5%	62.7%
Jun-95	69.9%	62.2%	60.1%
Dec-95	52.7%	48.0%	48.5%
Jun-96	69.8%	52.2%	65.1%
Dec-96	60.9%	46.7%	43.4%
Jun-97	64.5%	61.6%	62.3%
Dec-97	50.0%	36.6%	26.1%
Jun-98	55.1%	52.0%	47.5%
Dec-98	41.1%	35.2%	23.9%
Jun-99	47.7%	59.6%	45.9%
Dec-99	42.3%	33.7%	19.3%
Jun-00	54.5%	68.0%	42.0%

The revaluation proportions for the Australian CBD office stock suggest that an office property's return in any given six month period could represent different things. Since 1990, June and December revaluation proportions have hovered between 60% and 80% of total Australian CBD office stock. Assuming that all office properties that are valued semi-annually or quarterly appear in *both* the June and December figures, then it must be the case that approximately two-thirds of the value of the indices is valued annually *either* in June or December. Furthermore, as it is the index-construction policy of PCA to include properties in the indices at their last known valuation even if that valuation did not occur within the index period, it will be the case that individual office properties' semi-annual returns will be split approximately evenly between those with a 'true' semi-annual return, those with a zero capital return and those with a capital return attributable to a full year.

To some extent, six-monthly rolling annual returns suffer less heterogeneity in the basis of their return calculation. This is because every property has been re-valued at least once in the year preceding a June or December index date. While this alleviates the 'zero capital return' problem, it will remain the case that some properties' returns will be associated with a financial year that ended up to six months prior to the index date. As sample sizes are already of concern in a statistical sense, removal of these would only serve to aggravate this problem. The trade-off is that time series of cross-sectional statistics will exhibit a degree of serial correlation.

7.4 The real estate market model

The cross-sectional nature of the data contained in the PCA dataset dictates that it will not be possible to use this data to render observations about the total investment risk of individual ICRE assets. The reason for this is that the decomposition of the total risk of individual properties into its constituent parts requires individual times series of returns, along with identifying information, in order to attribute components of risk to various factors.

On what component of total investment risk does cross-sectional data grouped by property type contain information? A review of diversification studies in the ICRE context suggests that a model of the covariance in individual ICRE returns looks like Equation 5.[24] This model provides for multiple factors affecting the returns on all properties of a particular type. Which of these factors are priced by investors in an equilibrium sense is an empirical issue but it would not be unreasonable to assume that all properties of a particular type have identical loadings on the priced factors and thus have the same expected returns.

$$R_{p,t} = b_{p,A} I_{A,t} + b_{p,M} I_{M,t} + b_{p,T} I_{T,t} + b_{p,R} I_{R,t} + b_{p,G} I_{G,t} + e_t$$

Equation 5

where:	$R_{p,t}$	=	the capital return on property *p* in time *t*
	$b_{p,--}$	=	sensitivity of property *p* to factor -
	$I_{A,t}$	=	index of the global asset market factor
	$I_{M,t}$	=	index of the real estate market factor
	$I_{T(p),t}$	=	index of the property type factor for property *p*
	$I_{R(p),t}$	=	index of the economic region factor for property *p*
	$I_{G(p),t}$	=	index of the geographic area factor for property *p*
	e_t	=	individual property return attributable to specific factors

This assumption is consistent with the real estate market model assumed by Y&G in their analysis of individual ICRE returns underlying the Russell-NCREIF Property Indices and PCA Investment Performance Indices: differences in the expected returns on individual properties are entirely captured by property type factors, such that cross-sections of returns represent asset-specific investment risk.

An assumption that all properties of the same type have the same expected return is not unreasonable. Such an assumption requires (by way of approximation) that properties of a particular type respond homogeneously to systematic events. It is probably the case in practice that heterogeneous property-specific characteristics give rise to a degree of variation in the effects of such events on returns.

[24] See e.g. Miles and McCue (1984b), Hartzell, Hekman and Miles (1986), Hartzell, Shulman and Wurtzebach (1987), Brown (1988), Eichholtz et al (1995) and Brown and Matysiak (2000).

However, an assumption that all remaining risk is asset-specific requires further investigation. For example, Equation 5 suggests that there is at least one source of covariance affecting the returns on subsets of properties of a particular type: the natural events that affect only the properties that fall within particular geographic areas. The analysis conducted in Chapter IV identifies numerous natural events that affect the prices of properties that are substitutes within a geographic area. In addition, when it is possible to partition all properties of a particular type according to their 'economic region', the natural events that affect only the properties falling within such regions will give rise to another source of covariance. This contrasts with the Y&G assumption that property type subindices explain all of the covariation between individual property returns of the same type.

It must thus be concluded that dispersion in the returns on individual properties of a particular type about a time period's cross sectional mean is not attributable entirely to property-specific factors only. Natural events affecting all of the properties in particular economic regions or geographic areas will also contribute to dispersion about the cross-sectional mean, even in the absence of property-specific risk.

Furthermore, because economic and geographic events affect properties which compete in economic regions and neighbourhoods, it is also likely to be the case that these events give rise to additional covariance in individual properties' returns. It should therefore be expected that such returns (particularly those in definable sub-markets) will tend to cluster in the cross-sectional distribution. The degree to which they cluster will be an empirical issue.

The main implication of this analysis for the empirical tests to be conducted in this chapter is that the cross-sectional PCA data can be used to test a distributional model that reflects the effects of regional, geographic and specific events only. It is also necessary to assume that the covariance between cross-sectional returns is small enough to permit these cross-sections to be viewed as collections of independent samples of unsystematic returns.

7.5 DMON model pre-specification for limited cross-sectional data

It is shown in Appendix A that all of the discrete mixture models which have been proposed in the capital markets literature to describe the unconditional investment risk of financial assets are weighted sums of an infinite series of normal distributions. In almost all of these, the weights of each normal component in these series are determined by the mean of the directing Poisson process, and the parameters of each component are linear functions of the parameters of the diffusion and discrete components of the stochastic price process.

However, fitting a DMON model with a large number of components to empirical data is impractical, as there is a trade-off between the increasing complexity of the model as the number of components, and the model's explanatory power. The approach that is thus most appropriate for fitting a DMON model to empirical data is that adopted by Kon (1986): begin by fitting a single normal distribution of unknown parameters to sample data, and then attempt repeatedly to fit models of an increasing number of components until a measure of optimality is maximised.

The difficulty in taking this approach with the PCA dataset is that it is of insufficient size to support an empirical specification of the DMON model. As will be discussed later in this chapter, the number of data observations required to fit a DMON model grows very quickly as the number of components increases. A degree of pre-specification based on some general assumptions is thus required.

In this section, consideration is given to constraining the DMON to an $N = 2$ specification (where N is the number of components), as the empirical data will not permit specification for a larger N. The question that must be answered is whether this is consistent with the theoretical understanding of the ICRE price process that has been developed.

A simple yet appealing version of an $N = 2$ specification of the DMON model was derived by Ball and Torous (1983). They assumed *a priori* that there is one source of discrete events governed by a Bernoulli distribution. As a result, no more than one information event occurs in each return measurement period, and each event produces a lognormally distributed change in price with mean μ_Y and scale δ^2. Without assuming that the mean jump size is equal to zero ($\mu_Y \neq 0$), this model results in a distribution of unconditional returns with density *f(x)* that is a Bernoulli mixture of normals:

$$f(x) = (1-\lambda)\phi\left(\mu, \sigma^2\right) + \lambda\phi\left(\mu + \mu_Y, \sigma^2 + \delta^2\right)$$

Equation 6

In order for this DMON model specification to be consistent with the PCA data and the empirical price process in the ICRE context, it must be assumed that lease events occur no more than once a year. This assumption is consistent with the analysis undertaken in Chapter V, which concluded that most institutionally-held office, retail and industrial properties in Australia experience about one major lease event per year.

To apply this model to the PCA dataset, it must also be assumed that the factors associated with the diffusion process give rise to price changes over one year that are sufficiently small to be approximated by a normal, rather than a lognormal distribution. As discussed in Appendix A, if each event in a diffusion process precipitates a proportional price change *dP/P* that is normally distributed, then the cumulative effect of these events would imply that *P* (and thus discrete return) is lognormally distributed. However, if it can be assumed that annual price changes are small, i.e. less than ± 20%, then the technical equivalence between discrete and continuous returns in this range permits the distribution of *P* (in the absence of specific events) to be modelled by a normal distribution.

For the purpose of the empirical testing of the discrete mixture hypothesis of individual ICRE risk, theoretical analysis indicates that an appropriate model for tests using PCA data comprising cross-sections of individual ICRE assets' returns grouped by property type is a mixture of two normal densities, as described by Equation 7 below. One of these densities represents a 'diffusion' component which, in any particular cross-section of empirical returns, will be contaminated by another distribution representing a sub-population of properties which have experienced no more than one 'jump' (reflecting a lease event).

$$f\left(x;\mu_1,\mu_2,\sigma_1^2,\sigma_2^2,p_1\right)=p_1 g_1\left(x;\mu_1,\sigma_1^2\right)+p_2 g_2\left(x;\mu_2,\sigma_2^2\right)$$

Equation 7

7.6 Expectations of relationship between parameters

At this stage it is worthwhile formulating *a priori* expectations about the relationships between the parameters of the distributions in the two component DMON model that will be tested in this chapter. These relationships, which can be established on the basis of observations made in earlier chapters, give rise to *a priori* expectations about the shape of empirical distributions. Evaluation of the shapes of empirical distributions with expectations facilitates evaluation of the ability of the DMON model to describe ICRE risk.

For example, implications for the values of the location parameters of the two normal components of Equation 7 arise from the real estate market model constructed in Section 7.4. In that model, it is assumed that expected returns vary solely on the basis of property type; differences in property types capture all differences in properties' expected returns. As a consequence, all other subsidiary factors (e.g. regional, geographic and asset-specific) have a zero expected return, implying that the locations of the two components of the DMON model should be the same in any particular cross-section. Over time, these cross-sectional locations will vary due to variation in the expected returns for properties of particular types.

Because it is not possible for the scale parameters of normal distributions to be less than zero, it is also to be expected that the scale parameter of the second component of the DMON model will be larger than the first (which reflects the effects of the diffusion part of the underlying stochastic process alone).

Furthermore, while the difference in the scales of the two components is an empirical issue, there is reason to believe that the scale of the second component will be *considerably* larger than the first. This is attributable to the asset-specific nature of the jump process, which the analysis in Chapter V suggests has the potential to precipitate very large price changes.

The analysis conducted in Chapter VI indicated that a factor exists which has the potential to distort the effects of lease events on returns, and thus has implications for the relationship between the means of the components of a DMON model of empirical returns. This factor is the systematic mark down in values (or prices) which occurs immediately prior to lease events. At any particular point in time, some properties have lease expiries and rent reviews pending in their forecast periods, while others will have just experienced new and renewal leases, rent reviews and lease terminations. Assuming that the sizes of these two subsets of properties generally differ along with the sign of the price change they sustain, then an excess of one subset over another will give rise to a non-zero location in the jump component of the DMON model.

Furthermore, since it is the case that the sizes of these subsets change over time according to the tenancy structures of individual assets, it is likely that the value of this non-zero location will change over time, taking on positive or negative values according to the preponderance of one subset over another. This will be an empirical issue.

In combination, the factors discussed in this section indicate that the two normal components fitted to empirical cross-sections of valuations-based returns should exhibit unequal locations ($\mu_1 \neq \mu_2$) and have scales such that the one associated with asset-specific events is greater than the other ($\sigma_1 << \sigma_2$). Furthermore, the value of the diffusion component's cross-sectional location should vary over time due to systematic factors, and the differences between the two components' means should also vary over time in magnitude and sign.

7.7 Sampling theory: The DMON model

The sampling theory for mixture of normals distributions is well developed, which is due in no small part to the great depth of the sampling theory which pertains to normal distributions, of which a mixture is simply a linear combination. The probability law describing the simplest case of a two-component univariate normal mixture can be expressed as follows:

$$f\left(x;\mu_1,\mu_2,\sigma_1^2,\sigma_2^2,p_1\right)=p_1 g_1\left(x;\mu_1,\sigma_1^2\right)+p_2 g_2\left(x;\mu_2,\sigma_2^2\right)$$

Equation 8

where $g_j(x)$ is a normal density function with parameters μ_j and σ_j^2, j = 1,2, and the mixing proportion is p_j, $0 < p_j < 1$, $p_1 + p_2 = 1$.

A peculiarity of a mixture of two distributions is its ability to appear unimodal, bimodal or uniform with varying degrees of skewness, depending on the magnitude of the differences between the parameters of the components. For example, the two-component univariate normal mixture is symmetrical if the two components have the same mean ($\mu_1 = \mu_2$) or are mixed in equal proportions and have the same standard deviation ($\sigma_1 = \sigma_2$). Everitt and Hand (1981) report that Eisenberger (1964) shows the following for two-component mixtures:

(a) If $\mu_1 = \mu_2$ then the mixture is unimodal for all p_j, $0 < p_j < 1$.

(b) A sufficient condition that a mixture is unimodal for all p is that

$$(\mu_2 - \mu_1)^2 < \frac{27\sigma_1^2\sigma_2^2}{4(\sigma_1^2 + \sigma_2^2)}$$

Equation 9

(c) A sufficient condition that there exist values for p for which the mixture is bimodal is that

$$(\mu_2 - \mu_1)^2 < \frac{8\sigma_1^2\sigma_2^2}{(\sigma_1^2 + \sigma_2^2)}$$

Equation 10

(d) For every set of values of the components' means and standard deviations, values of p exist for which the mixture is unimodal.

As a consequence, contaminating a normal distribution with another of differing mean and variance leads to non-normal skewness and kurtosis in the overall distribution of returns. Furthermore, varying the difference between the means gives rise to variation in the skewness of the overall distribution.

The bulk of the literature pertaining to the estimation of the parameters associated with a multi-component univariate mixture of normals appeared prior to the mid 1970s. The review undertaken by Everitt and Hand (1981) is comprehensive. The two primary approaches they consider are the methods of moments ("MM") and maximum likelihood ("ML"). Using ML to obtain estimates of the parameters for the two-component normal mixture distribution involves the identification of the real negative roots of a ninth-degree polynomial. While many methods are available for finding such roots, a difficulty arises when there are multiple real negative roots as this gives rise to multiple parameter estimates.

ML estimators, on the other hand, may be obtained by applying iterative techniques in order to calculate parameter values which make the first partial derivatives of the log likelihood function equal to zero. While such techniques can produce parameter estimates associated with local rather than global maxima in the likelihood function, this difficulty tends to arise with small samples or when the two components are not well separated. As ML estimators are also well known to have desirable asymptotic properties that MM estimators lack, ML estimation techniques are selected for this study.

Hasselblad (1966) considers the problem of using ML estimation with empirical samples to estimate the $m = 3K - 1$ parameters of a K-component mixture of normals. He begins with the assumption that sample observations have been grouped into N intervals with midpoints $x_1, x_2, \ldots, x_n$ such that there are s_i observations in each interval $S_i = (x_i - h, x_i + h)$. Given the cumulative normal distribution:

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-t^2/2} dt$$

Equation 11

The probability of any sample observation from distribution *j* falling in the *i*th interval is the difference in the cumulative probabilities $\Phi\lfloor(x_i + h - \mu_j)/\sigma_j\rfloor - \Phi\lfloor(x_i - h - \mu_j)/\sigma_j\rfloor$. When the length of the interval 2*h* is small relative to the σ_i's, this quantity may be approximated by the product of 2*h* and Φ(*x*) evaluated at the midpoint of the interval:

$$q_{ij} = \frac{2h}{\sqrt{2\pi\sigma_j^2}} e^{-(x_i - \mu_j)^2 / 2\sigma_j^2}$$

Equation 12

Defining the new variable Q_i as the sum of these probabilities for *K* components, each weighted by p_j, the mixing proportion for distribution *j*:

$$Q_i = \sum_{j=1}^{K} q_{ij} p_j$$

Equation 13

Then the log of the likelihood function is approximated by:

$$L = \sum_{i=1}^{N} s_i \operatorname{Log}(Q_i)$$

Equation 14

Taking the partial derivatives of Equation 14 with respect to each of the *m* unknown parameters in the *m*-dimensional parameter $\boldsymbol{\theta} = (\theta_1, \theta_2, \ldots, \theta_m)$ and setting them equal to zero yields a system of *m* equations. An iterative approach is required to solve these equations as they have no explicit solution. This involves the selection of initial estimates of the *m* parameters, which are then inserted into the ML equations to obtain revised estimates; iterations continue until some convergence criterion is met. As Everitt and Hand (1981) discuss numerous issues concerned with the selection of initial estimates and alternative iterative schemes in some detail, they will not be covered here.

The asymptotic variance-covariance matrix of the ML estimators may be obtained from the inverse of Fisher's information matrix, that is, the inverse of the matrix $\boldsymbol{I}$ whose *uv*th element (where $u,v = 1,2,\ldots,m$) is given by:

$$E\left[\frac{\partial \log f(x;\boldsymbol{\theta})}{\partial \theta_u}\frac{\partial \log f(x;\boldsymbol{\theta})}{\partial \theta_v}\right]$$

Equation 15

Behboodian (1972) presents a numerical method for computing this matrix in the case of a two-component mixture of normals. He shows that the elements of $\boldsymbol{I}$ are linear functions of the following integral, evaluated numerically for $i, j = 1,2$ and $c, d = 0,1,2$:

$$M_{cd}(g_i, g_j) = \int_{-\infty}^{\infty}\left(\frac{x-\mu_i}{\sigma_i}\right)^c\left(\frac{x-\mu_j}{\sigma_j}\right)^d \frac{g_i(x)g_j(x)}{f(x)}\mathrm{d}x$$

Equation 16

Behboodian investigates four methods for evaluating the integral in Equation 16: Hermite-Gauss quadrature, Romberg's algorithm, a power series and Taylor's expansion. He suggests that evaluation can be simplified by transforming the integral (by standardising the normal components' variables) to an equation in three positive parameters and a sign factor. His comparison of the results of the four methods using numerical data finds that they agree with each other up to three or four decimal figures.

The Hermite-Gauss quadrature method is given the most extensive treatment by Behboodian, as use of this procedure requires the re-expression of the transformed integrals in the form of convergent integrals. Errors appear in the first and fourth equation in Behboodian's equation set (4.6). Their corrected versions are as follows:

$$c_{mnij} = r^{-(m+n)/2} r_i^{-1/2} r_j^{-1/2} \frac{\sqrt{2\pi}}{\pi} \qquad \text{and}$$

$$A_{ijk} = 2\left(\frac{1}{r_i} + \frac{1}{r_j} - \frac{1}{r_k} - \frac{r}{2}\right) / r$$

Implementation of the Hermite-Gauss quadrature formula using the corrected equations and appropriate Hermite polynomials can be effected using spreadsheet software. Tests against the entries in Behboodian's tables of standard information matrix elements show that these agree at worst to three decimal places.

Behboodian also makes observations concerning the relationship between sample size and the asymptotic variances of parameters. He shows that, as the component densities in a mixture become increasingly close, the information matrix approaches a singular matrix with some diagonal elements equal to zero. This also happens when the mixing proportions p_j tend to one or zero. He concludes that very large samples may be needed for estimating the parameters in mixtures where the components are not well separated or a mixing proportion is close to zero.

7.8 Sampling theory: The stable Paretian model

The development of sampling theory in the case of stable Paretian distributions has been hampered by the lack of a closed form expression for their density function. Evidence of this is provided by Mandelbrot (1963) in which the author is able to make use only of simple graphical techniques to estimate the characteristic exponents (α) of the distributions of changes in log cotton prices. Fama (1965) applies a similar technique to estimate the α of changes in log returns of listed equities.

In an important advance, Fama and Roll (1971) develop a far simpler method of parameter estimation using simple functions of pre-determined order statistics. They are able to estimate the location parameter δ consistently and the shape and scale parameters α and c almost consistently, i.e. with at most a small asymptotic bias. However, their method is restricted to the symmetrical case where the skewness parameter $\beta = 0$ and is further restricted to α values in the range [1, 2].

Since the work of Fama and Roll (1971), several methods have been devised for estimating the parameters of stable distributions. For example, Leitch and Paulson (1975) fit a Fourier transform of sample data to the characteristic function and Hsu et al (1974) employ a minimum χ^2 procedure assuming symmetrical sample distributions. Others apply the maximum likelihood principle to data with and without bracketing. While all of these techniques are theoretically more accurate than that of Fama and Roll, they are also much more complicated and numerically intensive.

In a generalisation of the Fama and Roll approach, McCulloch (1986) develops a set of asymptotically normal estimators for all four stable Paretian distribution parameters based on indices that are simple functions of five pre-determined sample quantiles. Importantly, these estimators apply to distributions with α in the range [0.6, 2] and β in its full permissible range [-1, 1]. Application of these techniques involves using the indices to enter two-dimensional tables (supplied in McCulloch (1986)), supplemented by bivariate linear interpolation.

Two provisos apply to the use of these tables to calculate sample estimates of parameters. First, McCulloch notes that, with finite samples, the calculated index for estimating α may be less than its smallest permissible value. In this case, the sample estimate of α should be set equal to 2.0 and the sample β set to ±1 as appropriate. Second, sampling error can yield a calculated index for estimating β that is too high to be consistent with the index for α, or an interpolated estimate of β greater than 1.0. In both of these cases, the sample estimate of β should be set to ±1.0 as appropriate.

McCulloch (1986) also provides simple techniques to estimate the standard errors of his parameter estimators, based on their asymptotic normality. These are also applied through the use of supplied tables and interpolation. McCulloch's Table VIII shows that the normalised asymptotic standard deviations of sample estimates of β approach infinity as the sample estimate α approaches 2.0 from below. This is attributable to the difficulty in estimating accurately the skewness parameter of samples that are nearly symmetric.

Of greater concern are the asymptotic efficiencies of the McCulloch estimators, being the ratios of the asymptotic variances of the maximum likelihood estimates (as reported by previous authors) to those of McCulloch's estimates. These efficiencies range from as little as 0% to as much as 81% in certain boundary cases, implying that use of the McCulloch estimates instead of a maximum likelihood estimate is equivalent, with a very large sample, to a loss of between 19% and 100% of the sample, depending on the parameter. [25]

[25] McCulloch (1986) himself observes that his estimates are useful initialisation values for more efficient estimation routines.

Chapter VIII EMPIRICAL TEST OF THE DISCRETE MIXTURE MODEL PART 2: RESULTS AND EVALUATION

8.1 Introduction

In this chapter, the results of empirical tests of the ability of discrete mixture and stable Paretian models to describe individual ICRE investment risk are presented in evaluated.

First, the individual returns contained within the PCA dataset are examined graphically and by means of simple statistical tests to ascertain which of the two alternative distributional hypotheses are preliminarily indicated as being superior. The two hypotheses imply some over-identifying characteristics on the sample moments. In addition, predictions about the shape of the empirical distributions are implied by the *a priori* expectations of the values of DMON parameters developed in the previous chapter.

The DMON and stable Paretian models are then fitted to the sample data provided by the PCA in order to produce sample estimates of their parameters, and the asymptotic variances of these estimates. While estimation of the stable Paretian parameters of the PCA dataset has already been undertaken in Graff et al (1997), it is necessary to repeat and expand this exercise in order to (a) verify their estimation results and (b) secure numerical values for the asymptotic variances. The latter are needed to assess the validity of statistical tests that use the sample parameter estimates.

Once the models' parameters and asymptotic variances are estimated, statistical tests are used to assess the models' comparative abilities to describe empirical risk, and the degree to which the DMON parameter estimates agree with *a priori* expectations are evaluated.

8.2 Consistency of the empirical data with a DMON model

For each period within the three real estate sectors, sample statistics are shown in Table 8, Table 9 and Table 10. Natural logarithms of the raw PCA returns have not been taken, as this is inappropriate if the objective is to deduce the implications that the shape of empirical ICRE risk has for single-period portfolio optimisation (see Chapter III).

Table 8
Sample Statistics
Property Council of Australia – Office Properties

Year ended	**Sample size**	**Mean**	**Standard deviation**	**Skewness**	**Kurtosis**	**Bera-Jarque**
Dec-85	100	18.3%	19.6%	0.76	8.15	120.2*
Jun-86	105	17.6%	19.2%	1.06	9.14	184.4*
Dec-86	132	17.7%	15.3%	1.58	6.46	120.7*
Jun-87	146	21.4%	17.8%	1.56	7.90	205.2*
Dec-87	158	29.6%	22.8%	1.99	9.87	416.0*
Jun-88	173	34.4%	24.7%	1.83	7.85	265.9*
Dec-88	187	32.3%	22.9%	1.11	5.77	98.2*
Jun-89	206	24.2%	19.4%	1.31	7.83	259.1*
Dec-89	228	16.6%	14.8%	0.77	7.83	244.1*
Jun-90	240	11.6%	14.9%	0.39	7.58	215.5*
Dec-90	254	2.6%	16.0%	(0.05)	5.82	84.5*
Jun-91	273	-8.5%	17.3%	(0.24)	2.41	6.7*
Dec-91	273	-13.1%	16.1%	(0.20)	2.71	2.8
Jun-92	276	-11.5%	16.9%	(0.28)	4.88	44.1*
Dec-92	273	-11.3%	17.8%	0.17	4.50	26.7*
Jun-93	276	-10.8%	17.4%	(0.23)	3.39	4.2
Dec-93	263	-6.6%	16.3%	0.02	3.36	1.4
Jun-94	253	2.1%	17.0%	(0.14)	4.52	25.2*
Dec-94	244	10.0%	15.9%	0.57	6.12	111.7*
Jun-95	243	9.3%	15.9%	0.51	7.28	196.3*
Dec-95	241	5.6%	14.3%	0.16	7.32	188.8*
Jun-96	230	4.7%	13.6%	0.58	5.83	89.9*
Dec-96	227	5.5%	12.5%	0.43	6.91	151.7*
Jun-97	201	5.8%	14.4%	(0.25)	4.23	14.8*
Dec-97	205	7.8%	14.3%	(0.91)	5.76	93.4*
Jun-98	201	7.2%	12.2%	(1.14)	5.82	110.5*
Dec-98	202	8.1%	12.6%	0.62	10.26	457.0*
Jun-99	199	7.3%	9.8%	(1.04)	6.71	150.2*
Dec-99	210	7.8%	10.1%	(0.06)	6.51	107.7*
Jun-00	189	10.5%	10.2%	0.77	10.20	426.4*

* Statistically significant at the 5% level

Second Order Correlation Matrix
Property Council of Australia – Office Properties

Measure	**Mean_{t-2}**	**std dev_{t-2}**	**skewness_{t-2}**	**kurtosis_{t-2}**
mean_t	0.76	0.45	0.66	0.63
std dev_t	0.28	0.69	0.68	0.21
skewness_t	0.53	0.58	0.60	0.49
kurtosis_t	0.53	0.11	0.19	0.39

Table 9

Sample Statistics
Property Council of Australia – Retail Properties

	Sample size	Mean	Standard deviation	Skewness	Kurtosis	Bera-Jarque
Dec-85	43	17.6%	8.9%	1.39	5.34	23.7*
Jun-86	46	16.6%	9.0%	0.57	6.30	23.4*
Dec-86	52	17.4%	15.0%	0.49	7.38	43.7*
Jun-87	56	19.8%	15.6%	1.45	6.86	54.5*
Dec-87	56	22.1%	17.7%	1.61	6.99	61.5*
Jun-88	61	25.5%	25.2%	4.10	24.90	1,389.7*
Dec-88	66	26.4%	24.9%	2.71	15.30	496.7*
Jun-89	79	21.9%	17.4%	1.32	7.35	85.2*
Dec-89	82	17.4%	11.7%	2.65	15.51	630.2*
Jun-90	87	12.8%	8.9%	0.44	4.79	14.5*
Dec-90	94	11.1%	9.9%	0.54	3.88	7.7*
Jun-91	100	7.2%	12.4%	(0.65)	4.14	12.4*
Dec-91	100	5.5%	12.8%	(0.92)	5.52	40.6*
Jun-92	98	9.4%	11.1%	(0.65)	6.97	71.5*
Dec-92	98	12.8%	14.0%	0.30	5.16	20.5*
Jun-93	100	15.2%	12.4%	0.32	4.25	8.3*
Dec-93	98	15.4%	10.8%	(0.56)	4.28	11.8*
Jun-94	96	16.6%	8.7%	0.48	3.17	3.7
Dec-94	100	15.9%	9.0%	1.70	8.96	196.2*
Jun-95	108	13.0%	7.4%	(0.55)	4.32	13.3*
Dec-95	117	10.2%	8.5%	(1.63)	10.43	320.9*
Jun-96	119	9.9%	7.9%	(0.82)	7.56	116.1*
Dec-96	119	9.8%	9.2%	0.17	10.87	307.4*
Jun-97	113	9.8%	7.5%	(0.18)	4.87	17.1*
Dec-97	141	11.1%	9.1%	0.05	5.03	24.3*
Jun-98	151	11.9%	9.2%	(0.32)	5.69	48.3*
Dec-98	157	12.3%	10.5%	0.82	12.43	599.4*
Jun-99	153	13.9%	9.7%	1.61	12.09	592.7*
Dec-99	153	14.1%	10.4%	2.23	13.19	789.4*
Jun-00	146	12.7%	7.7%	2.39	16.37	1225.8*

* Statistically significant at the 5% level

Second Order Correlation Matrix
Property Council of Australia – Retail Properties

	Mean_{t-2}	std dev_{t-2}	skewness_{t-2}	kurtosis_{t-2}
mean_t	0.63	0.59	0.43	0.23
std dev_t	0.42	0.48	0.35	0.11
skewness_t	0.50	0.48	0.37	0.33
kurtosis_t	0.33	0.25	0.26	0.19

Table 10
Sample Statistics
Property Council of Australia – Industrial Properties

	Sample size	Mean	Standard deviation	Skewness	Kurtosis	Bera-Jarque
Dec-85	59	13.1%	12.0%	(1.53)	11.70	208.9*
Jun-86	59	15.5%	14.0%	(0.06)	10.40	134.6*
Dec-86	69	16.7%	11.5%	1.46	4.70	32.7*
Jun-87	65	19.2%	13.7%	1.31	4.64	25.9*
Dec-87	65	23.5%	16.8%	1.13	5.81	35.2*
Jun-88	65	25.1%	16.6%	1.21	6.46	48.2*
Dec-88	71	24.9%	16.8%	(0.20)	5.00	12.4*
Jun-89	69	24.2%	17.1%	(0.17)	4.03	3.4
Dec-89	72	21.8%	15.1%	(0.49)	6.99	50.6*
Jun-90	73	13.9%	12.9%	0.70	4.63	14.1*
Dec-90	75	2.7%	12.4%	0.41	6.78	46.7*
Jun-91	81	-4.5%	12.8%	(0.80)	3.75	10.5*
Dec-91	82	-8.8%	13.3%	(0.43)	3.06	2.5
Jun-92	84	-4.6%	15.1%	(0.30)	2.89	1.3
Dec-92	84	3.9%	14.9%	0.14	3.93	3.3
Jun-93	90	3.9%	14.4%	(0.25)	4.03	4.9
Dec-93	90	6.2%	11.9%	(0.27)	3.60	2.5
Jun-94	88	15.1%	15.2%	0.77	5.45	30.7*
Dec-94	92	18.4%	13.8%	0.54	5.22	23.5*
Jun-95	105	16.1%	10.3%	0.54	4.05	9.9*
Dec-95	110	15.7%	11.6%	3.74	27.93	3,104.0*
Jun-96	111	14.5%	11.9%	3.41	27.74	3,045.9*
Dec-96	119	12.3%	10.1%	(0.92)	5.67	52.2*
Jun-97	112	15.8%	12.1%	1.02	11.73	374.6*
Dec-97	138	16.2%	9.8%	1.72	13.74	731.4*
Jun-98	168	15.7%	9.5%	0.29	7.17	124.2*
Dec-98	196	15.4%	7.5%	(0.32)	4.89	32.3*
Jun-99	222	14.4%	7.2%	0.92	6.23	127.6*
Dec-99	188	13.8%	8.1%	0.84	8.66	273.2*
Jun-00	113	13.3%	8.1%	(0.01)	5.33	25.5*

* Statistically significant at the 5% level

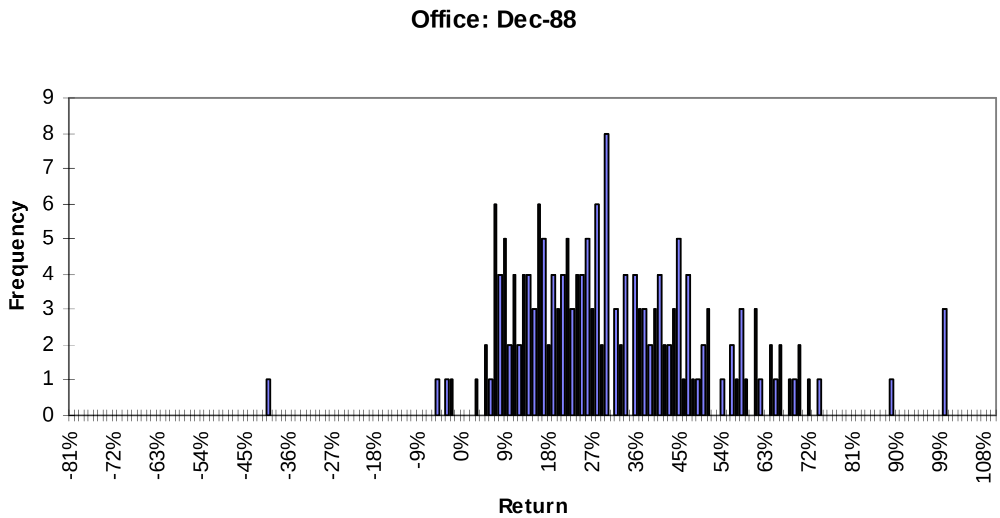
Second Order Correlation Matrix
Property Council of Australia – Industrial Properties

Measure	Mean_{t-2}	std dev_{t-2}	skewness_{t-2}	kurtosis_{t-2}
mean_t	0.63	0.11	0.24	0.13
std dev_t	(0.08)	0.71	(0.10)	(0.28)
skewness_t	0.19	(0.18)	(0.18)	(0.11)
kurtosis_t	0.23	(0.22)	0.04	0.01

These statistics yield important observations. First, the skewness and kurtosis statistics of all three sectors indicate that unsystematic real estate risk is non-normal in the vast majority of time periods. This conclusion is supported by Bera-Jarque statistics which are significant at the 5% level in 80 out of 90 time periods.

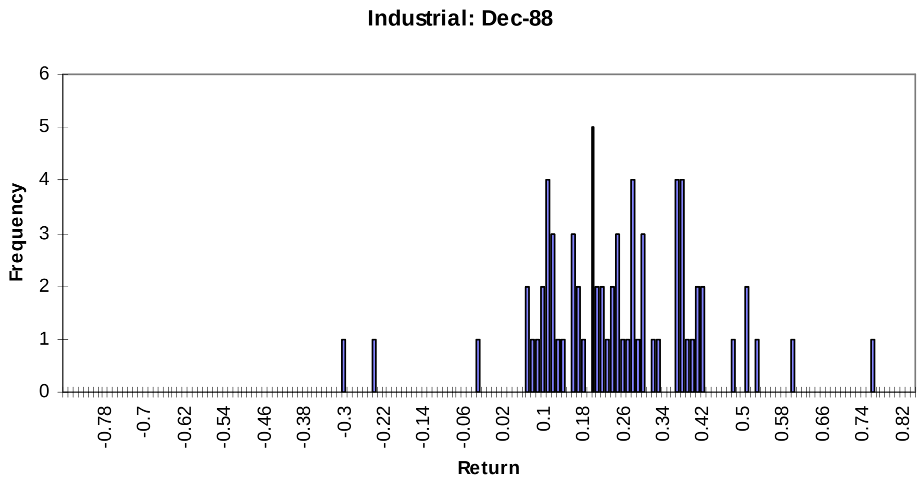
Examination of empirical histograms suggests that, consistent with *a priori* expectations, skewness is often attributable to asymmetry in the frequency of outlying observations. In the example histogram shown in Figure 3 for CBD office properties in December 1988, returns observations produce primary and secondary modes. This is consistent with a mixture of symmetric distributions of unequal locations. Additional examples are shown in Figure 4 (next page).

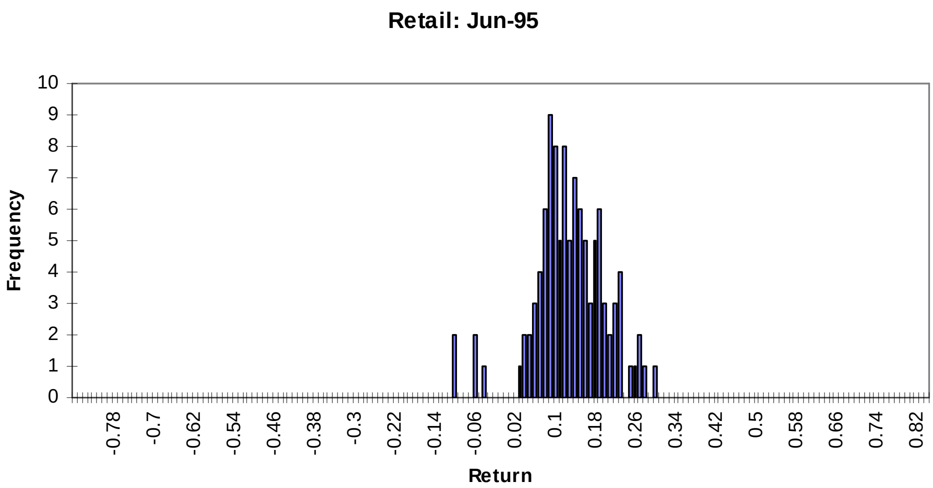
Figure 3
Histogram of Individual Property Returns
Property Council of Australia



The presence of extreme outliers in what are otherwise fairly tightly clustered sample distributions also accounts for the high frequency of leptokurtosis. This is consistent with a mixture model in which the components possess unequal scales.

Figure 4
Sample Cross-sectional Histograms
Property Council of Australia – All Sectors





While the empirical distributions appear to support a DMON model of unsystematic risk, it is necessary to consider whether these characteristics are attributable to the income, rather than capital, component of returns. It may be the case that cross sections of PCA properties encompass multiple income distributions due to regional factors. Examination of cross-sections of empirical income returns provided by PCA indicates that this is not the case; income returns in each period are consistently unimodal and fall within very narrow ranges.

Second, it is also evident that the sample statistics for all three property types vary substantially over time. Mean returns peaked during the period embracing the October 1987 stockmarket crash and bottomed out in 1991. The standard deviation, skewness and kurtosis pf office and retail property risk also peaked around October 1987. Over time, the sector with the widest variation in cross-sectional scale was retail, followed by office and industrial. These results are in keeping with industry perceptions. In contrast, cross-sectional skewness and kurtosis fall within much larger ranges for retail and industrial than for office.

It is noteworthy that the variations in the mean, standard deviation and skewness for each property type appear to be cyclical over time, though this effect appears less pronounced in the case of industrial property. This cyclicality manifests itself in high second order serial correlations, which are used as measures of linear autocorrelation due to the six-monthly frequency of rolling annual returns. Table 8, Table 9 and Table 10 show that mean returns exhibited linear dependence of 0.63 and above. Corresponding figures for the other statistics suggest that standard deviations in all three sectors were also linearly dependent. While it is likely that these second order dependencies are an artefact of the overlap in individual assets' valuation periods, it is likely that they are also indicative of the long cycles that characterise ICRE markets globally, and the serial correlation in the systematic component of valuation-based returns (see Brown and Matysiak (1997)).

Of some interest is the contemporaneous correlations that appear to exist between cross-sectional means and skewnesses in the cases of CBD office and retail properties over the period covered by the data. Zero order correlations between means and kurtosis statistics in the case of CBD office and retail properties were 0.71 and 0.75 respectively, whereas the same statistic for industrial was 0.32. Figure 5 and Figure 6 (next page) show graphically the relationships between these statistics for CBD office and retail over time.

Figure 5
Sample Mean and Skewness vs. Time
Property Council of Australia – CBD Office Properties

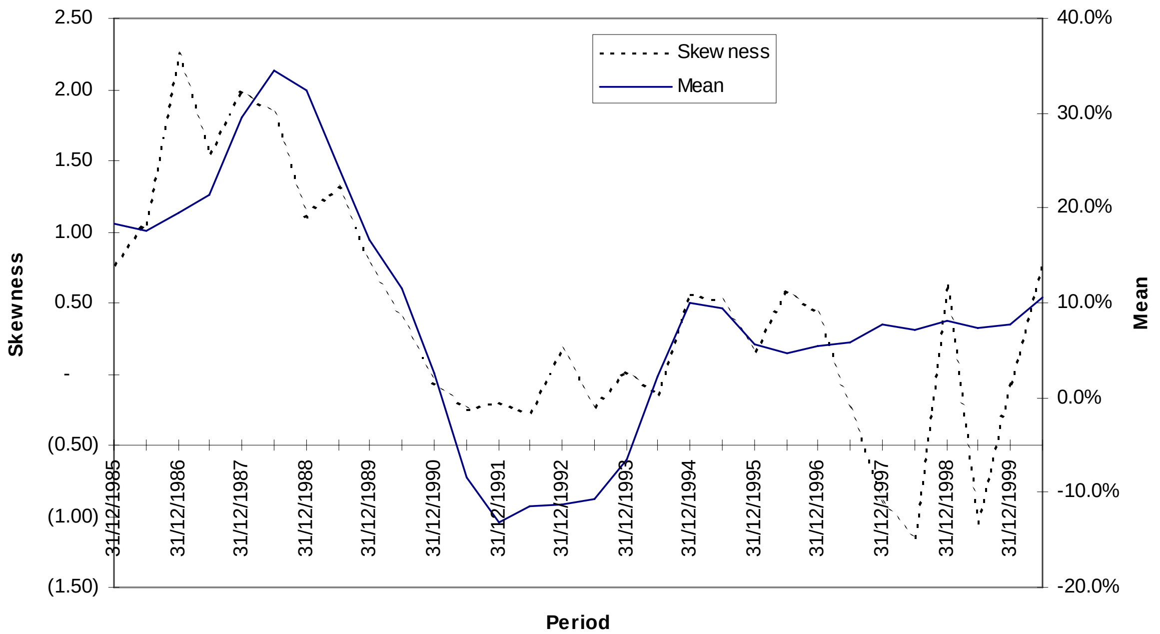
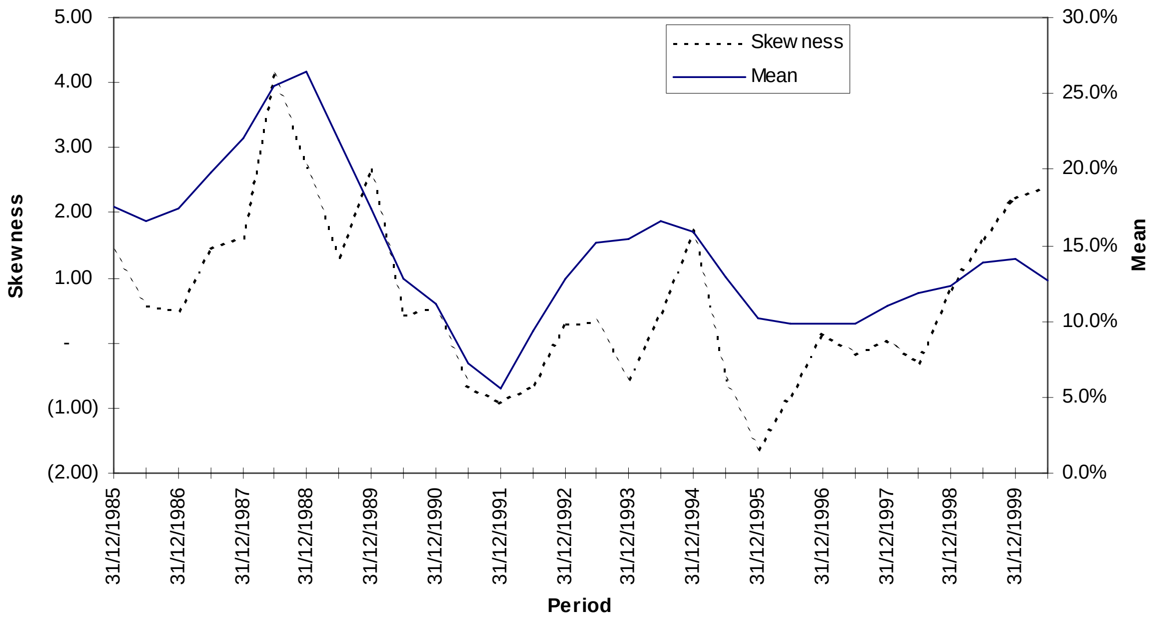


Figure 6
Sample Mean and Skewness vs. Time
Property Council of Australia – Retail Properties



The high correlation between cross-sectional means and contemporaneous skewness may be evidence of one of the *a priori* expectations developed in Section 7.6. In that section, it was hypothesised that the systematic mark down in valuations/prices should give rise to a time-varying difference between the means of the proposed DMON model's two components. This implies that cross-sectional distributions should exhibit time-varying skewness. In the figures on the previous page, it is clearly evident that skewness indeed varies over time in a cyclical manner, with particularly high levels of skewness associated with the bull markets that Australia experienced in the late 1980s.

During this time, a large volume of new construction was undertaken, which was accompanied by the execution of many new leases. This may have given rise, in conjunction with the identified pricing effect around lease events, to a preponderance of upward biased returns. This effect would be exacerbated by the 'irrational rental capitalisation bias' hypothesised by Hendershott (1996a). The results of fitting a DMON model with $N = 2$ later in this chapter should provide insights in this area.

As the behaviour of outlying observations appear to be a driving force behind the non-normality and time-varying distributional characteristics of cross-sectional ICRE returns, more investigation of the empirical returns that lie far from the sample means is warranted. Table 11 shows the highest and lowest order statistics for each sector and time period expressed as absolute percentage deviations from their sample means.

Table 11
Deviations from Sample Mean (% per annum)
Property Council of Australia – All Properties by Type

	OFFICE		RETAIL		INDUSTRIAL	
	MIN	**MAX**	**MIN**	**MAX**	**MIN**	**MAX**
Dec-85	-80	82	-12	32	-58	34
Jun-86	-80	81	-28	31	-60	52
Dec-86	-41	97	-49	57	-17	54
Jun-87	-41	92	-30	58	-25	43
Dec-87	-44	130	-31	68	-40	62
Jun-88	-38	117	-36	154	-41	58
Dec-88	-72	94	-55	135	-55	51
Jun-89	-64	102	-50	70	-54	39
Dec-89	-54	71	-16	68	-65	40
Jun-90	-66	72	-27	31	-38	40
Dec-90	-55	81	-25	31	-31	54
Jun-91	-45	43	-40	28	-39	27
Dec-91	-47	38	-51	34	-36	26
Jun-92	-66	71	-49	30	-44	36
Dec-92	-45	86	-50	44	-38	51
Jun-93	-52	55	-31	39	-48	37
Dec-93	-42	58	-36	28	-39	30
Jun-94	-49	69	-18	25	-39	56
Dec-94	-44	66	-20	41	-39	47
Jun-95	-59	72	-23	17	-30	35
Dec-95	-62	69	-41	22	-29	65
Jun-96	-39	65	-39	22	-29	87
Dec-96	-42	66	-44	44	-38	26
Jun-97	-51	48	-25	21	-39	67
Dec-97	-62	36	-29	32	-30	60
Jun-98	-55	31	-34	32	-39	40
Dec-98	-38	73	-35	64	-33	21
Jun-99	-40	30	-28	59	-18	32

Dec-99	-33	47	-29	58	-30	40
Jun-00	-42	57	-20	51	-29	30

A clear first impression from this table is that individual annual ICRE returns fall across a very large range which appears to vary erratically over time within sectors. These statistics provide very clear empirical proof that the unsystematic risk of ICRE investments is large, thus supporting the conclusions reached by previous research.

More importantly, even when sectors are indicated as being either at the peak (trough) of a cycle, there remain individual properties producing extremely poor (favourable) total returns.

Moreover, because the variability of individual property returns is attributable almost entirely to changes in capital values, Table 11 effectively suggests that (at least) some properties in any given year experience substantial price movements irrespective of market conditions. Further examination of the income returns on individual properties in the PCA dataset shows this to be the case; in all three sectors within most time periods, the variance of income returns contributes very little to that of total returns while approximately 10% of the sample properties in any given period exhibit total returns in absolute value greater than 25%.

8.3 Preliminary tests of the stable Paretian hypothesis

Just as in the case of the DMON model, the stable Paretian model of unsystematic real estate risk proposed by Y&G implies that empirical returns should exhibit some over-identifying characteristics. For example, stable Paretian distributions exhibit the fat tails and weak shoulders associated with excess kurtosis (relative to the normal). The statistics contained in Table 8, Table 9 and Table 10 indicate that empirical returns frequently exhibit such characteristics. Indeed, much of the inductive argument made by Y&G in favour of a stable Paretian hypothesis rests on the presence of such characteristics in empirical returns.

Another characteristic of samples from stable Paretian distributions on which other authors have relied in their empirical tests is that sample variances (or standard deviations) should trend upwards as sample size increases. This follows from the premise that a random variable can be expected to possess a stable Paretian distribution if it represents the summation of a large number of independent variables which themselves possess infinite variance. One implication of this is that sample variances should increase without bound as sample sizes increase if observations are independent drawings from a stable Paretian distribution. In this analysis, it has been assumed that cross-sectional data is composed of independent drawings from an unsystematic risk distribution. This characteristic is used by Mandelbrot (1963) in the case of cotton prices and Fama (1965) in the case of listed equities as a preliminary test of the appropriateness of stable infinite variance probability laws.

Figure 7, Figure 8 and Figure 9 graph the standard deviations and sizes of the cross-sectional returns data provided by the PCA for each of the three ICRE sectors. It is worth noting that, while there are 30 data points for each sector, these are not independent because sequential returns cover overlapping measurement periods. Nonetheless, this poses little complication for the conclusions that can be drawn from these figures about the asymptotic behaviour of sample standard deviations. Though the data covers a relatively short time period, it does not suggest a tendency toward infinity in the sample variance as sample size increases.

Figure 7
Standard Deviation vs. Sample Size
Property Council of Australia – Office Properties

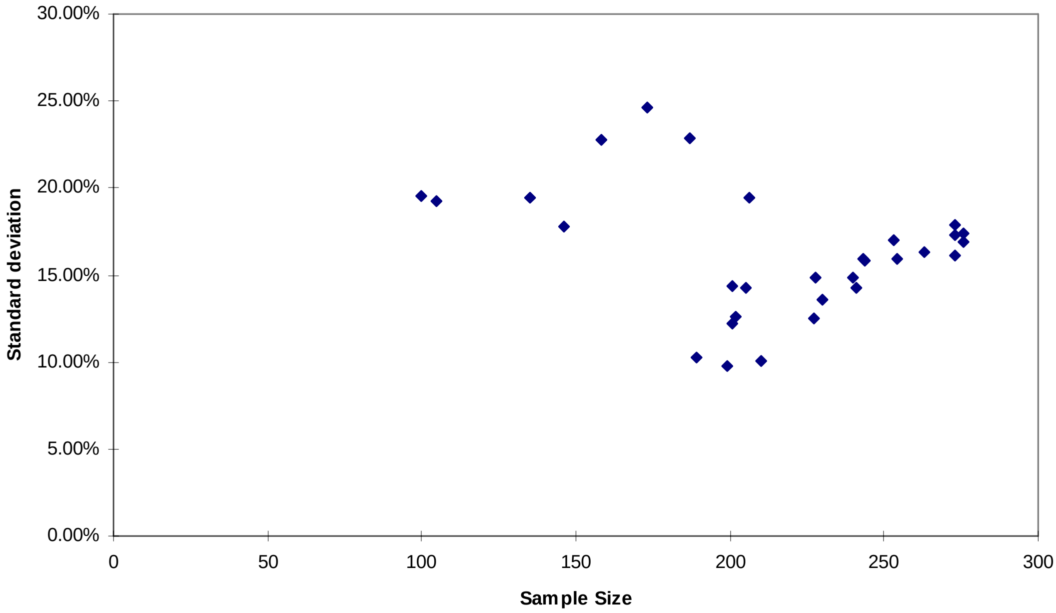


Figure 8
Standard Deviation vs. Sample Size
Property Council of Australia – Retail Properties

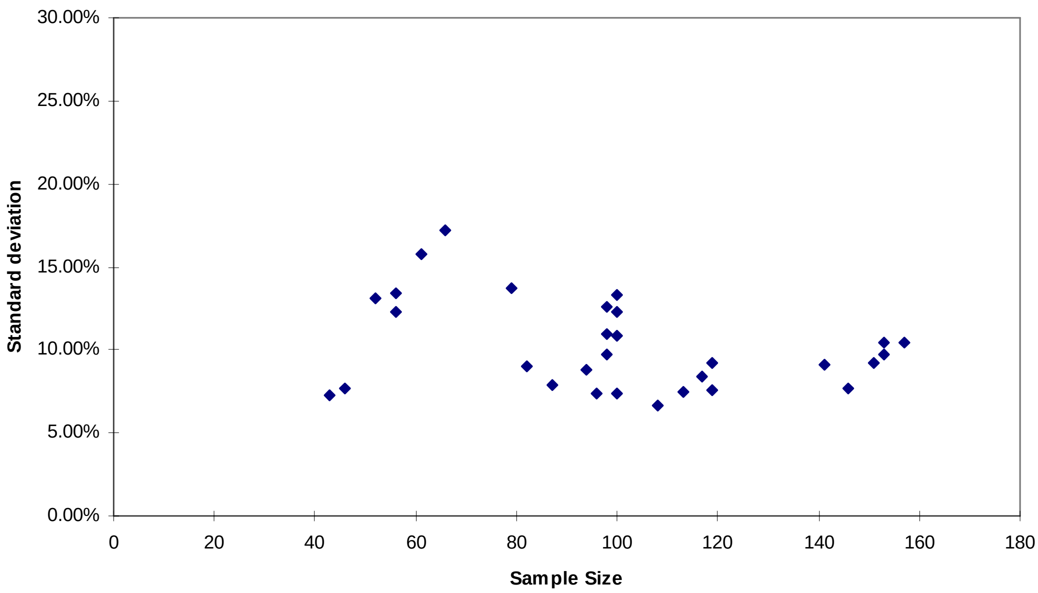
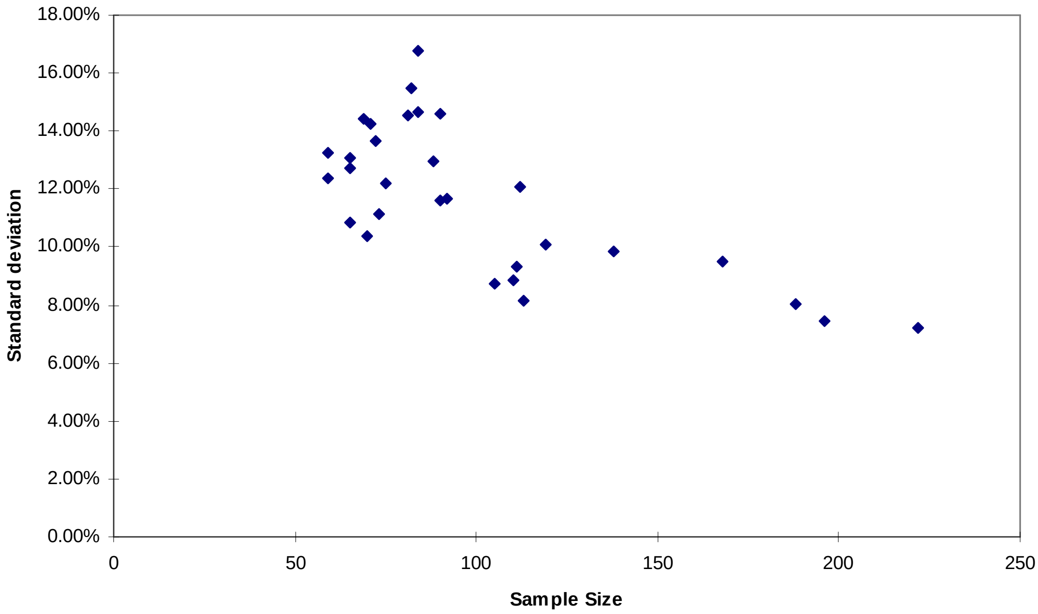


Figure 9
Standard Deviation vs. Sample Size
Property Council of Australia – Industrial Properties



8.4 Empirical curve-fitting

In this section, the procedures that have been used to estimate sample parameters of the DMON and stable Paretian models fitted to the cross-sectional PCA data are discussed. Reference is made to the sampling theory presented in the previous chapter.

8.4.1 Mixtures of normal distributions

In order to fit the two component DMON model to the PCA data, Hasselblad's (1966) generalised steepest descent approach was implemented using Microsoft Excel® in order to obtain solutions to the five (2*N* - 1) maximum likelihood ('ML') equations. This involves the initial use of data analysis tools to create empirical histograms. Seed values for the five sample parameters are then used in the five ML equations to arrive at revised parameter estimates. A simple macro routine is then used to replace the seed values with the revised estimates. The process is then iterated manually. Iteration is halted when no parameter estimate varies in its fourth decimal place as a result of the next iteration.

In practice, this procedure converged in all but two cases (out of a total of 90) in which the component normals were not well separated. In these cases, iteration was halted when the changes in parameter values at each iteration were minimised. Furthermore, tests revealed that final parameter estimates did not vary with the choice of initial values, as this typically lead only to a change in the number of iterations required to converge.

In order to calculate the asymptotic variances of the ML parameter estimates, the integrals shown by Behboodian (1972) (see Equation 16) to underlie the computation of the Fisher information matrix were evaluated. This was done initially by using the Hermite-Gauss quadrature method to evaluate them numerically using Excel®. Tests against the entries in the tables of standard information matrix elements contained in Behboodian (1972) showed that the two agree at worst to three decimal figures.

However, this level of agreement was shown by the process of inverting the Fisher matrix to be insufficient, as this served to amplify errors. As a consequence, an alternative and more direct numerical approach to evaluating the integral was taken in which Excel® was used to manually calculate the area under the function *G(x)* (see Chapter V). This was done by first calculating the value of the function at each of 500 equidistant points in the range $-1.75 < x < 1.75$, as the function's value declines to less than 1×10^{-5} outside of this range for all *c*, *d*, *i* and *j*. Summing these values and then dividing the sum by 0.007 (= 3.5 ÷ 500) produced values that agreed fully and consistently with the entries in Behboodian's tables of standard matrix elements.

8.4.2 Stable Paretian distributions

In order to fit stable Paretian distributions to the PCA data, the procedure presented in McCulloch (1986) was utilised. In this procedure, indices are calculated using five sample quantiles. These indices are used to enter tables provided by McCulloch in order to arrive at estimates of the four parameters which describe stable Paretian distributions. Bivariate interpolation is used when the indices fall between standard table entries. A similar procedure is used to calculate the standard errors of parameter estimates. The estimation of parameters was automated somewhat by copying the tables supplied by McCulloch into Excel®, and using its functions to identify sample quantiles, enter the tables and interpolate the entries in these tables.

In some cases, the calculated index necessary for estimating α was less than 2.439, its minimum permissible value. In these cases, McCulloch recommends that the estimate of α be set equal to 2.0 and the estimate of β be set equal to ±1.0, depending on the sign of its index. It is noteworthy that this situation arose when fitting parameters to five out of the 30 time periods contained in each of the office, retail and industrial subsets of the PCA dataset, suggesting that the sample data in these cases had *thinner* tails than a normal distribution.

Similarly, it was also the case at times that the calculated index for estimating β was too high to be consistent with the calculated index for estimating α, or the interpolated estimate of β was greater than 1.0 in absolute value. In these cases, the sample estimate of β was set at ±1.0. These conditions arose between three and six times in the 24 time periods contained in each of the three property-type data subsets.

8.4.3 Goodness-of-fit

In order to assess the goodness-of-fit of the estimated DMON and stable Paretian models to the PCA data, the non-parametric χ^2 test was applied to each property type and sample period. Since the data was already grouped for the purpose of estimating the DMON model parameters, calculation of the χ^2 statistic involved (1) ascertaining the fitted DMON and stable Paretian density function value for each group, and (2) the further aggregation of these groups in order to ensure that a minimum of five observations was theoretically expected for each group. The degrees of freedom for each test equalled the (number of groups) – (number of parameters + 1).

For the first step, Equation 8 was used in each sample period and property type to calculate the DMON density directly using the sample estimates of the parameters.

The tabulated density function values presented in Holt and Crow (1973) were used for the stable Paretian case due to the non-availability of a closed form expression for the density function. The Holt and Crow tables of interest to this investigation provided density function values for the standard variable x = 0.0 (.1) 8.0 (1) 30 for α = 1.25, 1.50, 1.75 and β = 0.00 (±0.25) ±1.00. As a consequence, interpolation was necessary in order to arrive at density function values for estimates of α and β that fell between the tabulated values.

In order to ascertain the sensitivity of the χ^2 tests to effects of interpolation, tests were conducted for the sample periods in which interpolation appeared to be required. These tests showed that interpolated density functions generally yielded χ^2 statistics that differed very little from those which resulted from using the closest tabulated density. Therefore, interpolation was done only when sample parameter estimates fell near the midpoints of tabulated values.

A further indication of the goodness-of-fit of the DMON model specifically can be obtained by comparing the sample means and variances of the cross-sectional PCA data with those implied by the parameters of the fitted distributions. For this purpose, it is possible to take advantage of the fact that the parameters μ_i and σ_I of a normal density are equal to their population mean and standard deviation. From Stuart and Ord (1987) it is known that the following are true for a two component mixture of normals:

$$m_1' = p_1\mu_1 + p_2\mu_2$$
$$m_2 = p_1\sigma_1^2 + p_2\sigma_2^2 + p_1(\mu_1 - m_1')^2 + p_2(\mu_2 - m_1')^2$$

Equation 17

Where m_i' is the ith moment of a population around an arbitrary point a, with moments about the mean being written without the prime. The second moment about the mean, m_2, is thus the variance of a population. Sample means and standard deviations for all property types are contained in Tables 8 to 10.

Table 12
Mixture of Normals ($N = 2$) – Parameters and Variances
Property Council of Australia – Office Properties

	MLE Parameter Estimation						Asymptotic Variances					
	μ_1	μ_2	σ_1	σ_2	p_1	p_2	μ_1	μ_2	σ_1	σ_2	p_1	$P(\chi>x)$
Dec-85	11.7%	30.6%	7.1%	27.8%	65.3%	34.7%	1.1%	5.1%	0.1%	1.9%	6.5%	19.2%*
Jun-86	12.2%	31.8%	6.0%	30.8%	72.4%	27.6%	0.8%	6.1%	0.1%	2.6%	5.6%	91.4%*
Dec-86	13.0%	34.0%	5.9%	26.3%	72.3%	27.7%	0.7%	4.8%	0.1%	1.7%	5.0%	70.4%*
Jun-87	13.6%	27.8%	6.8%	19.1%	49.9%	50.1%	1.1%	2.5%	0.1%	0.6%	6.6%	63.9%*
Dec-87	23.3%	59.9%	13.3%	24.4%	85.0%	15.0%	1.3%	6.9%	0.3%	2.3%	3.8%	79.2%*
Jun-88	26.0%	60.1%	13.3%	21.8%	80.7%	19.3%	1.3%	5.1%	0.3%	1.6%	4.0%	75.7%*
Dec-88	19.4%	40.0%	9.5%	22.4%	42.3%	57.7%	1.6%	2.5%	0.2%	0.7%	6.0%	70.4%*
Jun-89	17.9%	33.4%	9.2%	24.1%	62.7%	37.3%	1.0%	3.1%	0.2%	1.0%	5.5%	12.7%*
Dec-89	15.0%	22.9%	8.3%	28.0%	80.5%	19.5%	0.7%	4.5%	0.1%	1.8%	4.0%	52.6%*
Jun-90	10.9%	16.4%	10.3%	30.7%	86.8%	13.2%	0.8%	5.9%	0.1%	2.6%	3.7%	62.6%*
Dec-90	4.4%	-4.4%	11.9%	24.9%	79.1%	20.9%	1.0%	4.1%	0.2%	1.4%	5.3%	94.5%*
Jun-91	8.8%	-10.9%	2.6%	17.0%	12.2%	87.8%	0.8%	1.1%	0.0%	0.3%	2.9%	80.6%*
Dec-91	5.6%	-15.4%	4.2%	15.5%	10.8%	89.2%	1.5%	1.1%	0.1%	0.2%	3.1%	3.6%
Jun-92	-8.9%	-17.8%	11.8%	24.1%	71.1%	28.9%	1.1%	3.1%	0.2%	1.0%	5.7%	15.2%*
Dec-92	-11.3%	-11.3%	16.1%	29.1%	90.2%	9.8%	1.1%	7.8%	0.3%	2.7%	5.3%	40.1%*
Jun-93	-5.4%	-14.1%	10.5%	19.8%	38.5%	61.5%	1.7%	1.7%	0.3%	0.5%	7.3%	46.8%*
Dec-93	8.3%	-8.8%	4.8%	16.2%	12.9%	87.1%	1.7%	1.1%	0.1%	0.2%	3.9%	9.0%*
Jun-94	8.6%	-2.5%	7.0%	20.1%	41.6%	58.4%	1.0%	1.8%	0.1%	0.5%	5.4%	11.4%*
Dec-94	10.6%	8.9%	7.4%	23.5%	60.8%	39.2%	0.8%	2.5%	0.1%	0.9%	5.2%	25.3%*
Jun-95	9.9%	8.1%	6.4%	25.8%	66.5%	33.5%	0.6%	2.9%	0.1%	1.1%	4.5%	22.3%*
Dec-95	7.4%	2.6%	6.6%	21.5%	62.9%	37.1%	0.7%	2.4%	0.1%	0.7%	5.0%	5.3%*
Jun-96	4.0%	7.8%	9.9%	23.2%	81.2%	18.8%	0.8%	4.0%	0.1%	1.3%	5.1%	10.0%*
Dec-96	5.7%	4.8%	8.6%	21.8%	79.6%	20.4%	0.8%	3.5%	0.1%	1.1%	5.1%	36.7%*
Jun-97	8.6%	4.4%	3.9%	17.0%	31.6%	68.4%	0.8%	1.5%	0.1%	0.4%	5.4%	59.3%*
Dec-97	10.3%	5.9%	4.9%	18.2%	43.2%	56.8%	0.8%	1.7%	0.1%	0.5%	5.7%	0.1%
Jun-98	9.3%	6.1%	3.3%	15.0%	47.0%	53.0%	0.5%	1.5%	0.0%	0.3%	5.3%	6.8%*
Dec-98	9.3%	4.9%	4.6%	22.1%	71.9%	28.1%	0.5%	3.0%	0.0%	1.0%	4.4%	21.7%*
Jun-99	9.2%	3.3%	4.5%	15.2%	67.8%	32.2%	0.5%	2.0%	0.0%	0.4%	5.1%	49.7%*
Dec-99	9.0%	8.0%	3.5%	12.9%	55.2%	44.8%	0.4%	1.4%	0.0%	0.3%	5.4%	67.0%*
Jun-00	10.7%	9.8%	5.8%	19.6%	80.0%	20.0%	0.6%	3.3%	0.1%	1.0%	4.6%	9.6%*

*Significant at the 5% level

Table 13
Mixture of Normals ($N = 2$) – Parameters and Variances
Property Council of Australia – Retail Properties

	MLE Parameter Estimation						Asymptotic Variances					
	μ_1	μ_2	σ_1	σ_2	p_1	p_2	μ_1	μ_2	σ_1	σ_2	p_1	$P(\chi>x)$
Dec-85	14.2%	28.1%	4.7%	9.9%	75.4%	24.6%	0.9%	4.1%	0.1%	0.5%	8.6%	68.3%*
Jun-86	15.4%	21.7%	5.1%	16.1%	79.6%	20.4%	1.0%	5.7%	0.1%	1.3%	9.3%	12.2%*
Dec-86	16.0%	20.9%	7.2%	25.0%	70.7%	29.3%	1.4%	6.7%	0.2%	2.4%	9.8%	1.7%
Jun-87	16.9%	34.6%	10.3%	25.9%	83.8%	16.2%	1.7%	10.4%	0.3%	3.5%	7.9%	24.0%*
Dec-87	18.1%	43.8%	11.1%	27.3%	84.2%	15.8%	1.8%	11.7%	0.3%	4.1%	7.2%	67.5%*
Jun-88	17.9%	32.2%	7.5%	20.3%	64.7%	35.3%	1.5%	5.0%	0.2%	1.3%	9.6%	17.3%*
Dec-88	16.7%	32.2%	6.3%	22.9%	50.7%	49.3%	1.5%	4.3%	0.2%	1.3%	9.0%	27.9%*
Jun-89	16.3%	32.9%	8.7%	23.8%	66.5%	33.5%	1.5%	5.3%	0.2%	1.7%	8.3%	3.8%
Dec-89	14.0%	26.5%	6.3%	16.8%	73.3%	26.7%	1.0%	4.2%	0.1%	0.9%	7.5%	37.7%*
Jun-90	11.1%	14.7%	4.1%	11.8%	50.8%	49.2%	0.9%	1.9%	0.1%	0.3%	9.6%	40.1%*
Dec-90	9.1%	14.9%	6.4%	13.3%	65.1%	34.9%	1.1%	2.7%	0.1%	0.5%	9.9%	7.1%*
Jun-91	9.8%	4.9%	5.5%	15.7%	46.9%	53.1%	1.2%	2.3%	0.1%	0.5%	9.1%	29.4%*
Dec-91	10.1%	1.6%	4.2%	16.0%	46.4%	53.6%	0.9%	2.3%	0.1%	0.5%	7.6%	1.3%
Jun-92	10.2%	7.7%	5.3%	17.5%	66.0%	34.0%	0.8%	3.1%	0.1%	0.8%	7.7%	80.7%*
Dec-92	11.2%	14.3%	5.2%	18.4%	47.0%	53.0%	1.1%	2.6%	0.1%	0.7%	8.3%	68.5%*
Jun-93	13.8%	16.8%	5.7%	17.2%	54.8%	45.2%	1.1%	2.7%	0.1%	0.7%	8.7%	13.3%*
Dec-93	16.9%	3.5%	8.6%	16.3%	88.5%	11.5%	1.0%	6.6%	0.1%	1.5%	5.9%	78.1%*
Jun-94	34.1%	14.9%	3.5%	7.0%	8.9%	91.1%	1.5%	0.8%	0.1%	0.1%	3.3%	97.6%*
Dec-94	14.7%	43.7%	6.5%	12.2%	95.8%	4.2%	0.7%	7.8%	0.1%	1.3%	2.3%	30.4%*
Jun-95	13.0%	13.0%	4.6%	9.8%	57.0%	43.0%	0.8%	1.6%	0.1%	0.2%	10.9%	61.2%*
Dec-95	10.8%	8.2%	4.3%	15.6%	77.0%	23.0%	0.5%	3.1%	0.0%	0.7%	5.9%	72.8%*
Jun-96	10.1%	8.3%	6.1%	16.1%	88.6%	11.4%	0.7%	4.9%	0.1%	1.1%	5.4%	5.2%*
Dec-96	9.6%	12.5%	6.1%	23.2%	90.8%	9.2%	0.6%	7.4%	0.1%	2.5%	4.0%	55.2%*
Jun-97	9.9%	9.7%	3.8%	11.3%	62.7%	37.3%	0.6%	1.8%	0.0%	0.3%	7.9%	11.2%*
Dec-97	10.4%	11.9%	4.3%	12.9%	57.2%	42.8%	0.7%	1.7%	0.0%	0.3%	7.2%	7.9%*
Jun-98	11.9%	11.9%	4.1%	13.4%	59.0%	41.0%	0.6%	1.8%	0.0%	0.3%	6.7%	37.3%*
Dec-98	13.3%	8.7%	5.8%	19.3%	78.7%	21.3%	0.6%	3.5%	0.1%	1.0%	5.1%	24.9%*
Jun-99	12.5%	17.3%	4.2%	15.9%	70.1%	29.9%	0.5%	2.5%	0.0%	0.6%	5.5%	12.1%*
Dec-99	12.5%	21.6%	4.9%	20.5%	81.9%	18.1%	0.5%	4.1%	0.0%	1.2%	4.3%	20.2%*
Jun-00	11.8%	20.8%	4.9%	18.4%	90.8%	9.2%	0.5%	5.5%	0.0%	1.4%	3.4%	64.2%*

*Significant at the 5% level

Table 14
Mixture of Normals ($N = 2$) – Parameters and Variances
Property Council of Australia – Industrial Properties

	MLE Parameter Estimation						Asymptotic Variances					
	μ_1	μ_2	σ_1	σ_2	p_1	p_2	μ_1	μ_2	σ_1	σ_2	p_1	$P(\chi>x)$
Dec-85	13.9%	12.2%	5.8%	17.0%	58.1%	41.9%	1.4%	3.6%	0.1%	0.9%	11.4%	34.0%*
Jun-86	14.0%	24.7%	6.4%	31.0%	85.0%	15.0%	1.0%	10.8%	0.1%	4.9%	6.2%	19.3%*
Dec-86	11.7%	33.3%	4.7%	15.5%	73.3%	26.7%	0.7%	4.5%	0.1%	0.9%	6.4%	16.4%*
Jun-87	11.6%	26.4%	3.5%	15.6%	48.9%	51.1%	0.8%	3.0%	0.0%	0.6%	8.1%	62.8%*
Dec-87	20.1%	31.6%	8.4%	26.1%	70.2%	29.8%	1.5%	6.4%	0.2%	2.3%	8.9%	14.5%*
Jun-88	22.4%	35.1%	9.2%	28.8%	78.7%	21.3%	1.5%	8.5%	0.2%	3.4%	7.9%	14.0%*
Dec-88	25.0%	24.2%	11.9%	30.1%	82.6%	17.4%	1.8%	9.5%	0.3%	4.0%	8.5%	8.5%*
Jun-89	8.7%	26.4%	0.9%	17.0%	12.6%	87.4%	0.4%	2.2%	0.0%	0.5%	4.8%	24.6%*
Dec-89	19.6%	28.3%	9.5%	23.9%	75.0%	25.0%	1.6%	6.3%	0.2%	2.1%	9.2%	6.7%*
Jun-90	9.3%	17.5%	3.5%	16.0%	44.7%	55.3%	0.8%	2.6%	0.0%	0.6%	8.4%	30.6%*
Dec-90	7.8%	-2.3%	4.3%	15.1%	49.3%	50.7%	1.0%	2.6%	0.1%	0.5%	8.6%	42.7%*
Jun-91	-0.3%	-18.3%	8.8%	13.6%	76.4%	23.6%	1.3%	4.2%	0.2%	0.8%	7.1%	63.5%*
Dec-91	-3.1%	-20.4%	9.5%	11.9%	67.1%	32.9%	1.5%	3.1%	0.2%	0.5%	8.0%	64.7%*
Jun-92	1.5%	-19.8%	11.3%	11.9%	71.1%	28.9%	1.7%	3.2%	0.3%	0.5%	7.2%	29.6%*
Dec-92	-2.5%	4.6%	14.5%	14.7%	9.8%	90.2%	13.9%	1.8%	2.7%	0.4%	22.1%	18.0%*
Jun-93	4.6%	2.9%	9.8%	19.2%	60.8%	39.2%	1.9%	3.6%	0.3%	1.0%	12.6%	18.0%*
Dec-93	9.7%	5.6%	1.4%	12.6%	13.4%	86.6%	0.8%	1.4%	0.0%	0.3%	5.7%	68.7%*
Jun-94	13.5%	19.1%	9.6%	23.5%	72.1%	27.9%	1.5%	5.2%	0.2%	1.7%	9.0%	85.6%*
Dec-94	17.7%	19.1%	5.7%	19.0%	52.6%	47.4%	1.1%	3.0%	0.1%	0.8%	8.7%	32.0%*
Jun-95	11.5%	18.6%	3.4%	11.7%	35.0%	65.0%	0.9%	1.5%	0.1%	0.2%	7.7%	11.6%*
Dec-95	13.1%	20.3%	2.9%	17.9%	64.2%	35.8%	0.4%	2.9%	0.0%	0.8%	5.8%	16.0%*
Jun-96	14.0%	20.3%	7.3%	20.0%	94.0%	6.0%	0.8%	9.0%	0.1%	2.5%	4.1%	3.8%
Dec-96	14.0%	9.2%	5.5%	14.9%	65.4%	34.6%	0.8%	2.5%	0.1%	0.5%	7.6%	15.1%*
Jun-97	15.7%	16.4%	7.2%	26.9%	86.2%	13.8%	0.8%	7.1%	0.1%	2.9%	4.9%	10.6%*
Dec-97	15.6%	21.7%	6.1%	24.6%	90.3%	9.7%	0.6%	7.1%	0.1%	2.6%	3.7%	75.7%*
Jun-98	15.1%	18.2%	5.7%	17.7%	80.2%	19.8%	0.6%	3.3%	0.1%	0.8%	5.0%	39.2%*
Dec-98	14.8%	15.7%	3.8%	9.3%	43.5%	56.5%	0.7%	0.9%	0.0%	0.1%	7.5%	18.8%
Jun-99	13.8%	24.4%	4.1%	8.9%	84.9%	15.1%	0.3%	2.1%	0.0%	0.2%	3.4%	36.5%*
Dec-99	13.4%	17.2%	5.1%	18.2%	87.7%	12.3%	0.4%	4.0%	0.0%	1.1%	3.6%	11.1%*
Jun-00	12.2%	14.0%	2.6%	10.0%	38.3%	61.7%	0.6%	1.2%	0.0%	0.2%	7.7%	93.8%*

*Significant at the 5% level

Table 15
Stable Distribution – Parameters and Variances
Property Council of Australia – Office Properties

	Stable Parameter Estimates				Asymptotic Variances				
	α	δ	c	β	α	δ	c	β	$P(\chi>x)$
Dec-85	1.46	20.7%	8.0%	1.00	0.28	5.6%	1.1%	0.59	10.7%*
Jun-86	1.19	26.8%	5.6%	0.82	0.23	8.7%	1.0%	0.31	0.0%
Dec-86	1.25	23.0%	5.5%	0.78	0.21	8.5%	0.7%	0.29	72.3%*
Jun-87	1.65	21.1%	8.9%	1.00	0.25	2.3%	1.0%	0.92	31.3%*
Dec-87	1.57	31.9%	11.3%	1.00	0.23	3.4%	1.2%	0.68	13.1%*
Jun-88	1.67	35.4%	12.9%	1.00	0.23	2.9%	1.3%	0.90	32.6%*
Dec-88	2.00	27.9%	14.5%	1.00	0.29	1.9%	1.3%	∞	2.9%
Jun-89	1.72	23.4%	10.1%	1.00	0.22	1.8%	0.9%	0.93	16.8%*
Dec-89	1.55	17.5%	6.8%	0.34	0.15	1.4%	0.6%	0.27	20.4%*
Jun-90	1.73	11.2%	8.3%	0.11	0.18	1.2%	0.7%	0.41	42.8%*
Dec-90	1.69	2.6%	8.9%	-0.51	0.17	1.4%	0.7%	0.47	96.3%*
Jun-91	2.00	-6.9%	14.0%	-1.00	0.24	1.5%	1.1%	∞	1.7%
Dec-91	2.00	-13.2%	12.4%	-1.00	0.24	1.3%	0.9%	∞	0.0%
Jun-92	1.75	-12.4%	9.9%	-1.00	0.19	1.4%	0.8%	0.87	8.4%*
Dec-92	2.00	-10.8%	12.9%	-1.00	0.24	1.4%	1.0%	∞	0.5%
Jun-93	1.74	-11.9%	10.5%	-0.77	0.18	1.4%	0.8%	0.69	39.5%*
Dec-93	2.00	-6.1%	11.9%	-1.00	0.25	1.3%	0.9%	∞	0.0%
Jun-94	1.55	1.3%	9.3%	-0.70	0.17	2.0%	0.7%	0.37	1.2%
Dec-94	1.39	8.5%	7.4%	-0.14	0.12	2.4%	0.6%	0.20	31.1%*
Jun-95	1.20	9.0%	6.2%	-0.05	0.10	2.8%	0.6%	0.19	3.6%
Dec-95	1.40	5.4%	6.5%	-0.30	0.13	2.2%	0.6%	0.19	2.6%
Jun-96	1.77	4.8%	8.2%	-0.11	0.19	1.1%	0.7%	5.43	11.9%*
Dec-96	1.68	5.9%	7.2%	-0.15	0.17	1.1%	0.6%	0.38	27.4%*
Jun-97	1.50	6.4%	7.8%	-0.19	0.14	1.7%	0.7%	0.23	5.7%*
Dec-97	1.42	8.4%	6.5%	-0.15	0.14	2.1%	0.6%	0.22	0.0%
Jun-98	1.16	4.8%	4.1%	-0.28	0.12	102.1%	0.5%	0.19	0.0%
Dec-98	1.19	5.9%	3.8%	-0.29	0.13	64.3%	0.4%	0.19	0.8%
Jun-99	1.36	6.4%	4.2%	-0.39	0.14	2.1%	0.4%	0.20	55.4%*
Dec-99	1.21	6.5%	3.9%	-0.20	0.12	41.2%	0.4%	0.19	26.1%*
Jun-00	1.39	9.5%	4.4%	-0.14	0.14	1.6%	0.4%	0.23	4.4%

*Significant at the 5% level

Table 16
Stable Distribution – Parameters and Variances
Property Council of Australia – Retail Properties

	Stable Parameter Estimates				Asymptotic Variances				
	α	δ	c	β	α	δ	c	β	$P(\chi>x)$
Dec-85	1.54	18.2%	4.1%	1.00	0.44	2.5%	0.8%	1.14	60.6%*
Jun-86	1.91	15.4%	5.0%	1.00	0.55	1.4%	0.9%	∞	0.0%
Dec-86	1.45	17.0%	6.5%	0.29	0.28	3.8%	1.2%	0.43	1.2%
Jun-87	1.53	18.3%	7.2%	0.10	0.28	2.8%	1.2%	0.50	8.8%*
Dec-87	1.42	22.3%	7.2%	0.48	0.30	5.7%	1.4%	0.40	50.2%*
Jun-88	2.00	20.8%	9.6%	1.00	0.51	2.2%	1.6%	∞	1.7%
Dec-88	2.00	21.0%	11.4%	1.00	0.49	2.5%	1.8%	∞	0.2%
Jun-89	2.00	18.6%	9.8%	1.00	0.45	2.0%	1.4%	∞	0.0%
Dec-89	1.77	17.4%	6.0%	1.00	0.36	1.5%	0.9%	1.59	35.7%*
Jun-90	1.48	12.7%	4.1%	0.26	0.22	1.5%	0.6%	0.33	15.9%*
Dec-90	1.44	13.0%	5.4%	0.40	0.22	2.8%	0.8%	0.31	3.8%
Jun-91	1.39	6.7%	6.1%	-0.30	0.20	3.4%	0.9%	0.30	37.7%*
Dec-91	1.51	4.0%	6.3%	-0.88	0.28	2.5%	0.8%	0.60	0.6%
Jun-92	1.34	9.8%	4.7%	0.01	0.18	2.6%	0.6%	0.32	70.5%*
Dec-92	1.28	14.7%	6.0%	0.30	0.19	4.9%	0.9%	0.28	47.7%*
Jun-93	1.27	15.2%	6.0%	0.12	0.17	4.2%	0.8%	0.29	6.2%*
Dec-93	2.00	14.6%	6.9%	1.00	0.41	1.2%	0.9%	∞	1.3%
Jun-94	1.59	17.3%	5.2%	0.44	0.25	1.6%	0.7%	0.51	78.2%*
Dec-94	1.65	15.7%	4.3%	0.27	0.25	1.1%	0.6%	0.54	63.3%*
Jun-95	2.00	12.7%	4.7%	1.00	0.39	0.8%	0.6%	∞	1.0%
Dec-95	1.44	10.3%	3.8%	-0.06	0.18	1.4%	0.5%	0.30	64.6%*
Jun-96	1.53	9.5%	3.9%	-0.15	0.20	1.0%	0.5%	0.34	5.3%*
Dec-96	1.69	9.7%	4.4%	-0.02	0.24	0.9%	0.5%	0.52	67.0%*
Jun-97	1.35	10.7%	3.6%	0.17	0.17	2.0%	0.5%	0.28	26.5%*
Dec-97	1.37	11.7%	4.1%	0.22	0.16	1.9%	0.5%	0.25	12.1%*
Jun-98	1.28	11.6%	4.1%	-0.05	0.14	2.1%	0.5%	0.25	32.2%*
Dec-98	1.46	11.7%	4.7%	-0.38	0.17	1.7%	0.5%	0.25	16.2%*
Jun-99	1.34	13.9%	4.0%	0.27	0.15	2.1%	0.5%	0.23	8.2%
Dec-99	1.40	15.0%	4.0%	0.51	0.18	2.2%	0.5%	0.24	23.5%*
Jun-00	1.81	12.2%	3.8%	0.69	0.27	0.7%	0.4%	19.17	53.4%*

*Significant at the 5% level

Table 17
Stable Distribution – Parameters and Variances
Property Council of Australia – Industrial Properties

	Stable Parameter Estimates				Asymptotic Variances				
	α	δ	c	β	α	δ	c	β	$P(\chi>x)$
Dec-85	1.48	14.3%	4.9%	-0.01	0.25	2.1%	0.8%	0.44	11.3%*
Jun-86	1.23	20.1%	4.4%	0.49	0.26	6.3%	0.9%	0.31	25.4%*
Dec-86	1.14	25.3%	4.1%	0.72	0.27	∞	1.0%	0.33	0.0%
Jun-87	1.63	18.1%	7.2%	1.00	0.37	2.9%	1.2%	1.30	3.9%
Dec-87	1.42	26.9%	7.8%	0.73	0.32	6.8%	1.3%	0.54	4.2%
Jun-88	1.43	27.6%	7.0%	0.63	0.30	5.5%	1.2%	0.47	0.3%
Dec-88	2.00	24.5%	11.8%	1.00	0.48	2.5%	1.8%	∞	6.2%*
Jun-89	2.00	22.3%	12.0%	1.00	0.48	2.6%	1.8%	∞	0.2%
Dec-89	2.00	20.3%	9.2%	1.00	0.47	1.9%	1.4%	∞	0.0%
Jun-90	1.38	15.5%	5.6%	0.66	0.28	5.6%	0.9%	0.42	1.0%
Dec-90	1.94	4.6%	7.1%	-1.00	0.44	1.5%	1.0%	∞	22.7%*
Jun-91	2.00	-3.4%	8.3%	-1.00	0.45	1.6%	1.2%	∞	1.5%
Dec-91	1.98	-7.2%	9.1%	-1.00	0.44	1.8%	1.3%	∞	0.0%
Jun-92	2.00	-4.5%	11.2%	-1.00	0.44	2.2%	1.5%	∞	1.0%
Dec-92	1.96	4.3%	10.0%	-1.00	0.42	2.0%	1.4%	∞	0.8%
Jun-93	1.84	5.3%	8.9%	-0.44	0.35	1.9%	1.2%	38.42	14.8%*
Dec-93	1.81	7.0%	7.4%	-0.56	0.34	1.6%	1.0%	24.97	7.8%*
Jun-94	1.58	15.7%	8.2%	0.25	0.25	2.4%	1.1%	0.47	83.8%*
Dec-94	1.33	18.5%	6.0%	0.17	0.19	3.8%	0.9%	0.31	12.9%*
Jun-95	1.95	14.9%	6.6%	1.00	0.38	1.2%	0.8%	∞	0.0%
Dec-95	1.23	16.2%	3.1%	0.40	0.18	2.9%	0.5%	0.24	11.2%*
Jun-96	1.27	14.4%	3.8%	0.08	0.16	2.5%	0.5%	0.28	4.5%
Dec-96	1.36	11.7%	4.5%	-0.22	0.17	2.4%	0.6%	0.27	4.9%
Jun-97	1.50	15.1%	5.0%	0.05	0.19	1.5%	0.6%	0.32	10.6%*
Dec-97	1.70	15.9%	4.7%	0.76	0.25	1.0%	0.5%	0.88	72.4%*
Jun-98	1.70	16.7%	4.8%	0.75	0.23	0.9%	0.5%	0.79	43.9%
Dec-98	1.63	15.1%	4.5%	0.04	0.17	0.8%	0.4%	0.35	17.5%*
Jun-99	1.56	14.5%	3.8%	0.21	0.15	0.7%	0.3%	0.27	22.6%*
Dec-99	1.55	13.7%	3.6%	-0.01	0.16	0.8%	0.3%	0.29	0.2%
Jun-00	1.45	13.4%	4.0%	0.19	0.19	1.5%	0.5%	0.30	76.1%*

*Significant at the 5% level

Table 18
Mixture of Normals ($N = 2$) – Sample vs. Implied Means and Standard Deviations – Property Council of Australia – All Properties

	Sample and Implied Means						Sample and Implied Standard Deviations					
	Office		Retail		Industrial		Office		Retail		Industrial	
	Sample	Implied	Sample	Implied	Sample	Implied	Sample	Implied	Sample	Implied	Sample	Implied
Dec-85	18.3%	18.3%	17.6%	17.6%	13.1%	13.2%	19.6%	19.5%	8.9%	8.8%	12.0%	11.9%
Jun-86	17.6%	17.6%	16.6%	16.7%	15.5%	15.6%	19.2%	19.1%	9.0%	9.0%	14.0%	13.9%
Dec-86	17.7%	18.8%	17.4%	17.4%	16.7%	17.5%	15.3%	17.5%	15.0%	15.0%	11.5%	13.1%
Jun-87	21.4%	20.7%	19.8%	19.8%	19.2%	19.2%	17.8%	16.0%	15.6%	15.5%	13.7%	13.6%
Dec-87	29.6%	28.8%	22.1%	22.2%	23.5%	23.5%	22.8%	20.3%	17.7%	17.6%	16.8%	16.7%
Jun-88	34.4%	32.6%	25.5%	23.0%	25.1%	25.1%	24.7%	20.4%	25.2%	15.1%	16.6%	16.5%
Dec-88	32.3%	31.3%	26.4%	24.4%	24.9%	24.9%	22.9%	20.8%	24.9%	18.4%	16.8%	16.6%
Jun-89	24.2%	23.7%	21.9%	21.9%	24.2%	24.2%	19.4%	18.0%	17.4%	17.3%	17.1%	16.9%
Dec-89	16.6%	16.6%	17.4%	17.3%	21.8%	21.8%	14.8%	14.8%	11.7%	11.6%	15.1%	15.0%
Jun-90	11.6%	11.6%	12.8%	12.8%	13.9%	13.9%	14.9%	14.8%	8.9%	9.0%	12.9%	12.8%
Dec-90	2.6%	2.6%	11.1%	11.1%	2.7%	2.7%	16.0%	15.9%	9.9%	9.8%	12.4%	12.3%
Jun-91	-8.5%	-8.5%	7.2%	7.2%	-4.5%	-4.5%	17.3%	17.2%	12.4%	12.3%	12.8%	12.7%
Dec-91	-13.1%	-13.1%	5.5%	5.5%	-8.8%	-8.8%	16.1%	16.1%	12.8%	12.7%	13.3%	13.2%
Jun-92	-11.5%	-11.5%	9.4%	9.4%	-4.6%	-4.6%	16.9%	16.8%	11.1%	11.1%	15.1%	15.0%
Dec-92	-11.3%	-11.3%	12.8%	12.9%	3.9%	3.9%	17.8%	17.8%	14.0%	13.9%	14.9%	14.8%
Jun-93	-10.8%	-10.8%	15.2%	15.2%	3.9%	3.9%	17.4%	17.4%	12.4%	12.4%	14.4%	14.3%
Dec-93	-6.6%	-6.6%	15.4%	15.4%	6.2%	6.2%	16.3%	16.2%	10.8%	10.7%	11.9%	11.8%
Jun-94	2.1%	2.1%	16.6%	16.6%	15.1%	15.1%	17.0%	16.9%	8.7%	8.7%	15.2%	15.1%
Dec-94	10.0%	10.0%	15.9%	15.9%	18.4%	18.4%	15.9%	15.8%	9.0%	9.0%	13.8%	13.7%
Jun-95	9.3%	9.3%	13.0%	13.0%	16.1%	16.1%	15.9%	15.9%	7.4%	7.3%	10.3%	10.2%
Dec-95	5.6%	5.6%	10.2%	10.2%	15.7%	15.7%	14.3%	14.3%	8.5%	8.4%	11.6%	11.5%
Jun-96	4.7%	4.7%	9.9%	9.9%	14.5%	14.4%	13.6%	13.5%	7.9%	7.9%	11.9%	8.7%
Dec-96	5.5%	5.5%	9.8%	9.8%	12.3%	12.3%	12.5%	12.5%	9.2%	9.2%	10.1%	10.1%
Jun-97	5.8%	5.7%	9.8%	9.8%	15.8%	15.8%	14.4%	14.3%	7.5%	7.5%	12.1%	12.0%
Dec-97	7.8%	7.8%	11.1%	11.1%	16.2%	16.2%	14.3%	14.2%	9.1%	9.1%	9.8%	9.8%
Jun-98	7.2%	7.6%	11.9%	11.9%	15.7%	15.7%	12.2%	11.3%	9.2%	9.1%	9.5%	9.5%
Dec-98	8.1%	8.1%	12.3%	12.3%	15.4%	15.3%	12.6%	12.5%	10.5%	10.4%	7.5%	7.4%
Jun-99	7.3%	7.3%	13.9%	13.9%	14.4%	15.4%	9.8%	9.8%	9.7%	9.6%	7.2%	6.4%
Dec-99	7.8%	8.5%	14.1%	14.1%	13.8%	13.8%	10.1%	9.0%	10.4%	10.4%	8.1%	8.1%
Jun-00	10.5%	10.5%	12.7%	12.6%	13.3%	13.3%	10.2%	10.2%	7.7%	7.7%	8.1%	8.1%

8.5 *Evaluation of the results of model-fitting*

Estimates of the empirical parameters and their asymptotic variances for the two alternative distributional models under consideration are presented in Table 12 through Table 17. The last column in each table is the probability that χ^2 is greater than the value of the statistic calculated for each sample against the fitted density.

The results of the χ^2 goodness-of-fit tests clearly indicate that the ability of a two component DMON model to describe empirical unsystematic real estate risk is strong in absolute terms and far superior to that of a stable Paretian model. Of the 30 sample periods, the DMON model is rejected at the 5% level in just two periods for office and industrial returns and three periods for retail returns. In contrast, the stable Paretian alternative is rejected in 13 periods in the case of office returns, 10 periods in the case of retail returns and 16 periods for industrial returns.

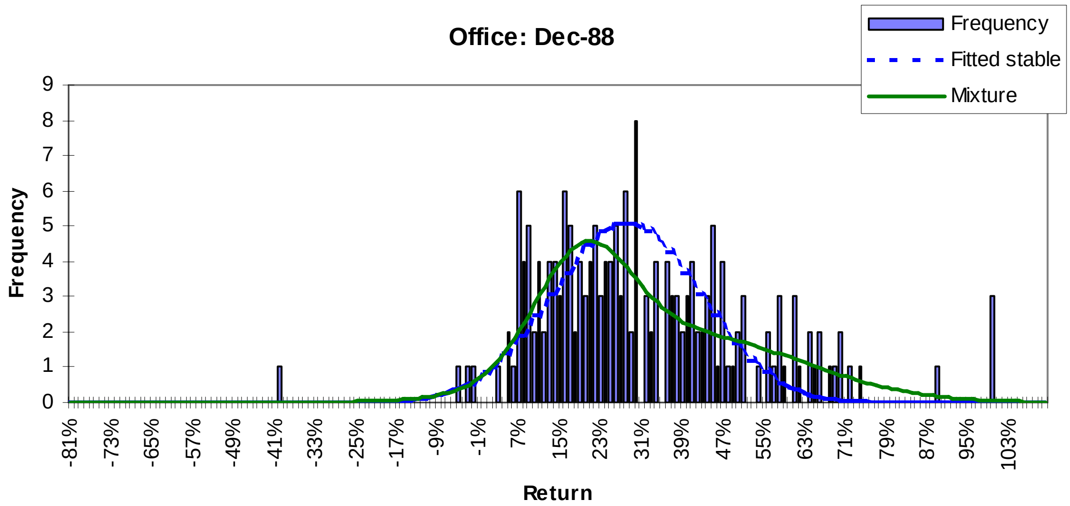
The high rate of rejection of the stable Paretian model is not surprising, given the difficulties which arose in fitting this model to empirical data (see the previous section). These difficulties manifested themselves in the frequency with which it was necessary to force the empirical estimate of α to 2.0. While this particular difficulty may be an artefact of sampling error or the finiteness of the sample set, it raises a clear warning about the appropriateness of this model and the need to conduct goodness-of-fit tests.

Additional evidence of the ability of the DMON to fit the empirical PCA data is provided by the statistics listed in Table 18. These figures demonstrate an extremely high degree of correspondence between the means and standard deviations of the sample data, and the values of these statistics implied by the parameters of the DMON distributions fitted to this data.

An example of the clearly superior ability of the DMON distributional model to fit the empirical data is shown in Figure 10. Fitted density functions for the two candidate models are overlaid in this figure on the histogram of CBD office returns for the year ended December 1988. While the conclusions that can be drawn from a visual fit of hypothesised models to one histogram are by no means definitive, the better fit of the DOMN model in this single case appears indisputable.

As a consequence, while it may be concluded from Table 15 through Table 17 that a stable Paretian probability law is better than a normal law at explaining empirical ICRE risk, it is clearly not as powerful as a DMON probability law.

Figure 10
Stable and DMON Densities and Sample Histogram
Property Council of Australia – Office Properties



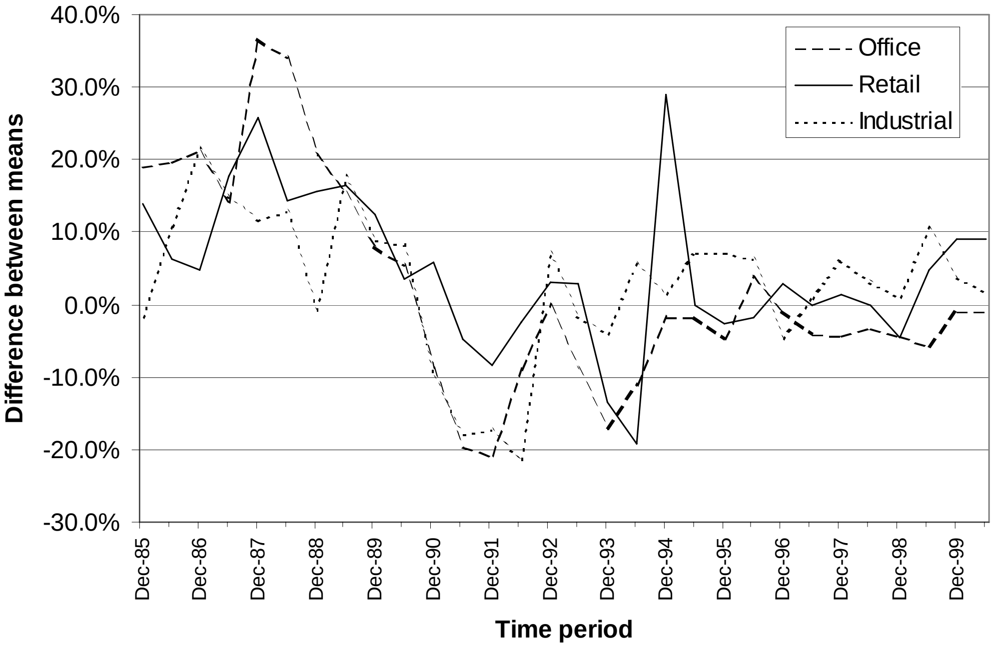
In addition to the goodness-of-fit tests, indications of the appropriateness of the candidate models may be obtained by considering the degree to which their sample parameter estimates are reasonable and consistent with *a priori* expectations.

In the case of the DMON model, the estimates in most time periods across all three property types verify that samples of returns can indeed be partitioned into a mixture of two normals of differing locations with one component possessing relatively much greater variance. This is consistent with the expectations developed in the previous chapter that cross-sectional data should exhibit the characteristics of a diffusion process contaminated by a jump process.

A good example of the expected effect is exhibited by the parameter estimates for December 1987 and June 1988 for CBD office, when the market peaked. The estimates show that the bulk of returns can be described by a normal component with a location of about 25% per annum and a scale of 13.3%. However, between 15% and 20% of properties were better described by a normal component with a location of 60% per annum and a scale of 22% to 24% per annum. These sample parameters are clearly consistent with biases associates with new leases in new buildings, capitalised at irrationally low capitalisation rates that ignored the mean reversion of rents.

Time variation in the differences between the locations of the higher and lower risk components is also wholly consistent with expectations. As shown in Figure 11, these differences were substantial across all property types, with the differences peaking in June 1988, at the height of both the rental and investment markets.

Figure 11
Differences Between Component Means
Property Council of Australia – All Properties



Three years later near December 1991, the situation temporarily reversed itself when the first rent reviews associated with the leases written at the height of the market occurred. The reduction in market rents coupled with the valuation bias that appears to surround lease events precipitated a negative location in the second, higher risk component of the DMON model.

One alternative explanation for the bimodality of the cross sectional distributions that is particularly evident in the early years covered by the sample data is that geographic sub-markets in Australia had differing expected returns and cross-sectional dispersions. While the latter cannot be checked using the data available, it is possible to investigate the former by examining the sub-market indices produced by PCA. In Table 19, data on the sub-market weightings and total returns for the Australian CBD office sector for the period June 1986 to June 1991 are presented.

Table 19
Capital Weightings and Index Returns
Property Council of Australia – CBD Office Properties

	Capital Value Weighting			**Total Return**		
	Sydney	**Melbourne**	**Brisbane**	**Sydney**	**Melbourne**	**Brisbane**
Jun-86	51.2%	25.7%	9.4%	5.6%	9.2%	4.6%
Dec-86	49.3%	26.4%	9.2%	10.4%	15.1%	8.5%
Jun-87	51.0%	24.3%	10.8%	9.4%	9.2%	8.8%
Dec-87	50.9%	24.7%	9.6%	20.2%	15.1%	7.1%
Jun-88	49.3%	28.5%	8.4%	21.3%	12.6%	10.9%
Dec-88	50.1%	27.1%	8.7%	22.6%	11.5%	7.8%
Jun-89	55.5%	23.7%	7.6%	8.6%	8.5%	8.9%
Dec-89	54.0%	22.7%	8.9%	6.5%	4.2%	6.7%
Jun-90	52.4%	22.9%	10.2%	2.8%	2.1%	9.9%
Dec-90	50.6%	22.4%	11.2%	-4.3%	-4.8%	4.4%
Jun-91	52.1%	20.2%	12.5%	-9.7%	-11.2%	-2.3%

Examination of the data in this table suggests that differential performance between sub-markets is not an alternative explanation for the bimodality exhibited in cross-sectional returns. During the years 1987 and 1988, while Melbourne CBD office property constituted a minority of all property in the CBD office sector, it actually produced value-weighted average returns (as evidenced by the index return) that were less than those produced by Sydney CBD office properties. It thus appears unlikely that the second, contaminating component identified by the DMON curve-fitting exercise is associated with the returns on Melbourne office properties.

Assessment of the stable Paretian parameter estimates involves tests of the degree to which they are consistent with theoretical expectations that derive from their infinitely divisible nature. For example, the stability property of Paretian variables means that sample characteristic exponents should remain constant as the returns measurement period lengthens. An ideal test thus involves fitting characteristic exponents to periods of ever increasing length.

Unfortunately, data for conducting this sort of test is not available, as the individual returns provided by the PCA are not tied together from year to year. Furthermore, the overall length of the PCA time series is insufficient to render statistically significant results for return measurement periods longer than one year.

Alternatively, a stable Paretian model would be supported by evidence that the empirical estimates of α do not vary over time. Y&G and Graff et al (1997) test this hypothesis statistically by taking advantage of the asymptotic normality of the McCulloch estimators. When the true values of α across n time periods are all equal, the statistic defined by Equation 18 is distributed as χ^2 with $n - 1$ degrees of freedom.

The values obtained by Y&G using Russell-NCREIF data and Graff et al (1997) using PCA data indicate that the hypothesis "α is time invariant" cannot be rejected.

$$\sum_{i=1}^{n} w_i \left(\alpha_i - \overline{\alpha}\right)^2$$

Equation 18

where: w_i ≡ the reciprocal of the asymptotic variance of α_i

Furthermore, it is on the basis of these results that Y&G justify their failure to consider alternative finite-variance models of ICRE risk. In specifically discounting the mixture of normals class of models, Y&G state:

> …it is exceedingly difficult to imagine an economic process that could mix samples from different normal distributions in such a way as to generate nearly fifty distinct sample distributions across which skewness and scale parameters vary substantially but which have statistically identical characteristic exponents.

The clear theoretical and empirical superiority of a DMON model over a stable Paretian model demonstrated by the research reported in this chapter suggests that Y&G may have placed undue faith in the results of their statistical test of the time invariance of α.

Further investigation of the reliability of the test performed by Y&G indicates at least three shortcomings that affect the validity of its results. First, the test of time variance is applied only to the time series of annual characteristic exponents fitted to the Russell-NCREIF *combined* property data base (from which the 1991 data has been trimmed). The time series of characteristic exponents for each of the four individual property types are not tested. However, visual inspection of Exhibit 6 in Y&G suggests that these are not time-invariant. It thus appears that cross-sectional aggregation across property types may give rise to a diversification effect that leads to reduced time variation in the characteristic exponents of cross-sectional samples. In other words, Y&G's initial assumption that all types of properties have the same asset-specific risk function may be invalid, as discussed earlier.

Second, the validity of the test of time invariance is questionable due simply to the poor ability of stable Paretian distributions to describe empirical ICRE risk. The problem in this case is that the specification of the test of the time invariance of α does not take account of the poor goodness-of-fit of the stable Paretian model. A conclusion of time-invariance may therefore be an artefact of this poor fit.

Third and finally, the results of Y&G's test of the time variation of α based on the statistic defined by Equation 18 are poor in quality due to the low asymptotic efficiencies of the McCulloch estimators. As discussed in Chapter VII, low efficiency implies that the asymptotic variances of the McCulloch estimators are much higher than those produced by 'super-efficient' maximum likelihood estimation. For sample estimates of α such as those in this study that fall in the range (1.25, 1.75), asymptotic efficiencies range from 0.13 to 0.69 depending on the sample estimate of β. This means that the asymptotic variances of McCulloch's estimators of α are between 1.45 and 7.7 times those of MLE estimates. While the statistic defined by Equation 18 takes the variances of the α parameter estimates into account, it is nonetheless the case that a hypothesis of time invariance cannot be rejected because the relatively large asymptotic variances cause these estimates to be statistically indistinguishable.

8.6 Conclusion

In this chapter, tests were conducted of the ability of a two component DMON model and a stable model to explain the shape of unsystematic ICRE risk. The analysis focussed on unsystematic risk because of the cross-sectional nature of the empirical data available. The market model assumed that properties vary in expected return according to their type, and that type factors explain all covariance between assets' returns. However, the model did not assume that properties of all types have the same unsystematic risk function (in terms of its shape).

The analysis in this chapter supports the conclusion reached by Graff et al (1997) that the unsystematic risk of individual ICRE assets in Australia is not normally distributed for any year during the period 1985-2000, and that this risk is better described by a stable probability law with a characteristic exponent α_t that is less than 2.0.

However, the more important conclusion of the research in this chapter is that a two component DMON probability law is superior to the stable Paretian law in its ability to describe empirical unsystematic risk. Support for this conclusion comes from three sources. First, preliminary tests suggested that the distributional characteristics of empirical data are consistent with a DMON model, but not indicative of a stable Paretian model.

Second, formal χ^2 tests of the results of fitting these models to sample data indicate that a DMON with $N = 2$ is powerful in its ability to explain this risk. Comparison of sample statistics with those implied by a two component DMON model reinforced these results.

Third, review of the tests of time invariance conducted in Y&G and Graff et al (1997) indicate that the validity of their results are flawed, thereby calling into question their support for the stable Paretian hypothesis. The main reasons for this are the inefficiency of the asymptotic variances of their parameter estimates, and the invalidity of assuming that properties of all types have the same specific risk function.

It is also worth noting that the DMON model tested in this chapter may be more powerful than the empirical results imply. It is quite possible that a mixture of normals model that is unconstrained *a priori* to a two component specification would exhibit even greater power at explaining empirical unsystematic risk. It was not possible to let the empirical data drive the selection of optimal model specification because of its insufficient quantity.

This chapter also produces two additional conclusions of note. First, the effects that the bias apparent in price movements prior to rent reviews and lease expiries can have on the distributional characteristics of returns are supported by empirical distributions. Time varying skewness, and the signs of this skewness, are consistent with those which would be expected to result from valuation biases.

Second, unsystematic risk appears to be large in scale, but more importantly, this large scale means that individual assets can suffer poor returns (in absolute terms) in bull markets, and indisputably high returns in bear markets.

Chapter IX SUMMARY, IMPLICATIONS AND FURTHER RESEARCH

9.1 Introduction

The research reported in the preceding chapters produces important conclusions about the theoretical and empirical investment risk of ICRE assets. These conclusions are important because they have implications for key aspects of ICRE portfolio management.

The purpose of this chapter is to summarise the conclusions produced by this research, evaluate and discuss their implications, and identify areas for further research.

The chapter begins in the next section with a discussion of the implications which arise from a conclusion that ICRE investment risk is not normally distributed, being better described by a DMON probability law. This has direct implications for the specification of investment selection rules, portfolio optimisation techniques, equilibrium asset pricing models, and the forecasting of assets' returns.

In Section 9.3, the discussion moves up a level from portfolio management tools and techniques to issues of strategy and investor skill. A conclusion that ICRE prices are poorly informed has important implications for the portfolio management strategies that investors should pursue, taking account of their forecasting skills. Thus, the discussion in this section focuses on the implications of poorly informed prices for portfolio strategy selection and operational active management.

Finally, the chapter concludes in Section 9.4 with a brief discussion of the areas which the current research suggests warrant further attention.

9.2 The distribution of ICRE investment risk

One topic that this research has sought to investigate is the distribution of the investment risk of individual ICRE assets.

Knowledge of this risk is important to investors because it affects the specification of the tools and techniques that should be used to manage ICRE portfolios:

i. Investment selection models and portfolio construction tools such as those embodied in modern portfolio theory ('MPT'), which is commonly used in the ICRE context, make assumptions about the distribution of risk.

ii. The shape of the distribution of ICRE risk also affects the specification of the asset pricing and returns forecasting models which are appropriate within the ICRE context.

It is worth investigating the distribution of ICRE investment risk further because the conclusion of published research to date, which is that unsystematic risk is described by a stable Paretian probability law, suffers two main shortcomings. First, it is supported by empirical analysis alone. Second, stable Paretian risk poses very serious difficulties for the specification of portfolio management tools and techniques.

The theoretical and empirical analysis undertaken in earlier chapters concludes that individual ICRE risk is better described by a discrete mixture of normals ('DMON') probability law. This conclusion is supported theoretically by the earlier conclusion that ICRE prices evolve according to a jump process, which capital markets research suggests give rise to a discrete mixture model of unconditional risk. Tests also showed that a DMON law is quite superior to a stable Paretian law as a model of empirical, unsystematic ICRE risk.

A conclusion that the risk of individual assets in the ICRE market in Australia possesses a DMON distribution has several implications for ICRE portfolio management:

- *MPT-based portfolio construction tools are not appropriate in the ICRE context.*

As noted in Chapter I, one of the main reasons for investigating the distribution of ICRE risk is the widespread use of tools and techniques in the ICRE context which rely on an assumption of normally distributed risk. These include MPT-based optimisation techniques and equilibrium asset pricing models.

A question that naturally arises as a result of a conclusion that investment risk is distributed according to a DMON probability law is whether the use of MPT optimisation in the ICRE context remains valid.

Bawa (1978) has shown that a mean-variance selection rule such as MPT maximises expected utility for rational investors when returns are distributed according to any probability law that is a member of the generalised location and scale ('GLS') family of distributions. Bawa begins with the assumption that rational investors prefer wealth, are averse to uncertainty (i.e. the scale of the returns distribution), have a preference for skewness and exhibit declining absolute risk aversion with increasing wealth. (Thus, investors do not possess quadratic utility functions.) He then shows that the integral expressions for expected utility imply in general that a mean-variance rule is valid for ranking alternative investments whose returns possess a distribution that is a member of the GLS family.

This result obtains for two reasons. First, the symmetry of GLS laws obviates the need to take account of investors' preference for skewness. Second, because mean and variance are uniquely related to location and scale (respectively) and GLS laws are wholly and uniquely described by their two parameters, the mean and variance of a distribution contain full information about its shape.

It is immediately evident that a DMON model of investment risk invalidates the application of MPT in the ICRE context because of the tendency of risk to be asymmetric. The results of Chapter VIII show that the unconditional distribution of unsystematic risk is rarely symmetric in the ICRE context because of a difference in the location parameters of the two-component DMON law which describes it. This means that ICRE risk is frequently skewed; empirical data shows this can be positive or negative.

Alternatively, even if it were the case that risk tends (at least at times) to be symmetric in the ICRE context, MPT would remain inapplicable because DMON laws are not fully and uniquely described by their mean and variance. It is clear from Equation 8 that there are numerous combinations of two component normal parameters that could give rise to the same mean and variance statistics. Since these combinations would give rise to distributions that differ in shape, it cannot be said that mean and variance uniquely describe risk. Thus, these statistics cannot be used as basis for ranking alternative investments

This conclusion precipitates a need to identify alternative investment selection rules for use in the context of DMON-distributed risk.

Appendix D contains a review of five investment selection rules that have been put forward in the capital markets literature. All are concerned with distilling from the opportunity set of investment alternatives an *admissible set* ordered under the constraints of a particular class of utility function. This is done by eliminating from the opportunity set the members that are inferior to others by application of some rule consistent with the utility function.

An overall conclusion of Appendix D is that third-order stochastic dominance ('TSD') is the best for rule for ranking investments with uncertain prospects when investors are wealth-seeking, averse to uncertainty, and exhibit a preference for skewness. Furthermore, when the class of utility functions is further constrained to those exhibiting decreasing absolute risk aversion, a TSD rule in conjunction with a comparison of assets' mean returns are sufficient criteria for ranking assets.

One problem with TSD is that it can be cumbersome to apply. In order to rank two alternatives, it is necessary to compare the double integrals of their probability functions across the full range of possible outcomes. For probability laws that are not twice integrable analytically, the numerical computation required can be resource-intensive, and this intensity grows exponentially when the opportunity set is extended to include all linear combinations of alternatives.

However, Bawa (1978) shows that it is possible to construct a close approximation to the TSD efficient set by combining the efficient sets created by applying a mean–lower partial moment rule of order two, i.e. a mean–lower partial variance ('mean–LPV') rule, to the opportunity set using target rates of return across the range for which assets' probability distributions are defined. This approximation makes implementation of a TSD rule tractable.

Application of a mean–LPV rule in the ICRE context is particularly tractable because of the attractive properties of DMON probability laws. One of these properties is their ease of integration. The expression for a DMON law, being the sum of two normal distributions, is easily integrated analytically. The other attractive property is their stability under addition. Sums of random variables which possess DMON probability distributions themselves possess such distributions, with the parameters being functions of the components' parameters. Calculation of the parameters of the distributions which describe the risk of portfolios of assets is thus quite straightforward.

Gaining the acceptance of mean–LPV portfolio optimisation by institutional investors in Australian real estate should be straightforward. Downside risk measures such as LPV are intuitively appealing to investors, and institutional investors as a group in Australia tend to focus on downside risk because they are, in the majority, trustees of pension plans. This is consistent with the capital market literature which shows that pension and life fund managers take the character of the claims against their funds into account when making investment decisions.

Interestingly, several recent studies have sought to investigate the use of mean–downside risk rules as an alternative to MPT for the purpose of optimising portfolios in the ICRE context. Generally, these studies use historic time series of aggregate returns by property type (i.e. property sector indices) to ascertain which portfolio mixes would have been optimal *ex post* over the period for which the indices exist. They tend to conclude that MPT is inferior.

While the conduct and results of these studies would appear to support the conclusion of this research that downside risk rules are more appropriate for optimising portfolios of individual properties, caution should be exercised in reaching this inference. The main reason for this is that the studies in question universally cite no defensible rationale for adopting downside risk rules over MPT other than that they produce optimal *ex post* portfolios which are more consistent with those observed in practice. Furthermore, the degree of consistency with practice is closely tied to the authors' choice of a single target rate of return, whereas Bawa (1978) shows that efficient sets are found by combining the results of optimisations using multiple target rates of return. Some of the studies have also argued that downside risk optimisation is superior to MPT because efficient sets produced by the former are superior to those of the latter when plotted in mean-downside risk space. This result is pre-determined.

- <u>*Equilibrium asset pricing models may need to be re-specified in order to take*</u>

account of the non-normal distribution of ICRE investment risk.

As discussed earlier in this chapter, the aim of active management is to earn abnormal returns by placing bets on assets in order to capitalise on forecasts of their returns. Returns are abnormal when they exceed those which would be considered 'fair'. Treynor and Black (1973) argue that, in principal, the amounts which should be invested in individual assets should be a function of the forecast premium associated with each asset, and the confidence that an investor has in each forecast. An asset's forecast premium is the difference between its forecasted return and the rate of return the market expects it to produce over the forecast period. The latter may be estimated using a model of equilibrium expected returns.

Models of expected returns developed in the capital markets relate expected returns to systematic risk factors. Two widely accepted models are the capital asset pricing model ('CAPM'), and arbitrage pricing theory ('APT'), of which the CAPM is a special case. These models are built on the assumptions that investors rank assets on the basis of their mean and variance, and one or more factors give rise to unavoidable dispersion in the returns of all assets to a varying degree. The market attaches prices to each of these systematic factors.

It is apparent that APT and the CAPM are inappropriate in the ICRE context where assets returns are described by a DMON probability law. In the previous section it was shown that a mean−variance rule is inappropriate for ranking investments with DMON−distributed returns because (a) rational investors prefer positive skewness, (b) DMON returns are typically skewed, and (c) mean−variance rules do not differentiate between assets' skewness. Thus, capital market models of equilibrium expected returns built on an assumption of mean-variance investor behaviour are inappropriate in the ICRE context.

There are, however, at least two other models of expected returns developed by capital markets researchers which are candidates for application in the ICRE context. Both the three-moment model developed by Kraus and Litzenberger (1976) (the 'K-L' model) and the mean-LPV model developed by Bawa and Lindenberg (1977) take account of skewness in assets' returns and the preference that investors exhibit for positive skewness.

The K-L model, which builds on the three-moment portfolio framework of Jean (1971), relates expected returns to the systematic dispersion and both the systematic and unsystematic skewness of assets' returns distributions. The two components of skewness enter the relationship because positive skewness is desirable and reduced by diversification, whereas negative skewness is undesirable but must be borne to the extent it is systematic. The results of their empirical tests using the returns on public equity support the hypothesis that investors pay a premium for positive skewness.

The mean-LPV model of Bawa and Lindenberg (1977), which builds on Bawa's earlier discussion of the theoretical consistency of mean-LPV investment selection rules with third-order stochastic dominance, relates expected returns to the systematic and unsystematic components of assets' lower partial variance at a target rate of return *t*. Their results similarly support a conclusion that asymmetry in assets' returns distributions is priced by investors.

While empirical tests appear to support the assertion of both of these models that *ex ante* asymmetry in assets' returns distributions (both positive and negative) is priced by investors, there is greater theoretical support for a mean-LPV model of equilibrium expected returns. As noted by Bawa (1975):

> It should also be noted that since the LPV function provides for explicit consideration of asymmetry or skewness of the probability distribution, it is

> to be preferred to selection rules based on mean, variance and third moment of the distribution function. Indeed, it can be easily shown that selection rules based on the first *n* moments ($n \geq 3$) use neither a necessary nor a sufficient condition for dominance for the class of [risk-averse, decreasing ARA] utility functions and instead the mean-LPV rule should be used. Thus, at least on theoretical grounds, the approaches recently advocated in Jean (1971) should be abandoned in favour of the mean-LPV rule.

Of course, theoretical consistency with TSD and DMON-distributed returns are not sufficient conditions for adopting a mean-LPV model of equilibrium expected returns in the ICRE context. Investors considering adoption of a mean-LPV model must also satisfy themselves that it describes the empirical pricing of assets.

Unfortunately, empirical testing is made difficult in the ICRE context because of the lack of suitable data. At the very least, a basic test of a mean-LPV model requires time series of returns on a sufficiently large sample of individual properties to enable significant cross-sectional tests of in-sample pricing to be conducted. Not only are databases of this kind rare in the ICRE context, but the low frequency with which valuations are conducted means that time series covering extraordinarily long periods (i.e. decades) would be required. Lengthening the time period raises the potential for non-stationarity to affect the validity of test results.

Furthermore, the lack of publicly available data also makes the application of a mean-LPV model (or any model for that matter) difficult in the ICRE context. Use of such models to estimate a particular property's expected return requires estimation of its *ex ante* sensitivities to the priced factor(s). Estimation of these sensitivities requires a time series of historic returns for the property in question, or a 'fundamental beta' model of the type developed in the capital markets context. The latter process is data intensive.

To conclude this discussion of asset pricing models in the ICRE context, it is worth making two observations. First, while empirical testing and application of models of equilibrium expected returns which are more suitable in the ICRE context is difficult, it is well worth making the effort. For example, if it is found that *ex ante* positive or negative skewness in returns is not priced by ICRE investors, it may then be concluded that the ability to forecast skewness has the potential to be a very valuable skill. The forecasting of returns in a DMON world are considered in the next section.

Second, investors' pricing of skewness may offer another explanation for the apparent under-diversification of ICRE portfolios. In the ICRE context in Australia and elsewhere, it is quite common for investors to hold sectoral portfolios of just a few assets, or portfolios of larger numbers of assets of which the performance is dominated by the returns on a few large-value assets. However, researchers have shown that the correlation structure of returns in the ICRE context implies that large numbers of assets are required for portfolios to be well diversified.

Several factors have been put forward to explain the apparently poor diversification of ICRE portfolios. In addition to the large scale investment required to diversify portfolios of lumpy, heterogeneously valued assets, it is likely that economies of scale in management motivate investors to favour portfolios of smaller numbers of larger assets. The potentially large pricing inefficiency in ICRE markets discussed earlier in this chapter also causes active investors to favour portfolios concentrated in fewer assets with larger forecast premiums.

The degree to which positive total skewness or negative co-skewness is priced may also act to reduce the motivation of investors to diversify. While diversification reduces the dispersion of a portfolio's distribution of returns, it also reduces its unsystematic skewness. Thus, if some of the investments in an investor's opportunity set have positively skewed *ex ante* returns, they will tend to be favoured at the expense of diversification. The balance between the risk-reducing benefits and skewness-destroying costs of diversification is an empirical issue.

- *Forecasting the distribution of ICRE returns in a world of DMON-distributed risk is more complicated, but forms a new opportunity for active management.*

In addition to a model of equilibrium expected returns that provides an accurate depiction of empirical asset pricing, a second important component of active portfolio management is the ability to forecast assets' actual return distributions. These two components of the active decision-making process lead to the identification of forecast premia for all assets. In the ICRE context where only long positions are possible, the distributional characteristics of these premia determine (in a theoretically ideal sense) the amount of investment in each asset.

In contrast to an MPT world, the forecasting of assets' returns in a mean-LPV world is more complicated. In a mean-variance world, active investors are concerned with forecasting the mean and variance of assets' returns using their private information or superior evaluation skills. In a mean-LPV world, the shape of the returns distribution must also be forecast because the portfolio optimisation process requires fully specified 'premium distributions' in order to take account of an investor's preference for skewness.

However, while a need to forecast the shape of the return distribution adds to the burden of active management, it also creates another opportunity for active investors to earn abnormal returns. The extent to which skill at 'shape forecasting' adds value will be a function of the degree to which the ICRE market actually prices skewness. In the previous section, empirical testing of a mean-LPV model is advocated. If skewness is priced, then an ability to forecast skewness is an absolutely necessity for active management. If it is not priced, however, such an ability offers great potential for an active investor to earn abnormal returns.

It is evident from the discussion in Chapter VII that forecasting the shape of an asset's return distribution translates operationally into forecasting the parameters governing the jump component of the ICRE price evolution process. As discussed, the jump component is associated with lease events with uncertain outcomes that give rise to unpredictable changes in the net operating income that a property will produce in future. It is the occurrence of lease events which causes the price diffusion process to experience a discontinuity, and the unconditional distribution of returns to be governed by a discrete mixture probability law.

Clues to the characteristics of the jump process governing a specific property can be obtained through review of Equation 7. This equation for a two component DMON probability law indicates that forecasts should be concerned with the likelihood of a lease event occurring in a forecast period, and the parameters of the distribution governing lease events.

Forecasting the timing of the occurrence of a lease event in the ICRE context is not as straightforward as it appears. It will be recalled from earlier chapters that the lease events in question include lease expiries, rent reviews, and the execution of new leases. Since lease expiries and rent reviews are governed by the terms of a lease, it is possible for investors to forecast with a fair degree of certainty when the negotiations between a landlord and tenant will commence under these terms. However, the timing of the conclusion of these negotiations is quite unpredictable. Similarly, while the quantum of vacant space available in a building is always known with certainty, it is quite difficult to forecast when tenants will take up this space.

To some extent, investors and analysts are accustomed to forecasting the occurrence of lease events, but anecdotal evidence suggests that the quality of their forecasts is poor. In preparing discounted cash flow analyses of individual properties, it is necessary to allow for the timing of lease events in forecasting cash flows. However, common investment appraisal practice in Australia involves assuming 'standard' periods of time for lease events, rent reviews and new leases to be concluded. This is not unexpected in the ICRE world where detailed information on market conditions is scarce, and research budgets have traditionally been limited.

If a lease event is forecast to occur, then forecasting the parameters of the probability distribution governing the price changes that result from the occurrence of lease events is a two step process. In the first step, the location of the distribution is forecasted by identifying the most likely outcome of the predicted event. In the second step, assessment of the range of possible outcomes results in an estimate of the scale of the distribution.

While ICRE investors and analysts are accustomed to forecasting the expected outcomes of lease events, anecdotal evidence suggests that the quality of these forecasts tend to be poor, and the attention paid to assessing the range of possible outcomes is perfunctory. As part of the investment appraisal process, forecasting a property's cash flows requires assessment of the rents that current and future leases will produce over time. Common practice is to assume that lease events will cause rents to be marked-to-market, and that future market rents can be estimated by simply adjusting current market rents up or down by some constant factor which reflects a general assessment of how the balance between supply and demand will change over time. Moreover, it is rarely the case that explicit attention is paid to assessing the range of market rents that could prevail at future points in time.

This discussion suggests that most parties in Australia will need to improve the quality of their research and analysis in order to engage in the activity of forecasting the shape of the *ex ante* distribution of assets' returns. Improvements could be achieved in three areas. One of these is the acquisition of more detailed information about the motivations of landlords and tenants, the availability of competing supply, and the demand curve of tenants with unsatisfied space requirements at the time a lease event is expected to occur. Another is the use of more sophisticated models to forecast future supply and demand conditions. Third, formal techniques could be applied for recognising and quantifying the errors in forecasts.

9.3 The information content of ICRE prices

In the previous section, it was shown that a conclusion that unsystematic investment risk is described by a DMON probability law has serious implications for the tools and techniques used by ICRE investors to manage their portfolios. In essence, this conclusion causes MPT-based optimisation, asset pricing models and returns forecasting models to be no longer applicable in the ICRE context. Alternative tools and techniques based on the mean-LPV investment selection rules proposed by Bawa (1975) are identified as being robust and valid replacements for those based on MPT.

At a higher level, however, the manner in which most portfolio management tools and techniques should be applied is a function of the strategy adopted by an investor. In order to choose a strategy, it is necessary to establish whether the prices of individual ICRE assets are sufficiently informed for a naïve investor to pursue a passive portfolio strategy, or sufficiently uninformed for an active investor to earn excess returns on a net-of-costs basis. It is mainly for this reason that the extent to which ICRE prices are informed is the second topic addressed by the current research.

In addition to the issue of strategy selection, knowledge of the information content of prices is also important to investors for other reasons. The extent to which prices in a market are informed is a key determinant of:

i. The research and analysis techniques which should be applied by investors who choose to pursue an active strategy.
ii. The integrity of transaction prices as signals for 'true' (fully informed) prices.
iii. The willingness of some investors to participate in the market.
iv. The allocational efficiency of the market.

This topic requires further investigation because only a small volume of published research has examined the informedness of individual ICRE prices, and this has produced limited conclusions. Most likely due to the extreme scarcity of empirical data, few empirical studies have investigated the information content of prices. Moreover, no theoretical studies have been undertaken. The studies which have been conducted generally conclude that ICRE markets appear to be weak-form informationally efficient. Unfortunately, the information set to which weak-form tests relate (i.e. historic prices) is a but very small part of the global set I_t which is relevant to the pricing of ICRE assets. Thus in absolute terms, very little is known about the informedness of ICRE prices.

The analysis undertaken in Chapters IV and V, which is entirely theoretical because of the continuing scarcity of asset-specific data, concludes that the prices of individual ICRE assets in Australia are poorly informed. By "poorly informed," it is meant that much of the information reflected in ICRE prices is out of date and inaccurate, and prices individually tend to reflect a subset of the global set I_t. This state of affairs is attributable to several factors:

i. A large proportion of the global information set I_t is privately held and considered commercially sensitive by its holders.

ii. The information that does become publicly available can take months to do so.

iii. Because much of the information that becomes publicly available is transmitted through informal channels, it frequently lacks integrity.

A conclusion that the prices of individual assets in the ICRE market in Australia are poorly informed has several direct and indirect implications for investors:

- *Passive strategies are inappropriate in the ICRE asset class.*

In any market with poorly informed prices, pursuit of a passive portfolio strategy is inappropriate. If it cannot be assumed that the prices at which assets can be traded are full and timely reflections of the information set I_t, then investment decisions cannot be made without supporting research and analysis. This is because research and analysis are required to produce forecasts of assets' future cash flows and prices, which are themselves needed to verify the fairness of the prices at which assets may be traded. Since a passive strategy is by definition one in which assets are acquired at their market prices because they are assumed to be fair, pursuit of such a strategy is inappropriate in markets with poorly informed prices.

This conclusion suggests that the ICRE investors in Australia who pursue passive strategies are acting inappropriately. In Australia, it is common for some investors to buy or sell ICRE assets on the basis of simple analysis conducted for the purpose of determining whether the prices at which assets can be traded are consistent with the prices at which comparable assets have traded. In other words, such analysis aims to confirm assets' poorly informed market prices; it does not aim to ascertain whether assets' market prices are fair.

- *In the Australian ICRE market, there is potential for active investors to earn substantial abnormal returns through control of information.*

A conclusion that prices are poorly informed suggests that there is potential in the ICRE market in Australia for investors to earn substantial abnormal returns. This is because prices deviate substantially from their 'full information' equivalent, i.e. there is substantial mis-pricing. Investors with the ability to identify this mis-pricing could thus earn large abnormal returns.

The analysis in Chapter V indicates that the key factor in active management of ICRE portfolios is the scale of an investor's information endowment, rather than their analysis skills. In capital markets, a high proportion of data relevant to assets' pricing is in the public domain. Active investors are thus differentiated according to their ability to interpret the common dataset for forecasting purposes. In contrast, prices in ICRE markets are poorly informed because a large proportion of I_t, mostly comprising data on the existing leases in properties, is not available to the public in an accurate form. The factor that differentiates active investors in ICRE markets is thus the scale of their holdings of information on existing leases.

In view of this conclusion, the next question that naturally arises is: what alternative information strategies are available to active investors in ICRE markets? The analysis conducted in Chapter V implies that there are two main ways in which to acquire information on existing leases:

i. Natural endowment – owners automatically enjoy access to their own lease information.

ii. Information gathering – lease data is procured by soliciting it from tenants.

The attractiveness of either of these information strategies as a basis for active management is a function of the costs of pursuing them. While it is not possible to identify these costs accurately without undertaking further research, it is possible to make some general observations in order to ascertain the strategies' relative costs:

i. Natural endowment – Owners bear no direct costs in obtaining the information contained in the leases to which they are a party. However, any individual owner would need to be quite large (in terms of the number of assets) for the volume of captive lease data to have meaningful mass as a proportion of the totality of information which pertains to a local market or property type.

ii. Information gathering – It is difficult to acquire detailed lease information from tenants because many are protective of it, and some are constrained from disclosure. (If many investors began to make a practice of soliciting information from tenants, its limited availability would quickly disappear.) Furthermore, lease information is dynamic (i.e. due to terminations, new leases, renegotiations) so gathering it would require constant effort. All of this suggests that the costs of information gathering are substantial.

These observations give rise to at least two theoretical conclusions about active management based on information control in ICRE markets. First, investors with a natural endowment of sufficient scale are likely to be best placed to earn substantial abnormal returns. In this context, the term ‘sufficient’ refers to a scale which is so large as a proportion of all properties of a particular type or within a local market that it affords an investor a clear advantage over the majority of other investors.

Second, it is likely that all of the investors who do not possess a sufficient natural endowment of information but seek to pursue an active strategy will face a roughly level playing field in terms of the overall quantity of information they possess. The limited availability of tenant-provided lease data and the scale of the information gathering task, even within a property type or local area, should lead to the emergence of a few third-party information gatherers. The individual information sets of most active investors will be supplied by these third parties in aggregated form, and will thus be differentiated by the limited (insufficient) private information with which each investor is naturally endowed. Third party information will be available in aggregated form because the prices which gatherers would likely seek for detailed information would be too much for investors to bear.

These conclusions are generally consistent with observed practice in the ICRE market in Australia. Most of the largest wholesale managers in Australia believe that the emphasis of research should be on information gathering rather than analysis, and recognise that growth in scale (in terms of assets under management) confers information power over other managers and investors. Furthermore, most investors rely on third-party information gatherers as their primary source of lease data, which is customarily acquired in aggregate form.

However, these conclusions are at odds with some investors' practices, indicating that reconsideration of their information strategies may be worthwhile. Some large wholesale investors appear to espouse the view that research is not worthwhile. For example, review of the investment appraisal systems of one very large manager with a significant natural information endowment indicates that no account is taken of the large volume of 'free' information the firm possesses for forecasting rents in the analysis supporting buy-sell decisions. Research is undertaken with the sole aim of conducting top-down analysis using macroeconomic data. This suggests that opportunities for earning abnormal returns on the basis of low cost information are being ignored.

Furthermore, two of the largest managers do not devote resources of any significance to internal or external information gathering and analysis. Their publicly stated view is that the ICRE market is "generally efficient" and property-specific analysis in search of mispricing is not worthwhile. While informational efficiency may indeed hold for the majority of ICRE investors who do not possess information naturally, the substantial scale of these two particular investors suggests that the marginal cost of their information is very low, making its application within their investment appraisal processes seemingly worthwhile.

- *Investors should not rely on comparables-based valuations for investment decisions.*

In ICRE markets globally, investors in debt and equity customarily make use of valuations (i.e. professionally prepared estimates of market price) for a multitude of purposes:

i. Investment appraisal – valuations are used by investors to confirm the fairness of the prices at which assets are to be traded.

ii. Financing decisions – lenders use valuations as a basis for assessing the degree to which loans secured by ICRE assets are collateralised.

iii. Performance measurement – investors and managers rely on valuations as estimates of (unobservable) market prices for the purpose of calculating historic performance.

iv. Financial reporting – investors rely on valuations as a basis for preparing financial accounts.

The assumption in all of these cases is that valuations are estimates of the 'true' or fully informed market price of ICRE assets.

Two main approaches are used by valuers to estimate the prices of properties: comparables and discounted cash flow ('DCF'). Under the comparables approach, valuers have regard to the prices at which similar assets have traded in order to deduce the market price of a property. One way of doing this is to use a hedonic pricing technique in which a vector of prices is used to calculate the market prices of various physical attributes. Alternatively, under the capitalisation technique, the relationship between traded assets' prices and passing incomes is captured in capitalisation rates which are then blended into a single rate which is then used to value the passing income of a particular asset.

Under the DCF approach, the net operating income of an asset is first forecasted over a projection period (e.g. 10 years) along with its expected future value at the end of this period. Then these sums are discounted using a rate constructed from bond yields and risk premia.

In Australia, the comparables approach is favoured by valuers commissioned by institutional investors. This is because the courts have tended to find in favour of valuations based on comparables when disputes have arisen (see Jefferies (1995)). The judicial system apparently finds it difficult to argue with the weight of transactions-based evidence.

It is well known, however, that the practice of comparables-based valuation is fraught with problems that make the estimation of an asset's market price difficult. For example, it is usually the case that a valuer has very few comparable transactions with which to construct a pricing vector. Furthermore, comparable transactions pre-date a valuation and are thus not contemporaneous indications of market pricing. In order to construct a vector of 'sufficient' size, valuers frequently must look quite far back in time, aggravating this effect. Last but not least, because transaction prices are distributed about assets' market prices (see Chapter V), they can be relied on by valuers only as noisy indicators of market pricing.

With all of this in mind, the conclusion of this research that prices are poorly informed gives rise to one clear implication: comparables-based valuations are likely to be exceedingly poor estimates of assets full information market prices. This is worrisome, given the range and importance of the uses to which valuations are put in Australia (and elsewhere).

What can be done to deal with this state of affairs? Until such time as the informedness and quantity of price information at any time *t* improves, investors should be wary of using valuations as the basis for investment decisions. Furthermore, valuers should take whatever steps are necessary to establish DCF analysis as the technique of choice in institutional valuation. This would be consistent with the steps which are already being taken in the valuation industry to up-skill valuers in the use of techniques grounded in financial economics and prevalent in the capital markets.

- *Poorly informed prices mitigate the allocative efficiency of the ICRE market.*

The previous implication showed that investors rely frequently on market valuations and these may be seriously flawed due to their basis in poorly informed transaction prices. This suggests that the investment decisions made on the basis of these valuations may also be flawed.

While flawed investment decisions at the level of the individual investor is of serious concern, another lies at a higher level. If investors are collectively relying on market valuations which are poor signals of the 'true' prices of assets, then the allocation of scarce resources to assets is sub-optimal in the ICRE market. This is because the efficiency of resource allocation in an economy is closely linked to the ability of prices, on which investors base their investment decisions, to signal the future risk-adjusted benefits of individual assets.

The policy implication of this conclusion is that it provides a motivation for regulatory authorities in Australia to consider taking steps to increase the information content of prices. This could be done by moves which serve to reduce the imperfections in the information structure and trading mechanism in the ICRE market. These might include, for example, efforts to reduce the direct costs of trading, increase the accuracy and timeliness of the reporting of transaction prices, increase the public disclosure of lease contracts or modernise the techniques being used by valuers to estimate assets' market prices.

To some extent, the market itself is moving to enhance allocative efficiency by drifting toward publicly listed vehicles as the preferred method of investing in ICRE assets. Because such vehicles securitise ownership and face a requirement for greater disclosure, they provide better price signals to investors.

- *The poor information content of prices weighs in favour of investors avoiding participation in the ICRE asset class.*

In Chapter V, several factors are cited as mitigating the ability or willingness of investors to participate in ICRE markets. The lumpy nature of ICRE assets makes creation of a well diversified portfolio extremely costly, liquidity in the ICRE market is poor, and the management of ICRE assets is a business that requires specialist skills that most investors do not possess. Additionally, the lack of public information creates 'estimation risk' that motivates investors to prefer other markets with better information availability (see Klein and Bawa (1977)).

Other factors have also been discussed which work to reduce the attractiveness of the ICRE asset class to investors. The lack of a market pricing mechanism forces investors to rely on valuations to measure performance, and it is known that valuations are noisy estimates of market prices. ICRE markets also lack high-integrity performance benchmarks. These in combination make it virtually impossible for investors to benchmark the performance of managers, and increases the costs that must be incurred to monitor performance.

It should not be surprising, then, that institutional investors of the types prevalent in Australia, whether active or passive, treat ICRE as a non-core asset class, along the lines of private equity and hedge funds. A large proportion of institutional investment in Australia is undertaken by the trustees of superannuation schemes. These are fiduciaries who represent interests of others and face strong prudential obligations. For investors of this kind, asset classes such as private equity, hedge fund and ICRE in which performance assessment is difficult, benchmarks are poor or non-existent and a high level of monitoring is required are relatively unattractive when compared to publicly traded equities and fixed interest.

A conclusion that prices are poorly informed works to further mitigate the attractiveness of the ICRE asset class to investors. For example, the first implication presented in this section observed that it is not appropriate for a passive investment strategy to be pursued in the ICRE market in Australia. This is because it cannot be assumed that prices are constantly being driven by an ‘invisible hand’ to their fair, full information values. But only passive strategies are appropriate for naïve investors, who (by definition) lack the skills and resources to produce the forecasts necessary for active portfolio management. Thus, naïve investors should avoid the ICRE asset class.

Of course, it is possible for naïve investors to acquire active management services from a third party. However, discussion earlier in this section shows that the majority of active investors operate on an equally poor footing in terms of their information resources. It is also to be expected that truly good managers will price their services in such a way that the majority of abnormal return associated with their skills will accrue to them. Thus, naïve investors secure little compensation for taking on the risk of mispricing which they could otherwise avoid by investing in other asset classes.

Another implication discussed in this section which further mitigates investors' interest in the ICRE asset class is the effect that poorly informed prices have on investment decisions. Because valuations play an important role in important investment decisions in the ICRE context, and most valuations are prepared on the basis of comparable transactions, the poor information content of prices contributes to a degradation in the validity of these decisions. It is to be expected that revelation of this reasoning to investors would cause some to reduce or abandon their participation in the ICRE asset class.

9.4 Further research

In Chapter I, it was stated that the goal of this research is to make a contribution to the body of knowledge on the investment risk of individual investment-grade commercial real estate assets. To that end, the research sought to answer two questions of interest to investors which pertain to the distribution of investment risk, and the information content of prices. The conclusions which were produced by this research give rise to serious implications for portfolio management in the ICRE context.

In view of the seriousness of these implications, it is clear that additional research is required to confirm the underlying conclusions. This is required due to shortcomings in the empirical analyses which support them.

For example, the finding of this research that individual ICRE investment risk is distributed according to a DMON law is supported empirically by testing the goodness-of-fit of a two-component DMON model to cross-sections of returns segregated by property type.

However, because of the limited availability of performance data, these tests rest on a real estate market model which assumes that differences in property type explain all differences in properties' expected returns. They therefore provide empirical support for assertions only about unsystematic ICRE investment risk. Ideally, confirmation of the DMON hypothesis for total investment risk requires empirical tests using time series of individual property returns which are supplemented by details of the assets' characteristics.

Similarly, the finding of this research that ICRE prices are poorly informed rests solely on theoretical analysis because of data unavailability. Ideally, empirical testing of the speed, accuracy and degree of reaction of ICRE prices to natural events should take the form of event studies. However, such tests also require detailed individual returns data at a much high frequency than annual in order to produce worthwhile observations about the information content of prices.

Another finding of this research not explored in this chapter but which requires further investigation is the apparent mark-down in valuation or price that occurs when a property approaches the occurrence of a lease event. The analysis conducted in Chapter VI suggests that properties tend to experience a systematic reduction in the valuation which immediately precedes a major lease event.

At least three aspects of this effect require further research attention if suitable empirical data can be procured to do so. First, is it a valuation or market pricing issue? The former has implications for the practice of valuation, while the latter implies apparent irrationality which would certainly demand further investigation. Second, do properties which are marked down in value experience predictable reversals? If so, this would suggest that there is a rational basis for their occurrence. Third, does the quantum of value reduction depend on market conditions, i.e. the degree to which a property is over- or under-rented?

In addition to confirming the conclusions which underlie the implications discussed in this chapter, additional research is required to explore the issues which have been raised in the course of evaluating the implications of this research for portfolio management. These issues, expressed in the form of questions, are discussed briefly as follows:

- *Are mean–LPV rules more consistent with investor behaviour in an empirical sense?*

The identification of the mean–LPV promoted by Bawa (1975) as an appropriate alternative to MPT in a world of DMON-distributed risk and strictly rational investors rests on the theoretical assumption that the behaviour of ICRE investors can be described as strictly rational. Further research is required to ascertain whether ICRE investors can be described in this way, or more directly, whether mean–LPV optimised portfolios are superior to those under MPT from the perspective of ICRE investors.

- *Are positive skewness or negative co-skewness priced by the ICRE market?*

This is a key question that was raised in the context of noting that equilibrium pricing models based on MPT are inappropriate in a world of DMON-distributed investment risk. The answer to this question dictates the form of pricing model that investors should use in the ICRE context, and determines the quantum of abnormal return that investors can seek to earn through forecasting the shape of *ex ante* ICRE returns.

- *Is it possible to develop a model for the purpose of forecasting the shape of the distribution of individual property asset's returns?*

In discussing the implication of DMON-distributed investment risk for the forecasting of assets' returns, attention was briefly paid to identifying the factors which determine the shape of the *ex ante* distribution of returns.

The question that naturally arises, of course, of whether it is actually possible to construct a model with ability to forecast the shape of a property's future returns distribution. Additional research is required to verify the factors which determine shape, and specify a model that can translate estimates of the future values of these factors into forecasts of the parameters of the *ex ante* probability distribution of returns.

Research attention may also need to be directed toward construction of a multi-period forecasting model. Throughout this chapter, it has been assumed that investors forecast over a single investment period of about one year. There is evidence to suggest, however, that investors look farther into the future.[26] This makes sense, as the relatively high transaction costs and the slow trading process in the ICRE context pose obstacles to active trading within a year. In other words, effecting revisions to the composition of ICRE portfolios is a multi-year process. It may therefore be necessary for research attention in this area to be directed toward the formulation of multi-period forecasting models (which may be possible, for example, by modelling multi-period forecasts as a series of single periods).

- *Do investors with natural information endowments earn abnormal returns at the expense of naïve investors who buy information to trade actively?*

In discussing the implications of the poor information content of prices for ICRE portfolio management, it was noted that a key determinant of the potential for success in actively managing portfolios is the information endowment of an investor, and the cost that must be incurred to procure it. Deductive reasoning suggested that investors who possess a natural information endowment because of the scale of their ownership of property should enjoy an advantage over those who must gather their information from third parties. Additional research is clearly required to verify or refute this assertion, as

[26] The manager research database of Frank Russell Company Pty Ltd suggests that it is common practice for some managers to forecast returns over anticipated holding periods of much greater than one year.

the result of such research would be of great interest to active investors in ICRE markets. While this might take the form of longitudinal studies of active investors' risk-adjusted returns, actual pursuit of such research is problematic due to the shortage of suitable data.

Another, ancillary issue worthy of attention in this vein concerns the strategies that investors believe themselves to be pursuing versus the skills and information they actually possess. Anecdotal evidence and industry periodicals suggest that most ICRE investors in Australia consider themselves active investors.[27] However, it is highly unlikely that all of them possess competitive advantages in the requisite areas, and many of them trade 'core' assets very rarely. An in-depth cross-sectional study of the resources, experience, data sources and decision-making systems of self-proclaimed active investors would yield insights into the degree to which they truly possess heterogeneous competitive advantages.

- *Are comparables-based valuations less reflective of 'true' market prices?*

An important implication of the finding that ICRE prices are poorly informed is the idea that comparables-based valuations, by their nature, are poor estimates of 'true' (fully informed) market prices. The corollary to this is that DCF-based valuations, because they are based on estimates of 'fundamentals', are superior estimates of such prices and should be preferred over comparables-based valuations.

Further research should be devoted to this issue because it has serious implications for the practice of valuation and the reliability of valuations produced on

[27] There also appears to be a degree of confusion in ICRE markets about the precise meaning of the term 'active investor'. Some parties mistake their interventionist or proactive approach to asset management as being evidence of an active portfolio strategy.

alternative bases for the purpose of investment decision-making. Initial research could simply focus on testing the correspondence between comparables- and DCF-based valuations, and the prices at which contracts are contemporaneously agreed (rather than settled).

- *Does poor information actually cause investors to avoid the ICRE asset class?*

Theoretical studies conducted in the capital markets context assert that investors prefer markets where fundamental information relevant to asset pricing is publicly available (in a relative sense). Such an assertion is reasonable, and consideration of the nature of institutional investors in Australia suggests that this effect should also hold true in the ICRE context.

The question which naturally arises is whether it is indeed the case that institutional investors in Australia consciously avoid or reduce their participation in the ICRE market because of its relative lack of fundamental pricing data or the poorly informed nature of prices. Formal analysis of the decisions taken by such investors with respect to their allocations to private ICRE is required to answer this question, as anecdotal evidence suggests that boards of trustees are indirectly cognisant of these information issues. Furthermore, the results of research in this area would be relevant to the longevity of ICRE as an asset class worthy of the attention of institutional investors. This issue is of topical interest.

In summary, it appears from the relatively long list of topics discussed in this section that a great deal of research remains to be pursued in the area of ICRE investment risk.

Appendix A – Distributional Models of Financial Assets

Research by Bachelier (1900) is generally regarded as being the earliest known effort to theorise a distributional model of changes in the prices of financial assets. His work in this area actually formed a necessary part of a larger study that concerned the pricing of option-like instruments traded on the French Bourse.

By assuming that the changes in common stock prices over fixed time periods reflect the cumulative effect of a large number of sequentially independent increments, Bachelier (1900) was able to propose that prices follow a continuous stochastic process that may be expressed in the form of the following equation (see Ingersoll (1987)):

$$dP = \mu\, dt + \sigma\, dz$$

Equation A-1

where:	$P(t)$	$\equiv$	price of financial asset at time t,
	μ	$\equiv$	instantaneous expected return on the stock,
	σ^2	$\equiv$	instantaneous variance of the stock return,
	z	$\equiv$	standardised random unexpected change in price.

Equation A-1 is composed of deterministic and random elements. The instantaneous expected rate of return per unit time μ and standard deviation σ are assumed to be constants. The random part is assumed to be driven by a Gaussian white noise process z, in which the unexpected innovations in prices in the continuum of infinitely short time periods are assumed to be independent drawings from a standard normal random variable. A solution of this equation is that $P(t)$ is normally distributed. Therefore, the change in price across a time interval of unit length and ending at time t, $\Delta P(t) = [P(t) - P(t\text{-}1)] \sim N(\mu, \sigma)$.

A normal distribution arises for $P(t)$ due to the Central Limit Theorem's assertion that it is the limiting distribution of the sum of a very large number of independent, identically distributed (i.i.d.) random variables with finite variance. As such, the normal distribution possesses the characteristic of infinite divisibility. In this case the i.i.d. variables correspond to the price increments occurring in time intervals of very short length, i.e. prices evolve continuously. The reproducibility characteristics of the normal distribution are such that the *shape* of the risk distribution does not change over time, though its location and scale may do so.

After a long period of relative inattention to the subject of returns distributions, the presentation of MPT by Markowitz (1952) precipitated renewed research interest. The main focus was on testing whether the empirical changes in prices of financial assets are normally distributed, i.e. coincident with the assumptions underlying MPT. Normally distributed price changes over fixed time intervals are consistent with a simple random walk model of the price process in which increments within very short time periods are independent drawings from a stationary probability distribution of finite variance. However, as noted by Fama (1970), these early studies were actually empirical tests in search of a theory, as none established *a priori* grounds for assuming that price changes indeed follow a random walk.

Osborne (1959) extended Bachelier's work by drawing an *explicit* parallel between the motion of particles subjected to random forces and pricing mechanisms in securities markets. He addressed one of the few shortcomings in Bachelier's work by suggesting that prices must possess a skewed distribution due to the finite lower bound associated with limited liability.

Osborne further argued that investors' psychological concern might be with proportional, rather than absolute changes in prices, arguing that "the stimulus of price in dollars, and the subjective sensation of value in the mind of the trader or investor, are related in accordance with the Weber-Fechner law." The Weber-Fechner law states that ratios of physical stimulus result in directly proportionate sensations, thus pointing to relative rather than absolute measures of price response as being more appropriate.

Osborne's proposition that relative rather than absolute returns are important may be expressed as a minor revision of Equation A-1:

$$\frac{\mathrm{d}P}{P} = \mu\,\mathrm{d}t + \sigma\,\mathrm{dz}$$

Equation A-2

In the price process described by Equation A-2, the potential magnitude of price increments is related to the absolute level of prices. One solution is $\Delta P(t) = \log P(t) - \log P(t\text{-}1) \sim N(\mu, \sigma)$. Price changes stated in continuously compounded terms are normally distributed thus absolute price changes are lognormally distributed (see Johnson (1949)). Prices may now be said to follow a geometric diffusion process. Osborne's analysis lead him to investigate the distributional characteristics of securities' log price changes rather than absolute price changes. Taking logs pulls in right-tail outliers and extends the lower bound to infinity. This also improved the normal distribution's goodness-of-fit to Osborne's empirical data.

It is noteworthy that both Bachelier and Osborne did not base their normality hypothesis on any formal model of the processes that produce asset prices. They avoided doing so by assuming that these processes possess certain properties that give rise to price increments with convenient and intuitively appealing qualities.

A.1 The stable Paretian hypothesis

As noted by Fama (1965), most of the research that predated his own (e.g. Kendall (1953) and Moore (1962)) contradicted the normality hypothesis by showing that the distribution of empirical log price differences possess 'weaker shoulders' and 'fatter tails' relative to the normal. To address this contradiction, Mandelbrot (1963) suggested that changes in prices might be described better by the class of infinitely divisible distributions known as *stable*. The normal distribution ($\alpha = 2$) is a special finite variance case, while Paretian distributions ($\alpha = 2$) possess infinite variance. This is the conclusion that Osborne would have reached had he not assumed that random price increments are driven by a continuous finite variance process.

Mandelbrot applied the stable Paretian hypothesis to a very large dataset of changes in the logarithms of daily and monthly cotton prices, as his empirical tests indicated that the variance of these changes did not tend to a limiting sum as the sample time series lengthened. Mandelbrot initially concluded that a stationary, stable distribution does not provide a good fit to the observed data. However, by postulating that empirical scale parameters are heteroscedastic, he was able to fit a symmetric stable infinite-variance distribution to the data with a time-invariant α of approximately 1.7. This application was limited in precision due to the lack at the time of anything more accurate than simple graphical techniques for estimating sample parameters of stable distributions.

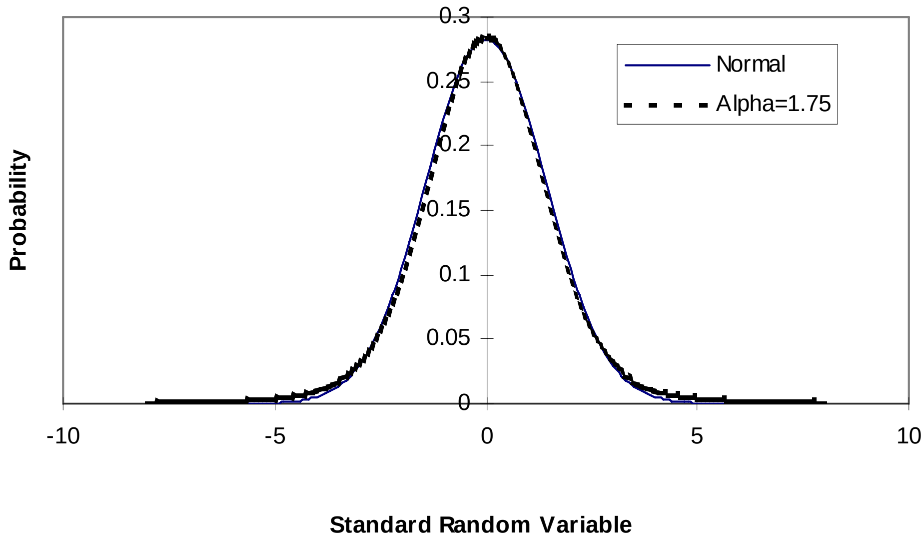
Interestingly, though Mandelbrot observed that the data appeared slightly positively skewed, he insisted that the degree of skewness was small and proceeded on the assumption that the sample distribution could be modelled by a symmetric stable distribution. While this sidestepping of skewness may have been motivated by a lack of tools for the estimation of the β parameter, it also conveniently avoided conflict with the intuitively appealing belief that log returns are symmetrically distributed.

Fama (1963) considered the types of information that affect prices, the mechanisms by which orders are translated into transactions, and how these can produce stable Paretian risk distributions of infinite variance over finite time periods. He showed that, if new information arrivals produce price changes distributed as Paretian variables with the same characteristic exponent α, then the Generalised Central Limit Theorem implies that price changes over finite time periods will also be distributed as stable variables with the same characteristic exponent α.

In a subsequent examination of the distribution of log price changes of U.S. stocks, Fama (1965) hypothesised an infinite-variance Paretian distribution to explain the erratic variances and a relatively larger number of “abrupt” changes (than would be the case under the normal hypothesis) displayed by his empirical data. This hypothesis was put forward as an alternative to one which attributed the phenomena of peakedness and fat tails to non-stationarity in the price process. Using rudimentary techniques (albeit the best that may have been available to him at the time), he eliminated this explanation.

One clear appeal of Fama’s research was that it tested a class of candidate probability distributions that encompasses the normal law for their ability to model holding period returns. In fitting symmetric stable laws to his data, Fama found α lies in the range 1.85 to 1.95 – indicating a mild departure from normal. As can be seen in Figure A-1, a stable distribution with $\alpha = 1.75$ is indeed characterised by slightly weaker shoulders and fat tails relative to a normal distribution of the same scale. Though Fama’s empirical data suggested a varying degree of skewness over time, with positive skewness appearing more frequently than negative, he ignored this aspect, most probably for reasons similar to those in the case of Mandelbrot (1965).

Figure A-1
Stable Distributions (α = 2 (normal), 1.75)



A.2 Contra-indications to the stable Paretian hypothesis

While Fama's research provided an argument in favour of the superiority of stable infinite variance probability laws over the Gaussian law as a model of continuously compounded security returns, several issues stand in the way of its adoption as the model that should serve as the basis for consequential theories of portfolio strategy and asset pricing.

First, development of the sampling theory requisite for the application of stable distributions to asset prices has proven difficult. This is because the density functions of stable distributions cannot be expressed in closed form over their entire domain (i.e. only central densities may be expressed analytically). The need for significant computing resources to tabulate standard stable densities using power series representations of the characteristic function delayed the appearance of tables until the work of Holt and Crow (1973). While fairly robust methods have long been available for estimating the parameters of *symmetric* stable distributions (see Fama and Roll (1971)), simple methods for estimating them in the asymmetric case only appeared fairly recently (see McCulloch (1986)).

Second, the variance of all stable Paretian distributions except the normal is infinite and Pearson's coefficient of correlation is undefined due to the non-convergence of the integrals associated with all moments of order greater than α. As a result, alternative measures of scale must be employed and no other measure of codependence has yet been developed. This poses an obstacle to the respecification of MPT in the stable Paretian context.

Assuming all assets have the same skewness (e.g. symmetry), MPT can be recast in a two-dimensional space using the location and scale parameters of stable Paretian distributions and index models of covariation. Fama (1965) shows how to calculate the location, scale and skewness of linear combinations of distributions with the same characteristic exponent. However, respecification of MPT in the stable Paretian context makes mean-scale optimisation much less understandable by the statistical novice. Much more importantly, the limitation imposed by working in just two dimensions eliminates the benefit or value associated with an investor's ability to predict the higher-order moments of distributions. Respecification of MPT also has serious implications for the vast amount of option and asset pricing theory that has already been formulated within the mean-variance framework.

Of course, this difficulty may be overcome when and if statistical theory evolves far enough to discover potentially more appealing stable finite variance alternatives.

Sharpe (1970) observed that, in analyses such as those conducted by Fama (1965), "the cards are stacked" in favour of a conclusion that assets' returns possess infinite variance. This is due to fact that the normal case ($\alpha = 2.0$) is the only finite variance alternative in the range of potential stable distribution models.

Third, a theoretical barrier to respecification of MPT and all derivative theory lies in the difference between continuous and discrete returns. As noted earlier, it is commonly assumed that the objective of investment is the maximisation of expected utility. This quantity may be expressed as a linear function of future wealth, which may itself be expressed as a linear function of current wealth and the discrete return on an investor's portfolio.

A consequential difficulty arises in the interpretation of the results of studies that suggest continuously compounded returns possess a stable Paretian distribution. The reason for this is that the conversion of empirical returns from discrete to continuous compounding involves taking natural logs, a non-linear transformation. Elton et al (1975) show that if log returns follow a stable Paretian distribution, discrete returns do not. They further show that if log returns follow a non-normal stable distribution, then the mean discrete return is infinite unless log returns are maximally left-skewed.

This suggests that respecification of MPT and derivative theory using stable Paretian distributions is inappropriate when the justification for this exercise is empirical evidence that shows continuously compounded returns fit such a distribution.

Fourth, the efficiency of diversification as a reducer of risk is progressively mitigated as characteristic exponents move away from two (the normal or Gaussian case). For example, when $\alpha = 1$, diversification does not produce any reduction in scale. As shown by Fama (1965), an infinite variance risk model thus has serious implications for the numbers of assets required in equally-weighted portfolios to achieve given levels of risk reduction. While this should not pose a hindrance to adoption of such a model, it lacks intuitive appeal.

Finally, the results of the Fama and Mandelbrot empirical studies have not gone unquestioned, and subsequent empirical tests have produced mixed results. For example, Cootner (1964) expressed misgivings about the conclusions for financial assets that could be drawn from a study of cotton prices, which would be expected to behave quite differently. Furthermore, Godfrey et al (1964) examined selected securities in both the time and frequency domains, and concluded that none of the series exhibited characteristics consistent with an infinite variance price-generating process.

Teichmoeller (1971) examined the properties of sample characteristic exponents ($\hat{\alpha}$) of non-overlapping sums of daily log returns of increasing size. The sample exponents did not tend to converge toward a value of 2.0, as would be expected if daily returns are distributed as a simple mixture of normal distributions. Furthermore, the mean value of his 30 estimates of α had a confidence interval that placed it more than two standard deviations below 2.0, the normal case. He concluded that daily returns are distributed either as symmetric stable with $\alpha < 2$ or as more complex mixtures of variables which have distributions with finite second moments.

Teichmoeller's study can be criticised on several issues. First, weekend price changes were excluded from the dataset, limiting the applicability of the results. Second, the security issues were of heterogeneous type, with common stock being mixed with preferred stock and the shares of investment companies. Third, it is difficult to draw conclusions about trends in the characteristic exponents of lengthening sums of daily returns using sums of only 1, 2, 5 and 10 days' returns. Finally, his study (like many others) make an inappropriate implicit assumption that securities' expected returns are constant over time. This takes no account of low-frequency structural shifts such as major changes in firms' capital structures that would result in step changes in securities' expected returns.

Officer's (1972) examination of daily and monthly log returns of stocks tracked by the Center for Research in Security Prices ('CRSP') suggested that, while empirical distributions are indeed fat-tailed, the tails of the distributions of longitudinal sums of increasing length tend to become thinner. Further, standard deviation as a measure of scale appeared to be well behaved, even with respect to daily returns over a fairly short time span of seven years (reducing the potential effect of non-constancy of distributional parameters).

Using a different data set of daily stock price changes, Barnea and Downes (1973) replicated the Teichmoeller study. They confirmed that the sample characteristic exponent appeared to be a function of the type of security issue, and that the distributions of some stocks did not seem to be stable. Their results, however, were inconclusive.

In their empirical comparison of the Student's *t*-distribution and the symmetric stable laws, Blattberg and Gonedes (1974) again considered the properties of the characteristic exponents of longitudinal sums of returns. They found that log returns converge to normality when sum sizes proceed from one to five daily returns, suggesting that daily returns are not consistent with a symmetric stable Paretian hypothesis.

Based on their investigation of daily and monthly log price changes, Hsu et al (1974) asserted that rates of return are not well represented by a stationary non-normal stable distribution. Chi-square tests of daily data for a limited sample of firms over a seven year period indicated clearly that they are not consistent with symmetric stable distributions. However, monthly data over a 34 year period supported a symmetric stable hypothesis. Interestingly, this same monthly data indicated that a major structural shift in firms' characteristic exponents occurred at the beginning of World War II, leading to a uniform shift toward normality post-war.

Hsu et al noted that this shift in distributional shape was accompanied by a shift in scale, suggesting that tests of the stability of sample characteristic exponents of empirical time series may produce spurious results due to heterogeneity across sub-periods of returns. As a consequence, in raw form their empirical data passes the test of longitudinal stability but fails the same test when daily returns are randomised prior to the fitting of characteristic exponents to sums of increasing length.

Hsu et al concluded that the distribution of rates of return is nonstationary in the scale parameter over time, and distributions with finite variances (primarily the normal distribution or a mixture of normals) would be adequate within sub-periods of homogeneous behavior.

Fielitz and Smith (1972) identify a property of log returns that bodes poorly for the research results previously described: daily log returns on 200 stocks on the NYSE appear to exhibit positive skewness of such significance as to suggest that symmetric stable distributions should be abandoned.

Following through on this assertion, Leitch and Paulson (1975) estimated the stable Paretian distribution parameters for arbitrary $-1.0 \leq \beta \leq 1.0$ of the monthly log returns of 20 NYSE common stocks over 10 years. To do this they developed a new numerical technique based on the fitting of Fourier transforms of the data to the characteristic function of stable Paretian distributions. They determined that most distributions were highly skewed, though β could be positive or negative for individual stocks.

Lending weight to these assertions, Simkowitz and Beedles (1980) tested monthly log returns of the Dow-Jones Industrial stocks for skewness, concluding that significant skewness is the rule rather than the exception. They similarly showed that distributions can be positively or negatively skewed, with the former occurring with significantly greater frequency.

Capitalising once again on the tendency of the sample variances of stable Paretian returns to approach infinity as sample size increases, Perry (1983) sought to identify trends in the sample variances in the daily log returns of 37 NYSE-listed stocks. In order to adjust for the homogeneity problems identified by Hsu et al (1974), Perry calculated bi-directional variances from the raw data, and uni-directional variances on randomised time series. He also adjusted for the common 'market' effect in all securities' returns by working with the residuals of a single-index market model. His results rejected the hypothesis that security returns distributions have an infinite variance, and suggested that return variances change over time in a complex fashion.

A.3 Alternative distributional models – continuous mixtures

The lack of clear empirical support for the stable Paretian model, and the barriers to its use in portfolio theory posed by infinite variance and the general lack of sampling theory, act as motivations for researchers to pursue alternative hypotheses.

This was facilitated by the development of improved sampling theory in other areas, and the revisitation of the economic assumptions underlying the stable Paretian model.

Mandelbrot and Taylor (1967) precipitated renewed interest in *subordinated stochastic processes* by hypothesising that "the Gaussian random walk as applied to transactions is compatible with a symmetric stable Paretian random walk as applied to fixed time intervals." In essence, this hypothesis is constructed by taking an alternative view of time. They begin by defining $P\ (t)$ as the stochastic stock price process on a physical time scale, $X\ (v)$ as the stochastic stock price process on a "local" time scale measured in volume or number of transactions, and $T\ (t)$ as the stochastic transaction process, being the cumulative volume or number of transactions up to physical time t.

In combination, these processes produce a new process defined as $P\ (t) = X\ [T\ (t)]$. $P\ (t)$ is now subordinated to $X\ (v)$ and the process $T\ (t)$ takes on the role of a *directing process*. It will be evident that the distribution of unconditional stock price $P\ (t)$ will depend on the probability distribution of the price changes that occur at each transaction, and the probability distribution governing the evolution of the number of transactions or trading volume. Mandelbrot and Taylor show that a stable Paretian law for $P\ (t)$ is consistent with Gaussian (normal) conditional price changes and transaction volume distributed as a positive stable variable where $0 < \alpha < 1$.

The clear difference between this model and the original stable Paretian model put forward by Mandelbrot (1963) and Fama (1965) lies in the fundamental economic assumption about the price evolution process. In the original model, prices are assumed to evolve through Gaussian increments that occur continuously and evenly spaced through time. In this model, increments evolve discontinuously and the number of increments that occur in a given physical time period is itself governed by a probability distribution (in this case, a maximally right-skewed stable law).

As a consequence, the unconditional distribution of prices $P(t)$ is a continuous mixture of normal distributions which, in this case, reduces to a stable Paretian law with characteristic exponent $\alpha < 1$. The conditional variance of this process varies according to the rate with which transactions evolve, while the unconditional variance remains constant.

Without explicit reference to the concept of subordinated distributions, Praetz (1972) hypothesised another continuous mixture of normals model in which conditional variance is a random variable distributed as an inverted Gamma. Praetz did this by drawing an analogy between the changing levels of activity in financial markets and the changing temperature of a gas. Both imply variability in the conditional variance of the respective Brownian motion process. As a consequence, the unconditional price process is distributed as a scaled Student's *t*.

Praetz compared his model's ability to fit weekly share price indices for seven years from the Sydney Stock Exchange against such other models as the normal, symmetric stable Paretian and "compound events" model proposed by Press (1967) (see below). Praetz estimated the unknown parameters of these models by selecting values that minimised chi-square statistics. His results indicated that his model produces a fit that was clearly superior to the others, as measured by chi-square statistics. A doubt arises about these results, however, due to the method he used to standardise the data prior to model-fitting. This was done by subtracting the sample mean and dividing the sample standard deviation. It has already been established that sample standard deviation is a poor estimator of the scale parameter for stable data.

As previously discussed, Blattberg and Gonedes (1974) considered two alternative models of stock returns: a Student's *t*-distribution with very few degrees of freedom, and a symmetric stable infinite variance distribution. In addition to examining the stability of log returns, they also tested these models' ability to fit daily stock market discrete returns. In contrast to the previous study of this kind by Praetz (1972), Blattberg and Gonedes show explicitly how the two distributional models can be derived using subordination concepts and differing assumptions about directing processes. They also make use of improved estimators of the models parameters, and use likelihood ratios to compare the effectiveness of the two models.

Blattberg and Gonedes show that Student's *t*-distributions with between two and eight degrees of freedom and non-stationary parameters provide a better empirical description of returns than the symmetric stable distributions. However, the weight of their results is mitigated by varying skewness found to be sometimes present in their data. Furthermore, neither model was able to deal with the short term dependency found in the return series.

Clark (1973) took a somewhat different approach using the concept of subordinated distributions with the aim of identifying an unconditional distribution possessing finite variance. Building on the work of Mandelbrot and Taylor (1967) and others who suggested a dependence between price changes and transaction volume, Clark began with a very important hypothesis that links trading activity with the flow of unexpected information into a market:

> The price series for cotton futures evolves at different rates during identical intervals of time. The number of individual effects added together to give the price change during a day is variable and in fact random, making the standard Central Limit Theorem inapplicable.

> The different evolution of price series on different days is due to the fact that information is available to traders at a varying rate. On days when no new information is available, trading is slow, and the price process evolves slowly. On days when new information violates old expectations, trading is brisk, and the price process evolves much faster.

The challenge in this context is to propose a distribution for the arrival of information (and, consequently, trading volume) that is an appropriate representation of reality and, ideally, results in an unconditional price process with finite variance. Clark proposes the lognormal distribution for this role due the frequency of its appearance in economic statistics and convenient and well-developed sampling theory.

Prior to testing the empirical fit of his model and the stable Paretian alternative, Clark performs an empirical test of his hypothesised relationship between trading volume and the speed of the price evolution process. An implication of this relationship is that daily trading volumes and the variance of daily price changes should be correlated. Regression tests suggest that this is indeed the case; daily price change variance appeared to be related curvilinearly to daily volume with respect to cotton futures prices. Moving backward from this result, Clark used the results of his regression exercise to (a) adjust empirical daily price changes in order to infer price changes in 'transactions time', and (b) adjust empirical daily volumes in order to infer the times between transactions. An hypothesis of normality could not be rejected for the first resulting dataset, and an hypothesis of lognormality could not be rejected for the second.

Finally, Clark used two approaches to test his lognormal-normal ('LN') model against the stable model using the cotton futures data. Using a modified maximum likelihood technique, it was found that the LN model produced far higher posterior probabilities for the two samples in question than the competing symmetric stable model. Kolmogorow-Smirnov statistics testing each sample against the maximum likelihood distributions produced similar indications.

Clark himself acknowledged several technical shortcomings encountered in his research. The main criticism offered by Mandelbrot (1973) in his comment on Clark's work is its apparent focus on identifying a model of unconditional returns that possesses finite variance. He observed that there is otherwise little difference between a lognormal law and a stable law with $\alpha < 1$ as directing processes. He further criticised the use of a constructed series of cotton futures prices for empirical data due to the exchange-imposed limitations on maximum daily price changes. Furthermore, an important technical shortcoming of Clark's proposal is its inability to express the unconditional density function of the LN model in a closed form.

A large number of studies appeared subsequent to Clark (1973) that lent considerable support to the assertion that the absolute value of price changes and transaction volumes of financial assets and commodities are dependent. Most traced this dependency to the reaction of traders to new information, and the rate with which new information arrives. Karpoff (1987) provides a comprehensive review of the research in this area.

Two more recent studies are worthy of specific consideration. Hall et al (1989) applied the stability-under-addition test of stable distribution parameters to 20 lengthy time series of log changes in daily closing futures prices in order to compare the stable Paretian and continuous mixture of normals hypotheses. Sum sizes for the full data set were 2, 4, 10, 20 and 30 days.

Though their results were suggestive of the mixture model, the largest sums still were not normally distributed. However, when the data was randomised, sums did appear normally distributed. As noted by Hall et al, these results can be explained by price changes not being independent, with the most likely reason being that conditional variance is serially correlated. It is thus no surprise that the popular ARCH/GARCH models can be represented in terms of mixture of distributions models (see, for example, Nelson (1990)).

A study by Richardson and Smith (1994) conducted direct tests of the mixture of distributions model. The authors developed a general procedure for testing whether empirical data conforms to alternative mixture models, based on the moments of the unconditional distributions implied by the assumed distributional laws governing the rate of information arrival (i.e. the directing process). Their main assumption, however, is that the means and variances of daily price changes *and* trading volumes are *both* linearly and positively related to the rate of information flow.

In the context of this model specification, Richardson and Smith observed that the evidence in favour of the mixture model is less strong than implied by previous studies. Furthermore, their results suggested that unobservable information flow is positively skewed, highly kurtotic and narrowly dispersed about its mean. Of some interest was their final observation that a lognormal model of information flow is superior to symmetric, inverted Gamma and Poisson models.

A.5 Alternative distributional models – discrete mixtures

A parallel research route taken to explain the erratic variances of empirical returns gave rise to *discrete* mixtures of distributions. In an important early contribution in this area, Press (1967) proposed a “compound events” model in which one-period log price changes are driven by a continuous Wiener process representing random price fluctuations, and a stochastic number of discrete 'jumps' that represent the occurrence of independent "information events."

This model, in which the discrete process is assumed to possess a Poisson distribution, is shown (expressed as a stochastic differential equation) in Equation A-3. The intensity of the Poisson process, defined as λ, is the mean number of random information events per unit time. When such an event occurs, there is an instantaneous jump in the stock price of size (Y - 1), with Y being defined as one plus the percentage change in stock price arising from the jump. The random variable Y is assumed to be independent of the lognormal diffusion process and, for the purposes of analytical convenience, distributed as $\ln Y \sim N(\mu_Y, \delta^2)$.

$$\frac{dP}{P} = \mu dt + \sigma dz + dq$$

Equation A-3

where:	q	$\equiv$	Poisson process, assumed independent of z,
	μ	$\equiv$	redefined to be the instantaneous expected return on the diffusion part (or drift) of the process,
	σ^2	$\equiv$	instantaneous variance of the stock return, conditional on no arrivals of 'abnormal' information,
	λ	$\equiv$	the mean number of information arrivals per unit time.

Press, *a priori*, constrained the instantaneous expected rate of return of the Wiener process to be zero, $\mu = 0$. This results in periodic log price changes possessing an unconditional density *f(x)* that is a Poisson mixture of normal densities:

$$f(x) = \sum_{n=0}^{\infty} \frac{e^{-\lambda}\lambda^n}{n!} \phi\left(n\mu_Y, \sigma^2 + n\delta^2\right)$$

Equation A-4

where: $\phi\left(x; \mu, \sigma^2\right) = \left(2\pi\sigma^2\right)^{-1/2} \exp\left(-\left(x-\mu\right)^2 / 2\sigma^2\right)$

Because lambda is directly proportional to the length of the return measurement period, it is evident from Equation A-4 that the number of components that make a contribution of any significance in the overall mixture will also depend on the length of the return period.

Employing the method of cumulants and a sample of ten NYSE listed common stocks over the period 1926 - 1960, Press frequently obtained negative estimates of the variance parameters σ^2 and δ^2 . The graphical comparisons of his empirical and estimated theoretical distributions are in poor agreement generally.

Implicit support for the supplementation of the diffusion process with a 'jump' element was offered by Hsu et al (1974) when they suggested, after a review of empirical data, that a normal probability model with a nonstationary variance subject to step changes at irregular points in time would be a more appropriate model of stock returns.

Merton (1976) incorporated the Press (1967) specification of the stochastic stock price process into a revised option pricing model. However, he took a slightly different view of the sources of variation in stock price changes, suggesting that market-wide information events manifest themselves through the diffusion process rather than the Poisson process:

> (1) the 'normal' vibrations in price, for examples, (are) due to a temporary imbalance between supply and demand, changes in capitalisation, changes in the economic outlook, or other new information that causes marginal changes in the stock's value. This component is modeled by a standard geometric Brownian motion with a constant variance per unit time and it has a continuous sample path. In general, any continuous diffusion process would work equally well.
>
> (2) The 'abnormal' vibrations in price are due to the arrival of important new information about the stock that has more than a marginal effect on price. Typically such information will be specific to the firm or possibly its

> industry although occasionally general economic information could be the source. It is assumed that this important information arrives only at discrete points in time, and it is reasonable to expect that (*ex post*) there will be 'active' periods for the stock when such information arrives and 'quiet' periods when it does not although (*ex ante*) the 'active' and 'quiet' periods are random. This component is modelled by a 'jump' process with an inherently noncontinuous sample path reflecting the non-marginal impact of information. The prototype for the jump component is a 'Poisson-driven' process.

An implicit assumption of the link that these authors assert exists between firm- or industry-specific natural events and information arrivals is that the outcomes of such events are announced as they occur, rather than accumulated and released in bursts. In the latter case, the price impact announcements would not be normally distributed (see Damodaran (1985)).

Empirical support for the 'information arrival' effect on the variance of price changes was provided subsequently by several authors, including Beaver (1968) and Patell and Wolfson (1981). Beaver empirically verified that seasonal announcements on the part of firms concerning their quarterly earnings result in return observations with higher variance during the disclosure period. Patell and Wolfson took this one step further by showing that the market's *ex ante* assessments of the variance around these announcements also exhibit an information effect.

Beckers (1981), in modifying the Press procedure, guaranteed a symmetric unconditional return distribution by constraining the mean jump size to zero ($\mu_Y = 0$) rather than the instantaneous expected return on the diffusion component ($\mu = 0$). Again employing the method of cumulants, Beckers often obtained negative estimates of σ^2 and δ^2. His model similarly implies a density *f(x)* of periodic security returns that is a Poisson mixture of normals:

$$f(x) = \sum_{n=0}^{\infty} \frac{e^{-\lambda}\lambda^n}{n!} \phi(\mu, \sigma^2 + n\delta^2)$$

Equation A-5

A restrictive aspect of the Press model is its assumption that unconditional expected returns are constant over time. Financial theory predicts that changes in the investment and financial decision variables of firm managers will result in adjustments to the expected return and standard deviation parameters of the distribution of a security's return. Boness et al (1974) found that with weekly return data before and after a capital structure change, the parameters of the price process do indeed shift. Theoretical and empirical evidence is also provided by Christie (1982), who found that capital structure changes indeed give rise to time ordered ('structural') shifts in the parameters of empirical returns. Similar sorts of effects are attributable to stock splits, acquisitions, etc.

Building on his own observations as well as those of Beaver (1968) and Patell and Wolfson (1981) concerning 'cyclical' shifts in empirical parameters, Christie (1983) (as reported by Kon (1984)) conducted a test in order to ascertain whether all firm-specific events exert an information effect on the variance of the return process. To do this, Christie assumed that market-wide or 'noninformation' events occur continuously (i.e. many times each day) and that a discrete number of firm-specific 'information' events occur in each return period.[28] Non-information events were assumed to follow a continuous Wiener process while information events precipitate lognormally distributed price changes with potentially non-zero mean μ_Y.

[28] Christie (1983) uses the terms "information" and "non-information" to differentiate between price changes that are driven by new information and noise, respectively.

Rather than make *a priori* assumptions about the expected returns or variances on the continuous or jump processes, or the probability distribution governing the arrival of information events, Christie let the latter be driven by empirical data in the form of references to firms in the *Wall Street Journal*. His results demonstrated clearly that the distribution of empirical returns experiences parameter shifts due to firm-specific information.

Another restrictive aspect of the Press (1967) model that limits it application in practice is the assumption of Poisson distributed information arrival. The consequence of this is an unconditional density function *f(x)* that is an infinite series and thus not a closed form solution to Equation A-4. A way of overcoming this difficulty is to adopt an alternative directing process.

Ball and Torous (1983) derived a simplified specification of the Press process by assuming *a priori* that, if the return measurement period is sufficiently short, discrete events are governed by a Bernoulli jump process. As a result, no more than one information event with lognormally distributed effect occurs in each return measurement period. In order to simplify the sample estimation of parameters, Ball and Torous further assumed (following Beckers (1981)) that the mean jump size is equal to zero, $\mu_Y = 0$. This model results in a security return whose unconditional density *f(x)* is a Bernoulli mixture of Gaussian densities:

$$f(x) = (1-\lambda)\phi(\mu, \sigma^2) + \lambda\phi(\mu, \sigma^2 + \delta^2)$$

Equation A-6

On the basis of maximum likelihood estimates of the four unknown parameters fitted to 500 daily return observations on 47 NYSE stocks for the period September

1975 to September 1977, Ball and Torous concluded that only five stocks did not demonstrate the presence of jumps at the five percent significance level.

A third interesting aspect of the basic model proposed by Press (1967) is its simplifying assumption that information arrivals produce log price changes that are drawings from a single normal distribution of mean μ_Y and variance δ^2 (see Equations A-4 and A-5). Press also proposed a multivariate compound events model that could be used to study the joint behaviour of a group of securities. The inspiration for this was the work of King (1966), who hypothesised that changes in the market values of stocks grouped according to common characteristics tend to co-vary in response to natural events. King's industry index model can be written as follows:

$$R_i = b_{im} I_m + b_{i1} I_1 + b_{i2} I_2 + \cdots + b_{iL} I_L + e_i$$

Equation A-7

where:	R_i	=	the rate of return on stock *i*.
	e_i	=	component of stock *i*'s return that is independent of other explanatory variables.
	I_m	=	the market index.
	I_j	=	one of *L* industry indices that are constrained to be uncorrelated with the market and each other.
	b_{im}	=	the responsiveness of the return on stock *i* to changes in the market index.
	b_{ij}	=	the responsiveness of the return on stock *i* to changes in index *j*.

The defensibility of King's model was supported by his empirical tests, which showed that about one half of the variation in stock price changes is attributable to industry factors compared to 31% attributable to the market index. Furthermore, in an extension of King's research, Rosenberg (1974) shows that fundamental variables and industry membership coefficients explain "extra-market covariance", i.e. the residuals of a market model. In both the King and Rosenberg cases, the independent extra-market variables are measuring the effects of natural events grouped on the basis of the specificity of their effects on the returns of firms' securities. Grouping in this way has intuitive appeal.

Press hypothesised that independent Poisson processes are aligned with each source of return covariance. In essence, this partitions the sources of "abnormal variations" mentioned by Merton (1976) into their component parts according to the sizes of asset groups they affect, and then assigns an information distribution to each. The result is a stochastic model in which changes in the log price of a security are composed of random price fluctuations representative of Brownian movement and two Poisson-directed jump processes, one for information arrivals applicable to a industry group as a whole and another for those peculiar to individual securities.

It can be seen that this is the $L = 2$ specification of a general 'multiple source' jump process described by the following equation:

$$\frac{dP}{P} = \mu dt + \sigma\, dz + \sum_{i=1}^{L} dq_i$$

Equation A-8

where:	q_i	$\equiv$	Poisson process i, assumed independent of z,
	L	$\equiv$	the total number of non-market information distributions.

The intensity of each Poisson process, defined as λ_i, is the mean number of 'abnormal' information arrivals of type i per unit time. When such events occur, there is an instantaneous jump in the stock price of size Y_i. The unconditional distribution of log returns in this case is a complex Poisson mixture of normals. As with the original Press model, the number of 'significant' components in the mixture will be a function of the values of each λ_i, which vary with the length of the return measurement period. The value of each λ_i is an empirical issue.

In an effort to derive and test a model that is capable of dealing with both structural and cyclical effects on the parameters of pricing processes, Kon effectively duplicated (without reference) the multivariate model of Press (1967) when he proposed a discrete mixture of normals ('DMON') model. Kon postulated that structural and cyclical effects might give rise to a mixture of normals for the market portfolio and a mixture of more than two normals for the total return distribution on individual stocks. For example, return innovations may be drawings from a 'non-information' distribution (e.g. a day of the week effect), and firm-specific and market-wide information distributions (of which there may be multiple versions if a structural shift has occurred).

In an approach similar to that of Christie, Kon does not constrain his model with *a priori* assumptions about the means and variances of the distributions or the frequencies with which they are drawn. The generalised model proposed by Kon simply views each stock return observation r_t as having been generated by one of the following N distinct equations:

$$\begin{array}{cccc} r_t & = & \mu_1 + u_{1t} & t \in I_1 \\ r_t & = & \mu_2 + u_{2t} & t \in I_2 \\ & \Downarrow & & \Downarrow \\ r_t & = & \mu_N + u_{Nt} & t \in I_N \end{array}$$

where I_i, $i = 1, 2, \ldots, N$ are the homogeneous information sets with T_i observations in each set and $\sum_{t=1}^{N} T_i = T$. The standardised information distributions u_{it} are independently and identically normally distributed with zero means and variances σ_i^2, $0 < \sigma_i^2 < \infty$, $i = 1, 2, \ldots, N$.

By defining $\lambda_i = T_i / T$ as the proportion of observations associated with information set I_i, this model results in a security return whose unconditional density $f(x)$ is the following mixture of Gaussian densities:

$$f(x) = \sum_{i=1}^{N} \lambda_i \phi(\mu_i, \sigma_i^2)$$

Equation A-9

An empirical test conducted by Kon (1984) showed that a DMON model is superior to a (symmetric) Student's *t* model in its ability to explain the distributions of an 18.5 year time series of daily rates of returns for a sample of 30 common stocks and 3 indexes.[29] In this test, optimal parameter estimates (based on a log-likelihood ratio criterion) were obtained for all stocks and indices when $N = 2$, while 15 of 30 reached optima for $N = 3$, and 10 of 30 reached optima for $N = 4$. It is worth noting that the technique used by Kon to estimate mixture parameters is unable to separate out the effects of multiple distributions that affect all stocks in a particular measurement period. They will thus be identified as one component of a mixture.

For $N = 2$, virtually all stocks in Kon's sample possessed optimal mixtures in which the means are significantly different, suggesting mean non-stationarity. This was consistent with the skewness evident in individual stocks' time series of returns. Furthermore, strong evidence of shifts in the variance parameter explained the kurtosis also observed in empirical returns. The latter in particular was verified by the disappearance of kurtosis in the subsets of the stock returns sample constructed by

[29] Kon justifies his use of discrete returns rather than log price relatives by referring to the approximate equivalence of the two when price changes are small in proportion to price levels.

grouping empirical returns into distributions according to the posterior probability of their membership.

A.6 Summary of distributional hypotheses

It will be evident that the primary difference between the alternative distributional hypotheses lies in the underlying assumptions that are made about the characteristics of information arrivals. As these become more complex, so do the implied unconditional distributions of returns. However, this increased complexity tends to be offset by greater explanatory power with respect to empirical data. Paradoxically, some of the more complex models also possess better developed sampling theory relative to simpler models.

Assumptions concerning the distributional characteristics of information arrival determine whether limiting arguments can used to deduce the distributions of periodic price changes. Osborne (1959) shows that log returns are normally distributed if a large number of information events are evenly distributed throughout each return measurement period, and these events can be assumed to precipitate relative price changes that are drawings from finite variance distributions. Mandelbrot (1963) shows, using a similar argument, that log prices will possess a non-normal stable Paretian distribution when incremental returns are drawn from infinite variance distributions. In both cases, no other restrictions on the distributional form of the price changes induced by information events are assumed.

Mandelbrot and Taylor (1967), Praetz (1972) and subsequent authors in the same vein hypothesised that the process of information arrival may be slightly more complex, with the rate of information arrivals varying over time. Continuous unimodal probability distributions such as the stable distribution with $\alpha < 1$, the lognormal, and the inverted Gamma have been proposed (among others) as directing the information arrival rate. In this world, conditional variances are time-varying, and unconditional distributions are stable Paretian, LN and Student's *t* (respectively).

Taking a cue from King (1966), Press (1967) postulated that there may be more than one information distribution from which information arrivals are drawn at different rates. This idea was derived from King's hypothesis that the forces driving returns coalesce into covariance factors. Press initially assumed that, while a large number of non-information events occur in any particular period of length *t*, discrete numbers of information events occur in the same period. In this case, conditional distributions are normal with time-varying location and scale, and unconditional distributions are sums of a discrete number of normal distributions.

Appendix B – Factors Affecting the Market Price of an ICRE Asset

As discussed in Chapter IV, the market price of an ICRE asset is theoretically equal to the sum of the present values of (i) leases in place, (ii) operating expenses and capital expenditure, (iii) new leases in the future and (iv) a continuous option to convert or rehabilitate. These are considered in turn as follows:

i. Leases in Place

The debt-like characteristics of institutional-grade leases suggest that they derive their value from a combination of contractually-determined cashflows minus an option to default. In other words, the present value of an existing lease is equal to (a) the cash flows it is expected to produce over its life, discounted at rates appropriate to the risks of these cash flows, minus (b) the value of an option granted to the tenant to put the space they occupy back to the landlord in exchange for their lease obligation (see Fabozzi and Fabozzi (1987)).

There is reason to believe that, of these two components of a lease's present value, the first component is far more important than the second. To exercise an option to default, a tenant may incur stiff penalties, and/or lose the value of any improvements that have been made. Since the value of a put option is an inverse function of its exercise price, the value of a tenant's option to default is thus very small, at least in comparison to the value of a lease that derives from its expected future cash flows.

The net cash flows that a building's existing leases can be expected to produce over their terms are determined by its tenancy structure. A building's tenancy structure is defined by the terms and conditions of the leases in place. Lease terms and conditions tend to vary according to the type of property, providing for fixed and/or variable components with periodic adjustments. Variable components are commonly linked to the revenue produced by a tenant's business (i.e. in the case of retail leases). Periodic adjustments are typically tied to the notional fair market rent for a tenant's premises.

By deduction, it will thus be evident that the net cash flows that an existing lease can be expected to produce over its life are primarily a function of the terms and conditions of the lease (which determine how rentals are set) and the time profile of fair market rents for the respective premises. The time profile of market rents for an existing lease is defined as the sequence of market rents that will prevail at key points in time for the space governed by that lease. In the case of a retail lease, expected future cash flows will also be a function of the time profile of tenant business activity. The time profile of business activity is defined as the sequence of the revenue or earnings volumes that will occur in each sub-period of time over the life of a lease.

The term and conditions of an existing lease that pertain to its remaining life are generally known with certainty at any particular point in time. This is because the terms and conditions of leases are modified after they are executed in only the rarest of circumstances.

The market rent that will prevail at any point in time in the future will be a function of the market demand at that time for the space in question, given its physical and locational characteristics, the terms and conditions of its lease, and the lease's remaining life. [30]

In turn, the market demand for a particular space at any future point in time will be a function of the general market demand for space that offers a similar bundle of

[30] This definition is important because the terms and conditions of a lease, and its remaining life, determine its market rent (see Geltner (1990)).

attributes, and the available supply of such space. The market demand for space with a specified set of attributes will be a function of the scale and composition of commercial activity in general, and the efficiency of tenants' space utilisation. The supply of substitute space will be a function of the physical stock of space, the regulations governing its use, and the terms and conditions of encumbering leases.

The volume of activity generated by a tenant's business in any future time period will be a function of the marketing mix of the tenant's business, general economic conditions, regional economic demography, and the characteristics of the location and physical structure in which the tenant conducts business.

As noted earlier, the second main determinant of the present values of existing leases is the term structure of discount rates appropriate to a building's expected cash flows. The term structure of discount rates is itself a function of three things.

i. The real spot rates of return available on riskless investments of similar liquidity in future time periods.

ii. The capital market's expectations of future inflation rates.

iii. The premia that investors will require for bearing the risk of investing in ICRE assets.

ii. Operating Expenses and Capital Expenditure

The cash flows that a property can be expected to generate in future will be mitigated to the extent that the landlord retains liability to bear the costs of specific aspects of building operation. This liability will be determined by the terms and conditions of leases. The operating expenses which a landlord may be required to bear comprise some or all of the following: real estate taxes, plant and machinery maintenance, utilities, janitorial, repairs, insurance, and physical management fees.

Future operating expenses will be a function of the volume of usage, and the cost per unit.

Expected future cash flows will almost always be mitigated by the costs of maintaining the physical structures of properties. Under most leases, owners are responsible for this. Cash outflows are associated with capital expenditure on the periodic replacement of plant and equipment, and upgrade of common areas, as well as the repair of faulty structural elements.

iii. Future Leases

The present values of future leases as at the date of their commencement are a function of the same variables underlying the present values of existing leases, thus all of the factors that affect the former also affect the latter.

However, the present value at any time *t* of a future lease is also a function of the vacancy period that transpires between sequential leases. Vacancy periods between leases are determined by the notice that landlords receive from sitting tenants of their intentions to renew or terminate, the skills of landlords at securing replacement tenants, or decisions to delay the execution of new leases, such as when vacant possession is desired for the purpose of undertaking development work (see the next section).

The periods of vacancy that will transpire at the ends of leases are determined by tenants' future credit ratings and lease clauses. Lease terminations can be voluntary or involuntary. In the former case, tenants usually must give notice of their intention to vacate their space or renew their lease in accordance with clauses contained in their lease. Such clauses provide landlords with notice periods to which they have agreed. In contrast, involuntary terminations are associated with tenant defaults. The probability that a default will occur in the case of any particular lease is proportional to the tenant's credit strength, which is in turn driven by the same factors that affect business activity.

The speed with which landlords will be able to secure replacement tenants in future will be a function of supply and demand conditions, and the operational efficiency of leasing markets at that time. The former has already been identified as a factor affecting values.

It is worth noting in the context of this discussion of supply and demand that owners are motivated to move quickly to rent vacant spaces when they come available. This is because the rights to occupy space through time cannot be accumulated. Since vacancy periods give rise to forever lost income, rational owners can be expected to be keenly motivated to fill vacant spaces as they have no ability to inventory space through time.

iv. Options to Change Use

At any particular point in time, the value of an option to change a property's use at any future time during its remaining economic life is a function of the range of alternative uses to which a property could potentially be put, the timing and economic values of each alternative, and the costs to exercise the option (e.g. lease buy-outs, construction and approvals costs, lost rental income).

The range of alternative uses will be a function of the types and intensities of uses permitted by prevailing planning regulations. These will, in turn, be a a function of legislation, public opinion and the political composition of government bodies.

The economic values of alternative uses will be primarily a function of the time profiles of market rents associated with these uses, and risk-adjusted discount rates.

Exercise costs will be a function primarily of the steps that must be taken to change a property's use, and consequential tenancy structure. For example, if vacant possession is required to effect physical changes to a property, then the cost of buying out leases will be a function of their terms and conditions, the transaction costs associated with negotiations, the time profiles of market rents and risk-adjusted discount rates. The opportunity cost of rentals foregone once a tenant has vacated and while redevelopment is under way is a function of the same set of variables.

Similarly, if construction work is required, then the costs will be a function of the type of building, its level of specification and the range of construction methods available. The costs of obtaining the necessary approvals will be a function of the time required to do so, and the fees charged by professionals and statutory authorities.

Appendix C – Discussion of the Observability of Natural Events

In this appendix, each of the pricing factors is examined in order to produce general statements about the observability of the natural events which affect them. Key issues of concern are who first observes these events, the degree to which these parties can observe events fully, accurately and in a timely manner, and the propensity of these parties to transmit their information to third parties (including the channels through which this occurs). Discussion proceeds for each factor excluding those which concern the term structure of interest rates.

i. The outcomes of the natural events that affect the terms and conditions of existing leases are first observed by the parties to the lease, and their professional advisors. This is because leases are private contracts between tenants and landlords. The details of completed leasing transactions in most jurisdictions do not become a matter of public record.[31] In fact, it is not uncommon for leases to contain clauses which place restriction on the contracting parties' abilities to disclose the terms and conditions, and for confidentiality clauses to be imposed on real estate brokers and valuers.

   However, the parties to leases do face some disclosure requirements that lead to a proportion of lease-specific information entering the public domain. For example, tenants in 'institutional-grade' properties face a requirement (in some jurisdictions) to disclose information on the leases to which they are a party for financial reporting purposes. Disclosure is usually limited to summary information and is frequently delayed until well after a transaction is completed. Owners such as life insurers, pension funds and funds managers face somewhat less onerous lease disclosure rules due to the fiduciary nature of their relationships with stakeholders.

   It should be noted that owners are motivated to restrict the general availability of information on leases because of the competitive advantage it affords them in negotiating rent reviews and new leases with tenants within the same property.

ii. The outcomes of natural events that affect the future levels of economic activity in general, and within tenants' business in particular, are initially observed accurately and quickly by the individuals within these firms. However, competitive pressures and the general lack of disclosure requirements ensure information on these events remains private until detail must be reported, where mandated, in public statements of accounts.

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[31] This is beginning to change (see Eagle (1994)).

iii. The outcomes of natural events which affect the efficiency with which tenants will utilise their spaces in future are initially observed by the parties who develop the systems by which tenants conduct their businesses. The commercial interest these parties have in promulgating these systems ensures that information on new developments becomes part of the public domain quickly and accurately.

iv. Of the natural events which affect the physical and locational attributes of a property, some are first observed, at times imperfectly, well after they have occurred. Acts of God such as mineral or fossil deposits, seismic activity and subsidence are examples of events of which the outcomes are difficult to observe and not always immediately apparent.

Furthermore, many of the natural events which affect the physical attributes of a property are first observed by tenants, landlords and their agents, and this information remains private to them. These parties are frequently the causes of events of this kind. Moreover, while information in the cases of some events must be disclosed to public authorities (e.g. physical alterations and environmental contamination), landlords and tenants face no general disclosure obligation.

Second, the outcomes of many natural events which affect a property's attributes are observable only by detailed inspection, and a large proportion of most buildings' physical areas is not generally accessible by the public. Tenants and owners will thus be in a special position to observe the outcomes of these events, of which examples include deterioration and obsolescence.

The outcomes of other natural events which have the potential to affect the physical attributes of a property, such as innovations in building design and construction technology, are generally disclosed to the public quickly, fully and accurately. The commercial motivations of providers are again the driving force behind this.

The observability of the outcomes of natural events that affect the infrastructure supporting a property (and thus its locational characteristics) is slightly different from that of other events due to the role played by public bodies. Natural events affect infrastructure by altering the quantities, qualities or types of public services available to a property, e.g. utilities, fire and police services, and transportation. Many of these alterations result in changes in the physical characteristics of these services and are thus observable directly by all market participants. However, some alterations either do not remain in open view to the public once they are completed, or do not result in observable changes in physical characteristics. In any case, the natural events that effect these alterations (e.g. public works) tend to be notified publicly and a matter of public record.

It is also the case, however, that many parties obtain foreknowledge on infrastructural changes. Information on the activities and decisions of public bodies (themselves natural events) is generally observed first by staff and contractors. While these parties generally face obligations with regard to the dissemination or non-disclosure of material information, they are difficult to enforce because violations are hard to detect.

For example, anecdotal evidence suggests that local, state and national government bodies freely 'leak' information on public infrastructure projects through private networks. The decision-making of regulatory authorities, being politically motivated in many cases, is open to manipulation. Some decisions made by public utilities on the installation or modification of services are never announced or make their way into the public domain slowly through the contracting or physical construction processes.

v. The observability of the natural events that can give rise to changes in the future supply of space that could compete with a particular building is essentially covered elsewhere in this section. Such events affect the current tenancy structures of other properties, or the physical configurations, permitted utilisations, and locational attributes that these properties could possess. The observability of the natural events that underlie changes in these characteristics of other properties are discussed elsewhere in this section.

vi. The natural events that affect the ways in which a property can be utilised in future are observable generally in a timely and accurate manner. Changes in legislation, and the election or appointment of officials are public events and, as such, become a matter of public record. However, there can be a significant time lag between the making of a decision by a public body, and the entering of the result of this decision into the public record. Shifts in public opinion are more difficult to observe as these tend to manifest themselves only when an issue requiring the expression of opinions arises.

vii. Because the natural events which have the potential to alter the future economic demography of a region fall within multiple domains, assessment of their observability is somewhat more complex. For example, some of these events occur within the confines of commercial enterprises that are operating in an area, or are contemplating doing so. The observability of these events is the same as other intra-firm events examined earlier.

Other natural events in this category occur through natural processes. These are generally observable quickly and easily by all.

A substantial proportion of the important natural events in this category are instigated by public authorities (e.g. infrastructure projects, economic development programmes, tax policies). The observability of such events has also been examined already.

x,xi. The observability of the outcomes of the natural events that have the potential to change a property's future operating expenses and capital investment requirements is also made more complicated by the fact that they fall in multiple domains. Some of these act on a building's physical fabric or plant, in which case they are generally observed initially and solely by the landlord, though public authorities may ultimately receive information.

Others occur within the domains of tenants, acting to change the demands they place on the physical fabric of buildings, or the services provided by landlords. Landlords and tenants are thus well placed to observe the outcomes of these events, either directly or through the effects they have on current operating and maintenance costs. Third parties gain information on these events through the efforts of data intermediaries.

xii. The outcomes of natural events which affect the future operating efficiency of leasing markets are generally observable quickly and easily by all ICRE market participants. Some participants will have a slight advantage over others in observing these events because of the leasing activities they undertake. However, the commercial motivations of the intermediaries active in leasing markets will serve to ensure that information on changes in technology or market practices are disseminated quickly and fully.

xiii. The outcomes of natural events which have the potential to affect tenants' credit ratings are observed initially by the tenants themselves, or other firms within their industries. Because the disclosure obligations on tenants in ICRE assets, if any, are limited to the publication of annual accounts, information on these events is not available to third parties in a timely or detailed manner. Certain lease clauses, however, alleviate this problem for landlords by placing an obligation on tenants to privately disclose the occurrence of some of the natural events that can give rise to changes in their capacity to make rental payments.

xiv. Because the factors which underlie the time profile of market rents associated with a property's alternative uses are the same as those which underlie the time profile of rents associated with its current use, explicit consideration will not be given again here to the observability of relevant natural events.

xv. The outcomes of natural events which affect the costs of future construction projects are generally observable in a timely and accurate manner by ICRE market participants. Some of these events affect the costs of materials and services or the range of design and construction techniques available; the commercial motivations of suppliers will ensure these are widely and accurately disseminated. Other events within the domain of public authorities affect the standard of work that must be done, or the procedures that must be followed to obtain approvals. The relevant public authorities are required to publicise such events. Still other events within the domains of tenants will affect their preferences in terms of the specifications of the finished product. Comments made earlier pertaining to the observability of intra-firm events apply again.

xvi. Because the natural events which affect the transaction costs associated with new leases and terminations tend to act across the leasing market as a whole, their outcomes are generally observable in a timely and accurate manner, though landlords may enjoy a slight advantage.

Appendix D – Alternative Models of Investment Selection

Five investment selection rules have attracted attention from finance researchers. These will be considered roughly in the chronological order of their appearance, with the aim of identifying their relative advantages and disadvantages:

i. Mean-Variance
ii. Principle of Safety First.
iii. Skewness Preference.
iv. *N*-order Stochastic Dominance
v. Mean-Lower Partial Variance

i. Mean-Variance

Markowitz (1952) hypothesises that investors seek portfolios that offer them maximum return and minimum risk, and that these quantities are measured by the means and variances (the first and second moments) of the returns distributions of individual and groups of assets. In support of this hypothesis, he cites investors' tendency to diversify and shows how variance is reduced by combining into portfolios, assets that have imperfectly correlated returns.

Markowitz's simple mean-variance rule for choosing between investments can be stated as follows: given two assets or portfolios *x* and *y* with returns probability distributions $F_x(r)$ and $F_y(r)$, *x* is preferred to *y* if:

$$\mu_F = \mu_G \text{ and } \sigma_F < \sigma_G \quad \text{or} \quad \mu_F > \mu_G \text{ and } \sigma_F = \sigma_G$$

where: μ_F, μ_G = means of distributions *F* and *G*
σ_F, σ_F = standard deviations of distributions *F* and *G*

Implicit in this rule is an assumption that investors prefer more to less and exhibit decreasing marginal utility of wealth. Markowitz also assumes that the utility function has a third derivative equal to zero (i.e. investors exhibit no preference for positive skewness). This constrains his analysis to the class of utility functions that are quadratic. He later showed (Markowitz (1959)) that one need not make this assumption if assets' returns are jointly normally distributed: a symmetrical two-parameter distribution such as the normal obviates the need for an assumption about investors' preferences for skewness.

Markowitz's approach quickly became acclaimed as modern portfolio theory (MPT) for two main reasons. First, it reduced the portfolio selection problem to a quantitative model specified in terms of variables (e.g. mean and standard deviation) that are familiar to many. In addition to portfolio construction, MPT offered a framework for ex post performance assessment. Furthermore, the quadratic programming techniques necessary for the implementation of an algorithm that could consider an infinite range of linear combinations of assets was already in existence at the time of MPT's first publication. This was enabled by the assumption of jointly normal returns distributions: portfolios of normally distributed assets are themselves normally distributed and the means and variances of portfolios are algebraic functions of the means and variances of individual assets, as well as their correlations.

There are theoretical problems with MPT in terms of its underlying assumptions. Assuming investors have quadratic utility functions implausibly implies increasing absolute risk aversion. This is highly counter-intuitive and a number of authors have pointed out that economic phenomena indicate the opposite is true. Also, an assumption of normality is not realistic as it completely rules out asymmetry or skewness in the probability distributions of returns. Progressive taxation, the limited liability of corporations and the variation in the seniority of securities imply that the distributions of returns are quite likely to be skewed.

Furthermore, empirical evidence suggests that many assets' short term returns are non-normal, but that returns on portfolios over longer holding periods are approximated by the normal. The latter is due to the effect of the Central Limit Theorem as assets' returns are aggregated and the dilution of the impacts of very important economic events on prices as the return period is lengthened.

In light of these problems, Markowitz (1959) himself later questions the use of variance as a measure of risk. He and others (Mao (1970), Hogan and Warren (1972)) propose semi-variance as a more attractive measure of risk on the grounds that it concentrates on "downside" returns outcomes and is congruent with the general theory of choice offered by stochastic dominance (to be discussed later). Hogan and Warren's development of an algorithm to optimise portfolios in mean-semivariance space also overcame what had previously been a major problem: semivariance's relative computational intractability in the face of an infinite opportunity set.

It should be noted at this stage that in putting forth a statistical argument for risk reduction through diversification, Markowitz (1952) intuitively reasoned that there is a limit to the benefits of portfolio expansion:

> This presumption, that the law of large numbers applies to a portfolio of securities, cannot be accepted. The returns from securities are too intercorrelated. Diversification cannot eliminate all variance.

This pre-saged a concept that would ultimately prove to be of great importance to the financial world: systematic (undiversifiable) versus diversifiable variance.

ii. Principle of Safety First

Coincident with efforts by other researchers to develop portfolio selection rules within an expected utility framework, Roy (1952) endeavoured to develop an approach based on (what he believed to be) more objective concepts. His safety-first criterion reflects a belief that investors are more concerned in practice with disaster-avoidance than maximisation of expected utility, with 'disaster' being defined as a situation where the terminal value of a portfolio is less than or equal to some predefined target minimum. An alternative way of stating the safety-first objective is that the optimal portfolio is that which minimises the probability that actual return falls short of a fixed target minimum.

Given a target minimum rate of return *t* and two assets *x* and *y* with probability distributions of returns $F_x(r)$ and $G_y(r)$, *x* is preferred to *y* if:

$$\left(\mu_x = \mu_y \text{ and } F_x(t) < G_y(t)\right) \quad \text{- or -} \quad \left(\mu_x > \mu_y \text{ and } F_x(t) = G_y(t)\right)$$

Roy thought it unlikely that investors could be called upon to produce completely specified probability distributions for all of the investments in their opportunity set, but experience might enable them to render estimates of the means and standard deviations of these distributions. Optimistically assuming these are known with perfect foresight, one is then able to use Tchebyshev's inequality to calculate an upper-bound value for the probability of return actually falling short of the target, making only weak assumptions about the shape of the true underlying distributions.

As noted in Pyle and Turnovsky (1970), Telser and Kataoka separately developed two variants of Roy's criteria. Kataoka offered another perspective on Roy's criteria by suggesting that investors seek a portfolio that maximises the lower limit *t* subject to the constraint that the probability of a return less than or equal to *t* is not greater than some predetermined value δ. Telser suggested that investors maximise expected return, subject to the constraint that the probability of a return less than or equal to *t* is not greater than a predetermined δ. It should be noted that Telser's criterion calls for the investor to specify in advance two parameters, *t* and δ.

All three specifications of the safety-first criterion may be used in conjunction with quadratic programming methods (in a manner similar to the mean-variance procedure) to ascertain the admissible set and an investor's optimal portfolio given the μ's and σ's of assets in the opportunity set and either or both a target minimum return *t* and/or maximum δ. In (σ, μ)-space the indifference curves produced by the safety-first criteria are linear. Under Roy's rule, an investor's optimal portfolio may be found at the point where the maximum slope indifference line is tangent to the admissible set. Under Telser's criteria, the indifference curves are a series of parallel lines corresponding to different *t*. The optimal *t* is determined again by the tangency between a 'maximum *t*' indifference curve and the admissible set.

With respect to Kataoka's criterion, however, Pyle and Turnovsky (1970) show that in the absence of a riskless asset, it is possible to select a combination of *t* and δ such that there is no intersection between the indifference curves and the admissible set. In this case the "maximum μ" objective fails, for there is no portfolio which will permit the investor to meet his disaster level with the required probability.

An important conclusion drawn by Pyle and Turnovsky (1970) involves the compatibility of the safety-first criteria with expected utility maximisation obtained via the mean-variance portfolio selection approach originally proposed by Markowitz

(1952). Assuming (i) no riskless asset, (ii) normally distributed returns distributions and (iii) utility functions specified only in terms of μ and σ, they show that for any portfolio chosen by a utility maximiser under these assumptions, it is always possible to find a safety-first investor who will choose the same portfolio. However, for any portfolio chosen under any specification of the safety-first principle, there is generally an infinity of expected utility functions that will cause a utility maximiser to behave similarly.

In addition, once a riskless investment is assumed to be available for unlimited lending or borrowing, the correspondence between safety-first and mean-variance breaks down entirely. This is because the efficient frontier under mean-variance in the presence of riskless lending/borrowing is a straight line (reflecting linear combinations of the riskless asset and the portfolio of risky assets offering the highest return per unit of risk). The linear indifference curves associated with safety-first criteria either coincide with the efficient frontier (leading to an infinite number of optimal portfolios) or, in the vast majority of cases, intersect it at points of infinite borrowing or 100% lending.

These conclusions make intuitive sense if one reflects on Roy's criterion: maximise return while minimising the probability of falling short of t. If the admissible set were to consist of all linear combinations of *any* risky portfolio and a riskless asset offering a return r_f, the prescription should be 100% investment in the riskless asset if $t < r_f$. Similarly if $t > r_f$, the prescription would be to choose the combination with the minimum proportion in the riskless asset (which has a 100% probability of falling short of t). In this case, no restriction on riskless borrowing leads to a recommendation to borrow as much as possible and reinvest the proceeds in the risky asset.

While the breakdown of Roy's criterion and its variants in the presence of riskless lending and borrowing reduces their appeal, their basis in 'disaster-aversion' lends further weight to the conclusion by Markowitz and others that the returns below a specified target are those of concern to investors.

iii. Skewness Preference

The effect of asymmetry in returns distributions was originally investigated by Arditti (1967), who hypothesised that investors consider the skewness of an asset's returns distribution in selecting among alternative investments. His attempt to prove this hypothesis by showing that securities' prices are sensitive to skewness was inconclusive, primarily due to a small sample size and, as was later learned, a mis-specified model.

Jean (1971) took up the issue of the pricing of higher moments of returns by attempting to develop a general extension of the portfolio analysis process to include skewness. His rationale for this exercise was his characterisation of the nature of financial security contracts, wherein the variation of 'seniority' gives rise to asymmetrical payout distributions to common stockholders. He also asserted that skewness should not be ignored for the purpose of mathematical simplicity (a covert reference to MPT) as the Taylor expansion of the expected utility equation implies potential sensitivity to skewness in investor's behaviour.

Jean's work advanced understanding of the portfolio selection process in three-dimensional (μ, σ^2, m^3) space (mean, variance and skewness, respectively) by showing analytically that (a) the skewness of a portfolio of assets is a complex interaction of the individual assets' third moments, (b) utility indifference *surfaces* must be convex so that a single optimum portfolio can be assumed to exist for any given investor, and (c) the skewness quantity of interest to investors in their pricing of assets is the assets' degree of 'coskewness' with the overall market portfolio.

Further empirical work by Francis (1975) did not support the theoretical argument for skewness preference. However, Arditti (1975) observed that Francis's work suffered from the same problem as his own previous work, namely that the regressions were specified without carefully considering the mechanism by which skewness affects pricing. In further support of his skewness preference hypothesis, Arditti referred to published cross-sectional studies of expected returns versus variance and skewness that show the skewness coefficient to be significantly negative, as expected. He also referred to a study by McEnally (1974) in which 545 stocks are grouped by risk class. McEnally found that the highest risk group provided a below-average risk-adjusted return but *markedly higher relative skewness* values.

Following in this vein, Simkowitz and Beedles (1978) undertake a theoretical and empirical study of the effect of diversification on portfolio skewness. They hypothesise that, just as in the case of variance, the skewness of assets' returns can be attributed to systematic forces affecting all assets and specific forces affecting individual assets. As diversification occurs, systematic skewness remains constant while the skewness of a portfolio's returns distribution decreases, assuming individual assets' skewness are imperfectly correlated and, on average, positive. Hence it appears there is a case for differentiating between systematic and diversifiable skewness.

Testing their hypothesis on 549 common stocks that were continuously listed on the NYSE between 1945 and 1965 produces the result that raw positive skewness at the individual asset level is, indeed reduced by diversification: in the subject dataset, 92% of diversifiable skew is eliminated by the five-stock level. Furthermore, the cube root of relative skewness (defined as the ratio of raw skewness to the cube of standard deviation) decreases continuously with increasing diversification. The behaviour of this ratio suggests that skewness per unit of risk decreases with increasing diversification. Simkowitz and Beedles (1978) suggest this may partially account for what appears to be under-diversification in the portfolios of many individuals. Kane (1982) offers a theoretical rationale for a similar suggestion.

The implications of this result are potentially immense if it can be shown conclusively that (a) investors take the concepts of systematic and diversifiable skewness into account when selecting investments from the opportunity set (and consequently, pricing those investments) and (b) investors have a positive preference for skewness that is identifiable *a priori*. This would stand at odds with the normative prescription of MPT, which is to maximise diversification at any given level of expected return.

Scott and Horvath (1980) address the second point by making a theoretical case that investors who prefer more to less, are risk-averse and exhibit consistency of moment preference will have positive (negative) preference for positive (negative) skewness. This is derived from a generalisation that investors, irrespective of the strictness of their consistency of moment preference, must exhibit on average negative preference for even central moments and positive preference for odd central moments.

Kraus and Litzenberger (1976) seek to address (a) and the shortcomings of previous researchers' work by testing empirically the relationship between the expected returns on assets and the skewness of their returns distributions. Their results support the hypothesis that investors pay a premium for positive skewness, refuting the validity of quadratic utility and, therefore, MPT as an investment selection and asset pricing framework. However, Kane (1982) shows that a three moment approximation to expected utility is only useful over a defined range; in the presence of riskless lending and borrowing, excess skewness leads to infinite borrowing while minimal skewness has the three-moment investment selection rule converging to a mean-variance decision (which is optimal in such a situation). As was the case in the analysis of the safety first principle, this problem may have more to do with the assumption of an opportunity for limitless borrowing than a flaw in the investment selection theory. Nonetheless, taking theoretical and empirical results together with intuition, there appears to be a case for believing that investors select assets on the basis of skewness as well as risk and return.

iv. Stochastic Dominance

Bawa (1975) offers a comprehensive review of stochastic dominance as a method for optimally ordering alternatives with uncertain outcomes. Three orders of stochastic dominance rules developed by other authors[32] correspond to three increasingly restrictive classes of utility functions. Bawa extended the rules to the class of utility functions that exhibit decreasing ARA.

Assume that consideration is being given to two alternative assets *x* and *y* for which the probability distributions of end-of-period wealth over the interval [*a*, *b*] are $F_x(W)$ and $G_y(W)$ with $F(a) = G(a) = 0$ and $F(b) = G(b) = 1$. First Order Stochastic Dominance (FSD) may be stated as follows: For all $W > 0$ and utility functions that satisfy condition (3), i.e. those with positive marginal utility of wealth, *x* dominates *y* if and only if $F_x(W) \le G_y(W)$ for all *W* and $F_x(W) < G_y(W)$ for at least one *W*. On a graph

[32] See Quirk and Saposnik (1962), Hanoch and Levy (1969) and Whitmore (1970) for presentations of the First, Second and Third Order Stochastic Dominance rules, respectively.

of wealth versus cumulative probability, the curve of $G_y(W)$ always lies to the left of the curve of $F_x(W)$.[33]

Second Order Stochastic Dominance (SSD) applies to the subset of utility functions to which FSD applies, restricted to those which exhibit risk-aversity. In this case, x dominates y if and only if:

$$\int_0^W \left[G_y(W) - F_x(W)\right]dW \geq 0 \qquad \text{for all } W \text{ and} > \text{for some } W.$$

This means that x will dominate y for all risk-averse investors if the accumulated area under the cumulative probability distribution $G_y(W)$ is greater than or equal to the accumulated area under $F_x(W)$ for all values of W. This criteria holds for all risk-averse investors, regardless of the way their utility function is specified, and it applies to any probability distribution.

Third Order Stochastic Dominance (TSD) applies to the class of investors whose utility functions satisfy the same conditions as for SSD but are further restricted so as to have positive third derivatives, i.e. they are risk-averse and exhibit a preference for positive skewness. In this case, x will be preferred to y if and only if $\mu_F \geq \mu_G$ and:

$$\int_0^W \int_0^W F_x(W)dWdW \leq \int_0^W \int_0^W G_y(W)dWdW \qquad \text{for all } W \text{ and} < \text{for some } W.$$

While the class of utility functions addressed by TSD was the most restrictive of the three SD rules, Bawa noted that further restriction was required, to those functions which exhibit decreasing ARA. While this came at the expense of reducing the

[33] For every possible outcome, the cumulative probability of any lesser outcome is greater under G than under F.

admissible set further still, it arrived at a class of utility functions considered most representative of the practical investor. Under this class, Bawa demonstrated that *x* would be preferred to *y* if their probability distributions have equal means and satisfy the stated condition. For the general case of unequal means, Bawa showed that a larger mean is necessary for dominance and the TSD rule is sufficient but not all of the integral condition underlying the TSD rule is necessary. Since there is no known selection rule that is a necessary and sufficient condition for dominance under this restricted class of utility functions, the TSD rule may therefore be used as a reasonable approximation to the optimal selection rule.

This is an extremely powerful result: the TSD rule applies to all probability distribution functions and all risk-averse investors with decreasing ARA, irrespective of the specific shape of their utility functions. However, practical application of the TSD rule (e.g. using Bawa's efficient algorithm) requires the opportunity set to be finite with all probability distributions *completely prespecified*, as the algorithm involves iterative pairwise comparisons. This poses a problem in the portfolio selection context, for while the number of assets may be finite, there are infinite potential linear combinations of these assets.

A similar problem was implicitly addressed by Porter (1974) in the course of comparing the mean-variance and SSD rules. He considers empirical tests of these rules and concludes that SSD is the conceptually superior rule and a mean-semivariance rule would have lead to investment choices much more consistent with SSD. Noting that semivariance as it is generally defined is the expected squared deviation of outcomes below the mean or some other reference point *t*, he opts for the latter definition, reasoning that (a) investments managers frequently explain risk as the chance of failing to meet a target level of return, and (b) it gives rise to a class of utility functions that is superior to those associated with mean-variance in terms of implied investor behaviour.

As a result, Porter is able to show that every portfolio in an opportunity set that is admissible by the mean-target semivariance rule is also admissible under SSD. Furthermore, as t becomes large, the admissible set obtained by applying the mean-semivariance rule becomes a close approximation to that obtained by applying SSD.

Bawa (1975) proposes a similar solution to this problem by showing that the TSD admissible set contains all investments admitted under a mean-lower partial variance (LPV) rule.[34] This suggests that there is potential for using the algorithm originally put forward by Hogan and Warren (1972) for the optimisation of portfolios under mean-semivariance for the purpose of applying a mean-LPV rule and, implicitly, TSD.

It is interesting at this stage to recount Bawa's observations on the potential for LPV as a measure of risk in the context of (potentially) skewed returns distributions:

> It should also be noted that since the LPV function provides for explicit consideration of asymmetry or skewness of the probability distribution, it is to be preferred to selection rules based on mean, variance and third moment of the distribution function. Indeed, it can be easily shown that selection rules based on the first n moments ($n \geq 3$) use neither a necessary nor a sufficient condition for dominance for the class of [risk-averse, decreasing ARA] utility functions and instead the mean-LPV rule should be used. Thus, at least on theoretical grounds, the approaches recently advocated in Jean (1971) should be abandoned in favour of the mean-LPV rule.

[34] A technically more accurate term for target semivariance.

v. Lower Partial Moments

Within one year of each other, Fishburn (1977) and Bawa (1978) arrived seemingly independently at the same conclusions regarding the usefulness of *n*th-order lower partial moment (LPM_n) measures as a proxy for the stochastic dominance rules that are theoretically optimal for increasing restrictive classes of utility functions. While both cite as justification for their work the general interest of previous researchers in defining risk as some function of below-target returns, only Bawa gives due credit to Roy (1952) as the originator of the concept.

Bawa (1978) proves two important theorems: (a) for arbitrary probability distributions, the union of all the admissible sets identified by applying a mean-LPM_{n-1} rule to the opportunity set across a range of *t* values produces an overall admissible set which is a close approximation to the set produced by applying an *n*th-order stochastic dominance rule, and (b) if the class of returns distributions is restricted to the generalised location and scale family of distributions,[35] the ordered set produced by a mean-LPM_0 rule (i.e. Roy's criterion) forms an upper bound to the set produced by the SSD and TSD rules as well as the SD rule associated with decreasing ARA utility functions.

Fishburn (1977) came to the same conclusions as Bawa (1978), with the additional observation that the mean-LPM_n rule for $n < 1$ characterises a risk-seeking investor while $n > 1$ is consistent with one who is risk-averse. This is because it may be shown that, assuming certain types of probability distributions, the mean-LPM_0 rule (Roy's criterion) will prefer an actuarially fair gamble that offers a possibility of

[35]Normal distributions, *t*-distributions with same degree of freedom, and stable distributions with the same characteristic exponent and skewness parameter belong to this class.

exceeding a target return *t* over an alternative that will fall short of *t* with certainty. This is the observation made by Pyle and Turnovsky (1970) with respect to the existence of opportunities for riskless lending and borrowing.

In support of Bawa's assertions, Bey (1979) undertakes an empirical comparison of the TSD and mean-LPM_2 ordering rules to 300 preselected portfolios (50 portfolios of 1, 2, 5, 10, 20 and 50 securities each).[36] He finds that application of the latter rule over a relatively narrow range of *t* values yields a total efficient set (the union of all sets for given *t* values) that is always a subset of the TSD efficient set, containing on average about 90% of the TSD efficient set. He concludes that an investor who applies a mean-LPM_2 optimal search algorithm and allows *t* to cover a range of values will derive an efficient set that is a close approximation for the TSD efficient set.

In reviewing the literature pertaining to alternative approaches to investment selection, it appears that a strong case is made for the LPM rules' superiority to MPT on the grounds that LPM rules are approximations to the optimal stochastic dominance rules, hence they are much more robust with respect to the pre-specification of returns distributions.

[36] It will be recalled that preselection is required in order to apply the pairwise TSD ordering rule. The point of the exercise was not to find the optimal efficient set but to compare the efficient sets produced by applying the two ordering rules.

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