The Analysis of Real Estate in a Finance and Actuarial Framework

by

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Abstract

This research begins by developing and applying techniques for the evaluation and risk analysis of real estate investment that are commonly used in other areas of finance and in actuarial science. Option pricing techniques for the evaluation of real estate investments that have options embedded within their lease terms are then developed and applied to the valuation of upward only rent review properties under the assumptions of a variety of financial conditions. Techniques for pricing embedded options are developed that do not require the restrictive financial assumptions of traditional option pricing techniques. Finally, the research uses a form of asset/liability modelling to determine the optimal amount of real estate investment in different forms of pension scheme. The problem of "valuation smoothing" inherent in many asset allocation models using real estate data is recognised and overcome. These strands of research are linked in the essay that forms the first part of the thesis.

The Analysis of Real Estate in a Finance and Actuarial Framework

Linking Essay

Introduction

The objective of the papers that make up this PhD submission is to develop and apply techniques for the analysis of commercial real estate investment using methods that are compatible with actuarial and financial theory. There are three sections to the work. Section One develops techniques for the valuation and risk analysis of commercial real estate in a deterministic discounted cash flow (DCF) framework. Section Two develops option pricing techniques that are necessary to price options embedded in real estate contracts, particularly the upward only rent review clause. Section Three looks at real estate in a multi-asset portfolio. Section Three begins by setting out the basic framework and then examines how we can determine the optimal allocations to real estate in a multi-asset portfolio held to meet the actuarial liabilities of a pension fund.

Chronologically, the work in Section Two followed that in Section One and thus both the papers and the references in Section One have earlier publication dates than those in Section Two. The work in Section Three was undertaken broadly concurrently with that in Section Two but finished at a later date.

The link between Section One and Section Two of the PhD is clear. Section One sets out deterministic, expected present value methods of valuation and risk analysis. Section Two develops this work on valuation techniques to a higher level to price the option value within real estate contracts.

The link between Sections One and Two and Section Three is less clear and needs further explanation. In any asset allocation model three characteristics of the assets are important: the behaviour of the asset returns; the behaviour of the liability returns; and the interaction between the assets and the liabilities. The approaches to valuation and risk analysis in Sections One and Two bring out explicitly the financial factors that affect real estate performance. In turn, we can then draw out the links between the financial factors that affect different investment markets which is a key determinant of the relevant statistical information required for the multi-asset modelling in Section Three. In the liability model used in Section Three, the liability valuation is driven by real and nominal interest rates, price inflation and salary inflation. Links can be drawn explicitly between these financial factors and the financial factors that should determine real estate valuations, that are analysed in Sections One and Two. The kind of fundamental understanding of the impact of financial factors on real estate

valuations that is developed in Sections One and Two are therefore vital for framing the approach to asset/liability modelling in Section Three.

In a further paper by Booth and Marcato (2004), not included in this PhD (see reference list at the end of Section Three for full details), real estate stochastic investment models are developed. Such models can be used for the development of asset/liability modelling (in particular where a mean variance framework is not desired). It is clear from the discussion in Booth and Marcato (2004) that the financial variables that should be tested as parameters in a stochastic model are dictated by the kinds of real estate valuation framework discussed in Sections One and Two. Thus the link between Sections One, Two and Three in this PhD are not simply that they each use rational financial techniques for the analysis of real estate. They are more intrinsically linked in that the analysis in Sections One and Two is essential for a proper formulation of the asset/liability modelling problem in Section Three.

Section One: Deterministic Cash Flow Techniques for Real Estate Analysis

This section can be regarded as containing latitudinal developments of actuarial and financial theory applied to the analysis of real estate investments. Three of the papers in this section (Adams, Booth and Venmore-Rowland, 1993; Adams and Booth, 1996 and Adams, Booth and MacGregor, 1999), begin by developing expected present value DCF approaches to real estate valuation. These are now commonly used in most commercial practice with computations often being undertaken using commercial software packages. The language and notation used in the real estate field is different from that used in the actuarial science and finance fields, as is explained in the papers, but the principles of the DCF analysis of real estate are not different from the principles of the DCF analysis of other financial assets.

The original contribution of the DCF valuation aspects of the papers in Section One involves the development of a common framework of thinking using actuarial and finance techniques and the use of some particular notation and methods of valuation in particular circumstances. The explicit DCF method had already been developed by other authors, most notably by Baum and Crosby (1988).

A more important contribution to thinking in the papers in this section comes from the risk analysis aspects of Adams, Booth and MacGrgegor (1999) and Adams, Booth and Venmore-Rowland (1993). The paper by Adams and Booth (1995) is also included in this submission, despite the fact that it relates to equities rather than real estate, because the discussion contained within the paper helps develop the context for the application of the ideas to the analysis of real estate investments. In the risk analysis sections, these papers use an approach based on the concepts of duration/volatility/interest rate sensitivity, developed in the UK,

for application to fixed interest investments by Redington (1952) and earlier in the US by Macaulay (1938).

Other authors had looked at the interest rate sensitivity of property and equity investments and related it to the concept of duration: see, for example, Ward in MacLeary and Nanthakumeran ed, (1988) in the property case and Leibowitz et al (1989) in the equity case. However, the Adams, Booth and Venmore-Rowland (1993) and Adams, Booth and MacGregor (1999) papers extended this work to consider the sensitivity of real estate values to other financial variables. It then placed the valuation framework in real terms and derived inflation sensitivities which result from the periodic nature of upward only rent reviews. The work therefore went beyond previous work in the real estate field but also went beyond the parallel work in the equity field. The results indicate the sensitivity of real estate investment valuations to changes in real interest rates: such changes could be decomposed into changes in risk-free interest rates and changes in the risk premium.

It can, of course, be argued that real estate values are sensitive to a greater range of factors than real interest rates, inflation and real rental growth. For example, the credit cycle and monetary policy will be important despite the fact that these economic variables may have no direct impact on long-term real interest rates or long-term real rental growth. Indeed, all single growth rate expected present value DCF methods of valuation have difficulty dealing with changes in financial conditions that may not be enduring. Nevertheless, it is a useful exercise to identify the fundamental variables that should affect the value of real estate and develop forms of risk analysis based around those variables. The results are intuitive: high yield properties are more risky; and properties with long rent reviews have greater inflation sensitivity. But the papers go beyond those intuitive results to quantify the impact of changes in real interest rates, real rental growth and inflation sensitivity on DCF valuations. In commercial practice, it is now common to use various approaches to sensitivity analysis to examine the impact of financial variables on valuations and appraisals. This is the same sort of deterministic risk analysis as is developed in the papers in this section. In the paper by Adams and Booth (1995) we do, in fact, develop expected present value DCF methods to include short and long-term dividend growth rates. Further sensitivity measures could be developed from this approach.

Whilst more sophisticated forms of risk analysis can be developed, the importance of the sensitivity measures derived in the above papers should not be under-estimated. In the equity market, such sensitivity measures effectively illustrate the risk of low yield versus high yield stocks and, in particular, illustrate the increased risk of stocks where a larger proportion of profits is retained within the company. In the real estate market, the sensitivity measures illustrate the risk of low yield properties and the inflation risk of long rent review properties. A low yield property has both high real interest rate sensitivity and high real rental growth sensitivity. In a classic recession, brought on by a tightening of monetary

policy – perhaps in response to earlier laxity – low yield properties may well suffer disproportionately from falls in real rental growth expectations and a rise in real interest rates. However, it should be mentioned, and is discussed in the papers, that the sensitivity measures do not tell the whole story. The risk of a particular real estate investment will depend not just on the various sensitivities to the underlying variables but on the volatility of the underlying variables in the case of a particular property. For example, a London, West End shop may be on a low yield with high expected rental growth and still be less risky than a Liverpool warehouse on a high yield with low expected rental growth if there are risk factors that undermine the security of the rental growth in the latter case.

The paper by Adams and Booth (1996) which develops the DCF analysis of over-rented properties identifies the embedded option nature of the upward only rent review clause in property leases. I believe that this was the first identification of this issue in the UK real estate literature and the second section of the PhD is devoted to this problem.

It is frequently stated by real estate practitioners and academics that techniques used for real estate investment analysis have lagged behind those used in other investment markets. Nevertheless, the techniques of analysis traditionally used for real estate valuation are not irrational. In the papers by Adams, Booth and MacGregor (1999) and Adams, Booth and Venmore-Rowland (1993) we show how traditional real estate analysis techniques can be reconciled with DCF methods. Indeed, it seems quite clear that when real estate valuation methods were developed in the nineteenth century they must have had a rational – and for their time advanced – DCF underpinning. However, it would also appear that the lack of available computational technology led to the development of standard formulae that were only valid under a limited range of assumptions that were not made explicit. As these assumptions broke down – most notably in a period of high inflation – the standard formulae, being opaque to the underlying assumptions and variables, did not handle valuation in changing conditions. Indeed, it would, in fact, be an interesting area of historical research to compare the development of surveyors' valuation techniques with actuarial valuation techniques in the nineteenth century. It may help to allay what this author would regard as an unjustified inferiority complex that the surveying profession sometimes has about its methods and methodologies if it were appreciated just how soundly grounded traditional surveyors' valuation techniques were at the time of their development. The papers in Section One demonstrate how valuation techniques for commercial real estate can be developed and reconciled with techniques used in mainstream finance and actuarial science.

Areas for Further Research

There are two areas for further research that could be developed. The first is the development of DCF valuation and risk analysis techniques when there are non-uniform changes in the underlying variables. The implicit assumption in the

papers in this section is that the variables (rental growth, real interest rates etc) are constant over time. This assumption could be relaxed. Some indication of how this could be done is given in Adams and Booth (1995). Secondly, it should be noted that the actual sensitivity of real estate values will depend not just on the relationship between valuations and the underlying variables but on the degree of variability of the variables themselves. This will be property specific and the risk of a particular property will depend on the risk attached to rental growth rate and real valuation rate assumptions for that particular property. This is an issue that could be investigated further.

Indication of Co-authors' Contributions

The technical aspects of the work, including the derivation of all proofs and computer algorithms to calculate the figures within the tables were undertaken by Philip Booth; the traditional property valuation aspects of the triple-authored works were written by Piers Venmore-Rowland and Bryan MacGregor. Andrew Adams' main contributions were to conduct the literature search and share the detailed writing up. Bryan MacGregor also helped in the process of splitting this paper from Adams, Booth and MacGregor (2003) below: the two papers began as one. Much of the research in the paper by Adams and Booth (1995) was undertaken by Andrew Adams. However, as has been noted, this paper is only included to help set the context for the real estate-related papers.

References to papers in Section One of the PhD submission

Adams, A. T., Booth, P. M. and Venmore-Rowland, P., (1993), Theoretical Volatility Measures for Freehold Property Investments, *Journal of Property Research,* Vol. 10, pp 153-166.

Adams, A. T. and Booth, P. M., (1996), The Appraisal of Over-Rented Property, *Journal of Property Finance,* Volume 7, No. 3, pp 22-37.

Adams, A. T. and Booth P. M. (1995), Sensitivity Measures for Equity. Investments, *The Journal of the Institute of Mathematics and its Applications to Business and Industry*, Volume 6, No. 4, pp 365-374.

Adams, A. T., Booth, P. M. and MacGregor, B. D. (1999), Property Investment Appraisal, *British Actuarial Journal* (formerly Journal of the Institute of Actuaries volumes 1- 121), Vol. 5, Part 5, pp 955-982.

References to other work in Section One of this essay

Baum, A. and Crosby, N., (1988), *Property Investment Appraisal,* Routledge, London, UK.

Booth P. M. and Marcato G., (2004), The Measurement and Modelling of Commercial Real Estate Performance, *British Actuarial Journal,* Volume 10, Pt. 1.

Leibowitz, M. L., Sorensen, E. H., Arnott, R. D. & Hanson, H. D., (1989), A Total Differential Approach to Equity Duration, *Financial Analysts Journal,* Vol. 45, Part 5, pp 30-37.

Macaulay, F., (1938), *Some Theoretical Problems Suggested by the Movements of Interest Rates, Bond Yields, and Stock Prices in the United States since 1856,* National Bureau of Economic Research, New York.

MacLeary, A. R. and Nanthakumeran, N., (1988), *Property Investment Theory,* E.&F. N. Spon, London, U.K.

Redington, F. M. (1952), Review of the Principles of Life Office Valuation, *Journal of the Institute of Actuaries,* Vol. 78, Part 3, pp 286-315.

Section Two: Option Pricing Techniques for Real Estate Investments

The conceptual framework for Section Two is set out in Adams, Booth and MacGregor (2003), the paper that was published last chronologically. That paper sets out the institutional aspects surrounding various forms of option embedded within real estate investment contracts. Booth and Walsh (2001a) and Booth and Walsh (2001b) consider the valuation of the embedded options implied by the upward only rent review contracts that are common in UK real estate investments.

An upward only rent review clause does not exist in all lease contracts. Indeed, it is becoming less common. However, where it does exist, it arises from clauses that allow a freeholder to charge, after a review, the higher of the rent that was being charged immediately before the review (the passing rent) and the rent at the time of the review on similar properties that have been newly let (the market rent). The proper evaluation of properties with upward only rent review contracts should use option-pricing techniques to evaluate the option.

The upward only rent review embedded option is not unlike the embedded option within a number of long-term actuarial contracts (for example limited price indexation of pensions, guaranteed annuity contracts and so on). All these options are long term and the underlying investment is not liquid – this makes traditional option pricing techniques problematical.

There are other options embedded within property lease contracts too. They include break clauses allowing a tenant to "break" the lease. This can be done, for example, if the level of rents in the market is less than the rent being charged

on the particular property – or for other business reasons. It is shown in Adams, Booth and MacGregor (2003), using the put-call parity condition, that a property that has both a break clause and an upward only rent review clause is, in a market with no frictional or transactions cost, equivalent to the property having no embedded options at all. Different types of lease contract are also used in foreign markets and these often also have options of one kind or another embedded in them: again, this is discussed in Adams, Booth and MacGregor (2003).

The existence of an option in common forms of lease contract does not necessarily have any implications for the value of properties in general. If we take the example of a newly built property that has been acquired by a freeholder and is about to be let, the use of an embedded option in the lease contract does not of itself create value for the freeholder[2]. Rather it shares risk differently between tenant and landlord. In an open market, one would expect that properties with upward only rent reviews would be let at rents lower than those without upward only rent reviews. In equilibrium, the expected present value of the rents from properties without and with upward only reviews should be the same but the starting level of rents should be higher in a property without upward only reviews. The data now exists and lease terms are now varied enough to analyse the differences in rents between properties with different lease terms and this, of itself, would be an interesting area of future research. An additional interesting area of research would be to examine the causes of tenants exercising "breaks". If they are not generally exercised simply to obtain lower rents in the market (and preliminary evidence confirms that they are not: see Baum et al, 2001) then it undermines any attempt to value real estate options – particularly break clauses – using models that assume no frictional or transaction costs and perfect liquidity. We discuss this issue below and in the papers in this section of the PhD submission.

The literature on the application of option pricing techniques to the valuation of upward only rent reviews has used two basic methods of approach and two groups of techniques. Full references and discussion is given in Booth and Walsh (2001a) and Booth and Walsh (2001b). The work by Ambrose, French, Hendershott and Ward, referenced in the Booth and Walsh papers, has tended to use binomial pricing models or other closed-form methods of valuation. This work has also tended to concentrate on determining the difference, in equilibrium, between the rent that should exist on a property with upward only reviews and a rent that should exist on a property with upwards and downward reviews. This directly addresses the issue identified above. A freehold property should be worth approximately the same regardless of the lease contract but the type of lease contract should be a contributing factor that determines the initial level of rents. These authors answer the question "What should be the relative level of

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[2] Except in the sense that the wider the range of lease contracts that is allowed the greater must be the value of the property as it allows optimal financial arrangements to be brokered between landlord and tenant. This is important but probably of second order of magnitude with regard to the value of the property.

rents from different forms of lease contract?". This issue relates to one of the concerns of those who opposed any statutory reform of upward only rent reviews in the 1993 and 2001 government reviews: such reform would prevent optimal risk sharing arrangements from developing and would simply raise the equilibrium initial level of rents to be paid by tenants.

The work by Booth and Walsh takes a different approach. It considers the issue from the investment valuation perspective. It answers the question, "For a given level of rent and given lease terms, what is the value of the property after properly valuing all the attached options?". DCF techniques value the property as the value of the cash flows at the expected rental growth rate. However, because of the upward only rent review, the level of rent that would be received given the expected rental growth rate is less than the expected level of rent. This is because the rent that will be received after a review is not a linear function of rental growth. If rental growth is negative, the rent that will be received after the next review will be the same as the rent before the review rather than less than the rent before the review. Booth and Walsh recognise this and develop a number of appropriate option pricing techniques that can be used for valuation.

There are three main contributions of the paper by Booth and Walsh (2001a). The first is that it applies an option-pricing technique that is not dependent on the assumption of continuous hedging of the underlying asset. Such an assumption had been used by earlier authors, in order to apply traditional option-pricing techniques, using a risk-free interest rate in valuation. Secondly, it develops a "generalised discounted cash flow" method of valuation which, in principle, can be applied to a wider range of situations than traditional option pricing techniques. This generalised discounted cash flow approach did not assume that the underlying asset could be hedged continuously. Thirdly, the methods were applied to a valuation problem, rather than to examining the relationship between equilibrium rents under different forms of contract. The generalised DCF approach does not use a risk-free interest rate for the valuation: the interest rate to be used is a matter of subjective judgement. This has been criticised by some[3] as, it is suggested, the Black and Scholes formulae were developed precisely to avoid such subjectivism. However, the author would argue that the nature of the problem is such that the assumptions on which such approaches are based are not valid and it is not appropriate to simply assume away the most important aspects of the problem so that it can be solved using objective inputs.

The paper by Booth and Walsh (2001b) then considered two very complex problems in sections four and five. In Booth and Walsh (2001b) the two techniques developed in Booth and Walsh (2001a) were applied to two situations not considered in Booth and Walsh (2001a). The first of these is the valuation of a lease with more than one review remaining. This is a particularly complex problem because a "compound option" is created whereby the rent after (say) the

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[3] Including one of the referees of the Adams, Booth and MacGregor (2003) paper – although the referee allowed the paper to go through with appropriate discussion of the issue.

second review depends not only on whether market rents are greater than the passing rent but on whether the rent was increased at the first review. Secondly, properties with single and multiple reviews were than valued using two different processes for the evolution of market rents. The first of these processes was the random walk process and the second an auto-regressive process.

The option-pricing problem was noted by Adams and Booth (1996) when deterministic valuation and risk evaluation models were being developed by the authors. As has been mentioned above this is possibly the first identification of the problem in the UK literature. The work on real estate valuation therefore naturally evolved from that which forms Section One to that which forms Section Two of this PhD. The option nature of property contracts requires, in many cases, techniques that are more sophisticated than straightforward expected present value techniques. It is possible that within traditional and DCF approaches to valuation, practitioners have implicitly adjusted discount rates to try to account for features such as upward only rent reviews. However, such implicit approaches are vulnerable if there is a change in financial conditions. The move to a lower inflation environment was such a change. Lower inflation made it more likely that the upward only rent review option would be exercised and therefore raised its value.

Unless real estate options can be explicitly valued, the way in which the values of real estate investments change when financial variables change and as the characteristics of contracts change will not be properly understood. Whilst such options do not necessarily have to be valued explicitly in every practical circumstance the capability to value them should exist within surveyors' practices. The work in these papers shows how the value of the embedded upward only rent review options should vary with different financial characteristics (e.g. variability of market rents, whether the property is over-rented, expected rental growth etc.).

Areas for Further Research

There are many avenues for future research in this field. More complex processes for the evolution of rents could be considered (as far as I am aware, Booth and Walsh were the first to go beyond the random walk case); the impact of market frictions preventing embedded options being exercised could be considered; and the techniques could be applied to a greater range of embedded options. The US literature has begun to consider a greater range of embedded options.

Indication of Co-authors' Contributions

In the two papers co-authored with Walsh, most of the conceptual thinking, real estate valuation work and the development of the applications was undertaken by Philip Booth. The computations and development of the valuation formulae

were undertaken by Duncan Walsh. About 50% of the work was carried out by each author. In the paper by Adams, Booth and MacGregor, the literature search was undertaken by Andrew Adams and Bryan MacGregor; the identification of rental contracts used abroad was developed by Bryan MacGregor; the research into the various option-pricing techniques, the put-call parity relationship and the underlying economics were developed by Philip Booth.

References to papers in Section Two of the PhD submission

Adams, A. T., Booth, P. M. and MacGregor, B. D., (2003), Lease Terms, Option Pricing and the Financial Characteristics of Property, *British Actuarial Journal,* Vol. 9, Part 3.

Booth, P. M. and Walsh, D. E. P., (2001a), The Application of Financial Theory to the Pricing of Upward-Only Rent Reviews, *Journal of Property Research,* Vol. 18, No. 1, pp 69-84.

Booth, P. M. and Walsh, D. E. P., (2001b), An Option Pricing Approach to Valuing Upward Only Rent Review Properties with Multiple Reviews, *Insurance, Mathematics and Economics,* Vol. 28, pp 151-171.

References in to other work in Section Two of this essay

Baum A., Crosby N. and McAllister P., (2001), Pricing Flexi-Leases: Insights and Evidence from the Retail Sector, *proceedings of the RICS Cutting Edge Research Conference*, Oxford Brookes University.

Section Three: Commercial Real Estate Investment in an Asset Liability Framework

The final part of this submission consists of three papers on the subject of asset/liability modelling and the role of real estate in a multi-asset portfolio. The first paper, Booth (1997), sets out the framework for asset/liability modelling in general. This work and other standard textbook work (for example, Booth et al 1999) develop the subject of asset/liability modelling in a number of stages. The first stage involves approaches such as Redington's theory of immunisation. In that framework, we simply choose assets to match liability profiles in such a way that assets and liabilities move in a very similar way in response to changes in particular financial conditions, such as interest rates, in order to minimise risk. The next stage involves the development of models that are similar to the Markowitz (1952) approach to portfolio selection but with two important differences. The first difference is that risk measures other than standard deviation can be used[4]. The second difference is that objective variables other

[4] Although it should be noted that, as stated in a footnote in Markowitz (1991), he was well aware that other measures of risk could be used. He used variance of return because of the

than returns from an asset portfolio can be targeted. For example, if a particular institution is investing in assets to meet a portfolio of liabilities then the objective variable might be the surplus of the institution, defined as the difference between the value of the assets and that of the liabilities. An important variable that determines the probability distribution of the surplus is then the relationship between the returns from the assets and the value of the liabilities – we return to this issue below. The basic approach to asset liability modelling using this method is followed in the papers by Booth (2002) and Booth and Matysiak (2004, pending). This approach involves a generalisation of the Markowitz framework to target the surplus of the investing institution as the objective variable. In order to gain mathematically tractable solutions for optimal portfolios, it is necessary to make simplifying assumptions about the probability distributions of relevant variables and/or choose standard deviation of returns as the measure of risk.

A third approach to asset/liability modelling, discussed in Booth (1997) involves using stochastic simulation techniques to project probability distributions of returns from assets and liabilities and of the target variable, surplus. Stochastic projection models have to be built for the assets and for the liabilities and have to allow for interactions between assets and liabilities. The simulation approach allows rather more general problems to be solved. For example, the assumptions relating to the distribution of returns from different assets and relating to the interactions between the returns from different asset classes and between assets and liabilities can be relaxed. Also, more general decision criteria can be used to determine the optimal portfolio, rather than relying on choosing a portfolio that maximises a simple function of a risk measure and the expected value of surplus. However, for such a modelling approach to be credible, reliable models of assets values and liabilities need to be found. There is an introduction to this approach in Booth (1997). There is also further discussion of it in standard texts such as that by Booth et al (1999). Also, Booth and Marcato (2004, pending) develop a stochastic real estate model for asset/liability modelling. However, this paper is not part of this submission.

The remainder of this essay focuses on the approach to asset/liability modelling used in Booth (2002) and Booth and Matysiak (2004, pending) that effectively extends the Markowitz framework to include actuarial liabilities and links this aspect of the submission to the other aspects.

The first paper in the real estate finance literature to look empirically at the role of real estate in an a pension plan, using asset/liability modelling approaches, was that by Chun et al (2000). That paper took the approach described above and found optimal asset allocation polices for different forms of pension plan to maximise a function of the mean and standard deviation of surplus of the plan. The paper by Booth (2002) generalised the approach of Chun et al by using a liability model (which could be designed to represent any set of pension

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computational difficulties involved with using other measures at the time Markowitz developed his approaches.

liabilities). Booth (2002) also used a greater range of asset categories, used direct rather than indirect real estate performance data and applied the modelling to the UK context.

The approach involved selecting asset portfolios which, on the basis of the assumptions for future asset returns, the standard deviation of asset returns, the correlation between different asset classes and the correlation between the assets and the liabilities, optimised a function of "standardised surplus return" (i.e. the rate of increase of surplus adjusted for the initial level of assets). The function of standardised surplus return that was used included the standard deviation and expected increase of surplus return. Optimisation was carried out using different assumptions for risk tolerance (risk tolerance was adjusted by adjusting the weight on the standard deviation of surplus return in the objective function) and for different forms of pension scheme (mature and immature). Full results are given in Booth (2002). However, it is notable that optimal real estate weightings were around 10% in mature pension schemes and about 5% in an immature scheme with medium risk tolerance. These levels are not that different from those seen in practice. Optimal real estate holdings do vary with risk level but tend to peak at medium levels of risk tolerance. By way of comparison, optimal levels of real estate investment were also determined for "asset-only" portfolios – i.e. for situations where the investor had the objective of maximising a function of mean and variance of asset returns. The optimal proportion in real estate portfolios was much higher in this case.

The work of Booth (2002) used real estate performance data from the IPD index series. Such data could be regarded as being subject to "valuation smoothing". Work has shown that, if the impact of valuation smoothing is removed, by "de-smoothing" the real estate data series, optimal real estate allocations in multi-asset portfolios fall. The reason for this is that valuation smoothing artificially decreases the standard deviation of returns from real estate and reduces its correlation with other asset classes. However, it does not follow that optimal asset allocation in pension schemes would be affected in the same way if the impact of valuation smoothing is removed. The reason for this is that, when the impact of valuation smoothing is removed, the relationship between the assets and liabilities may become closer. The purpose of Booth and Matysiak (2004, pending) was to examine the impact on the optimal asset allocation for different types of pension plan, arising from removing the impact of valuation smoothing on direct real estate data. The results are analysed in full in the submission. However, it is notable that the impact on optimal asset allocation of removing the effect of valuation smoothing is not nearly as marked nor as consistent across different levels of risk tolerance in the case of a pension scheme as it is in the case of asset only portfolio optimisation. This is an important result. It means that the standard result that removing the effect of valuation smoothing from real estate data leads to lower optimal allocations to real estate cannot be generalised to institutions investing to meet financial liabilities.

As has been noted, the link between this part of the PhD and the other two parts is not as clear as the link between the first two parts. However, the link is no less important. It is the financial characteristics of real estate that determine its performance profile. These were examined in Part One. The relationship between the financial characteristics of different asset classes and between the financial characteristics of asset and liabilities determines how they interact in a portfolio. For example, the value of long-term pension scheme liabilities will be affected by inflation, long-term real interest rates, as well as by salary growth. The analysis in Part One shows that the value of real estate should be affected by inflation, long-term real interest rates and real rental growth. The analysis of Part One, and of Part Two, where the option nature of the upward only rent review is seen to complicate the financial characteristics of real estate as an asset, informs the empirical analysis of performance statistics necessary for Part Three. The empirical relationship between returns from different asset classes and between assets and liabilities is determined, at least in part, by their fundamental financial characteristics, analysed in detail in Parts One and Two.

Areas for Further Research

There are many possible future avenues for research in this field, which has only recently developed in the real estate finance literature. The techniques could be applied to pension funds with a greater range of liabilities; different liability valuation techniques could be used; stochastic modelling of assets and liabilities could be used and this, in turn, would allow the maximisation of different objective functions using different risk measures.

References to papers in Section Three of the PhD submission

Booth P. M., (1997), Property Forecasting in Actuarial Modelling and Asset Management, *Journal of Property Finance*, Volume 8, Part 4, pp 303-316.

Booth (2002), Real Estate Investment in an Asset/Liability Modelling Context, *Journal of Real Estate Portfolio Management,* Volume 8, Pt. 3, pp 183-198.

Booth P.M. and Matysiak G. (2004), How Should Unsmoothing Affect Pension Plan Asset Allocation?, *Journal of Property Investment and Finance*, Volume 22, No. 6, pp 472-483.

References to other work in Section Three of this essay

Booth P. M., Chadburn R., Cooper, D. R., James, D. and Haberman S., (1999), *Modern Actuarial Theory and Practice,* Chapman and Hall, London, U.K.

Booth P. M. and Marcato G. (2004), The Measurement and Modelling of Commercial Real Estate Performance, *British Actuarial Journal,* Volume 10, Pt. 1.

Chun G. H., Ciochetti B. A. and Shilling J. D. (2000), Pension Plan Real Estate Investment in an Asset/Liability Framework, *Real Estate Economics*, Vol. 28, No. 3, pp 467-492.

Markowitz, H.M. (1952) Portfolio Selection, *Journal of Finance*, Vol. 7, pp. 77–91.

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Indication of Co-author's Contribution

Only one co-author was involved, George Matysiak. Professor Matysiak developed the de-smoothed data set used in Booth and Matysiak (2004) from valuation-based data. The analysis was undertaken by Philip Booth.

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