

EKONOMI OCH SAMHÄLLE

Skrifter utgivna vid Svenska handelshögskolan
Publications of the Swedish School of Economics
and Business Administration

Nr 149

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MODELLING AND FORECASTING
PROPERTY RENTS AND RETURNS

Helsingfors 2005

Modelling and forecasting property rents and returns

Key words: commercial rents, office returns, econometric modelling, forecasting, asymmetric responses, cointegration, panel estimation

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ISBN 951-555-889-1 (printed)
ISBN 951-555-890-5 (PDF)
ISSN 0424-7256

Editia Prima Ltd, Helsingfors 2005

Acknowledgements

The completion of this doctoral thesis would not have been possible without the help and support of several people whom I would gratefully like to thank. First of all, I want to thank my advisor, Professor Eva Liljebloom, who has played a central role in my academic life. After I completed the Master's Programme in Real Estate Finance at Hanken, Professor Liljebloom encouraged me to continue my studies for the doctoral degree and subsequently became my advisor. I am sincerely indebted to her for providing all the necessary support, guidance and advice throughout my doctoral studies, and for her valuable comments, which have benefited my research.

I would also like to thank the official pre-examiners of my doctoral manuscript, Dr Sotiris Tsolacos (Jones Lang LaSalle) and Professor Martin Hoesli (University of Geneva). Their constructive comments and suggestions have led to significant improvement of the final manuscript.

During the course of my studies I had the privilege to get to know and work with many bright individuals from the Department of Finance and Statistics, all of whom deserve special thanks. I would especially like to thank Dr Niklas Ahlgren, whose help has been extremely valuable and important during all phases of my doctoral studies. I am deeply indebted to Niklas for the time and effort he took to read and comment on numerous versions of my essays. His suggestions and ideas have contributed significantly to many improvements in the thesis.

In the late stage of my doctoral studies, visits to foreign universities helped significantly in finalising my doctoral manuscript. I would like to thank Professor C.F. Sirmans and Professor John Glascock, respectively, for inviting me and for organizing my stays at the University of Connecticut and the University of Cambridge.

I would also like to thank Olli Olkkonen and Sanna Salin from the Institute of Real Estate Economics (KTI) for the provision of the crucial data for this thesis, and for their assistance throughout my PhD project. My research has also clearly benefited from fruitful discussions with my friends, Nana Bourtchouladze and Marko Multas. During the publishing process the help of Barbara Cavonius was valuable.

Further, I wish to thank the Foundation of the Swedish School of Economics, Liikesivistysrahasto, the Centre for International Mobility, the Marcus Wallenberg Foundation and Suomen Arvopaperimarkkinoiden Edistämissäätiö for providing financial support.

I am also grateful to all my friends for their help, understanding and willingness to share happiness and sorrow with me. Life would have been dull without these precious relationships. Finally and most importantly, I would like to thank my parents for their love, support and patience throughout my life.

Helsinki, August 2005

Olga Karakozova

CONTENTS

1. Introduction	1
2. The Finnish property market	3
3. Determination of commercial rents and returns: theory and empirical evidence	9
4. Real estate indices	16
5. Econometrics	21
6. Summary of the essays	25
7. Conclusions	29
References	30

THE ESSAYS

1. An econometric analysis and forecasts of office rents in the Helsinki area	35-71
2. A comparative analysis of commercial rents in Finland	73-94
3. Modelling and forecasting office returns in the Helsinki area (<i>Journal of Property Research</i> , 2004, Vol. 21, No 1, pp. 51-73.)	95-117
4. Note on modelling office returns: business cycle asymmetries	119-135

1. Introduction

Once upon a time, in a land not so far away, there was a unique asset called real estate. It was widely heralded as being the very best investment in the world.

Jaffe and Sirmans, *The Story of Real Estate: A Parable*

Real estate is an important component of nations' income and wealth. It constitutes nearly one-half of the wealth in the world, and thus, in terms of value, represents the most significant investment class.¹ Real estate has a number of characteristics which make it different from other investment assets, including fixed location, heterogeneity, high unit value, illiquidity and the use of valuations to measure performance (Hoesli and MacGregor, 2000). Because of these characteristics, real estate was traditionally treated differently than other investment assets. However, since the mid-1980s, investment analysis of real estate has expanded from the traditional building-specific level to the aggregate portfolio level. Investors have started considering real estate in a portfolio context by comparing its performance with that of alternative investment classes, such as stocks and bonds. To do this in a proper way requires investment analysis for property which is comparable with that of other asset classes. Thus, despite its distinctive features, real estate should not be treated in isolation. This means that techniques which are widely used for other assets classes can also be applied to real estate, albeit with some modifications.

Research on property markets has been much more limited in comparison to that on stocks and bonds. The main reason for this is that property data are not as plentiful and readily available as data on stocks and bonds. The limited availability of real estate data is the result of the characteristics of property markets, such as the lack of a central trading place, low transaction volumes, no requirement to disclose transaction prices and no centralised collection of data. However, research on property investment markets has grown substantially in the last few years. Because of the availability of data, most studies have been conducted for the US and UK property markets. Other European property markets remain relatively under-researched due to the lack of sufficient data.

¹ According to Corgel *et al.* (2000), real estate comprises 49% or \$21.41 trillion of the world's wealth (\$44 trillion) whereas stocks and bonds comprise 25.5% and 18.8%, respectively.

Among the more important lines of research in real estate have been identifying the fundamentals of movements in property rents, yields and total returns, and predicting them on the basis of these fundamentals. These issues have attracted significant attention not only in academic research but also in practical investment. In particular, institutional investors consider modelling and forecasting of real estate series an important part of an investment strategy which supports asset allocation in a multi-asset portfolio.

In Finland, for example, real estate has a significant role in investment portfolios, with total property assets of institutions and property companies accounting for over EUR 20 billion in 2004 (KTI, 2004).² Comparing the investment performance of Finnish property with other major asset classes such as stocks and bonds during the last six years shows that property significantly outperformed stocks during the economic slowdown in the 2000-2002 period. These features confirm the need for accurate property forecasts to ensure effective property portfolio and asset allocation decision-making.

The main objective of this thesis is to identify the main determinants and the most suitable methods for modelling and forecasting property rents and returns in markets which have experienced structural changes, using as a case study the Finnish property market. In particular, we investigate the main factors underpinning long- and short-run movements in commercial rents and returns in Finland and explore the degree of predictability in these property series using modern econometric tools.

The thesis consists of an introduction and four essays. In Essay 1 and 3 we model long- and short-run movements in Helsinki office rents and returns, respectively, and assess the suitability of alternative methods for forecasting these series. In Essay 2 we study the key drivers of changes in office, retail and industrial rents in the major Finnish cities. Finally, in Essay 4 we investigate whether office returns in Helsinki adjust asymmetrically to the business cycles, and whether accounting for such asymmetries produces forecast gains.

Although Finnish data are used in all essays, the models and techniques applied in the thesis should be useful for modelling and forecasting rents and returns in other markets which have a structure and characteristics similar to those of the Finnish

² Real estate's proportion of total investment portfolios of major pension institutions was 9.1% in 2004 (KTI, 2005).

market. The Finnish property market experienced structural changes during the period of the study (1971-2002). It developed from an over-regulated, low liquidity market to a modern and gradually international one. Since the early 2000s, the efficiency and transparency of the Finnish property market have been enhanced by active restructuring of institutional portfolios, major property outsourcings, market entry of new international investors as well as the use of more sophisticated investment strategies.

The remainder of the introduction is organised as follows. Section 2 gives background information on the Finnish property market. Section 3 presents the theoretical framework for the thesis and provides a brief literature review on modelling and forecasting commercial rents and returns. Section 4 considers issues related to the construction and quality of property return and rent indices. Some econometric methods applied in the thesis are described in section 5. The main findings of the thesis are discussed in section 6. Finally, section 7 concludes and summarises the contributions of the thesis.

2. The Finnish property market

If we could first know where we are and whither we are tending, we could better judge what to do and how to do it.

A. Lincoln

This section gives background information on the Finnish real estate market from the 1970s till present. Since one of the objectives of the thesis is how to model and forecast property rents and returns in a market with structural changes, section 2.1 provides a brief summary of the changes that the Finnish economy and the Finnish property market went through during the period of this study (1971-2002). In the thesis we model rents and returns in different property markets in Finland. Descriptive statistics and the main characteristics of the markets under investigation are presented in section 2.2.

2.1 Development of the Finnish real estate market 1970-2004

In the beginning of the sample period, in the 1970s, the Finnish property market was strictly regulated and difficult to enter. Market entry was constrained among others by

financial regulations and by agreements between financial institutions, construction companies and the government. Development activity was also restricted. During that time Finland had extremely high inflation, however, office rents still showed moderate positive growth. This made many investors to believe that real estate is a profitable investment. As a result, in beginning of the 1980s the number of real estate professionals increased and the Finnish property market became more liquid. These developments of the Finnish property market in the 1970s, in particular restrictions in development activity and constrains in market entry should be kept in mind when modelling property rents and returns and interpreting results of our empirical work.

In the middle of the 1980s, liberalisation of financial markets caused a financial and economic boom. The expansion of the domestic service sector created a high demand for commercial premises. There was almost no vacant space in the market and most of the newly completed premises were occupied as well. This resulted in constant rent growth. The economic boom was accelerated in the 1987-1989 period, when the Finnish economy was growing on average at a rate of 5%. High rental growth expectations led to low yields and high property values. As a result user and investment demand was high and property prices grew continually. The boom in the property market resulted in extensive growth in construction, especially of commercial properties. Most of the construction projects were started without proper investment analysis and were heavily leveraged.

In 1990 and 1991 an over-supply of commercial space coinciding with a recession of the Finnish economy resulted in a sharp drop in property values, rents and construction activity. By 1993, the value of real estate had fallen by half in most major markets. The collapse of the property market resulted in changes in the ownership structure. In particular, state-owned real estate companies were established to manage the stock of properties belonging to saving banks. Restrictions for foreign investors were also abolished. These structural changes in the Finnish property market, in particular the boom-bust cycle of the 1980s and 1990s, should be taken into account when trying to find the most suitable model for explaining movements in property rents and returns.

In 1994, when the Finnish economy came out of recession, the demand for space started to pick up and the real estate market has slowly recovered. Because of the rapid growth in the Finnish economy, occupational and institutional demand for real estate

has been strong till the end of the 1990s. However, since 2001, as a result of a global economic downturn, the Finnish economy has grown at a slower rate. The economic slowdown and the burst of the IT bubble, led to a decrease in rents, especially of office properties. Total returns on property investments, which remained at around 10% for several years, decreased to approximately 5.7% in 2002-2004 (see Table 1). In 2005, the Finnish property market is expected to produce a total return of 8.6% and rents are expected to increase as a result of higher growth in the Finnish economy (Aberdeen Property Investors, 2004).

Table 1. Total returns on different asset classes 1998-2004 (in %).

All returns are total returns, i.e. they include capital and income components. Real estate total return is from the appraisal-based Institute for Real Estate Economics (KTI) property index, which is compatible in sources and methods with the indices constructed by Investment Property Databank (IPD). The KTI index covers over 60% of the institutional market in Finland. The main categories of properties in the index are offices (57% of the total value), retail (18%), and residential (13%). The composition of the index reflects the fact that Finnish institutions mainly invest in offices and retail. The Helsinki Metropolitan Area constitutes nearly 75% of the index by value of properties covered. The number of properties included in the index in 2004 was 2091 and they were valued at over EUR 12 billion. Total stock returns are based on the Helsinki Stock Exchange Portfolio Index. In the HEX Portfolio Index the weight of each company is limited to 10% of the total market capitalization of the index. Bond total returns are based on the Sampo Government Bond Index B.

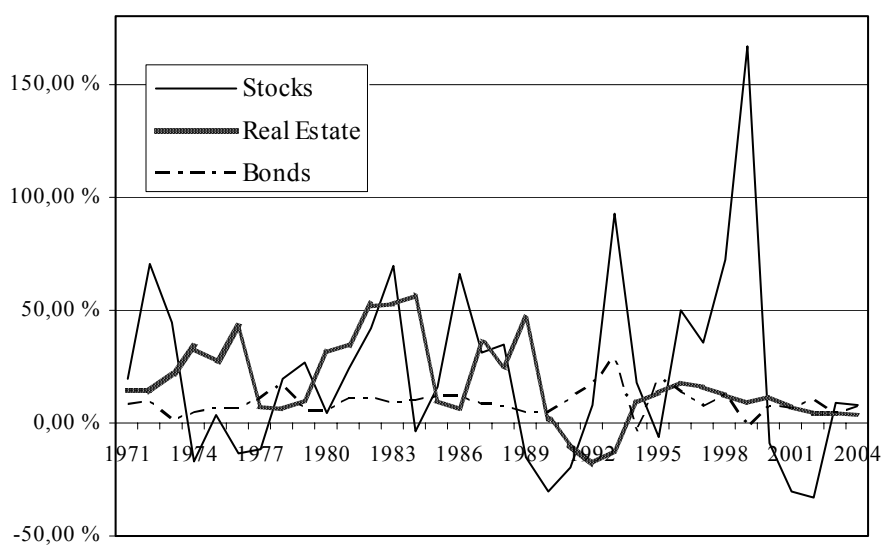
Asset Classes	1998	1999	2000	2001	2002	2003	2004
Real Estate	13,1	10,7	10,0	7,1	5,7	5,9	5,6
HEX Portfolio Index	17,7	71,8	-21,5	-18,2	-13,5	22,7	21,4
Bonds	12,2	-1,9	6,9	5,7	9,7	4,2	6,8

(Source: KTI.)

Comparing the investment performance of Finnish property with that of stocks and bonds, we can see from Table 1 that property outperformed stocks in 3 out of 7 years during the 1998-2004 time period. The performance of the three asset classes and their risk and return parameters during the longer time period, 1971-2004, are presented in Figure 1 and Table 2, respectively. Not surprisingly, stocks constitute the highest return and risk asset class, followed by real estate and bonds. Table 2 suggests that real estate represents a very good investment alternative in Finland as it yields a quite similar average return with a half lower risk than that of stocks. The interaction between the property market and the capital market, in particular, between property and stock returns, and bond yields are investigated empirically in Essay 3 of the thesis.

Figure 1. Performance of Finnish real estate, stocks and bonds, 1971-2004.

This figure depicts the performance of three asset classes in Finland during the 1971-2004 period. All returns are total returns, i.e. they include capital and income components. Real estate total return is for Helsinki CBD offices. From 1998 to 2004 total return is from the appraisal-based KTI property index. In 2004, the KTI index included 61 office properties from the Helsinki CBD, which were valued at over EUR 1.55 billion. Before 1998 the total return index was constructed by the two biggest real estate agents in Finland, Huoneistokeskus and Huoneistomarkkinointi. The capital value component of the index is constructed using the median of transaction prices. Income returns are based on the estimated market rent of an average building for the 1971-1985 period. From 1986 to 1997 income returns are based on the KTI rent index for Helsinki CBD offices. Total stock returns are based on the Helsinki Stock Exchange All Shares Index. In comparison to the HEX Portfolio Index the weight of each company is not limited to 10% of the total market capitalization of the index. From 1992 to 2004 bonds total returns are based on the Sampo Government Bond Index B. Before 1992 bonds total returns are calculated on the basis of Bank of Finland time series for government tax-free and non-indexed bonds.



(Source: KTI.)

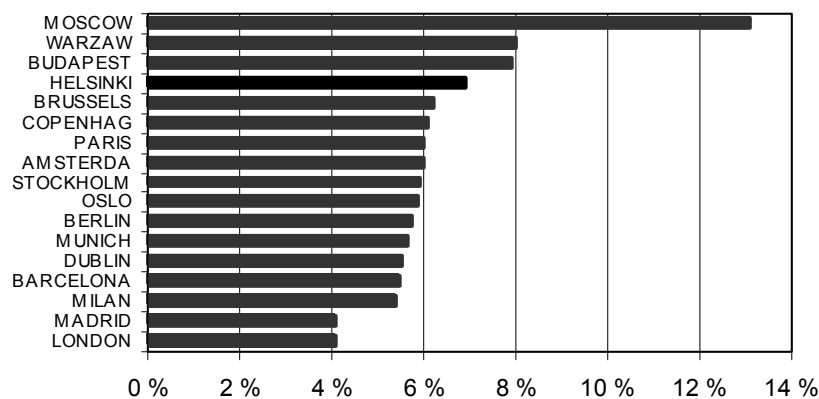
Table 2. Return and risk parameters for Finnish real estate, stocks and bonds, 1971-2004.

Asset Classes	Mean annual return	Standard deviation
Real Estate (Helsinki offices)	17,4 %	18,2 %
Stocks (HEX All Shares Index)	21,7 %	41,4 %
Bonds	8,7 %	5,9 %

(Source: KTI; see legend for Figure 1)

Since the 1990s the largest investors in the Finnish property investment market have been pension insurance companies and pension funds, which own almost half of the EUR 25 billion investment stock in Finland (Aberdeen Property Investors, 2004). However, recently the dominance of institutional ownership in the Finnish property market has been steadily decreasing as some major institutional investors have been restructuring their domestic property portfolios. Most of the pension insurance companies have also been investigating international investment opportunities through non-listed vehicles and a few of them have been already investing abroad. These developments have added to the liquidity of the Finnish property market, which has improved significantly in the last few years.

Figure 2. Prime office yields in the Helsinki CBD and other cities, 4th quarter 2004.



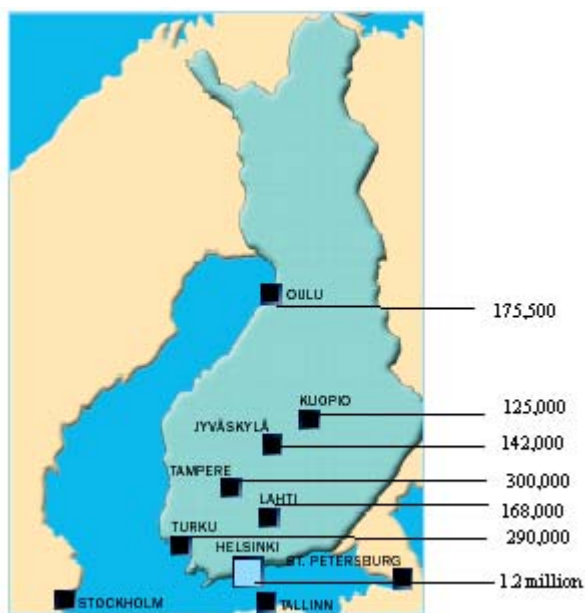
(Sources: Jones Lang LaSalle and KTI)

Another improvement of the Finnish property investment market is an increased interest of international investors, which has already resulted in several major transactions both of individual properties and major portfolios. The Finnish market is considered as attractive by foreign investors because of its good economic prospects, transparent legal and financial environments and relatively high yields (Figure 2). Among other improvements of the Finnish real estate market are major property outsourcing and the use of more sophisticated investment strategies. Since the Finnish property market is developing to more efficient and transparent, the quality and availability of property market information is becoming better. This in turn is attracting more international players with different investment strategies and thus is increasing the liquidity of the market even further.

2.2 The main property markets in Finland

In the thesis we model and forecasts commercial rents and returns in various property markets in Finland. The Finnish property market is characterised by the dominant position of its capital, Helsinki, and there are several interesting sub-markets inside it, with the Helsinki CBD being the most important one. In particular, the Helsinki CBD market is the most attractive office location as well as the centre of retail trade in Finland. Rentable space in this small area (about 355,000m²) constitutes approximately 20% of the total value of the Finnish office stock on market (KTI, 2004). In addition to this, most administrative buildings as well as major tourist attractions are also located in or around the Helsinki CBD. Thus, despite higher rents, many companies still consider the CBD area the most suitable location. In Essays 1, 3 and 4 of the thesis we model and forecast rents and returns in the Helsinki CBD office market.

Figure 3. Map of Finland (population 5.2m) and population of major metropolitan regions in Finland.



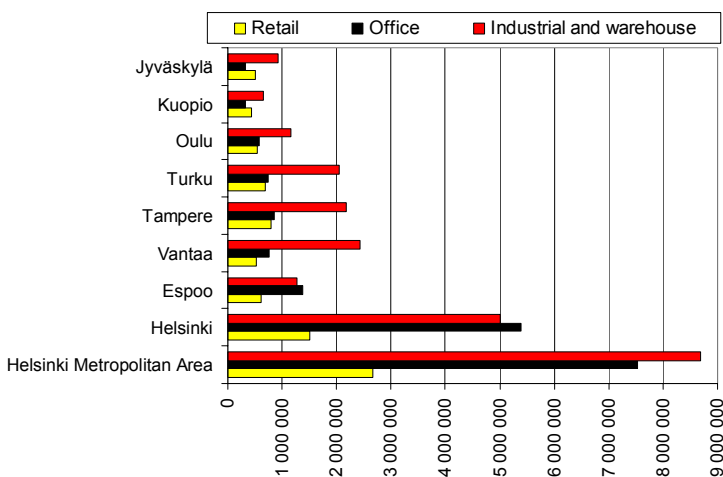
(Source: Statistics Finland.)

Another important property market is the Helsinki Metropolitan Area (HMA) including the cities of Helsinki, Espoo, and Vantaa. The relative importance of the HMA commercial property market in Finland is much greater than in many European cities of comparable size (KTI, 2005). Firstly, the Helsinki region has a dominant

position in the Finnish economy: it currently represents almost 29% of the jobs and 34% of the GDP of the entire country. Secondly, about half of the EUR60 billion commercial property stock in Finland and most government agencies and major companies' headquarters are concentrated in the Helsinki area as well. In Essay 2 we investigate the main determinants of commercial rents in the HMA market.

Other important property markets in Finland are the regional growth centres around the cities of Tampere, Turku, Lahti, Oulu, Kuopio, and Jyväskylä. The key drivers of commercial rents in these cities are explored in Essay 2. Some descriptive statistics, such as the number of inhabitants and the size of the commercial stock in these growth centres are given in Figures 3 and 4, respectively.

Figure 4. Commercial property stock in the major property markets in Finland (in sqm).



(Source: Statistics Finland.)

3. Determination of commercial rents and returns: theory and empirical evidence

It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.

Arthur Conan Doyle

This section presents the theoretical framework for each essay. In particular, we describe the main ideas of theoretical frameworks which have been used for modelling

and forecasting rents and returns in the UK and US property markets, and examine the pros and cons of adopting these frameworks to study the Finnish property market. We also provide a brief review of relevant studies.

3.1 Models of rent determination

3.1.1 The rental adjustment approach

Research on rent determination has generally followed different directions in the US and in Europe. The main focus in early US studies has been on estimating rental-adjustment models, which link the change in real rent to deviations in the vacancy rate from its natural or equilibrium level that is implicitly defined as the vacancy level consistent with constant real rents. In the face of such deviations, rents and vacancy rates must adjust until the latter returns to its equilibrium level. This approach has its origins in labour economics and its possible application to the office market was described among others by Shilling *et al.* (1987, 1992) and Wheaton and Torto (1988). Most US researchers have modelled the rent-vacancy adjustments in the framework of multi-equation or structural models, which describe the overall workings of the market and usually consists of three behavioural equations: for space demand, building development (new supply), and rent determination (Rosen, 1984, Hekman, 1985 and Pollakowski *et al.*, 1992).

Although the vacancy rate framework gives important insights, in that it sets the stage for estimating speeds of rent-vacancy adjustments, computing natural vacancy rates and analyzing their determinants, it has shortcomings as a representation of the dynamics of property market adjustments.³ In particular, one of the drawbacks of the vacancy rate approach is that it does not allow to determine and estimate the equilibrium rent level and to investigate the role it plays in the adjustment process.

Wheaton and Torto (1994), Hendershott (1995 and 1996), and Wheaton *et al.* (1997) were among the first to take this issue into account by explicitly modelling rent dynamics as an adjustment process towards an equilibrium level. These studies allow for a more general adjustment process with real rents adjusting to the gap between the

³ For a critique of the natural vacancy rate methodology, see among others, McDonald (2000), Sivitanidou (2002), Hendershott *et al.* (2002a) and Englund *et al.* (2005).

equilibrium and actual rent levels as well as to the gap between the current and natural vacancy rates. Although the above researchers develop and estimate more complete models of office markets, they still specify the change in rent as a function of the vacancy rate and thereby treat the latter as the exogenous variable without taking into account that in the short-run both the rent and the vacancy rate are jointly dependent variables, i.e., they are determined by other common variables (McDonald, 2000). The endogeneity of the vacancy rate in rent equations leads to invalid results and thus requires different estimation methodologies.

Such methodologies have been applied among others by Hendershott *et al.* (2002a and 2002b) and Englund *et al.* (2005). In particular, the above studies use cointegration analysis to specify a long-run equilibrium model of the space market and use this model to estimate the equilibrium rent. Then by applying an ECM approach they model short-run adjustments in rents to their long-run equilibrium level and to changes in demand and supply variables underlying rent movements. In Essay 1 of the thesis we also model and estimate the dynamics of rent adjustments towards their equilibrium level using an ECM approach.

A broad consensus emerges from existing US studies on the importance of the vacancy rate or the gap between the actual and natural vacancy rates as a key driver of rent movements. However, the significance of the vacancy rate approach for forecasting purposes has received limited attention as only a few US researchers have used rental adjustment or multi-equation models to forecast rents (Wheaton and Torto, 1988, Hendershott *et al.*, 1999). Although the vacancy-rate approach is not without limitations, given the importance attached to vacancy variables by existing research, it would be useful to include them in our study in order to test their significance for modelling and forecasting commercial rents. However, the lack of a sufficiently long vacancy series for the Finnish property market precludes their use in the thesis.

3.1.2 The reduced form demand-supply approach

In the UK and elsewhere in Europe, the application of the vacancy rate approach has been limited, reflecting the lack of vacancy rate data as well as model preference. Instead, a reduced form demand-supply model has been predominantly estimated with real rents as the dependent variable and demand drivers (such as consumer expenditure,

service sector employment or GDP, depending on the property type under consideration) and measures of supply (new construction orders or stock, if available) as explanatory variables. Such an approach has been applied to the UK and European property markets mainly by UK researchers (see among others, D'Arcy *et al.*, 1997a, 1997b, and 1999, Thompson and Tsolacos, 1999, Hoesli and MacGregor, 2000).

The reduced form demand-supply framework builds on the premise that flows of demand and supply continually underpin rent adjustments in a particular market. This may be a restrictive assumption since institutional factors such as legislation, lease structure, planning, and other institutional restrictions, may restrain the upward or downward rent adjustments imposed by the interaction of demand and supply (McGough *et al.*, 2000). Wei Chin (2004) finds that in mature institutional environment markets, institutional factors have less impact on office investment markets, which are mainly driven by demand and supply and thus can be successfully modelled using a reduced form approach. At least for the later years (since the 1980s), the Finnish commercial market has not been regulated. That is why in Essays 1 and 2 of this thesis, we follow the UK research tradition and use the reduced form demand–supply approach to model commercial rents.

An alternative approach would be to model commercial rents within the framework of a multi-equation model, which includes equations for space demand, building development (new supply), and rent. However, the lack of long, consistent and good quality data for the Finnish property market precludes the application of this framework. In addition to this, the multi-equation approach is not without limitations. In particular, it requires a very well developed theory of how property market works. If certain functions of the market are not described satisfactorily by the system of equations, the results will be spurious. In contrast, a well specified reduced form model, as the one used in the thesis, is less intensive on *a priori* information, since it requires theoretical inputs specific only to rent determination, and if well specified provides a proper tool for forecasting (D'Arcy *et al.*, 1999).

In existing studies, researchers have used different theoretical and econometric models and alternative macroeconomic, financial and property market factors to explain short- and long-run rental movements predominantly in the US and UK property markets. European property markets still remain relatively under-researched, indicating

the lack of consistent and good quality property data. Despite differing approaches, a general consensus emerges from previous studies on the significance of demand and vacancy variables as determinants of real rents. In contrast, supply variables are often found to be insignificant, probably because good quality supply data are rarely available. In some studies researchers have also generated rent forecasts and have demonstrated the suitability of the applied techniques for forecasting purposes. However, very few studies have thoroughly assessed the forecasting performance of different models or compared it with the predictive ability of alternative forecasting techniques.

The findings of existing studies need to be complemented with further research in individual European property markets in order to understand more fully the relationship between commercial rents and their determinants and to evaluate the suitability of alternative theoretical frameworks and econometric techniques for modelling and forecasting property rents in different market environments. These issues are addressed in Essays 1 and 2, where we investigate the key drivers and assess the suitability of alternative techniques for modelling and forecasting commercial rents in Finland.

3.2 Modelling of property returns and yields

Unlike rents, other property performance variables, such as direct real estate yields and returns have been little studied. One of the reasons for such a limited amount of studies is that modelling either property yields or total returns is much more difficult than modelling rents (Hoesli and MacGregor, 2000). Rents are determined by the interaction of demand and supply in the space market (the market for leasable space). In contrast, property returns and yields are determined in the property market by the interaction of both space and capital markets and are driven by expectations on these markets (Archer and Ling, 1997).

Property total return can be defined as (Hoesli and MacGregor, 2000):

$$TR_t = IR_t + CR_t = \frac{(CV_t - CV_{t-1}) + NOI_t}{CV_{t-1}}, \quad (1)$$

where TR , IR and CR are total, income and capital returns for period t , respectively; NOI is net operating income (or net rent), which is determined in the space market and CV is

the capital value of the property, which is simply the income capitalized at the property yield, y :

$$CV_t = NOI_t / y_t \quad (2)$$

Thus, Equation (1) can be re-written as (Hoesli and MacGregor, 2000):

$$TR_t = \frac{((NOI_t / y_t) - (NOI_{t-1} / y_{t-1})) + NOI_t}{NOI_{t-1} / y_{t-1}}, \quad (3)$$

In Equation (3) all terms are defined as in (1) and the property yield, y can be defined as (Hoesli and MacGregor, 2000):

$$y = RF + RP - g, \quad (4)$$

where RF is the risk free rate, which is determined in the capital (bond) market, RP is the risk premium determined in both capital and property markets, and g is the expected rental growth.

Equation (3) implies that total return is substantially influenced by changes in property yields. The sensitivity of capital values and thus of total returns to yield movements makes the modelling and forecasting of yields a significant task. Empirical models of property yields and returns are based on variables, which are linked to the components of yield and return: the risk-free rate, the risk-premium, rental growth, net operating income and capital value. To model property yields and returns, empirical measures of their components are required.

Similarly with studies on rent determination, most of quantitative research on modelling direct real estate yields and returns has been undertaken for North American property markets. The most notable pieces of such work are the studies by Geltner and Mei (1995), Jud and Winkler (1995), Sivitanides (1998), Viezer (1999), Chandrashekar and Young (2000), and Sivitanides *et al.* (2001).

Modelling of direct real estate yields and returns has attracted less research interest in Europe. The UK market, to a degree, is the exception (Hetherington, 1988, Key *et al.*, 1994, Tsolacos *et al.*, 1998, Brooks and Tsolacos, 2001, McGough and Tsolacos, 2001, Hendershott and MacGregor, 2003). The only study of office return determination on a global scale is that by De Wit and Van Dijk's (2003). It investigates the effects of

economic growth and demand and supply factors on direct office returns in major cities in Europe, Asia and the United States.

Existing research has provided significant insight into the determination of real estate yields and returns and into the relevance of property and capital market factors. Some of previous studies while interesting in investigating factors that drive changes in yield and return, have little value in forecasting because some of the explanatory variables are difficult to forecast. Overall, the issue of property yield and return forecasting seems to be overlooked in the existing literature. Although some of the studies have generated forecasts, only a few of them have tested the out-of-sample predictive ability of their models (McGough *et al.*, 2000, McGough and Tsolacos, 2001 and Brooks and Tsolacos, 2001). That is why forecasting of property yields and returns is an area requiring more attention and in particular international evidence. In further studies, the forecasting accuracy of models should be used as one of the criteria to assess models' performance and to achieve parsimony. This issue is addressed in Essay 3.

3.3 Asymmetries, nonlinearities and regime changes in property performance series

Existing studies on modelling real estate yields and returns mainly assume that the relationship between these property series and their determinants is linear and give little attention to the possibility of modelling property series from more than one regime. There are only a small number of studies that have departed from conventional assumptions to model property yields and returns by introducing more complex dynamics, such as nonlinearities, asymmetries and distinct regimes in their empirical models.

In particular, Sivitanides (1998), Sivitanidou and Sivitanides (1999), Okunev *et al.* (2000) and Brooks and Tsolacos (2000) establish the existence of nonlinear relationship between property yields, returns and their determinants in the UK and US property markets. Applying a threshold autoregressive approach and a Markov switching model, Lizieri and Satchell (1997), Lizieri *et al.* (1998), Maitland-Smith (1996) and Maitland-Smith and Brooks (1999) provide evidence for modelling UK and US real estate returns using more than one regime. Finally, Tsolacos (2002) finds the presence of asymmetric

property returns effects in the UK and demonstrates that introducing asymmetry in empirical models yields forecast gains.

These studies have provided some evidence in favour of the hypothesis that property time-series in the US and the UK contain nonlinearities and there is need to consider a mixture of regimes in their modelling. The findings of existing studies, however, need to be complemented with additional research in individual markets in order to explore whether European property markets exhibit similar behavioural traits with those in the US and UK markets. More international evidence is also required to find out whether introducing nonlinearities and distinct regimes in empirical models yields forecast gains and whether such gains are sufficient enough to justify the extra computational time and effort associated with the application of such models. These issues are investigated in Essay 4 of the thesis.

4. Real estate indices

*The problem is not whether you can see the handwriting on the wall,
but whether you can read it.*

Evan Esar

This section is concerned with the construction and quality of real estate indices. In particular, section 4.1 considers issues associated with the construction of property price and return indices, such as those used in Essays 3 and 4. Questions relevant to the construction of rent indices, used in Essays 1 and 2 are discussed in section 4.2.

4.1 Property price and return indices

Real estate data are far from being optimal. This is mainly the result of the characteristics of property and property markets, such as the heterogeneity of property investment, the lack of a central trading market, no requirement to disclose transaction prices, infrequent trading of individual properties and no centralised collection of transaction and operating income data. Because of these limitations, adequate transaction prices or other data relating to property characteristics and operating cash

flows are generally not available. This makes the construction of property indices, which can be used for measuring property performance difficult.

Ideally, we would like to measure the performance of real estate using a price or return index that possesses some specific characteristics. In particular, an optimal property index should control for the quality of properties, should be constructed on the basis of a representative sample of properties and should be stable when data for subsequent periods are added (Bourassa *et al.*, 2004). In practice, the performance of real estate, especially in the commercial sector, is measured by indices, which often do not fulfil the above criteria.

In particular, property performance is measured using either appraisal-based or transaction based indices. Because of the scarcity of data in the commercial sector, appraisal-based indices are mostly used, whereas transaction-based indices are more common for the residential sector, in which more transaction data are available. Transaction data used for the construction of indices can be either unadjusted (averages of transaction prices) or quality-adjusted by the hedonic or repeat sales methods (Hoesli and MacGregor, 2000).

Appraisal-based indices, which rely on regular valuations of the properties included in the sample, exist in several countries. In the US, the National Council of Real Estate Investment Fiduciaries (NCREIF) Property Index is the most widely used appraisal-based index. In the UK, the main property index is the Investment Property Databank (IPD) annual index, which contains information on the portfolios of major institutional investors. IPD indices also exist for a several other European countries, such as France, the Netherlands, Germany, Ireland and Sweden (Hoesli and MacGregor, 2000).

An appraisal-based index, called the KTI (Institute for Real Estate Economics) index, was created in 1998 also in Finland. The KTI annual index consists of income and capital components and is compatible with respect to data and methods with IPD indices. Sub-indices for retail, offices, industrial and residential properties as well as 11 geographical indices are also computed by KTI. In Essays 3 and 4 of the thesis, we use the capital return component of the appraisal-based KTI index for Helsinki CBD offices for the 1998–2001 period.⁴ Although appraisal-based indices are a valuable tool for measuring investment performance of commercial properties, they are smoothed and/or

⁴ In 2001, the appraisal-based KTI index for Helsinki offices included 49 properties with a total value of over EUR 1.3 billion.

lagged, which means that they understate the volatility of real estate returns (Hoesli and MacGregor, 2000).⁵ We believe, however, that the reported smoothing should not be a concern in Essays 3 and 4 because only four data points of the capital values series are based on the appraisal-based index.

When more data are available, as in the residential sector, transaction-based indices can be constructed. The easiest way to construct property indices based on transaction prices is to compute averages or medians of transaction prices (per square meter or foot). Median property price indices are widely available in several countries. An example of such an index for commercial properties is the National Real Estate Index (NREI), published by Liquidity Fund in the US. Another example is the total return index for Helsinki CBD offices, which covers the 1971-1997 period. This index consists of income and capital return components. The capital return component of the index is used in Essay 3 and 4 of the thesis. The index was constructed by two Finnish real estate agents (Huoneistokeskus and Huoneistomarkkinointi) and constitutes the longest time series available for the Finnish property market. The number of properties included in the sample for construction of the index varies from one year to another, increasing from the end of the 1970s onwards; the average number of transactions during the 1971-1997 period is about 9.⁶

Median price indices, such as the one used in Essays 3 and 4, are simple to compute and they do not require extensive data sets (price and attributes) for their construction. However, they have a main drawback in that they do not take into account the heterogeneous nature of properties. In particular, they do not control for differences in the characteristics of properties which sell at different periods. This means that changes in index values over time may be caused not only by changes in property prices but also by differences in the quality of the properties which have been transacted. It would be preferable to use in this thesis a quality-constant hedonic index, which accounts for physical and locational characteristics of the properties. However, the construction of such a quality-adjusted index requires a sufficient amount of information on transaction

⁵ Smoothing enters appraisal-based indices from two sources. First, from appraisers' partial adjustments at the disaggregate level, i.e. appraisers tend to smooth or only partially adjust property values over time. Second, from a temporal aggregation bias at the index level, that is the appraised values of individual properties made at various points in time are averaged to produce an index value as of a single point in time (Geltner, 1993).

⁶ Even in large data bases for commercial property markets, very few transactions occur in any short interval of time (Geltner, 1993).

prices and properties' attributes, which are not available for commercial properties in Helsinki for the whole data period. In addition to this, it can be argued that commercial real estate is an asset that produces directly observable income, thus the discounted cash flow model may be more appropriate than the pure hedonic models used in the housing literature (Webb *et al.*, 1992).

4.2 Rent indices

In addition to property price and return indices, indices for property rents are also available. When constructing rent indices, several issues should be taken into account. One of the issues is the rent data included. Usually rent data are for prime space but may also be averages for all spaces. For example, the rent index for Helsinki CBD offices, which we use in Essay 1, is for prime space, whereas the rent indices of commercial properties in the main Finnish cities used in Essay 2 are averages for all spaces.

Another issue to be considered is that rent data should be for effective rents, that is, contract rents should be adjusted for the effects of tenant improvements, moving allowances, expense stops, broker commissions, free rent and other concessions. Webb and Fisher (1996) report that base rents are higher and have less volatility than effective rents due to the use of different concessions which appear to increase when the market weakens and decrease when the market strengthens. Expense stops, free rent and other concessions are not common for Finnish lease contracts. In addition to this, when changes in rents are used rather than absolute values, like in our study, differences between base rents and effective rents are mitigated (Pollakowski *et al.*, 1992). Thus, we believe that the inability to control for such concessions as well as for tenant improvements, information on which is not available, is a minor problem in our analysis of rent determination in Essays 1 and 2.

Similarly with price indices, rent indices can be constructed using either unadjusted data (averages or medians of rents) or data which are quality-adjusted by the hedonic method. Examples of the former are median rent indices for commercial properties in major Finnish cities used in Essay 2. The construction of such indices does not require complex techniques and extensive data sets. However, they do not control for

differences in physical characteristics and contract features and thus may not reflect the true evolution of rent changes in property markets

A more sophisticated approach would be to compute rent indices using a regression-based hedonic method, which controls for the heterogeneous nature of properties and lease features. Such constant-quality indices for commercial properties have been constructed and compared to average rent indices by some US and European researchers (Webb and Fisher, 1996, Dunse and Jones, 1998, Gunnelin and Söderberg, 2003, Englund *et al.*, 2004 and 2005). There are several examples of large differences between the hedonic and mean rent indices. For example, Webb and Fisher (1996) and Englund *et al.* (2004 and 2005) find that although the average rent index follows the estimated hedonic index rather closely, in many years there are instances when they differ strongly. Although it would be preferable to use such constant-quality hedonic indices in Essay 2 of the thesis, their construction requires large databases of property attributes and contract features, which are not available for all commercial properties in the cities under investigation. This indicates that the hedonic method may be much less feasible with small commercial property databases than with much larger residential databases.

As for the construction method of the rent index for Helsinki CBD offices used in Essay 1, it differs from the methods described above. In particular, to investigate the main drivers of short-run and long-run rent movements in the Helsinki office market, we use a rent index, which consists of two parts. For the 1971-1986 period the index is based on estimates of market rent for an average building and is constructed by two Finnish property agents, Huoneistokeskus and Huoneistomarkkinointi. From 1986 the index switches to the KTI rent index for Helsinki CBD offices.

The KTI rent index is based on the KTI rent database⁷ and is widely used as a market benchmark. The index is constructed using the weighting method. In particular, all new lease contracts written during a half year period (on average about 60-70 for the Helsinki CBD offices) are divided into a number of groups on the basis of two criteria: the amount of contract rent and the tenant branch. Then a weight for each group is

⁷ The KTI rent database contains approximately 800 lease contracts for Helsinki CBD offices and about 24,000 contracts for commercial properties in more than 50 Finnish cities. Data on new contracts are supplied twice per year by 70 owners and corporations. Non-standard leases are excluded from the database on the basis of the following criteria: leases with exceptionally high or low contract rent, leases with unusually small premises (below 5 square meters) and leases for premises with mixed use. For each lease contract, the database contains information on contract rent, property location, total rental space, tenant branch, and lease length (Tomi Laine, personal communication, 2005).

obtained by dividing the number of new lease contracts in each group by the stock of the existing leases at the same group.⁸ It is important to remember that using the rent index constructed by two different methods will have an impact on our results. However, this is the only rent series long enough which is available for the Finnish property market.

In Finland as well as in many other European countries, there is a great demand for reliable, constant-quality indices, which can provide an accurate reflection of changes in real estate prices, rents and returns in commercial property markets. Such indices are crucial inputs for research aiming at modelling and forecasting real estate markets. For later research it would be imperative to construct such constant-quality property indices. This task is becoming easier since efficiency and transparency of the Finnish property market is improving significantly, which means that more rich, consistent, and better quality property data are starting to be available.

5. Econometrics

Now as you wish to know more and more about any phenomenon or as a phenomenon becomes more complex, you need more and more elaborate equations, more and more detailed programming, and you end with a computerized simulation that is harder and harder to grasp.

Isaac Asimov, *Prelude to Foundation*

This section presents two econometric methods that have been found useful for modelling property rents and returns in this thesis. They are cointegration analysis, which is applied in Essays 1 and 3, and dynamic panel analysis, which is used in Essay 2.

⁸ The weighting method has been found to be superior to the hedonic method for the construction of rent indices of commercial properties in Helsinki. The reason is that most variables describing property characteristics and lease terms appear to be insignificant in the hedonic equations (Olli Olkkonen, personal communication, 2005).

5.1 Cointegration

Like many economic and financial time series, real estate series exhibit nonstationary behaviour. If we call a stationary series $I(0)$ (integrated of order zero), then a series is said to be integrated of order one, $I(1)$, if taking a first difference induces stationarity. Regressing a nonstationary $I(1)$ variable, say Y_t , on another nonstationary $I(1)$ variable, say X_t , in levels may lead to a spurious regression, in which estimators and test statistics are misleading. Before the 1980s, conventional wisdom was that nonstationary variables should be differenced to make them stationary before including them in regression and time series. However, in the early 1980s, the concept of cointegration was introduced by Granger (1981, 1983) and Engle and Granger (1987). They showed that it is possible for a linear combination of integrated variables to be stationary. In this case the variables are said to be cointegrated, which is denoted $CI(1,1)$.

In general, cointegration can be thought of as a long-run relationship between economic variables to which a system tends. Although these variables can drift away from their long-run path, economic forces are expected to eventually restore equilibrium. In the context of the property market, the existence of cointegration means that in the long-run, property rents, prices and the variables which determine them follow similar paths and that any short-term deviations from this path is expected to be restored by economic forces.

The existence of a long-run relationship also has implications for the short-run behaviour of $I(1)$ variables, because there has to be some mechanism that drives the variables back to their long-run equilibrium level. The Granger representation theorem (Granger, 1983, Engle and Granger, 1987) states that if a set of $I(1)$ variables are cointegrated, then they can be regarded as being generated by an error correction model (ECM).

ECMs are widely used in econometrics. The main characteristic of an ECM is that it combines the long-run equilibrium relationship and short-run dynamics. The long-run relationship is specified in levels, and the short-run adjustments in first differences. For example, if two time series Y_t and X_t are stationary in first differences, or $Y_t \sim I(1)$ and $X_t \sim I(1)$, then the long-run equilibrium between these variables is in general of the form $Y_t = a_0 + a_1 X_t + \varepsilon_t$ and is well defined if the equilibrium error $\varepsilon_t = Y_t - a_0 - a_1 X_t$ is

stationary, $\varepsilon_t \sim I[0]$. If this term is stationary⁹, its lagged value can be used as an error correction term in the dynamic, first-difference regression:

$$\Delta Y_t = a_0 + a_1 \Delta X_t + a_2 ecm_{t-1} + \varepsilon_t, \quad (4)$$

where ΔY_t and ΔX_t denote the first difference of Y_t and X_t , respectively, and ecm_{t-1} is the error correction term, or in other words the lagged residuals from the estimated long-run model $Y_t = a_0 + a_1 X_t + \varepsilon_t$. The ECM describes how Y_t and X_t behave in the short-run consistent with a long-run cointegrating relationship. If Y_{t-1} is above the long-run equilibrium value that corresponds to $a_0 + a_1 X_{t-1}$, that is ‘the equilibrium error’ is positive, a negative adjustment in Y_t is expected. The parameter a_2 , $a_2 < 0$, determines the speed of adjustments to the long-run equilibrium defined by $Y_t - a_0 - a_1 X_t$. The parameter a_1 measures the short-run adjustment of Y_t to changes in the explanatory variable X_t . A more general specification can include multiple lags of ΔX_t and ΔY_t .

Although the application of equilibrium models to real estate markets is not new¹⁰, studies investigating long-run equilibrium using recent time series methods, such as cointegration analysis and error correction model, remain in their infancy. The rationale for applying an ECM to property markets is that real estate prices and rents are often viewed as periodically deviating from long-run steady-state equilibrium values. Such deviations largely stem from continuous exogenous demand or supply shocks. Rents and prices only slowly adjust toward their steady-state levels. The slow speed of adjustments is due to a number of factors such as long-term leases preventing tenants to adjust their space consumption to desired levels (Englund *et al.*, 2005), delays inherent in the microeconomic process of tenant search and landlord wait (Wheaton and Torto, 1994), and slow supply responses due to long construction lags and delayed entry of rational investors exercising their option to wait until expected benefits outweigh costs (McDonald and Siegel, 1996). Because of slow adjustments, only a fraction of deviations from long-run equilibrium values is eliminated each period. In reality, equilibrium values are never directly observable since the process is continually

⁹ Stationarity can be tested by applying unit root tests to the residuals of the estimated long-run model $Y_t = a_0 + a_1 X_t + \varepsilon_t$

¹⁰ Adjustments of property rents and yields towards their equilibrium levels and the factors which determine such levels have been examined by Hendershott (1995, 1996), Hendershott *et al.* (1999), Wheaton and Torto (1994), Wheaton *et al.* (1997), Sivitanidou and Sivitanides (1999), and Sivitanidou (2002). However, none of these studies uses cointegration analysis.

affected by shocks in determinants underlying rent and price movements. We only observe the outcome of an adjustment process where rents and prices tend to move towards equilibrium. In Essays 1 and 3, we apply cointegration analysis and an ECM to model and estimate rent and capital values dynamics as an adjustment process towards their equilibrium level.

5.2 Panel data analysis

Panel data sets, which combine cross-sectional and time-series dimensions in data, are widely used in economics. In comparison to purely cross-sectional or time-series data, panel data allow researchers to specify and estimate more sophisticated dynamic models, which account for heterogeneity across units. The linear panel model takes the following general form (Greene, 2002):

$$y_{it} = \beta' X_{it} + a_i + \varepsilon_{it}, \quad i = 1, \dots, n, \quad t = 1, \dots, T \quad (5)$$

where X_{it} is a K -dimensional vector of explanatory variables, not including a constant; n is the number of cross-section units and T is the number of time-series observations. In (5), a_i is the individual specific effect, which is assumed to be constant over time t and specific to the cross-sectional unit i . Finally, ε_{it} is the error term, which is assumed to be independent and identically distributed (IID) across all cross-section units and time.

Depending on the assumptions regarding the individual specific effects a_i , the following standard estimation methods of model (5) can be defined. If it is assumed that the a_i are the same across all units, meaning that there are no differences between groups, then ordinary least squares (OLS) provides consistent and efficient estimates of a and β in the pooled model (5). If we treat the a_i 's as n fixed unknown parameters to be estimated, the model (5) is referred to as the fixed effects model and because of the way it is estimated, (5) is also sometimes called the least squares dummy variables (LSDV) model. Finally, assuming that the intercepts of the individuals are different, but that they can be treated as drawings from a distribution with mean μ and variance σ_a^2 , leads to the random effects model, where the individual effects, a_i are treated as random, and

therefore as part of a composite error term $u_{it} = a_i + \varepsilon_{it}$. In this case, generalized least squares (GLS) estimation of model (5) gives consistent and efficient estimates.

One of the major advantages of panel data is the ability to examine dynamic effects on an individual level. However, the introduction of a lagged dependent variable in the linear model (5) complicates consistent estimation. The general approach to estimate dynamic panel models relies on instrumental variables estimators and most recently on GMM estimators (Arellano, 2003).

Panel analysis has been found useful for modelling real estate rents, yields and total returns in different international property markets. In particular, a panel approach has allowed researchers to alleviate the problem of relatively short property time-series, as well as to model and explain time invariant district-specific effects existing in different property markets (D'Arcy *et al.*, 1997b, Sivitanides *et al.*, 2001, Hendershott *et al.*, 2002, De Wit and Van Dijk, 2003). In Essay 2 of the thesis, we study the main determinants of commercial rents in major Finnish cities using dynamic panel analysis and explore the potential use of panel models for property forecasting.

6. Summary of the essays

If you want to understand some aspects of the Universe, it helps if you simplify it as much as possible, and include only those properties and characteristics that are essential to understanding.

Isaac Asimov, *Prelude to Foundation*

The objective of this thesis is to find the key drivers and the best methods for modelling and forecasting property rents and returns in markets, with structural changes and limited data, using as a case study the Finnish property market. The thesis consists of four essays. All data are annual and fit into the time period from 1971 to 2002. Essays 1 and 2 examine determinants of Finnish property rents, whereas essays 3 and 4 deal with modelling and forecasting of office returns. Below we summarise the key results of the four essays.

Essay 1. An econometric analysis and forecasts of office rents in the Helsinki area

The first essay attempts to find the most suitable method for modelling and forecasting commercial rents in a small property market which has experienced structural changes. In particular, it examines long- and short-run movements in office rents in the Helsinki central business district (CBD) over the 1971-2001 period. Real office rents are modelled in the framework of the reduced form demand-supply approach. The relationship between rents and their determinants is investigated using three alternative econometric methods: a regression model, an ECM and an integrated autoregressive-moving average model with exogenous explanatory variables (ARIMAX). These alternative techniques are used in order to examine whether for modelling and forecasting purposes the time series properties of office rents can be used, or whether more structural models and frameworks need to be employed.

The results indicate a marginal impact of supply-side effects (measured by new office building completions) on Helsinki office rents compared to that of demand-side drivers (growth in service sector employment, GDP and output from financial and business services). This finding is in line with the results of previous research, which have found different supply measures to be insignificant in explaining short-run movements in office rents (D'Arcy *et al.*, 1997b, White *et al.*, 2000, and Hendershott *et al.*, 2002). The results also suggest that a long-run relationship exist between demand drivers and office rents. The formulation of the ECMs is always supported by the data.

The study also evaluates the out-of-sample forecasting performance of alternative techniques. The parsimonious ARIMAX specifications containing past changes in real office rents and single demand-side variables are able to pick up the scale of shocks and resultant persistence effects present in the data and, thus provides the best forecasting tool of office rental growth in Helsinki. The more complex ECM models, which incorporate long-run information, cannot effectively take into account structural changes in the Helsinki property market, and thus result in better explanation of the past than in prediction of the future. Ex-ante forecasts are also produced. It is predicted that real office rents in Helsinki will grow on average at the rate of 0.5% during the 2002-2005 period.

Essay 2. A comparative analysis of commercial rents in Finland

In Essay 1 we model rents only for one property market, the Helsinki CBD, and only for one property type, offices. In Essay 2 we proceed further with modelling rents for several property types in several Finnish property markets. In particular, we investigate whether in a regionally integrated economy, like the Finnish, it is national or local factors that drive changes in local rents. For this purpose, the short-run movements in office, retail and industrial rents in nine major cities in Finland are modelled over the 1990-2002 period. The limitation of relatively short time-series is alleviated by using panel data. The nine cities are grouped into two panels based on the similarities between markets: the Helsinki Metropolitan Area and the rest of Finland. Dynamic panel models are estimated using an instrumental variable technique.

The results demonstrate that in all nine cities the demand-side variables (GDP, employment measures, consumer expenditure and disposable income) exert more influence on changes in commercial rents than a proxy for changes in supply (new commercial building completion). We find that both national and local factors appear to be important in explaining rental changes in Finnish cities, with national GDP growth having the strongest impact on all three property types. This result is consistent with the findings of previous studies in other European property markets (Giussani *et al.*, 1993 and D'Arcy *et al.*, 1997a, 1997b). The results also indicate that there are some differences in the timing and magnitude of rents' responses to changes in demand and supply across the cities. However, commercial rents in all nine cities behave in broadly the same way. They are driven by fluctuations in demand and supply and can be explained to some extent solely by national macroeconomic factors.

Essay 3. Modelling and forecasting office returns in the Helsinki area

After having found in Essay 1 that rents in markets with structural changes can be successfully modelled, we proceed with the more difficult task of modelling and forecasting property returns. In particular, the third essay, published as Karakozova (2004) in *Journal of Property Research*¹¹, investigates the variation in office returns in

¹¹ The article is reproduced in the thesis with permission from the publisher, Taylor and Francis Ltd and is available at <http://www.tandf.co.uk/journals>.

the Helsinki CBD during the 1971-2001 time period. We examine the determinants of office capital growth, which is the most volatile component of office total return, by using the same techniques as in Essay 1: regression, ECM and ARIMAX models. The empirical models of office capital return are based on variables which are linked to its component: the risk-free rate, the risk-premium and net operating income.

The results indicate that all explanatory variables are important in explaining variations in capital growth, with demand drivers being the most influential. We also establish the existence of a cointegrating relationship between capital values and the variables which explain them, and demonstrate that long-run information, in the form of the error correction mechanism (*ecm*), improves the explanation of short-run movements in office returns.

The study also assesses and compares the out-of-sample predictive ability of the alternative techniques. We find that for both short and long predictive horizons, the forecasting performance of the selected models is better than that of the naïve forecasting technique, with the ARIMAX specifications producing the most accurate forecasts. Similarly with the findings for office rents in Essay 1, the results suggest that ARIMAX models incorporating past values of capital growth and growth in service sector employment and in GDP are able to account for structural changes in the Helsinki property market and, thus provide the best forecasting tool for office returns.¹² The ECM models appear to be suitable for modelling and forecasting the Helsinki office market only during some periods. Forecasts for up to four years ahead are also generated. These suggest that office capital returns in Helsinki will grow in real terms, at a rate of 0.1% during the 2002-2005 period. This implies that real office total returns will be on average 5.7% over the same time period.

Essay 4. Note on modelling office returns: business cycle asymmetries

Having discovered in Essay 3 that it is possible to predict office returns, we continue investigating whether the best forecasting model can be improved further by accounting

¹² It is worth mentioning, that even though Essays 1 and 3 find that the ARIMAX models produce the most accurate out-of-sample forecasts, there can be added value for forecasting office rents and returns from other models as well. In particular, different models have different merits, thus using several models and combining their forecasts can improve further the forecasting accuracy of a single model. For more on the notion of pooling forecasts in real estate markets, see Wilson and Okunev (2001).

for asymmetric effects of office returns. Specifically, in Essay 4 we examine asymmetric responses of Helsinki office returns to the business cycle over the 1971–2002 period. To test for asymmetric responses of office returns, i.e. for whether returns adjust sharper to economic downturns or upturns, we use the ARIMAX model, which was found to be the best forecasting tool of office returns in Essay 3. In order to introduce asymmetry and to examine different responses of office returns to their main driver, GDP, the latter is decomposed into two components, growth rate above and below a pre-specified threshold. These two GDP growth rates represent downturns and upturns in the Finnish economy.

The results demonstrate that office returns in Helsinki adjust asymmetrically to upturns and downturns of the Finnish economy, with adjustments to downturns being sharper. Similar results have been found for the US and UK property markets (Lizieri *et al.*, 1998 and Tsolacos, 2002). The study also finds that introducing asymmetry improves the out-of-sample forecasting performance of the models. In this case the improvement in forecasting accuracy is large enough (forecast errors decrease by one half) to justify the greater computational effort and time associated with the application of asymmetric models.

7. Conclusions

*Simplicity, simplicity, simplicity! I say let your affairs be as two or three and not a hundred or a thousand...
Simplify, simplify!*

H.D. Thoreau, *Walden*

In empirical research, the availability and quality of data to some extent always dictate the methods and approaches which can be applied. As a result, in stock and bond markets, data for which are plentiful, almost any kind of model and approach can be examined empirically. However, the scarcity of property data limits the methods which can be used for modelling property markets. The main contribution of this thesis is a detailed empirical evaluation of alternative econometric methods for modelling and forecasting rents and returns in property markets which have experienced structural

changes. We use as a case study the Finnish property market, which is a small European market with structural changes and limited property data. We find that the choice of econometric model depends on the intended use of the model, i.e. testing of theory, policy analysis or forecasting. In particular, if the purpose is to empirically evaluate the suitability of theoretical frameworks for modelling rents and returns, then it is worth using theory-based econometric methods, such as ECMs. These models are constrained by long-run information and thus are better for explaining the past than for predicting the future. In contrast, if the aim is to forecast rents and returns, the results in the thesis suggest that simple time series techniques should be used, as they are able to account for structural changes in the way markets operate, and thus provide the best forecasting tool. We also show that the forecasting performance of time series models can be improved by introducing asymmetries, and that the improvement in the forecasting accuracy is sufficient to justify the extra computational time and effort associated with the application of these techniques. Finally, we demonstrate that despite the limitation of short time series, commercial rents in local markets can be successfully modelled using national macroeconomic variables and a panel approach. The findings in this thesis indicate that it is possible to use modern econometric tools for modelling and forecasting property markets, which have a structure and characteristics similar to the Finnish market, and that this yields interesting and useful results. In the future, the availability of more data will allow researchers to examine the suitability of more complex theoretical frameworks and empirical techniques and to assess their potential use for forecasting.

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