AN EVALUATION OF THE USE OF COMBINATION TECHNIQUES IN IMPROVING FORECASTING ACCURACY FOR COMMERCIAL PROPERTY CYCLES IN THE UK

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Abstract

In light of the financial and property crisis of 2007-2013 it is difficult to ignore the existence of cycles in the general business sector, as well as in building and property. Moreover, this issue has grown to have significant importance in the UK, as the UK property market has been characterized by boom and bust cycles with a negative impact on the overall UK economy. Hence, an understanding of property cycles can be a determinant of success for anyone working in the property industry.

This thesis reviews chronological research on the subject, which stretches over a century, characterises the major publications and commentary on the subject, and discusses their major implications. Subsequently, this thesis investigates property forecasting accuracy and its improvement. As the research suggests, commercial property market modelling and forecasting has been the subject of a number of studies. As a result, it led to the development of various forecasting models ranging from simple Single Exponential Smoothing specifications to more complex Econometric with stationary data techniques.

However, as the findings suggest, despite these advancements in commercial property cycle modelling and forecasting, there still remains a degree of inaccuracy between model outputs and actual property market performance. The research therefore presents the principle of Combination Forecasting as a technique helping to achieve greater predictive outcomes. The research subsequently assesses whether combination forecasts from different forecasting techniques are better than single model outputs. It examines which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts best. As the results of the study suggest, Combination Forecasting, and Regression (OLS) based Combination Forecasting in particular, is useful for improving forecasting accuracy of commercial property cycles in the UK.

Declaration

The thesis is submitted to Edinburgh Napier University for the Degree of Doctor of Philosophy. The work described in this thesis was carried out under the supervision of Professor Brian Sloan and Dr. Andrew Brown. The work was undertaken in the School of Engineering and the Built Environment.

In accordance with the regulations of Edinburgh Napier University governing the requirement for the Degree of Doctor of Philosophy, the candidate submits that the work presented in this thesis is original unless otherwise referenced within the text.

The following published papers were derived from the work in this thesis. As set of papers is bound where possible with the thesis and may be found inside the back cover. Full permission from the relevant publishers or copyright holders has been obtained. The numbering sequence makes no attempt to follow that of the thesis proper, the pagination follows that of the parent journal or proceeding as appropriate.

1. Jadevicius, A, Sloan, B and Brown, A (2010) *Is 100 years of research on property cycles enough to predict the future of UK property market performance with accuracy?* In: Egbu, C. (Ed) *Procs 26th Annual ARCOM Conference*, 6-8 September 2010, Leeds, UK, Association of Researchers in Construction Management, pp.111-120.
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Abbreviations

ACF	Autocorrelation Function
AIC	Akaike Information Criterion
AR(p)	Autoregressive (model)
ARIMA	Autoregressive Integrated Moving Average (model)
ARIMAX	Integrated Autoregressive Moving Average model with Exogenous Explanatory Variable(s) (model)
BGS	British Government Securities
BIC	Bayesian Information Criterion
BLT	Brown’s Linear Trend (model)
BoE	Bank of England
BR	Bank Rate
CBHP	CB Hiller Parker
CBRE	CB Richard Ellis
CCs	Construction Costs
COr	Construction Orders
COt	Construction Output
CSt	Construction Starts
DES	Double Exponential Smoothing
DW	Durbin-Watson (statistics)
E	Employment
ES	Exponential Smoothing (model)
ESRC	Economic and Social Research Council
GDP	Gross Domestic Product
GFD	Global Financial Data
GNP	Gross National Product
HLT	Holt’s Linear Trend
HMRC	Her Majesty's Revenue and Customs
HP	Hodrick-Prescott (filter)
HW	Holt-Winters (statistics)
IPD	Investment Property Databank

IPF	Investment Property Forum
JLL	Jones Lang LaSalle
JLW	Jones, Lang & Wootton
LCES	London & Cambridge Economic Services
LSE	London Stock Exchange
MA	Moving Average
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
ME	Mean Error
MFE	Mean Forecasting Error
MPE	Mean Percentage Error
MR	Multiple Regression
MSE	Mean Squared Error
MSFE	Mean Square Forecasting Error
MSPE	Mean Squared Percentage Error
NBER	National Bureau of Economic Research
ODPM	Office of the Deputy Prime Minister
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
ONS	Office for National Statistics
PACF	Partial Autocorrelation Function
PASW	Predictive Analytics Software
RICS	Royal Institution of Chartered Surveyors
RM	Regression Model
RSS	Residual Sum of Squares
SES	Single Exponential Smoothing (model)
SPSS	Statistical Package for the Social Sciences
SR	Simple Regression (model)
UK	United Kingdom
US	United States of America
VAR	Vector Autoregressive (model)
WT	White’s Test

Glossary of property and financial terms[1]

Absorption	Total demand for goods and services by all residents (consumers, producers, and government) of a country (as opposed to total demand for that country's output).
Autocorrelation	The state of an econometric relation such that some or all of the explanatory variables are highly correlated with each other; poor specification of the relationship between variables in the regression equation is often the cause.
Average	A value showing the central tendency of a set of data and often used to compare that set with others.
Base rate	The rate of interest that a UK clearing bank uses as the basis of its structure of interest rates for lending and receiving deposits; lending rates are above, and rates on deposits below, base rate.
Boom	A period of expansion of business activity.
Business cycle	Recurrent but non-periodic fluctuations in aggregate economic activity as measured by fluctuations in real GDP about its trend.
Capital consumption (M2)	Depreciation; given that fixed assets have only limited life-span, it is necessary to add to the annual costs of an enterprise or a national economy an estimate of the amount nationally spent on the wear and tear of such assets.
Depression	A prolonged and severe slowing-down of economic activity exemplified by mass unemployment and a level of national income well below its potential level; more severe and long-lasting that recession.
Finance	The provision of money at the time it is needed.

[1]RICS (1994); Friedman (2000); Rutherford (2002); Dixit (2005); Collin (2007), Communities (2009)

Institutional investor	A group of investors who have funds to invest as a consequence of the conduct of their business; the group includes insurance companies, banks and investment trusts, and industrial companies who administer their own pension schemes or have other funds available.
Investment yield	Annual rent that is passing as a percentage of the capital value.
Macro-economics	A branch of economics concerned with analysis of the economy in the large, i.e. with such large aggregates as the volume of employment, saving and investment, the national income, and so on.
Market risk	Risk that results from trends in market prices and which cannot be avoided by diversification.
Micro-economics	A branch of economics concerned with analysis of the behaviour of individual consumer and producers, particularly with the optimistic behaviour of individual units such as households and firms.
Property cycle	Recurrent but irregular fluctuations in the rate of all-property total return, which are also apparent in many other indicators of property activity, but with varying leads and lags against the all-property cycle.
Recession	A significant reduction in employment and production, trade and investment; two consecutive quarters of decline in GDP.

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CHAPTER 1 INTRODUCTION

1.1 Background for the research

In light of the financial and property crisis of 2007-2013 it is difficult to ignore the existence of cycles in the general business sector, as well as in building and property. Moreover, this issue has grown to have significant importance in the UK, as the UK property market has been characterised by boom and bust cycles with a negative impact on the overall British economy. As a result, economists and scholars started researching this phenomenon in the belief that a better understanding of the cyclical nature of the economy and the property market would prevent cycles from happening in the future.

The nature, development, and reasons behind property cycles have been researched for a number of years (Hakfoort, 1992; RICS, 1993). As Rottke and Wernecke (2002, p.3) observed, ‘in the US research on property cycles began as early as the 1930s...The number of publications rose rapidly at the beginning of the 1980s…Up to now in the US and the UK, cycle research papers have increased enormously both in terms of quantity and quality’. According to Barras (2009), the situation changed particularly after the Great Depression when academics and professionals became determined to find ways to prevent the recurrence of such dramatic events in the future. Therefore, they began to focus their attention on investment in building, as the most volatile element of the aggregate economic activity.

The subsequent developments in the field of property cycles research led to the construction of various mathematical models helping to explain the behaviour of the real property market (McDonald, 2002; Tonelli *et al.*, 2004; Barras, 2009; Byrne *et al.*, 2010). As a result, significant progress has been made within property market modelling and analysis (McDonald, 2002) resulting in the development of various forecasting models, ranging from simple single-equation methods to more advanced multi-equation with stationary data techniques (Tsolacos, 2006; Lizieri, 2009b). The introduction of computer technology further accelerated the modelling process (Ball *et al.*, 1998; Barras, 2009). It therefore led some researchers to propose that the commercial property market movements are predictable (Wheaton *et al.*, 1997; Pyhrr *et al.*, 1999; Barras, 2009).

However, comparative studies, where authors assessed the accuracy of already produced forecasts with actual property market dynamics, suggest that despite these advancements, there still are inaccuracies within property market modelling and forecasting. Various factors were identified why models differ from actual property market performance. These were market uncertainty, object being forecasted, forecasting technique used, forecasting horizon, and data being employed (Newell *et al.*, 2002; Tonelli *et al.*, 2004; McAllister and Kennedy, 2007; IPF, 2012). Accordingly, it was suggested that greater forecasting performance could be achieved if any or all these forecasting inaccuracy causes are addressed.

1.2 Aims and objectives of the research

This research project aims to improve the forecasting accuracy of UK commercial property cycles. It therefore adopts the principle of Combination Forecasting as a means of improving overall modelling and forecasting accuracy. Researchers including Makridakis (1989), De Gooijer and Hyndman (2006), Goodwin (2009), Pesaran and Pick (2011) and Wallis (2011), were motivated by this concept and suggest that greater predictive results can be achieved from a combination of different methods and sources. Therefore, the principle of Combination Forecasting, which was developed by economists, has now been applied to UK commercial property market cycle analysis.

To complete this aim successfully, the following research objectives are set:

i) Examine the key components of business and commercial property cycles and review the research and commentary on the subject chronologically;

ii) Assess existing modelling and forecasting practices within the field of commercial property market research and explore the application of the principle of Combination Forecasting as an alternative methodology for UK commercial property cycle forecasting accuracy improvement;

iii) Examine properties of the dependent and explanatory variables and present their key characteristics;

iv) To draw conclusions from the data analysis and assess as to whether Combination Forecasting improves UK commercial property cycle forecasting accuracy;

v) To draw conclusions on the data analysis and assess as to whether Combination Forecasting improves UK commercial property cycle forecasting accuracy;

vi) To identify practical implications of this research project for commercial property market participants.

1.3 Methodological considerations

A multi-strand approach is proposed to address the objectives of the research. Initially, the study critically reviews the literature on the subject. A literature review presents how understandings of the property cycles have evolved over time, what the critical issues at each stage of cycle research were, and what the key considerations currently are. It allows for an assessment as to how the understanding and a critical analysis of the subject have changed over the century, and how the current investigation relates to previous studies. It then provides a rationale for the current study by revealing the contribution that the research makes to current knowledge.

The study then uses econometric modelling to assess potential improvements to the accuracy of UK commercial property cycle forecasting. The study selects key property market modelling techniques, including Exponential Smoothing, ARIMA/ARIMAX, Simple Regression, Multiple Regression and Vector Autoregression approaches. Following on from this, it then employs Combination Forecasting. There is a suggestion that forecasters and decision makers discover the best performing model, which is then accepted and used, while rejecting other alternatives. However, the aim of the research is to obtain the most accurate forecast. Therefore, discarding alternative models is unproductive. What is more, there is a difficulty in deciding which model to choose when different specifications suggest different results. As such, Combination Forecasting eliminates these modelling deficiencies and provides a solution in improving overall forecasting accuracy.

1.4 Outline of the thesis

Chapter 2 discusses Efficient Market Hypothesis and its links with the property market. It assesses the key characteristics of business and property cycles. It then examines similarities between business and property cycles and presents the pattern of an idealised property cycle. Subsequently, it reviews the research on the subject chronologically, over a one hundred year span, characterising the major publications and commentary on the subject, and discussing the major implications. Following on from this, it investigates property forecasting accuracy and its improvement. It suggests that property cycle research resulted in the development of various forecasting models ranging from single exponential smoothing specifications to more complex structural with stationary data techniques. However, the findings indicate that despite these advancements in property market modelling and forecasting, there still remains a degree of inaccuracy between model outputs and actual property market performance.

Chapter 3 discusses difficulties related with use of different forecasting methods and then presents the principle of Combination Forecasting as a robust way of improving commercial property market modelling and forecasting. It covers the general principles of model implementation using the statistical software package PASW 18 (SPSS 18). It also assesses the issue of modelling using spread-sheets. Following on from this, the Chapter presents each modelling technique used for the research, including Single Exponential Smoothing (SES), Holt's Linear Trend (HLT), Brown's Linear Trend (BLT), ARIMA, ARIMAX, Simple Regression (SR), Multiple Regression (MR), and Vector Autregression (VAR). It also considers the principle formulae for Simple Averaging and OLS based Combination Forecasting (CF). Subsequently, the Chapter addresses statistical difficulties related to the construction of a real estate model.

Chapter 4 discusses the importance of long-term series in analysing property cycles. It assesses difficulties related to UK property data and its acquisition. It then presents the principle of Chain-Linking as the solution for time-series combination. Following on from this, Chapter evaluates properties of the dependent and explanatory variables. Subsequently, it presents five variable reduction techniques which are employed to select the key variables for modelling.

Chapter 5 reports the empirical findings of the study. It presents estimates obtained using each modelling technique, as well as Combination Forecasting. Modelling accuracy in- and out-of-sample is discussed along with a graphical presentation of the findings. Chapter then analyses and interprets results. It transforms the modelling estimates obtained into credible evidence about UK commercial property market modelling and forecasting, and its accuracy improvement through Combination Forecasting.

Chapter 6 concludes the thesis. It presents the key findings and implications of the research for commercial property market stakeholders, critically evaluating them and then proposing avenues for further work.

CHAPTER 2 LITERATURE REVIEW

The objective of this chapter is to review the literature concerning property cycles, modelling and forecasting. It is divided into three sections.

Section 1 starts with a discussion on Efficient Market Hypothesis and its relation to fluctuations in real estate. The findings support the idea that asset markets, and property market in particular, are inefficient. Imperfect information, high levels of transaction, production time lags, are just a few facts which add to inefficiency and therefore market cyclicality. The section then characterises business and property cycles. It presents the pattern of an idealised property cycle and discusses similarities between business and property cycles. It then examines key publications on the subject and assesses how understanding of the property cycles has evolved over time. The discussion is divided into five principal parts which follow so called 'property cycles research eras'. 'The Early Studies' part reviews the earliest publications on the subject. Then follows 'Post-War studies' or as Barras (2009) calls it 'empirical work' period. This section concentrates on three key publications on the subject, one from the UK and two from the US, which offered a comprehensive analysis of the subject at that time. Subsequently, the 'Post-1970s Crash Period Studies' part assesses publications produced over the 1980s and explores the key findings of that time. Following on from this, the 'Post 1990s Property Crash' studies are examined. Finally, the so called 'Modern Studies' part assesses the most recent publications on property cycles.

Section 2 examines the issue of property market modelling. It assesses different property market modelling classifications discussed in the literature. It then presents a group of quantitative real estate forecasting methods and reviews their key characteristics. Subsequently, it discusses further issues in modelling, including stationarity and unit-root testing, Granger causality, and accuracy.

Section 3 assesses the accuracy of property market forecasting. It reviews studies on the subject where forecasters assessed the predictive capacity of their models by comparing them with actual property market performance. It then examines studies on indirect accuracy measurement where researchers assessed the accuracy of already produced forecasts by comparing them against established property market benchmarks.

2.1 Property and business cycles

2.1.1 Property market (in)efficiency

The Efficient Market Hypothesis (EMH) suggests that financial markets are information efficient. This means that markets adjust rapidly to new information (Fama et al., 1969). As such, prices of traded assets including corporate stocks, commodities, or real estate (Shiller, 2014) are well known in advance (Maier and Herath, 2009). Therefore investors cannot gain advantage in predicting future direction of these assets using publically available information (Cho et al., 2007). The principle behind EMH is random walk process. In his empirical study, Fama (1970) demonstrated that day-to-day price changes and returns on common stocks follow a random walk with their autocorrelations being close to zero, which means that their future prices cannot be predicted based on past information.

However, there is a body of knowledge suggesting just the opposite (Ding et al, 1993; Cho et al., 2007). Researchers are commenting that although EMH is plausible, there are a number of difficulties related to it (Beechey et al., 2000; Maier and Herath, 2009; Shiller, 2014). In property market research, as Maier and Herath (2009) comment, there are two major issues which need to be considered. The first issue relates to information. The second involves price volatility and cycle analysis.

Regarding information and property market (in)efficiency, Brown (1991), Evans (1995), Kummerow and Lun (2005) and Maier and Herath (2009) commented on the essential relationship between two facets. According to Smullyan (1994) and Kummerow and Lun (ibid.), property has always been an 'information business'. The information within the industry has always been 'thin'. Intrinsic property asset characteristics such as heterogeneity and low trading frequency combined with insider information add to the magnitude of price changes within the sector. All this combined can destabilise the overall economy. These suggestions corroborated earlier observations of Grossman (1978) and Grossman and Stiglitz (1980) who commented on information and market efficiency. According to both commentators, ‘informationally’ efficient markets are impossible. If markets were perfectly information efficient, returns on gathering and analysing this information would be nil. This would make asset trading obsolete. Therefore, the market would eventually collapse.

In terms of volatility, cycles and bubbles and their link with information asymmetry, Shiller (2014, p.21) in his Nobel Prize lecture, documented that real estate ‘prices are not at all well approximated by a random walk, as is the case for stocks, but often tend to go in the same direction, whether up or down, again and again for years and years”. What Shiller meant is that for ‘smart money’ to go in and out in the real estate market in response to news is impossible. This proposition was argued by Malpezzi and Wachter (2005) a decade ago. According to commentators, real estate prices are prone to cycles due to information arbitrage. Discovering prices is expensive, as such, prices become volatile. Similar findings were presented by Ball (2006) who argued that, on a European level, house prices varied over time implying market inefficiency. This therefore leads to boom-and-bust cycles in the property market.

Taken together, the discussion above suggests that market efficiency is important. Debates have continued for several decades. Thought results are inconclusive. However, the overriding idea is that asset markets, and property markets in particular, are inefficient. Imperfect information, low levels of transaction, and production time lags, are just a few factors which add to inefficiency and therefore property market cyclicality.

The following section discusses the key characteristics of the business and property cycle and the way they link together. It also presents a summary of the findings from property cycles research over a hundred year period.

2.1.2 Characterisation of the business and property cycle

The existence of cycles in the general business sector, as well as in building and property has been debated for more than a century (Mangoldt, 1907; Cairncross, 1934; Gottlieb, 1976; Hakfoort, 1992). According to Barras (2009, p.4), property cycles 'have been recorded throughout history'. However, as Cairncross (1934) observed, they have been neglected by researchers, their statistics unassembled, and their organisation practically unknown. The situation changed after the Great Depression when academics and professionals determined to find ways to prevent the recurrence of such severe economic causalities in the future. Therefore, as Barras (ibid.) suggested, focus shifted into building investment, as the most volatile element of aggregate economic activity.

The subject has grown to a significant importance in the UK, as the UK property market has been characterised by boom and bust cycles with a negative impact on the overall British economy. As a result, property cycles became a popular research topic amongst property professionals and scholars, with a greater understanding of the cyclical behaviour of the property market being seen as a major guide to the financial success (or failure) of property investments (Pyhrr *et al.*, 1999; RICS, 1994, Barras, 2009). This subsequently led RICS (1994; 1999) and Baum (2001) to suggest that the concept of cycles is firmly embedded within property research.

Commentators, including Ball *et al.* (1998) and Barras (2009), argue that property cycle formation theories are mostly derived from business cycle research. As their studies show, the correspondence between property and business cycles is in the way both phenomena are defined, i.e. linguistic issue; the way they are expressed, i.e. visual issue; as well as in the way they are constructed, i.e. theoretical issue.

According to the standard definition of the business cycles presented by Parkin and Bade (1988, p.31), 'business cycles are recurrent but non-periodic fluctuations in aggregate economic activity as measured by fluctuations in real GDP about its trend'. Following the RICS' (1994, p.9) definition of property cycles (which is now generally accepted within the property community) 'property cycles are recurrent but irregular fluctuations in the rate of all-property total return, which are also apparent in many other indicators of property activity, but with varying leads and lags against the all-property cycle'. As these definitions suggest, both phenomena are expressed as recurrent, however irregular fluctuations. What is more, they are quantitatively defined, i.e. the business cycle is measured as fluctuations in GDP, while property cycles are measured as fluctuations in the rate of All-Property Total Returns.

The similarity between business and property cycles is also visually observed. The idealised property market cycle is perceived as a four phase nomenclature which is similar to that of the business cycle (Mueller, 1999; Pyhrr *et al.*, 1999). Both business and property cycles follow four major phases: recession (trough), recovery, expansion (peak), and contraction. 'Peak' and 'trough' are the major turning points of the cycle. Peak constitutes the end of 'expansion' and the beginning of 'recession', and 'trough' – the end of recession and the beginning of 'expansion' (Zarnowitz, 1992; Su, 1996). What is more, both concepts are expressed as a sine wave which deviates around its equilibrium. This interrelationship is illustrated in the 'Schematic diagram of recurrent fluctuations in economic activity' (Figure 2.1) and idealised 'Property cycle phase nomenclature' (Figure 2.2).

However, not all property researchers adopted the same cycle nomenclature. Commentators including Roulac (1996) and Hewlett (1999) identified the sequence of the property cycle somewhat differently. Roulac (1996) presented the property cycle as a sequence of expansion, slowing, contraction, correction, recovery, and again expansion. Hewlett (1999) saw a property cycle as a three phase framework consisting of upturn, maturity and downturn. Nevertheless, as Ball *et al.* (1998) commented, the pattern of an idealised property cycle is still the same despite a terms to describe them.

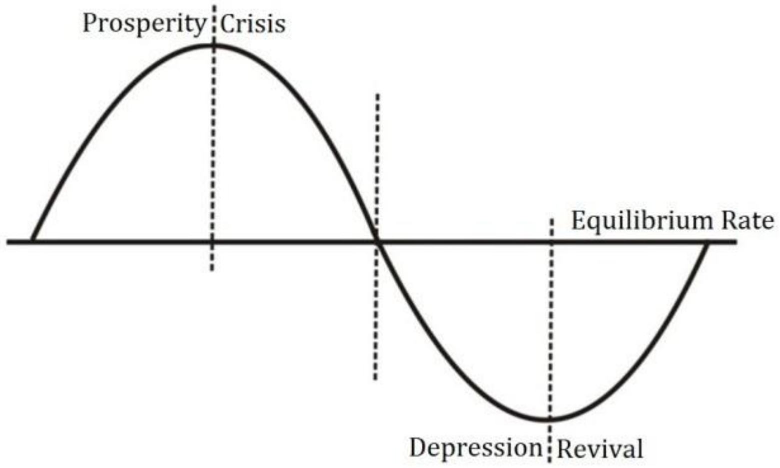

Figure 2.1 Schematic diagram of recurrent fluctuations in economic activity
Adapted from: Frank (1923)

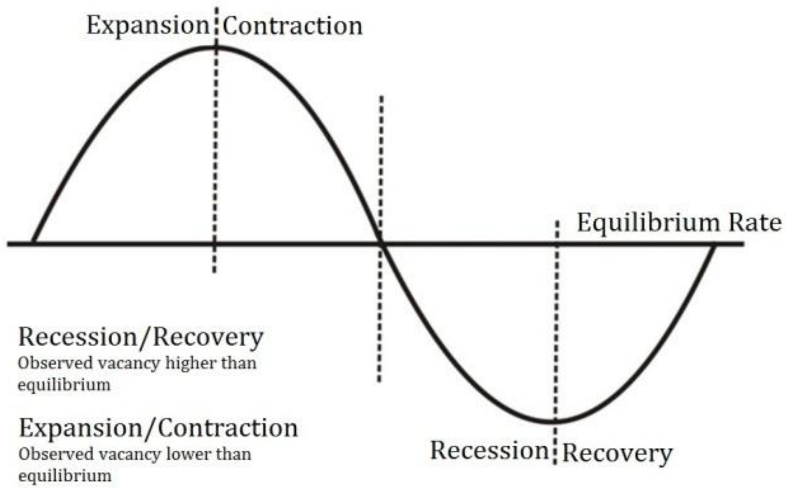

Figure 2.2 Property cycle phase nomenclature
Adapted from: Pyhrr *et al.* (1999)

As it was noted above, the relationship between property and business cycles is also evident in the way property cycles are characterised. According to Ball *et al.* (1998), the pattern of the idealised property cycle is as follows:

- *Business upturn and development*: an increase in the economic activity generates strong user demand for space; existing space is absorbed quickly; vacancy rates fall and rents rise; this thus works as a signal for new property developments to begin;
- *Business downturn and overbuilding*: business cycle turns downwards which reduces demand for space; however, new stock reaches the market (normally it takes few years to build the building); as a result, vacancy rates rise and rents fall;
- *Adjustment*: following on from this, growing vacancy rates trigger further falls in rents; developers and investors are unable to generate income from properties they hold. This leads to a series of bankruptcies;
- *Slump*: both demand for space and development activity are at their lowest levels, with vacancy rates being above equilibrium level and rents being below equilibrium level.
- *The next cycle*: when the next business upturn occurs, there is still a substantial level of vacant space available from the previous cycle, which implies limited need for new developments.

In general, this simple explanation of the property cycle suggests that the property cycle is a product of overall business dynamics. The hypothesis is that cyclical fluctuation in business activity generates demand for and production of property and *vice-versa*, which comes from the necessity to occupy property to undertake activity (Ball *et al.*, 1998). However, the idea that property and business cycles are interlinked with each other was not argued until more recently (Ball et al., 1998). The developments in understanding of property cycles are described in greater detail in the following section.

2.1.3 Understanding of the property cycle

Early studies

The first serious discussions and analyses of property cycles emerged during the late nineteenth and early twentieth century. As Gottlieb (1976) and Barras (2009) indicated, German scholars were pioneers of property cycle research. The major object of their investigations was the urban growth of German cities and its impact on residential construction, property market activity and land values. In his general work, Mangoldt (1907) demonstrated the tendency for urban growth to run in long waves in the city of Freiberg. Reich (1912) investigated the residential market in Berlin between 1840 and 1910. Eychmüller (1915) studied the economic development, urban land and building policies of the city of Ulm for the period 1850-1919. In her manuscript, Carthaus (1917) assessed the history of the land crisis in German big cities with a special emphasis on Greater Berlin. Eisenlohr (1921) in his study discussed urban and housing conditions of the city of Mannheim. These studies were subsequently followed by the researchers from other metropolitan areas.

It is considered that in the US research on the subject started in 1933 with Hoyt’s publication. In his book Hoyt investigated cyclical fluctuations of the Chicago property market. Generally, Hoyt suggested that business conditions, commodity price levels, value of money and especially a rapid increase in population within a relatively short period of time were the major causes of the real estate cycles. The author affirmed that past property cycles were mostly generated by the sudden and unexpected increase in population seeking greater industrial opportunities within the area. It therefore led Hoyt to hypothesise that future property cycles would be generated by the identical increase in population, which would result from an expansion of industrial opportunities. Accordingly, he identified relatively long and uncertain (on average 18 years) real estate cycles. These observations add to Wenzlick’s (1933) findings, who identified similar cycles for St. Louise, and Maverick’s (1933) observations, who estimated similar real estate fluctuations for Los Angeles and San Francisco.

In the aftermath of the Great Depression, Newman (1935) further investigated building cycles. In his monograph, the author stressed that 'it is highly important that the nature of, and reasons for, fluctuations in such activity be subject to rigorous inductive and deductive analysis' (ibid., p.2). The building industry was chosen due to its size and importance to the US economy, and the number of people employed. As Newman estimated, building comprised around 50 percent of the total US economy. He therefore expected fluctuations in private building to have a major effect on the economy. Newman used the term 'building industry' to refer to durable and fixed goods which provide shelter to individuals and businesses. His empirical estimates were based on the building activity index which was comprised from the dollar value of the building permits. The outstanding characteristic of this research was identification of so called 'major cycles', lasting between fifteen to twenty-one years. The other findings included a tendency for the building cycle to precede the business cycle (business lagged three months behind building) and considerable independence between movements of the two series. Newman also stressed a close relationship between building and population. However, he appreciated that factors such as availability of capital, or general business conditions play an important role in this process. He therefore concluded that 'fluctuations in building activity were found to be closely associated with shifts in population … and these shifts in population are, of course, reflections of economic and social alterations which make a change of residence desirable to a larger number of people' (ibid., p.56).

A significant contribution towards the research and understanding of building cycles was made by the American economist Clarence D. Long, Jr. In 1936, Long published a study on the building industry of Manhattan in which he explored the major components of the industry of that time. His statistical analysis suggested the existence of two types of building cycles, .i.e. major cycles of a period between 15 to 20 years, and minor cycles of around 5 years in length.

After this study on a local building market, Long (1939) published an article on national building activity. This study comprised both residential and non-residential building indices of the US for the 1856-1935 period. The value-index included 27 and the number-index included 29 of the most populous cities of the country. Similar to Newman (1935), Long (ibid.) pointed out that major building cycles were somewhat independent of the business cycle. He also hypothesised that building cycles precede the general business cycles in the downturn, however lag in the upturn. Subsequently, Long (ibid.) identified 18-19 years building cycles in both residential and non-residential building.

A year later, Long (1940) published, as some authors (e.g. Singer, 1942; Barras, 2009) indicate, a second major study on the subject after Hoyt's Chicago case study. For his analysis Long constructed a monthly Index of Building for the period between 1868 and 1940, which was based on the local figures of building permits. The results of the statistical analysis led him to identify short building cycles of an average of 4 years duration, and long cycles of around 20 years in length. To substantiate his findings, Long referred to previous studies on the subject, including Hubbard (1924), Clark (1934), and Newman (1935) who identified similar building cycles.

One of the first studies on the UK building cycles was that of Cairncross (1934). In his analysis of the Glasgow building industry (1870-1914), which was considered at that time as probably the best documented property market in the UK, Cairncross identified that demand for housing 'naturally fluctuate with the number and incomes of potential tenants' in around every twenty years (ibid., p.4). Similarly to Wenzlick (1933), Cairncross noted that the marriage-rate and migration all have a significant effect on building cycles.

With regard to research on the subject in the United Kingdom, the same year as Cairncross (1934) published his research on the Glasgow building industry, Shannon (1934) produced a Building Index (index of brick production) for England for the period between 1785 and 1850. Statistical analysis of the data led the author to identify 16 year-long building cycles, which were closely linked to population growth.

In 1937, Bowley published an investigation into fluctuations of the house-building and trade cycles for the 1924-1936 period for England and Wales. Her analysis led to the conclusion 'that there has been little causal connection between the trade cycle and house-building activity since the War [WWI]' (ibid., p.181). Population change was identified as the primary factor influencing demand for housing.

A more robust discussion on the building and trade cycle was presented by Bowen (1940). His national investment analysis covered the 1924-1938 period for all the UK. Bowen compared three series: Building Plans Passed, Ministry of Health Returns of Houses Completed, and Ministry of Labour Insured Unemployment Returns for the Building Industry. The results of the study suggested that building activity and the general trade cycle are interconnected.

Table 1 summarises the key publications on property cycles during this research era. It contains title, data and data analysis techniques which were employed by researchers, as well as outcomes of these studies. The following section reviews the key publications produced during the pot-war period.

Publication	Data employed	Statistical technique	Outcomes of the Study
Hoyt, H. (1933) One hundred years of land values in Chicago. The relationship of the growth of Chicago to the rise in its land values, 1830-1933. The University of Chicago, US, pp.452	Land values; New construction; Lots subdivided; Public improvements; Population; Foreclosures; Real estate transfers; Bank clearings; Canal-rail stock prices; Wholesale commodity prices	Data comparison; Turning point analysis; Time-series analysis (1830-1933); Visual data analysis (of maximum and minimum)	18 years building cycles; Real estate cycles may be a passing phase
Cairncross, A.K. (1934) The Glasgow Building Industry (1870-1914). The Review of Economic Studies, Vol.2, No.1, pp.1-17	House building and demolition; Rents; Site values; Heavy industry activity; Interest rates; Population (rate of marriage and immigration)	Data comparison; Turning point analysis; Time-series analysis (1870-1914); Visual data analysis (of maximum and minimum)	20 years building cycles; Real estate cycles have a great correlation with population
Newman, W.H. (1935) The building industry and business cycles. University of Chicago Press, Chicago, pp.72	Building permits; Building costs; Population growth; Bond yields; Rents; Operating expenses; B.B.N index	Time-series analysis (1875-1933); Turning point analysis; Correlation analysis; Index composition	15-21 years ‘major cycles’; 4-5 years ‘minor cycles’; Building cycles precede business cycles; Independence between movements of two series; Constant correlation between building space and population
Long, C.D., Jr. (1940) Building Cycles and the Theory of Investment. Princeton University Press, NJ, pp.239	Gross capital formation; Total construction; Building costs; Incomes; Interest rates; Building levels; Population; Taxes; Housing costs	Time-series analysis (1868-1940); Turning point analysis; Simple mathematical calculations (averages, deviations, medians); Correlation analysis; Assumption testing; Index composition; Index smoothing (by means of the Macaulay 43-term graduation)	4 years short building cycles; 20 years long building cycles; Greater volatility of cycles in building than in business; Building cycles precede business cycles; Correlation between long building cycles and the general business conditions
Bowen, I. (1940) Building Output and the Trade Cycle (U.K. 1924-38). Oxford Economic Papers, No.3, pp.110-130	Building plans passed; Returns of houses completed; Insured unemployment returns for the building industry; Savings	Time-series analysis (1924-1938); Correlation analysis; Data comparison; Visual data analysis; Data smoothing (3 year moving average); Trend analysis	Correlation between building an population; A greater role of building within the economy

Table 2.1. Key ‘Early era’ publications on property cycles

Post-War studies

During the 1930's there were a number of studies and publications produced on building cycles. However, the post-war period saw a decline in the volume of research on the subject. As Lewis (1960) and more recently Barras (2009) noted, individual studies such as Grebler (1954) or Cairncross and Weber (1956) were published, which mostly repeated the major studies of the 1930's only by adding newer data or extending the statistics of their predecessors.

One of the first attempts to renew the discussion on the subject was Lewis' (1960) empirical study. In this work, he proposed a theoretical dynamic regional building model. Regional building cycles were identified as the major elements of the total building cycle mechanism. Lewis (ibid*.*, p.533) pointed out that 'there can be no national building boom without there being at least one local boom, and the justification for a local boom must lie in local need'. Lewis hypothesised that national building booms occur at a time when several regional building booms coincide with each other purely by accident or during a period of national prosperity.

The importance of local building activity was also addressed by Saul (1962). His investigation into house building activity in England between 1890 and 1914 led to the conclusion that investment in housing 'was largely determined by causes special to the domestic housing market' (ibid*.*, p.120).

In 1965, Lewis published a major study - a historic survey of British economic growth from 1700 to 1950. In this publication, Lewis investigated the existence of the long building cycles. First, he undertook a historical review of the UK building industry. He then created a mathematical simulation model to test his hypotheses. The identification of building cycles of 18 to 20 years in duration was one of the central findings of the book. Lewis argued that building cycles were generated by a number of endogenous and exogenous factors. The endogenous factors which Lewis considered were level of production, income, population structure, migration, credit supply, and rent level. The key exogenous factors which the author emphasised were war and the level of harvest. Lewis appreciated the interconnection between these factors, as well as the economic context within which they occur. This led Lewis (ibid.) to suggest that, as these factors varied significantly over time, each building cycle was unique with its own inherent characteristics. Subsequently, study has shown that demand for building is a function of local factors, e.g. building activity in Manchester was linked to levels of the cotton industry, while in South Wales it was related to the coal trade, with both industries being the key to the region. What is more, two key factors, i.e. credit conditions and population in particular, were articulated by the author. According to Lewis, internal migration, emigration, and changes in the family structure were all powerful factors in determining housing demand.

Abramovitz (1964) published one of the major post-war studies on the subject in the US. As the author indicated, the purpose of this monograph was to 'review and assess the evidence bearing on the existence of long waves in aggregate construction and in the major types of construction activity in the United States' (ibid., p.1). The construction industry was chosen because of its size and importance to the US economy. The statistical analysis of the 38 annual time-series enabled Abramovitz to identify long waves in aggregate construction of duration between 15 and 25 years. Uniform long swings were also found in the other major areas of the American economy, including population growth and immigration, volume of import, and railroad development. Abramovitz therefore attributed the existence of long cycles within construction activity to the dynamics in the general economy, demographics and trade.

The study by Gottlieb (1976) offered probably the most comprehensive empirical analysis of the subject at that time. In this book, Gottlieb assessed the time-spread of long urban-building fluctuations in the US. Gottlieb then compared the dynamics of the building industry with the general business cycle, as well as with fluctuations of economic series in other countries. For his research Gottlieb employed over 200 long time-series produced by the NBER on building, finance, demographics and real estate activities for the US, UK, Sweden, France, Australia, Netherlands, Germany, Canada, Italy, and Japan. The study suggested the existence of long building swings in modern capitalistic societies and apparent synchronisation between local and national cycles. What is more, the results of this study suggested that both long local and national building cycles were virtually of the same duration. According to Gottlieb's statistical analysis, the average length of long local building cycles was 19.7 years, and the average length of long national building cycles was 19.0 years. The argument behind these findings was that 'local cycles were simply a local phase of a national movement, while the national movement was in turn mainly a coalescence of local cycles' (ibid., p.9). Another important finding which emerged from the study was the relationship between building cycles and demographic changes. According to Gottlieb, favourable economic conditions encourage or discourage formation of new households, which consequently has a direct effect on the volume of demand for additional dwellings. This demand also affects old stock, land and credit markets. All this in combination triggers greater building and real estate market activity.

Table 2 summarises the key publications of this research period, which includes title, data and data analysis techniques employed and outcomes of these studies. The following section presents the key post-1970s crash studies on property cycles.

Publication	Data employed	Statistical technique	Outcomes of the Study
Abramowitz, M. (1964) Evidences of Long Swings in Aggregate Construction since the Civil War. National Bureau of Economic Research, New York, pp.252	38 series on non-farm residential, private non-residential, farm, public and ship building, and transportation and public utilities	Data comparison; Time-series analysis (1870-1955); Turning point analysis; Visual data analysis (of maximum and minimum, and peaks and troughs); Data smoothing (5 and 10 year moving average); Amplitude measurement.	15-25 years building cycles; Close interaction between building and the economy; Structural change of the US economy leads to demise of cycles
Lewis, P.J. (1965) Building Cycles and Britain's Growth. Macmillan, London, pp.396.	20 time-series (import/export, building, marriage rate, bank rate, house prices, rents, etc.)	Time-series analysis (1700-1950); Turning point analysis; Correlation analysis; Index creation (artificial time-series); Probability modelling (experiments with multiplier-accelerator mechanism)	18-20 years building cycles; Correlation between building and population and credit; Building is a function of the local factors
Gottlieb, M. (1976) Long Swings in Urban Development. National Bureau of Economic Research, New York, pp.360	Around 200 long time-series (building, building costs, population, land values, etc.)	Time-series analysis (1840s-1930s); Comparison/Visual inspection; Smoothing (Time-series decomposition/Fixed term moving average); Turning point analysis; Correlation analysis; Data comparison; Visual data analysis (of maximum and minimum, and peaks and troughs); Amplitude measurement	20 years building cycles; Correlation between building and population, as well as local and national cycles

Table 2.2. Key post-war publications on property cycles

Post-1970s crash studies

According to Barras (2009), the 1960s was a period of apparent economic stability. It therefore led some commentators, including Abramovitz (1968) and Bronfenbrenner (1969), to question whether cycles were still relevant. However, the property market crash of the mid 1970s triggered a renewed wave of research on property cycles. As Barras (1994) indicated, his personal interest on the subject was first prompted by the 1970s property crash, which led to the publication of a number of papers including Barras (1983; 1984; and 1987), as well as a series of papers commissioned from the Economic and Social Research Council (ESRC) on building cycles in Britain, i.e. Barras and Ferguson (1985; 1987a; 1987b).

Barras (1983, p.1) proposed ‘a simple theoretical model of the office development cycle’ for Britain. He employed an accelerator type model and, by incorporating a long term production period between building order and its completion, explained how cycles are generated around their equilibrium growth path. The model was then tested in reality and compared with the results of previous empirical investigations.

Barras (1984) examined the major characteristics of the London office market. The researcher discussed the main factors which governed the growth of London as an international office centre. Subsequently, he illustrated the apparently cyclical nature of office development in the city. He then briefly reviewed development control policies, identifying difficulties associated with existing control strategies, and their effect on the property development industry. Finally, Barras assessed the 1980s development cycle. He particularly emphasised the impact of information technologies on user demand for London offices in the post 1980s development cycle.

Barras (1987, p.1) investigated ‘urban development cycles’ in Britain and their links with technological changes. According to the author, long swings of 20-30 years duration are normally generated by shorter cycles, i.e. two shorter cycles are generally superimposed by the dominant long swing, causing pronounced building cycles. The author also suggested that building activity is particularly prone to cyclical fluctuations in comparison with other capital investment classes.

A significant analysis and discussion on the subject was presented by R. Barras and D. Ferguson in their three stage research project. In the first paper, Barras and Ferguson (1985) investigated the detailed chronology of five major building sectors including private industrial, private commercial, private housing, public housing, and other public building. The authors employed spectral analysis to determine and compare each building series, their cyclical characteristics, and relationships between the cycles. What is more, informal turning point analysis was used to identify the precise chronology of each cycle. It all allowed Barras and Ferguson to suggest that UK post-war building experienced ‘strong cycles’, i.e. ‘short cycles’ of 4 - 5 years, ‘major cycles’ of 7 - 9 years, and ‘long swings’ of 28 years within housing investment and 19 years within other building. Short cycles were linked to general business cycles, major cycles – to production lags within the construction industry and public expenditure policy, and long swings – to ‘major waves of urban development’ (ibid., p.1389).

In the second paper Barras and Ferguson (1987a) developed a theoretical dynamic model of property cycles. The model incorporated both endogenous and exogenous elements of the built environment. Endogenous mechanisms were related to the production lag within the industry. The exogenous influences were associated with variations in economic activity, particularly in the GDP and bank interest rate. The researchers assessed industrial, commercial and residential property sectors. As the authors indicated, public building was excluded as this type of property ‘reflects not so much the dynamics of market behaviour, but rather the periodic shifts in public investment which result from changes in government policy’ (ibid., p.353). The theoretical dynamic model was based on Box and Jenkins (1976) (ARIMA) time-series modelling technique. The researchers also included an error-correction element into the framework in order to derive short-run adjustment dynamics and long-run equilibrium relationships between time-series. The user activity, which generated demand for space, was identified as being accountable for long-run equilibrium of property development, which at the same time is proportional to net investments in new buildings. Short-term property market dynamics was found to be highly dependent on exogenous variables, including building costs, property market prices, rents and yields, availability of finances, and financial performance of other types of long-term investments.

In the concluding paper, Barras and Ferguson (1987b) presented empirical results of their research for each property sector (private industrial, commercial and residential). As the results suggested, the equilibrium level of industrial and commercial property is dependent on the level of user activity which creates demand for this type of property. The residential property was identified as being a subject of investment activity. The commentators also identified that all types of property have one common component – construction lag, which serves as an endogenous cycle mechanism. This construction lag was distinguished as being the key driver behind the major cycle of a period of 35 quarters (8 years). The user activity, which generates fluctuations within business cycles, was identified as being the main exogenous mechanism which governs short building cycles within all types of property. It was also detected that user activity has links with movements in the level of GDP and investment activity. Development costs were identified as having the least impact on building cycles.

In the US, studies on the subject continued to be influenced by the NBER research agenda. In their publication, Grebler and Burns (1982) investigated short-term post-war cycles in the US construction sector following the established NBER methodology. The authors related these cycles to business fixed investment and ‘reference cycle’ in GNP. Their research concentrated on four key aspects. It assessed whether cycles became more severe over time, examined the impact of public activity on cycles, appraised the relationship between business and construction cycles, as well as evaluated whether construction cycles lead or lag the general business cycles. The data for the study covered the 1950-1978 period. The empirical analysis of duration, amplitude and number of cycles led the authors to identify six cycles in private residential construction (18 quarters on average), four in private non-residential (29 quarters in average), and four cycles in state and local construction (28 quarters in average). The analysis also suggested that these cycles were generated by their own inherent characteristics and determinants.

In the US the post-1970s crash studies particularly concentrated on the office market and its dynamics. According to Wheaton (1987), Clapp (1993) and Barras (2009), this particular asset class attracted great attention due to its expansion in the late 1980s. Moreover, this market segment exhibited high levels of volatility in comparison to other types of commercial property.

One of the key studies was Wheaton's (1987, p.1) investigation into 'the cyclical behaviour of the national office market'. In this research, Wheaton assessed the post-war US office market and identified the existence of the recurrent ten years 'national office market cycles' (ibid., p.283). Wheaton analysed data for the 1960-1986 period for national office employment, building starts, building completions, absorption, and vacancy rate. He also compared historic office vacancy rates amongst ten major US cities. Time-series analysis suggested that exogenous impulses from the wider economy had a greater impact on office cycles than endogenous 1-2 years construction lag.

The dynamics of the US office market was further investigated by DiPasquale and Wheaton (1992) and Clapp (1993). In their article, DiPasquale and Wheaton (1992) developed a universal equilibrium model of real estate space (rent) and real estate asset (capital). For their research the authors employed comparative statistical analysis of a number of macroeconomic indicators, including short-term and long-term interest rates, availability of construction finances, production level, and employment. Subsequently, they developed a four-quadrant diagram illustrating the interconnection between real estate space and real estate asset. The model demonstrated how exogenous forces impact the property sector as a whole.

In his work, Clapp (1993) presented the concept of the natural (normal) vacancy rate. According to the author, natural vacancy rate is estimated by dividing vacant space, which landlords keep vacant for possible repairs or search for better tenants, by the total amount of space. Subsequently, Clapp explored two possible models to measure this rate. The first model had a simple structure. The future of the office market was based on the expectations for the employment growth. The second model elaborated on this relationship and included expectations for employment at a less granular level. The equation considered managerial, technical, and clerical employment, and the expectations for the growth in this type of occupations.

Table 3 below summarises the key publications on property cycles which were produced during 1970s research period. It contains the title, data and data analysis techniques employed and outcomes of these studies. The following section presents the key post-1990s crash studies on property cycles.

Publication	Data employed	Statistical technique	Outcomes of the Study
Barras, R. (1983) A simple theoretical model of the office development cycle. Environment and Planning A, Vol.15, No.10, pp.1381-1394	Time-series (new orders, capital values, construction costs, returns) Statistics (inflation, interest rates, GDP)	Time-series analysis (1956-1980); Mathematical modelling; Historical overview; Correlation/Regression analysis; Turning point analysis	Model of the office development cycle; Clarification of the mechanics behind the cycle; Three crucial parameters – the length of the delay between new investment orders and completions, the adjustment rate and the depreciation rate; National average cycle period – 8 – 10 years
Barras, R. (1987) Technical change and the urban development cycle. Urban Studies, Vol.24, No.1, pp.5-30	Time-series of 5 sectors – private industrial, commercial and house-building, and public house-building and other public building	Time-series analysis (1958-1983); Time-series modelling; Spectral analysis; Turning point analysis	20-30 years 'urban development cycles'; Interconnection between 5 year, 10 year, and 20 year cycles; Suggestions for policy making
Wheaton, C.W. (1987) The cyclical behaviour of the national office market. Journal of American Real Estate and Urban Economics Association, Vol.15, No.4, pp.281-299	Time-series (construction, completions, office employment, absorption, vacancy rate)	Time-series analysis (1960-1986); Visual data analysis; Multi-equation modelling	10 year office cycles; Growing cycle amplitude over time; 3 possible scenarios (forecasts from 1986 to 1992)
DiPasquale, D. and Wheaton, W.C. (1992) The Markets for Real Estate Assets and Space: A Conceptual Framework. Journal of the American Real Estate and Urban Economics Association, Vol.20, No.2, pp.181-198	Interest rates; Construction finances; Production level; Employment; GDP; Rents; Vacancy rates	Comparative statistical analysis; Time-series analysis; Multi-equation modelling	Universal equilibrium model (four-quadrant diagram)

Table 2.3. Key post-1970s crash publications on property cycles

Post-1990s property crash studies

The 1990s property crash in the UK led to a renewed discussion on property cycles. As Barras (2005, p.63) observed, after this crash the same two questions were asked: 'why did it go wrong?' and 'how can we avoid it happening again?'. Property professionals and scholars blamed inaccurate data, its analysis and interpretation, and anticipated that things would improve next time (RICS, 1994; Barras, 2005). Subsequently, it prompted a number of important publications on the subject, including Barras (1994), RICS (1994; 1999), Grenadier (1995), McGough and Tsolacos (1995a; 1995b), and Renaud (1995).

A seminal study commissioned by the Royal Institution of Chartered Surveyors (RICS, 1994) jointly with the University of Aberdeen and the Investment Property Databank (IPD) examined fundamentals of the UK property cycles. It investigated both endogenous and exogenous forces that produced these cycles. Although it was indicated that there is a link between property and economic cycles, the research identified that inherent property market characteristics made property cycles more than just a simple reflection of economic cycles.

The RICS (1994) study employed post-war economic and property data for Britain, which covered the period between 1962 and 1992. The visual and statistical data analysis identified short 4-5 years 'recurrent but irregular fluctuations in the rate of total return' (ibid., p.27). Other findings suggested close timing between economic and property cycles. This led the authors to suggest that there are obvious links between swings in property and the economy. The development cycle was identified as a subset of the property market which gives most of its idiosyncratic features to the property cycle. It was also observed that building booms and busts are the product of inherent construction lags and developers' reaction to market signals. Generally, the RICS (ibid.) considered property cycles to be readily understood despite their irregularities.

In their second study, RICS (1999) examined property cycles and their links with economic cycles. The researchers combined time-series on All Total Property Returns for the period between 1971 and 1992 from their earlier publication, and from 1921 to 1997 compiled from the work of an economic historian Scott (1996). This combination extended the time-series back to 1921. The visual data analysis confirmed the existence of recurrent, but irregular property cycles. Spectral analysis identified cycles ranging from 4 to 12 years. The average length of the cycles was 8 years. As the authors indicated, some fuller statistical tests suggested the existence of major cycles of 9 years duration, and minor cycles of 5 years duration. The subsequent analysis of property returns suggested the existence of three separate UK property epochs. The first was the interwar period between the 1920s and 1930s, which was characterised as being highly volatile, but with particularly high returns on property. The second was the post-war period through the 1950s and 1960s, which exhibited less volatile property fluctuations. And the third was the highly volatile post 1970s period. Moreover, historic data analysis demonstrated different correspondence between fluctuations in property returns and those from gilts and equities. The study suggested that property exhibited a lower volatility than the other two asset classes, thus attracting a higher attention from the institutional investors and offering greater diversification possibilities for their investment portfolios.

Similar to the RICS (1994), Barras (1994) hypothesised that property cycles are not simply random phenomena, but rather a set of recurring events. He analysed the post-war UK property market and identified major forces which generated these cycles. Time-series the author was using covered the period from 1952 to 1992. The starting point for his paper were findings presented in Barras and Ferguson (1985) that the property market is highly cyclical, cycles are of different duration, and that cycles operate on the basis of demand and supply for buildings. Economic growth was expressed as fluctuations in GDP. Commercial development and bank lending was expressed as fluctuations in bank loans to property companies and commercial new building orders. Rents were expressed as fluctuations in All-Property Rents. From examining the findings, Barras demonstrated that both the 1970s and 1980s property cycles 'were triggered by the same particular combination of conditions in the real economy, the money economy and the property market'. It was also demonstrated that 'different cyclical forces are at work in the occupier market, the development industry and the investment market, sometimes opposing and sometimes reinforcing each other' (ibid., p.195). Subsequently, these hypotheses led Barras to suggest that a better knowledge of the interaction of these underlying forces leads to a greater understanding of the property cycles.

The study by McGough and Tsolacos (1995a) assessed forces generating the UK property development cycles. The property development cycles were referred to as cycles in office, industrial and retail building sectors. For the analysis of the demand for office space and its relationship with the real economy, the authors examined five alternative variables, i.e. GDP, GDP of service industries, output of business and finance, service sector employment and employment in financial services. The demand for industrial property was measured from the relationship between GDP, manufacturing output and manufacturing employment. The GDP, consumer expenditure and the volume of non-food retail sales were alternative variables which were representing the demand side for retail property.

The time-series the researchers employed covered the period from 1980 Q1 to 1994 Q4 quarterly. The raw data was smoothed using the Hodrick-Prescott filter. The study also included dynamics of other economic variables including movement of share prices, short-term and long-term interest rates, and rates of treasury bills. The commentators considered these indicators to reflect trends in economic activity, and thus demand for commercial space. After obtaining the data, the researchers estimated the statistical properties of the chosen variables: amplitude, persistence, procyclicality, and countercyclicality. Amplitude was measured by the standard deviation, persistence - by first order autocorrelation, and both procyclicality and countercyclicality - by cross-correlation. The empirical results indicated an existing relationship between GDP, manufacturing and business output and the office and industrial property, and between GDP, consumer expenditure and non-food retail sales and retail property. Rents and capital values also exhibited conformity between each other. Rents were procyclical with the office cycles, but lagged industrial and retail cycles, while capital values led the property cycles. Surprisingly, financial indicators exhibited no cyclical pattern with reference to any of the property sectors.

In the US, a significant discussion on the subject was presented by Grenadier (1995). Grenadier investigated underlying causes of prolonged real estate cycles. He subsequently developed a leasing and construction model explaining the recurrence of over-building and stickiness of vacancy rates. Initially Grenadier (ibid.) tackled two standard explanations of real estate cycles. One, which explains property cycles as a result of construction lags. The other, which states that because of non-recourse lending, developers continue to build while funding is available. As Grenadier argued, developers certainly make errors in their future market forecasts, however, they are well aware that it takes time to complete a project. Therefore, developers take into consideration the timing needed to complete the project while developing their strategies. Grenadier affirmed that the first explanation implies myopic behaviour of property developers, but which is an incorrect assumption. The second explanation, as the author indicated, also 'fails to stand up to closer scrutiny' (ibid., p.98). According to Grenadier, investors do learn from their past mistakes and are not willing to lend money to the property developers in booming times, suggesting that non-recourse lending does not account for overbuilding.

Following on from this, Grenadier (ibid.) employed an option pricing methodology to develop his model. The model was split into three stages. In the first stage, fully developed rental property was analysed. In this case, when the market is growing the property owner has an option to wait and let vacant space at a higher price. If the decision is made to rent the property, the owner loses the option to receive a greater income. Conversely, in a falling market the property owner offers discounted rent to keep the tenant if he wants to ensure a low vacancy rate. In the second stage, the developer faces greater uncertainty about the future demand for space because of construction lags. Therefore, there is an option of completing or withdrawing from the project. However, as the author emphasised, there is a difficulty to reverse construction once started. The third stage assessed the best timing to start the project. The timing was highly linked to land value. Therefore, as the model estimated, valuation of raw land can encourage or discourage developers to commence construction.

Table 4 below summarises the key publications on property cycles which were produced during this research era, containing title, data and data analysis techniques employed and outcomes of these studies. The following section presents the most recent studies on commercial property cycles.

Publication	Data employed	Statistical technique	Outcomes of the Study
Barras, R. (1994) Property and the economic cycle: Building cycles revisited. Journal of Property Research, Vol.11, No.3, pp.183-197	GDP; Capital values; Yields; Investments; Bank lending; Rents; Commercial development	Accelerator type model (second-order difference equation); Time-series analysis (1952-1992); Turning point analysis	Property market is highly cyclical; Cycles are of different duration; They operate on the basis of demand and supply for building; Suggestions for policy making; Predictions for the next decade
RICS (1994) Understanding the property cycle: Economic Cycles and Property Cycles. The Royal Institution of Chartered Surveyors, London, pp.97	Property returns; Rents; Yield; Construction; Investment; GDP; Consumer spending; Manufacturing output; Employment; Interest and gilts rates; Inflation	Time-series analysis (1962-1992); Visual data analysis; Property performance measurement; Turning point analysis; Spectral analysis; Simple regression modelling; Model testing	4-5 years property cycles; Close timing with economic cycles; UK property market is cyclical; UK property cycles are the product of economy and its endogenous (particularly development lag) characteristics; Statistical analysis; Existence of property cycles
RICS (1999) The UK Property Cycle - a History From 1991 to 1997. The Royal Institution of Chartered Surveyors, London, pp.57	Property returns; Yield; Rents; Capital growth; GDP; Building investment; RPI, Gilts, Equities, Treasury bills	Time-series analysis (1921-1997); Turning point analysis; Visual data analysis; Correlation analysis; Time-series simulation; Time-series desmoothing; Filtering (HP technique); Spectral analysis; Multivariate time-series regression with variable additions/deletion; Long-run cointegration; Modelling - capital asset pricing mode (CAPM)	4-9 years cycles; Correlation with the economy; Strong cyclical pattern; Long-run analysis adds little to the ability to understand or predict the market
McGough, T. and Tsolacos, S. (1995) Property cycles in the UK: an empirical investigation of the stylized facts. Journal of Property Finance, Vol.6, No.4, pp.45-62	GDP; Employment; Consumer expenditure; Industry output; Interest rates	Time-series analysis (1980-1994); Statistical analysis (amplitude – standard deviation, persistence – first order autocorrelation, procyclicality and countercyclicality – cross-correlation)	Tight correlation between GDP, manufacturing and business output and the office and industrial property; and between GDP, consumer expenditure and non-food retail sales and retail property; Establishment of stylized facts

Table 2.4. Key post-1990s crash publications on property cycles

Modern studies

A considerable amount of literature on property cycles was published from the late 1990s. As Barras (2004) observed, in both the late 1980s and late 1990s property cycles were truly global events, which affected most markets internationally. As a result, property scholars investigated cycles as an international phenomenon, as well as their links with capital markets. According to Barras (2009, p.71) 'the inevitable result was the launch of a new and more extensive phase of research on real estate cycles during the 1990s'. An international phenomenon of property cycles was discussed in Renaud (1995), Pyhrr *et al.* (1999), Dehesh and Pugh (2000), Pugh and Dehesh (2001), Sirmans and Worzala (2003), and Jackson *et al.* (2008). Links between property cycles and capital markets were discussed by Herring and Wachter (1998), ECB (2000), Davis and Zhu (2004), and Lizieri (2009a).

Renaud (1995) investigated the global property cycle for the period between 1985 and 1994. The author assessed international and domestic factors which generated this cycle. The data was obtained from the Organisation for Economic Co-operation and Development (OECD) and Newly Industrialised Economies (NIE). As the analysis suggested, liberalisation of the capital market and financial deregulation, new macroeconomic policies, individualised structure of the property sector itself, as well as lax fiscal policies and incentive structures, which all generated high levels of borrowing, were the primary domestic reasons behind this cycle. The international dominance of Japanese financial institutions was an international factor for this cycle to occur. These arguments were substantiated empirically and also by referring to the work of other researchers, including Glick (1991) and Werner (1993; 1994). The composite evidence collected from the research led Renaud to suggest that the next global property cycle, similar to the one in 1985-1994, is preventable. As the author suggested, better research, adequate policy making and institutional arrangements are all levers governments can employ to smooth the next global property cycle.

Dehesh and Pugh (2000) examined post Bretton-Woods 'Property Cycles in the Global Economy'. The research covered the post-1980s period with particular emphasis on Asian economies, especially Japan. The post Bretton-Woods period was characterised as an internationally integral and deregulated world economy with an open capital mobility and growing financial engineering. As such, the breakdown of the Bretton-Woods system has placed property in a wider context which made it an international assets class. According to the authors, this had two key implications. First, financial deregulation and growing competition between financial intermediaries led to over-investment in property. Second, international capital mobility created greater liquidity, and, as a result, led to the rise in property prices. Accordingly, commentators suggested that post-1980s major property cycles were products of the internationalisation of the economies.

In their following paper on the subject, Pugh and Dehesh (2001) investigated post-1980s property cycles, the role of institutional investors, as well as the international interdependence between property and finance. In this comparative evaluative review the authors identified that economic decline affects the socio-economic level of the national economies and thus has an impact on the finance and property sectors both locally and internationally.

The internalisation of property markets and global transmission of cyclical instability since the 1990s triggered property professionals and scholars to investigate links between property and financial markets (Barras, 2009). Some of the empirical studies on the subject focused particularly on residential property. As Davis and Zhu (2004) observed, this was because of the data available for this type of research. Country-specific studies identified a correlation between housing and the capital markets. Empirical analysis by De Greef and De Haas (2000) identified the link between housing and the mortgage market in the Netherlands. In the US, Quigley's (1999) study suggested that housing prices and financial conditions are interconnected. Gerlach and Peng (2002) indicated the existence of a long-run dynamic relationship between house prices and bank lending in Hong Kong.

Davis and Zhu (2004) assessed the interconnection between the commercial property market and bank lending from the macroeconomic perspective. The authors were motivated by the existence of a bilateral link between the banking and the commercial property markets. Although Herring and Watcher (1998) stated that property cycles may occur without a banking crisis, and that a banking crisis may occur without property cycles, the Davis and Zhu's study concluded that both phenomenon have demonstrated a high degree of correlation over a long period of time. For their research, the commentators catalogued annual data for 17 countries for the period between 1985 and 1995 collected by the Bank for International Settlements (BIS). They then developed a reduced-form single equation model based on the work of Wheaton (1999) in order to assess the relationship between banking and commercial property. Cross-country empirical analysis confirmed their hypothesis. The study also suggested that a rise in commercial property values triggers credit expansion, not vice versa. In addition to that, GDP was identified as having a dominant influence on both banking and property.

Subsequent research into the internationalisation of the property market, led property analysts and researchers to investigate the dynamics of the property market on a global scale. According to Chen and Mills (2005, p.1) 'global real estate investment has become an increasingly important component of efficient, global mixed-asset portfolios'. Researchers including Case *et al.* (1999), Jackson *et al.* (2008) and Stevenson *et al.* (2011) identified the high degree of synchronisation in cycles across international real estate markets. This therefore suggested significant concordance and commonalities across a large number of property markets. Despite the fact that Chen and Mills (2005) argued that economic and property cycles in different regions exhibit low levels of correlation, more recent research suggests that real estate markets across the globe and especially across the key office markets such as New York and London are correlated (Stevenson *et al.*, 2011). The relationship between the macro-economy and the property market and the effect of globalisation is well discussed in Barkham (2012).

In order to reflect this dynamics of the international property market, Grosvenor (2011) and IPD (2012) created global property market benchmarks. Grosvenor's (ibid.) global office yield composite indicator serves as a benchmark representing property market dynamics on an international scale. This index reflects the current position of the property market globally relative to its long term history. By using this indicator, investors can therefore minimise risk, enhance returns and maximise Net Asset Value (NAV) growth. IPD's Global Annual Property Index reports the market rebalanced returns of the 24 property markets where IPD and its partners operate. The index (partially) reflects the dynamics of the real estate market globally.

Table 5 below summarises the key 'modern' studies on the subject, containing title, data and data analysis techniques employed and outcomes of these studies. The following section turns into property market modelling and forecasting side of the subject. It reviews quantitative property market modelling techniques and discusses their accuracy.

Publication	Data employed	Statistical technique	Outcomes of the Study
Wheaton, C.W., Torto, R.G. and Evans, P. (1997) The Cyclic Behavior of the Greater London Office Market. Journal of Real Estate Finance & Economics, Vol.15, No.1, pp.77-92	Absorption; Rent; New construction orders; Vacancy; Total and occupied stock; Interest rates; Office employment; Real construction costs	Time-series analysis (1970-1995); Structural econometric methodology – multi-equation adjustment model; Econometric outlook (scenario planning)	Employment can explain London office market movements; London office market is volatile; Commercial property in European cities is forecastable; Shocks (positive/negative) generates and 'echo'
Barras, R. (2005) A Building Cycle Model for an Imperfect World. Journal of Property Research, Vol.22, No.2, pp.63-96	Take-up; Vacancy; Real rental growth; Building starts and completions	Time-series analysis (1970-2004); Multi-equation modelling (series of linear difference equations and set of second order linear difference equations); Building cycle simulation; Model testing	Property market is cyclical; Cyclical fluctuations are generated endogenously around and equilibrium growth path; The longer the construction lag, the longer the cycle period; 5 key parameters which determine model behaviour - the output growth rate; the depreciation rate; the construction lag; the combined transmission coefficient; the demand elasticity
Barras, R. (2009) Building Cycles: Growth and Instability (Real Estate Issues). Wiley-Blackwell, London, UK, pp.448	Output; Take-up; Building starts; Capital; Vacancy; Rents	Time-series analysis (1968-2006); Model simulation (series of difference equations); Model testing	6 key parameters which determine model behaviour - the size of initial displacement; the construction lag; the output growth rate; the rate of depreciation; the combined transmission coefficient; the demand elasticity; the greater the construction lag, the greater the period of the cycle
Barkham, R. (2011) Global Outlook: Grosvenor's research perspective on world real estate markets. Grosvenor, London, pp.4.	Stock market indices, bond rates, real estate spreads over bonds, GDP growth, national and international output gaps and indices of real estate rents and yields	Simple arithmetic average of the key office market yields	Indicator assesses long-ranged property cycle; presents current state of the property market relative to its long-term history

Table 2.5. Key 'modern' publications on property cycles

2.2 Property market modelling and forecasting

As the discussion above suggests, the developments in the field of property cycle research led to the construction of various mathematical models helping to explain the behaviour of the real property market (McDonald, 2002; Tonelli *et al.*, 2004; Barras, 2009; Byrne *et al.*, 2010). These models, as Byrne *et al.* (2010) noted, have been produced for a range of different reasons, i.e. to improve one's understanding on the subject and its processes, to predict, forecast or explore possible scenarios; or to provide a basis for decision-making. According to Harris and Cundell (1995, p.76), 'the market crash which traumatized the property industry between 1991 and 1994 has led the institutions in particular to seek greater predictive input to their portfolio management and investment decisions'. As McDonald (2002) pointed out, after the 1980s property boom property researchers have responded to the crisis situation, and as a result substantial progress has been made in property market research and forecasting.

Following Mitchell and McNamara (1997), Tsolacos (2006), and Barras (2009), the area of property market modelling and forecasting, which was primarily developed within academia, has been quickly adopted by practitioners. Tsolacos (2006) further suggested that property practitioners started to employ both qualitative and quantitative research methods to arrive at the final decision. It has therefore resulted in the development of forecasting models, ranging from simple single-equation methods to more advanced multi-equation with stationary data techniques. Accordingly, it led property researchers, including McGough and Tsolacos (1995a), Clayton (1996), Wheaton *et al.* (1997), Pyhrr *et al.* (1999) and Barras (2009), to suggest that the commercial property market is forecastable. Although Tonelli *et al.* (2004, p.1) argued that 'numerous econometric models have been proposed for forecasting property market performance, but limited success has been achieved in finding a reliable and consistent model to predict property market movements'.

2.2.1 Classification of real estate models

Ball *et al.* (1998) presented a general overview of quantitative real estate forecasting models. According to the authors, these models fall into four major categories: (i) multi-equation models of the US office market; (ii) multi-equation models of the London office market; (iii) single equation models; (iv) and local property market forecasting models. Econometric specifications developed by Rosen (1984), Hekman (1985) and Wheaton (1987) represent the first category. Wheaton *et al.* (1997) and Hendershott *et al.* (1999) constitute the second group. Single equation models come from RICS (1994). Modelling at the local level is presented in Jones (1995).

In his survey of office market econometric models, McDonald (2002) divided the research on office market modelling and forecasting into four general categories. One is the development of general market framework, e.g. DiPasquale and Wheaton (1992) and Wheaton (1999). Second are theoretical real estate market equilibrium models, e.g. Wheaton (1990). Third are studies on office rents and the creation of rent indices, e.g. Wheaton and Torto (1994). The fourth group constitutes complete econometric models of office markets, e.g. Wheaton (1987) and Wheaton *et al.* (1997).

Tonelli *et al.* (2004) presented an overview and classification of office rent models developed over the 20 year period before the date of publication. The authors assessed model determinants as well as equations and outcomes of the modelling. It led the commentators to identify twenty different quantitative forecasting models, which were subsequently divided into three major categories according to their input variables. The first category are econometric models which use macroeconomic determinants such as employment, inflation, economic activity (e.g. Giussani *et al.*, 1993). Second group are models based on industry determinants, such as interest rates, space supply, and vacancy rates (e.g. Hendershott *et al.*, 1996; 2002a; 2002b). The third group are those which use building determinants, such as location, lease structure, and rent level (e.g. Wheaton and Torto, 1988).

Lizieri (2009b) presented his classification of real estate forecasting methods. According to Lizieri, forecasting techniques fall into two broad categories: formal and informal (intuitive). Formal forecasting category is divided into quantitative and qualitative accordingly. Qualitative forecasting methods correspond to judgemental forecasting techniques, which include Life Cycle Analysis, Surveys, Delphi Method, Historical Analogy, Expert Opinion, Consumer Panels and Test Marketing. Quantitative forecasting methods are separated into two groups: causal and time- series. The time-series methods correspond to univariate (extrapolative) forecasting techniques. In other words, these models are not based on any underlying economic theory and produce estimates capturing empirically relevant properties of time-series itself. Causal methods equate to multivariate (explanatory) methods. These modelling techniques incorporate explanatory variables according to economic theory they correspond.

According to Barras (2009), modern commercial property market modelling studies can be separated into three major modelling traditions. One is stock adjustment models, developed in the UK. The second is rent adjustment models, developed in the US. The third is multi-equation models, which are an agglomeration of both. As Barras (ibid*.*) observed, the UK modelling studies are based on the hypothesis that major property cycles are generated by their endogenous forces. The stock adjustment process is at the core of this theory. The US based research, however, focuses on rent adjustment processes within the property market and considers exogenous impulses from the wider economy as having greater impact on property cycles. A third tradition, which is identified as multi-equation modelling, combines both adjustment processes into ‘circular transmission process which propagates cyclical fluctuations across all aspects of property market behaviour’ (ibid*.*, p.215).

As the discussion above suggests, there are various property forecasting models available to researchers. Subsequently, different authors classified these models into different categories, based on the object, time horizon, data, and approach being used. It all therefore resulted in development of various classification systems. Regardless of differences within property modelling classifications, according to Makridakis *et al.* (1998), Chatfield (2000), and Lizieri (2009b), forecasting methods can be grouped into three major categories, i.e. judgemental, univariate and multivariate.

The judgemental methods are based on subjective judgement, experience, intuition and any other relevant qualitative information. Univariate methods, also known as decomposition, extrapolative or time-series methods, which produce forecasts solely based on current and past values of the series being forecasted (Makridakis *et al.*, 1998; Jain and Malehorn, 2005; Brooks and Tsolacos, 2010). Multivariate methods, known as explanatory or regression methods, forecast any given variable from values of one or more variables that relate to the series of interest (Makridakis *et al.*, 1998; Chatfield, 2000). Exponential Smoothing and ARIMA are time-series methods. The Simple Regression, Multiple Regression, VAR and Econometric (also known as Simultaneous Equation model) are all regression specifications (Makridakis *et al.*, 1998; Jain and Malehorn, 2005; Brooks and Tsolacos, 2010) (Figure 2.3).

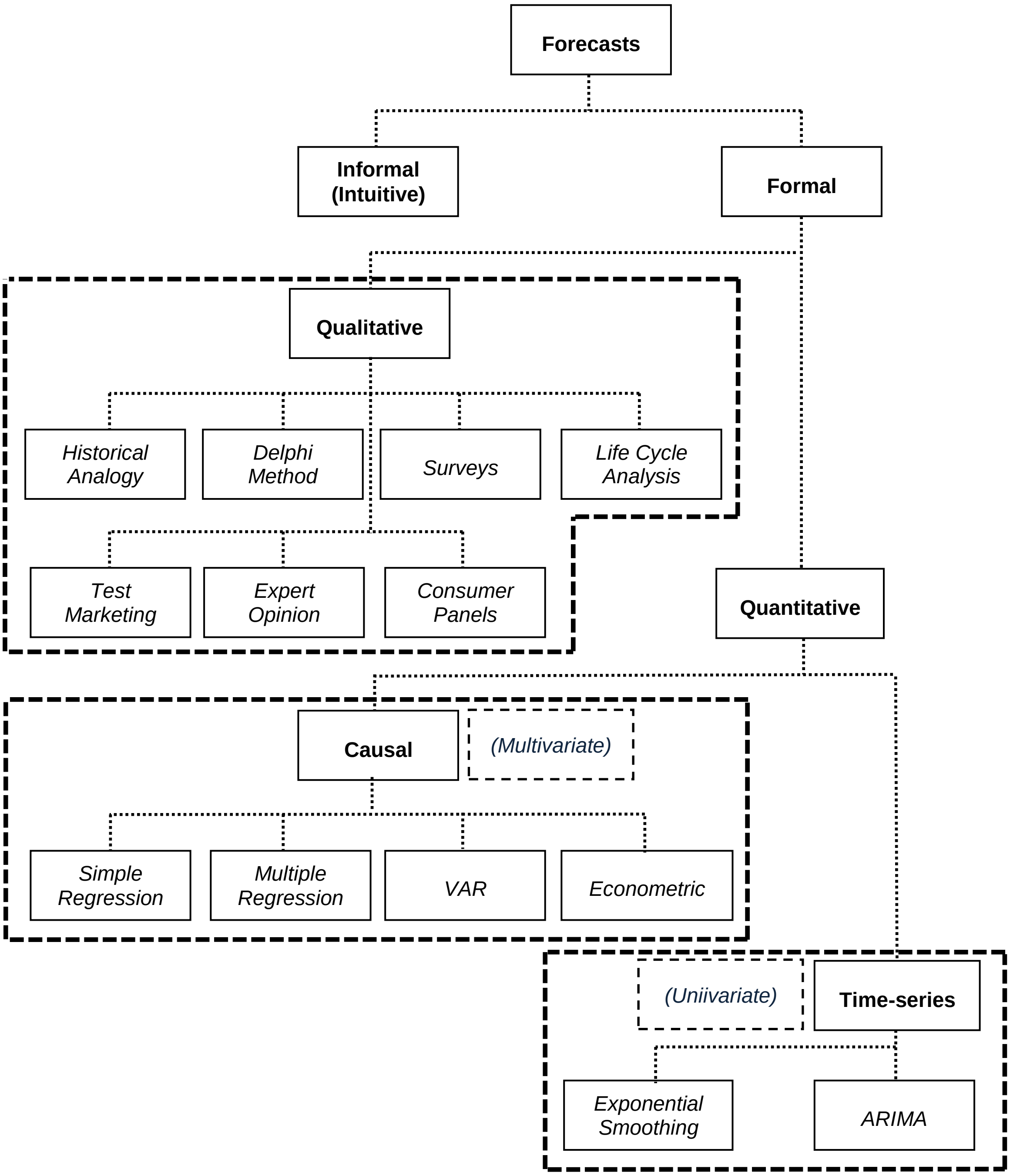

Figure 2.3 Real estate forecasting methods
Adapted from: Makridakis *et al.* (1998); Chatfield (2000); Lizieri (2009b)

Time-Series models

The Univariate time-series modelling approach is usually called atheoretical, as these models are not based upon any underlying economic or financial theory. These models produce forecasts capturing empirically relevant properties of selected series. It is suggested that these pure time-series models are of benefit when regression based models are difficult to apply, e.g. when data on explanatory variables is not available and it is of a different frequency. According to Stevenson and McGarth (2003) and Brooks and Tsolacos (2010), these models, therefore, became popular within the commercial property market research community. Studies which employed time-series models include Tsolacos (1995), Tse (1997), Stevenson (2007) and Miles (2008).

Exponential Smoothing, as Yafee and McGee (2000) report, is a univariate modelling technique which isolates trend and seasonality from irregular variations. According to Yafee and McGee (ibid.) and Brooks and Tsolacos (2010), the main principle behind this methodology is the geometrically declining weighting approach. There, the most recent observations are considered as having greater explanatory power over older observations. Therefore, a greater weight is attached to them.

According to Makridakis *et al.* (1998) and Yafee and McGee (ibid.), Single Exponential Smoothing (SES) and Holt's Exponential Smoothing (HES) are two of the most commonly used exponential smoothing methods. Gardner (1985; 2006) maintains that there are few other alternatives to this methodology, including Brown's Linear Trend model.

Single Exponential Smoothing (SES) produces forecasts of the time-series simply by adding a forecast from the previous period with an adjustment for the error that occurred in the last forecast. The advantage of this forecasting technique is that it requires little storage of historical data and fewer computations. It is therefore useful when a large number of items need to be forecasted (Makridakis *et al.*, 1998).

Holt's Linear Trend (HLT) model, also known as Linear Exponential Smoothing, is an extension of SES. It is suggested that HLT involves smaller errors and therefore produces more accurate extrapolations (Makridakis *et al.*, 1998).

Brown's Linear Trend (BLT) model, also known as Double Exponential Smoothing, is a special case of HLT. The BLT specification is applicable when the series contains a linear trend and there is no seasonality. Here, smoothing parameters are level and trend which are of equal weight, which makes this specification similar to an ARIMA model (PASW, 2010a).

Autoregressive Integrated Moving Average (ARIMA) specification is also known as Box and Jenkins model (Brooks and Tsolacos, 2010; PASW, 2010a). As Box *et al.* (1994) explain, if the autoregressive operator AR is of order *p*, the *d*th difference is applied, and the moving average MA operator is of order *q*, their combination creates ARIMA model of order (*p,d,q*), or in other words ARIMA (*p,d,q*) process. The AR component of the specification implies that future values of the times-series can be approximated and predicted from the current and past values of the time-series itself. The MA component, instead, involves current and past effects of random shocks or error terms in the series (Barras, 1987; Stevenson and McGarth, 2003; Karakozova, 2004).

According to Makridakis *et al.* (1998), ARIMA model can have a shortened notation if an element within its framework equals 0. For example, ARIMA (1,0,0) can be rewritten as AR(1), whereas this model does not contain differencing (*d*) and moving average (*q*). Similarly, ARIMA (0,0,1) can be rewritten as MA (1), and ARIMA (1,0,1) can be modified into ARMA (1,1).

ARIMAX is an Integrated Autoregressive Moving Average model with Exogenous Explanatory Variable(s). The principle of this specification is that it incorporates Autoregressive (AR) and Moving Average (MA) components, as well as Vector of explanatory variable(s) (X) into one equation. The hypothesis behind this approach is that by incorporating relevant explanatory variable(s), a greater forecasting accuracy can be achieved (Karakozova, 2004).

A difficulty with ARIMA models, however, is that these specifications can only be used with stationary data. For non-stationary data ARIMA models are extended by incorporating differencing of the data series (Makridakis *et al.*, 1998).

The empirical evidence suggests that there can be a variety of ARIMA(X) specifications. Barras and Ferguson (1987b) used eight AR (1; 2; 3; 4; 6; 7;

8; 10) and three MA (2; 4; 8) specifications. McGough and Tsolacos (1995b) experimented with three AR (1; 2; 3), two MA (1; 2), and three ARIMA (1,2,1; 1,2,2; 1,2,3) specifications. Stevenson and McGarth (2003) compared forecasting power of two AR (1; 2), two MA (1; 2), and four ARMA (1,1; 2,1; 1,2; 2,2) models. According to Makridakis *et al.* (1998), however, this ARIMA model flexibility creates difficulty in deciding which model specification is the most appropriate. As commentators suggest, both experience and good judgement is needed in order to accurately identify the best model specification. Brooks and Tsolacos (2010) also add that visual time-series analysis, as well as assessment of both Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) helps in deciding on appropriate model specification.

However, as Chaplin (1998; 1999), Stevenson and McGarth (2003) and Karakozova (2004) commented, visual analysis of ACF and PACF are unlikely to be helpful in identifying the most appropriate model specification. Therefore, researchers recommended using alternative techniques known as 'Information Criteria' in selecting the best ARIMA model specification. There are two common information criteria. One is Akaike Information Criterion (AIC) and other is Bayesian Information Criterion (BIC).

As the literature suggests, both AIC and BIC contain a 'penalty' for adding extra variables into the model. Accordingly, both information criteria select the most parsimonious model (Chaplin, 1999). The only caveat with these formulations however is that BIC favours lower-order models, while AIC selects higher-order specifications. Nevertheless, both techniques are considered to be superior model selection tools with lowest AIC and BIC values indicating the best model specification (Schwarz, 1978; Brooks and Tsolacos, 2010).

Regression models

Regression is an important tool for modelling and forecasting. As Koop (2006), Brooks (2008), Brooks and Tsolacos (2010) suggest, it has been extensively used by researchers. According to the commentators, regression is easy to use, it is uncomplicated to interpret, and thus it dominates empirical modelling.

Makridakis *et al.* (1998, p.187) define **Simple Regression** as a ‘regression of a single Y variable [dependent variable] on a single X variable [the explanatory or independent variable]’. Similarly, Brooks and Tsolacos (2010) indicate that this method assumes the dependence of *Y* on only one variable *X*. According to the commentators, the principle of Simple Regression is that an increase/decline in *X* will lead to an increase/decline in *Y*.

As the real estate literature suggests, the dependent variable in most cases is influenced by more than one independent variable. This is the main principle of **Multiple Regression** (Brooks and Tsolacos, 2010). The hypothesis behind this modelling tradition is that by using an equation with more than one explanatory variable, the dynamics of a dependent variable can be modelled more accurately. The advantage of Multiple Regression is that it makes the most of the interdependence of few explanatory variables to model a dependent variable (Makridakis *et al.*, 1998; Koop, 2006).

Vector Autoregressive (VAR) modelling approach, as identified by Brooks and Tsolacos (2010), is a hybrid between a Univariate time-series model and Econometric model (for a discussion on Econometric modelling approach please see the section below). The traditional VAR specification is an *n*-equation, *n*-variable linear model where every variable is explained by its past and current values, plus past and current values of the remaining *n*-1 variables. The empirical evidences of Holtz-Eakin *et al.* (1988), Sims (1989), Brooks and Tsolacos (2001; 2010), Stock and Watson (2004), advocate VARs to be powerful in data description and forecasting. VARs were employed by economists, including Sims (1989), Dungey and Pagan (2000) and Cogley and Sargent (2005), as well as property researchers, including Eng (1994), McCue and Kling (1994) and Brooks and Tsolacos (2003).

Brooks and Tsolacos (2010) suggest several advantages of VAR models. There is no need to specify which variables are exogenous and which ones are endogenous, as all are endogenous. VARs are more flexible than AR models. In general VARs are seen as being superior to ‘traditional structural’ models. What is more, VARs are easy to use. They also provide a framework to test for Granger causality between variables.

However, VAR models are not without criticism. Koop (2006) and Brooks and Tsolacos (2010) comment that VARs are ‘atheoretical’. Similar to univariate time-series models they utilise little theoretical information about the relationship between variables. Furthermore, there is always an issue in deciding on the lag length of the specification. The commentators also noted issues related to the level of parameterisation and stationarity.

Econometric or structural modelling approach is known as a combination of system of equations. According to Brooks and Tsolacos (2010, p.303), these models are used when the theory suggests ‘that causal relationships should be bi-directional or multi-directional’ and that variables incorporated into equations should be related to one another. Each equation is then estimated independently using the OLS approach.

Following Stevenson and McGarth (2003) and Barras (2009), the advantage of such an approach is that it links several equations together subsequently linking variables into one system. As Brooks and Tsolacos (2010) commented, such systems are often used within the private sector.

However, this approach is also not without criticism. According to Stevenson and McGarth (2003), large structures can limit flexibility of a whole system especially in generating forecasts. Brooks and Tsolacos (2010) also noted that the dynamic structure of a structural model may affect the ability of an individual equation to reproduce the historic series it is seeking to represent.

The difficulty with regression-based models, whether it is Simple Regression, Multiple Regression, VAR or Econometric specification, is the presence of Autocorrelation. While building a regression based model, there is always a need to assess whether Autocorrelated disturbances are present within the model. Put simply, there should be no relationship between explanatory variables within the framework. According to Brooks and Tsolacos (2010), the Durbin-Watson (DW) test provides a platform to test for Autocorrelation and it should be used when building a regression based specifications.

Another issue with regression is the presence of heteroscedasticity. As Gupta (1999, p.234) suggests, in any well formulated regression 'the distribution of the residuals should have no relation with any of the variables'. In other words, the variance of errors should always be constant across the period. However, it can be the case that regression residuals are not constant and/or they are different for every observation. It therefore causes difficulty with modelling. If variances are unequal, then the reliability of each observation is therefore unequal also. Accordingly, greater variance lowers the importance of observations. Researchers including D'Arcy *et al.* (1999) and Gupta (1999) suggest using White's test as one of the most popular checks for heteroscedasticity.

2.2.2 Accuracy of property forecasting models

The subsequent developments in property modelling and forecasting, especially with the aid of IT, resulted in a surge in the complexity of mathematical modelling. Considerable use of high technology equipment allowed researchers and particularly those within the industry to employ new and more complex quantitative property market research techniques (Ball *et al.*, 1998; Dehesh and Pugh, 2000; Barras, 2009; Lizieri, 2009a). As Brooks and Tsolacos (2000, p.1825) observed 'more sophisticated techniques are in demand as they may potentially allow a better understanding of the sources of past changes in the market environment and enable these changes to be built into the rent forecasts'. However, the research indicates that despite advances in property market modelling and forecasting, there still remains a degree of inaccuracy between model outputs and actual property market performance (Newell *et al.*, 2002; Newell, 2006; McAllister and Kennedy, 2007; Investment Property Forum, 2012).

Direct comparison of the accuracy of property forecasting models

In their research into the short-term forecasting of the UK commercial rental values, McGough and Tsolacos (1995b) employed an Autoregressive Moving Average (ARMA) modelling approach to examine retail, office and industrial rents over a 16 year period. The accuracy of their forecasts was then examined by comparing them against actual values of the Jones, Lang & Wootton (JLW) rental values index. As the modelling results demonstrated, ARIMA models for retail and office rents were able to predict the dependent variable. The Root Mean Sum Predicted Error for Retail Rental Index, Office Rental Index and Industrial Rental Index was 0.0078, 0.0079 and 0.0320 respectively.

In a subsequent paper, Tsolacos (1995) developed a single-equation regression model of retail rents determination. The outcomes of the study demonstrated that this particular specification successfully captured the dynamics of the rental index.

Clayton (1996) developed a Vector Autoregressive model to forecast the Canadian commercial property market. The good fit of the model led him to conclude that 'market volatility is not necessarily something to fear…real estate returns are predictable to some degree, and hence market movements may be detectable in advance' (ibid., p.363).

D'Arcy's *et al.* (1999) investigation into the Dublin office market suggested that a Single Equation regression rent determination model produced better results than a Double Exponential Smoothing (DES) and the Holt-Winters (HW) specifications. The error value for the econometric model for year 1997 was +3.0 percent, while it was -17.9 percent for DES and -13.6

percent for HW for the same year, suggesting that econometric model was seven times more accurate than the alternative specifications.

Chaplin (1998; 1999) in a series of papers assessed office rent prediction models. In his first study, Chaplin (1998) identified that the best fitting models exhibited poorer forecasting results than their naïve competitors. It therefore led him to conclude that 'overall the general tone of the results suggests that there is very little benefit, if any, from attempting to select a model based on best fit to the historic data' (ibid., p.35). The results of a following study (Chaplin, 1999) were similar, suggesting that naïve models outperformed econometric structures. In other words, no-change or same-change strategy generated better modelling outcomes than mathematically constructed models. Chaplin (ibid.) therefore concluded with a citation from Pant and Starbuck (1990, p.442) that 'more complex, subtle, or elegant techniques give no greater accuracy than simple, crude or naïve ones. More complex methods might promise to extract more information from data, but such methods also tend to mistake noise for information. As a result, more complex methods make more serious errors, and they rarely yield the gains they promised'.

Hendershott's *et al.* (2002a) comparative analysis of an alternative (reduced form) rental adjustment model suggested that model successfully tracked 72 percent of movements in the dependent variable with all the coefficients being significant.

A more robust examination of the forecasting ability of property econometric models was presented by Brooks and Tsolacos (2000). The study compared four UK retail rent prediction models - an unrestricted VAR model, AR model, a Long-Term Mean model, and Random Walk model. As the result of the study suggested, the greatest modelling accuracy for CBRE index was obtained from the AR model, while for LIM index VAR produced the best fitting outcomes. In their following paper, Brooks and Tsolacos (2001) suggested that VAR model produced poorer forecasting results for real estate returns than Long-Term Mean and ARIMA models.

Wilson's *et al.* (2000) study into forecasting accuracy of Spectral Analysis (SA), ARIMA and Exponential Smoothing (ES) modelling techniques suggested that, ES, which is considered to be a basic forecasting technique, exhibited comparable forecasting results to the other two more advanced methods.

McGough and Tsolacos' (2001) assessment of the forecasting accuracy of Vector Error Correction (VECM), ARIMA, and the Regression (RM) models indicated the VECM model to be the most accurate amongst four specifications, while the ARIMA produced the poorest results.

In their panel data study on 12 European office markets, Mouzakis and Richards (2004) identified that their Fixed Effects Error Correction specification was more accurate in generating forecasts than alternative Simple Autoregressive Distributed Lag model (ARLD). According to the authors, the R-squared of their model was 66.2 percent, and Mean Absolute Error (for 2000 – 2001) was 0.067.

Karakozova (2004) examined the forecasting accuracy of three alternative office returns determination models for the Helsinki office market. The selected models were Regression Model (RM), Error Correction Model (ECM), and Integrated Autoregressive-Moving Average Model with exogenous explanatory variables (ARIMAX). The forecasting results were then compared against Double Exponential Smoothing (DES) model performance. As results of the study indicated, all three alternative forecasting techniques outperformed the DES competitor, with the ARIMAX model being the most accurate. As the author explained, ARIMAX model did not contain long-run information, i.e. error correction component, and therefore performed better at picking-up shocks and persistence effects present in the data. The MAPE for ARIMAX model in a one-year ahead forecast (1998-2000) was 2.01, while it was 2.70 and 3.05 for Error Correction and Regression models respectively.

The investigation into ARIMA model forecasting accuracy by Stevenson (2007) suggested that, in general, ARIMA models are applicable to forecast rental values. However, as the author commented, ARIMA specifications are of greater benefit for short-term forecasting purposes only, whereas they tend to over- or under-estimate key turning points in the longer-term.

More recently, Füss *et al.* (2012) compared the accuracy of non-linear Smooth Adjustment Threshold (STR) and non-linear Instantaneous Adjustment (SETAR) specifications in predicting the UK industrial, office and retail rents. The accuracy of these two specifications was compared against linear ARDL specification. As the modelling results suggested, non-linear models had overall better in-sample fit. The R-squared of the ARDL model was 63 percent, 84 percent and 75 percent for industrial, office and retail price change respectively, while it was 75 percent, 88 percent and 80 percent of STR and SETAR models for the same series.

Indirect comparison of the accuracy of property forecasting models

Studies by Newell *et al.* (2002), Gallimore and McAllister (2004), McAllister *et al.* (2005a), Newell and MacFarlane (2006), McAllister and Kennedy (2007) and IPF (2012) adopted an alternative forecasting accuracy measurement approach. The researchers assessed accuracy of already produced forecasts by comparing them against established property market benchmarks.

Newell *et al.* (2002) assessed Jones Lang Lasalle (JLL) six-months ahead forecasts against the actual property returns reported by the Property Council of Australia. As the results of the study indicated, econometric forecasts were poorer that those obtained from the naïve forecasting method. The U-statistics for the Sydney office market was 1.76, for the Perth office market it was 1.58, and for the Canberra office market it was 1.49. Accordingly, it led the authors to conclude that property forecasting accuracy has ‘room for considerable improvement’ (ibid., p.6).

Gallimore and McAllister (2004) examined the quality of expert judgement of commercial property forecasting. The results of semi-structured interviews suggested that property professionals were inclined into ‘self-censorship’ or were ‘censored’ by their peers, as all parties were aware of the limitations of their models. Therefore, forecasters were unlikely to report sharp increase/decline in a series even if models suggested notable market corrections for the future.

Newell’s (2006) subsequent study into the accuracy and the role of expert judgement within property forecasting suggested major issues. These issues were high levels of consensus amongst forecasters, uncertainty, persistence of errors, as well as inability in pick-up market turning points.

McAllister *et al.* (2005a) compared the Investment Property Forum (IPF) quarterly forecasts with actual property market performance expressed as IPD indices for rental growth, capital growth and total returns. Visual and statistical analyses indicated errors in forecasting, high levels of consensus, as well as systematic bias amongst forecasters.

Similarly, Newell and MacFarlane (2006) assessed the accuracy of commercial property forecasting in Australia. The authors compared bi-annual consensus forecasts produced by the Australian Property Institute with actual commercial property performance expressed as PCA/IPD direct property indices. The results of the study suggested that forecasters tend to display high levels of optimism, as well as they exhibit an element of inertia in their forecasts. However, the calculations suggested that property forecasters outperform naïve property forecasting strategies for both retail and industrial property. Overall Theil’s U-statistics value for retail property was 0.74 and 0.52 for industrial.

Tsolacos (2006) assessed whether consensus forecasts for All Property Rents and Total Returns produce better results than simple forecasting techniques such as AR(1) and Simple Regression (SR). The findings of the study suggested that consensus forecasts were more accurate than econometric models in the short term. However, when the forecasting time horizon increases, the explanatory power of consensus forecasts declines, e.g. in a two year horizon, IPF forecast's MAE was greater (2.97) than that of AR (1) model (2.76).

The issue of the accuracy of property forecasting was further discussed by McAllister and Kennedy (2007). Their statistical analysis of the market rental data on 13 European cities suggested that property market data contains a large degree of uncertainty, which subsequently affects property market forecasts.

More recently, IPF's (2012) investigation into the accuracy of UK commercial property forecasting suggested that forecasting accuracy varies. This variation is determined by market conditions, object being forecasted, forecasting techniques used, as well as by the forecasting period. The study also suggested that forecasters avoid predicting 'big numbers', i.e. they over-estimate a bear market and under-estimate a bull market. According to the calculations, the Long-Term Average (LTA) forecasting approach proved to be more accurate than Consensus Forecast (CF). The LTA was 80 percent accurate for one-year-ahead period, and 75 percent accurate for two-year-ahead period in generating forecasts.

This assessment of property forecasting model accuracy subsequently allowed researchers to suggest that regardless of the increase in the complexity of property market modelling and forecasting, the forecasting adequacy of alternative specifications can be improved. Accordingly, the commentators identified five major reasons which contribute to forecasting inaccuracy. These are market uncertainty, object being forecasted, modelling technique used, forecasting horizon, and data being employed (Makridakis, 1989; Newell *et al.*, 2002; McAllister *et al.*, 2005a, IPF, 2012). The researchers therefore argued that by improving any or all of the above noted elements of forecasting inaccuracy, greater forecasting performance may be achieved.

The current study therefore focuses on property forecasting accuracy improvement through modelling. The research seeks an alternative econometric approach to achieve greater predictive outcomes. It critically appraises the prevailing practice in the industry and academia of selecting a single best model based on model fit. It then assesses the difficulty in deciding which model to choose when different specifications produce different results. It then presents an alternative modelling technique which was developed by economists but has now been applied to improve UK commercial property cycle forecasting accuracy.

2.3 Summary

In reviewing the literature it was found that property cycles have been debated for more than a century (Mangoldt, 1907; Hoyt, 1933; Hakfoort, 1992; Barras, 2009). However, serious discussions and analyses on the subject emerged only during the early twentieth century. German scholars including Mangoldt (1907) and Eisenlohr (1921) were pioneers of building cycle research. In the US research on the subject started in 1933 with Hoyt's publication on the Chicago real estate cycle. Cairncross (1934) wrote one of the first studies in the UK. Since then, the subject has attracted greater attention of scholars, who investigated different aspects of property cycles. In the UK, Lewis (1965) published a historic survey of British economic growth from 1700 to 1950. Barras (1987) published a study of the UK post-war building. RICS (1994; 1999) examined the main elements of the UK property cycles. Subsequently, as Barras (2009) indicated, research into property cycles began to be conducted in private sector consultancies rather than in academia with the purpose of commercial forecasting.

As the results of the literature review indicated, the pioneering studies on the subject were particularly concerned with fluctuations in building (especially in residential), which was identified as the largest and the most volatile component of aggregate investments. These studies were inclined towards statistical data analysis and its interpretation, as there was an obvious lack of robust and consistent data. Consequently, early researchers identified both short (around 5 years) and long (around 20 years) building cycles. The prime explanation for the existence of these cycles was a relationship between population growth and the state of the economy. Moreover, building cycles were seen as local phenomena, independent from fluctuations in business.

Early modern property cycle studies in the UK were based on the hypothesis that major property cycles are generated by their endogenous forces. The key factor for these cycles to occur was an inherent production lag within the construction industry. The minor cycles were seen as the demand-side phenomenon reacting to changes in business. Particular attention was also placed on the financial side of the phenomena. As Barras (2009) indicated, favourable financial conditions fuelled two speculative property booms, one in the early 1970s, another in the late 1980s/early 1990s, with both of them bringing the British economy into recession. According to Baum (2001), a growing property portfolio within financial institutions was another factor for cycles to occur.

The experience of the 1990s brought new perspectives into property cycles research. These studies underlined a need for a global view on property cycles and particularly their relationship with capital markets. As Herring and Watcher (1998), Davis and Zhu (2004) and Barras (2009) observed, ever closer integration of property and financial markets mean that instability in one market can be easily transmitted to another local or national market. Accordingly, financial engineering and international flows of capital connect both markets. An increasing internalisation of the property market and similar macroeconomic environment translate cycles between countries subsequently creating greater volatility within markets.

As the discussion above suggests, there has been a significant shift in understanding of property cycles as well as in the variables property cycle researchers used to explain this phenomenon. There has been a shift from more building/construction and population-oriented variables towards business/economic variables. Early property cycle researchers considered property/building cycles as a local phenomenon, mostly independent from the wider economy. It was suggested that a sudden increase in population, or migration within certain areas with greater industrial opportunities, was a major driver for property/building cycles to occur. However, later studies considered property cycles as an element of the broader economy. Researchers began analysing property markets in the context of general business and financial cycles.

The shift in the understanding of property cycles also relates to the way it relates to business cycles. Early scholars saw property cycles as a leading phenomenon. As it was noted in Section 2.1.3, property cycle researchers in the early 1930s commented that property leads general economy by around 2 years.

However, a more recent theory suggests that property market actually lags the business cycle. Although empirical estimates are inconclusive, the general suggestion is that property market lags business cycle by around 2 years. For an industrial property, this lag is around 1 year which is the time needed to build an industrial object. For an office building, it stands at around 2 to 3 year depending on the location and complexity of the project.

Additionally, the property market is now seen as a component of the general economy, and in financial centres such as New York, London and Singapore, property markets became a global asset class. This was a paramount shift in the way property is seen by industry participants. As previously noted, early commentators saw property as a local market, which related to a particular city or the region, while nowadays, property is considered as a financial instrument, which corresponds to macroeconomic dynamics.

The subsequent discussion on the subject suggested that developments within the field of property cycles research led to the construction of various mathematical models. These models were employed in order to explain the behaviour of the real property market. The study suggested that univariate and multivariate were the main quantitative modelling approaches used within the field. As it was noted, the key univariate real estate forecasting models are Exponential Smoothing and ARIMA, as well as their variations. The main multivariate or regression based models are Simple Regression, Multiple Regression, VAR and Simultaneous Equation structures.

Although these models fitted historical data, the discussion has shown, however, that these specifications can be better at forecasting. Both discussions on direct and indirect comparison of the accuracy of property forecasting models suggested that forecasting accuracy varies and that there is a set of components which result in forecasting inaccuracy. It therefore led researchers to comment that greater forecasting accuracy could be achieved if any or all of these components are improved.

The evidence presented in the literature review therefore suggests that there is scope for further analytical and empirical work in the field of commercial property market modelling and forecasting. It is apparent that current modelling techniques, which are available to property market researchers, can be improved. Consequently, it is considered that the field would benefit from the introduction of an alternative technique which could be used to improve the accuracy of commercial property market modelling and forecasting.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

This chapter introduces the modelling process of the research. It is divided into four sections. Section 1 discusses the use of different forecasting models and the difficulty in deciding on the modelling outcomes.

Section 2 then introduces the principle of Combination Forecasting as an alternative methodology for commercial property market cycle forecasting accuracy improvement. It starts with a discussion on Combination Forecasting. It then assesses the key methods of combination.

Section 3 discusses the process of model implementation using PASW 18 (known as SPSS) statistical package. It provides information on two key modelling functions used for this research. The first function is 'Time-Series Modeller', which is used to generate univariate time-series models including Exponential Smoothing and ARIMA specifications. The second is 'Regression' function which is used to produce OLS based models including Simple Regression, Multiple Regression and Vector Autoregression. The section then presents additional information on auxiliary functions of the statistical package. It also discusses difficulties associated with spread-sheets.

Section 4 presents each modelling technique used for this research and their formulae. It starts with the Exponential Smoothing Method and its three variations including Single Exponential Smoothing (SES), Holt's Linear Trend (HLT), and Brown's Linear Trend (BLT) models. It then presents ARIMA, ARIMAX, Simple Regression (SR), Multiple Regression (MR), and Vector Autregression (VAR) models, as well as Combination Forecasting (CF), including Simple Averaging and OLS based Combination structures. The section also addresses statistical difficulties related to real estate model building. These are issues of autocorrelation and heteroscedasticity in regression based models, and the issue of Information Criteria whilst constructing ARIMA models.

3.1 Difficulty in choosing an appropriate forecasting method

The literature, in particular Section 2.2.3 of Chapter 2, revealed that commercial property market researchers and analysts use different forecasting methods for different forecasting purposes and horizons. Exponential Smoothing and Moving Average methods were mostly used for short-term and less often for medium-term forecasting horizon. These methods were also employed as benchmarks for alternative modelling techniques. ARIMA methods of forecasting were not used very often for any forecasting horizon. Although empirical estimates suggested that this modelling approach is useful for short-term forecasting purposes. Regression proved to be the most popular modelling approach. It was used most often for the medium-term forecasting horizon. According to Makridakis *et al.* (1998), this is consistent with theoretical reasoning which suggests that in the medium- and long-term the importance lies with understanding explanatory variables and other factors which affect the dependent variable. Subsequently, by having this understanding, the interrelationship between the dependent and explanatory variables can be quantified.

The review then identified that commercial property market researchers were selecting an appropriate method for forecasting based on the method's accuracy or its statistical complexity/sophistication. For example, D'Arcy *et al.* (1999) estimated that an Econometric model was more accurate that Double Exponential Smoothing and Holt-Winters models as it had smaller forecast errors. According to Stevenson and McGarth (2003), Bayesian VAR model produced the best forecasts in comparison to ARIMA, OLS based Single Equation and a Simultaneous Equation models in predicting CB Hillier Parker London Office index as it had smallest Mean Absolute Error. Karakozova's (2004) study suggested that of all three alternative models, i.e. Regression, Error Correction, and ARIMAX, ARIMAX model provided with the best forecasting results for office returns in Helsinki. This particular specification had the smallest Mean Absolute Percentage Error among competing models.

This general practice in selecting a single best model based on the model's accuracy or its statistical complexity/sophistication, however, has been criticised by researchers, including Granger (1969), Wood (1976) and Wallis (2011). According to the commentators, in most cases forecasters and decision makers discover the best performing model, which is then accepted and used, thus rejecting other alternatives. However, when the aim of the research is to obtain the most accurate forecast, discarding alternative models is unproductive. Rejected methods may contain useful independent information.

Another issue is in deciding which model to choose when different specifications suggest different results. As Makridakis *et al.* (1998) questioned, what, for instance, a decision maker should do if a time series model predicts a 10 percent decline in sales while a regression model tells that sales will increase by 2.5 percent over the selected time horizon. The commentators further elaborated on this issue and presented it graphically. The Figure 3.1 displays forecasts obtained from Single Exponential Smoothing (SES), Holt's Linear Trend (HLT) and Damped Smoothing (DS) models[2]. The statistics of this example suggest that Holt's model is the best fitting specification. Its Mean Squared Error (MSE) is 1.57 which is smaller than that of Single Exponential Smoothing and Damped Smoothing models, which are 9.37 and 17.77 respectively. However, the most accurate post-sample predictions are obtained from the Single Exponential Smoothing with its MSE being the smallest of all three models. The post-sample MSE for the Single Exponential Smoothing is 1945.98, it is 3116.47 for Holt's Linear Trend and it is 2003.52 for Damped Smoothing. This example demonstrates the dilemma researchers and decision makes are facing, i.e. that different models generate different

[2] The damping parameter measures the persistence of the linear trend (McKenzie and Gardner, 2010)

results and that each of these model outcomes contain useful information about an object being modelled.

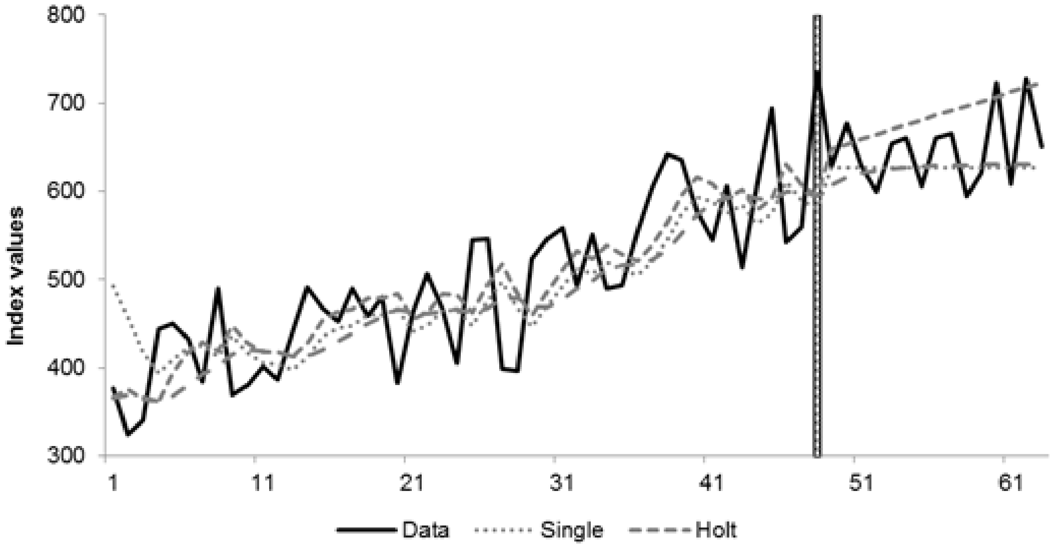

Figure 3.1 Model fit and forecasts for SES, HLT and DS models
Adapted from: Makridakis *et al.* (1998)

So what researchers should do having obtained these results? Makridakis *et al.* (1998) subsequently commented that a possible solution to this problem is to use improved, which mostly means more complex, modelling techniques. However, the solution to replace existing methods with more mathematical ones and train existing researchers so that they can work with new methods, unfortunately, does not work. According to Makridakis *et al.* (ibid.), this exercise tends to require more resources, greater skills and/or additional training to those already at work. What is more, the empirical evidence does not support the assumption that complexity improves modelling accuracy. This argument can be found within various fields of research, including environment, economics, and physiology, which is discussed below.

Outside the real estate discipline, the findings of Dorn (1950) and Hajnal (1955), who investigated demographics forecasting, suggested that complex population forecasting models, which typically incorporate large amounts of inputs, become overly complicated, and thus exhibit poorer accuracy. In their analytical survey, Armstrong *et.al.* (1984) assessed the relative accuracy of both complex and simple extrapolative methods. The commentators identified that simple methods (e.g. Exponential Smoothing) exhibit a comparable degree of accuracy to more complex ones (e.g. Box-Jenkins approach). In a subsequent paper, Armstrong (1986) made a qualitative review of the forecasting methods of the period from 1960 to 1984. The author arrived at the same conclusion that forecasters should be in favour of simple forecasting techniques over the more complex Econometric structures.

Clements and Hendry's (2003) investigation into economic forecasting was also not in favour of complex forecasting models. As the authors indicated, 'although which model does best in a forecasting competition depends on how the forecasts are evaluated and what horizons and samples are selected, 'simple extrapolative methods tend to outperform econometric systems' (ibid., p.304). More recent evidence from Buede (2009) suggests that although simple models contain a large variance in their predictions, complex models still have a large probability of producing wrong results. Orrell and McSharry (2009) also observed that, as models become more complex and parameterised, the number of elements they contain increases significantly. As a result, even small changes in these parameters can have significant consequences on modelling outcomes. Certainly, more parameterised models fit historic data better, their structure can also be more flexible. However, as the authors observed, such models are less helpful at predicting the future.

In the property forecasting literature, as the evidence suggests, simple models such as Exponential Smoothing, Simple Regression, or ARIMA specifications outperform the more complex forecasting techniques, including VAR and Econometric models, or at least generate highly comparable outcomes (Chaplin, 1999; Newell *et al.*, 2002; Stevenson and McGarth, 2003). This therefore led Newell *et al.* (2002) to suggest that despite the increased complexity in property market modelling methodologies, simple methods are found to be as good as complex econometric structures.

An alternative solution to the above noted modelling issue is to use the principle of Combination Forecasting. As it was suggested above, individual models use different data and they are specified on different parameters. As such, these models represent only a partial picture of reality, regardless of their complexity. This subsequently affects their accuracy (Makridakis, 1989; Goodwin, 2009). However, theoretical and empirical findings, which date back more than four decades, suggest that Combination Forecasting is a useful methodology in achieving greater modelling accuracy (Bates and Granger, 1969; Clemen, 1989; Makridakis, 1989; Kapetanios *et al.*, 2008; Pesaran and Pick, 2011; Wallis, 2011).

It is therefore decided to adopt the principle of Combination Forecasting for the purpose of this present study. As will be discussed in the following section, Combination Forecasting is a robust methodology which can be employed to improve the accuracy of commercial property market modelling and forecasting. This modelling approach was originally developed by economists, but is now applied to the UK commercial property market. This research subsequently assesses whether combination forecasts from different forecasting techniques are better than single model outputs. It examines which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts best.

The following section introduces the principle of Combination Forecasting. It presents this modelling approach in more detail, as well as discusses the key methods of combination.

3.2 Accuracy improvement through Combination Forecasting

3.2.1 The principle of Combination Forecasting

The principle of Combination Forecasting was developed within the field of economics and business research. The researchers were motivated that by combining forecasts from different methods and sources a greater predictive accuracy can be achieved (Makridakis, 1989; De Gooijer and Hyndman, 2006; Assenmacher-Wesche and Pesaran, 2008; Goodwin, 2009; Pesaran and Pick, 2011; Wallis, 2011).

According to Mahmoud (1984), Combination Forecasting is more accurate because it contains greater information on the object being forecasted. This therefore led researchers, including Clemen (1989), Makridakis (1989), Fildes (1991), and Goodwin (2009), to suggest that Combination Forecasting alleviates the weaknesses of the individual models which subsequently improves the overall forecasting accuracy. Accordingly, it was recommended that Combination Forecasting should become a standard practice within forecasting.

The efficiency of Combination Forecasting is well illustrated by Armstrong (2001, p.1): 'Assume that you want to determine whether Mr. Smith murdered Mr. Jones, but you have a limited budget. Would it be better to devote the complete budget to doing one task well, for example, doing a thorough DNA test? Or should you spread the money over many small tasks such as finding the murder weapon, doing ballistic tests, checking alibis, looking for witnesses, and examining potential motives? The standard practice in matters of life and death is to combine evidence from various approaches. Although it is not a matter of life and death, combining plays a vital role in forecasting'.

However, as Bates and Granger (1969) and more recently Kapetanios *et al.* (2008) and Banternghansa and McCracken (2010) observed, Combination Forecasting does not necessarily lead to better forecasting performance. Bates and Granger's (ibid.) observations suggested that if unbiased forecasts are combined with biased forecasts, it is likely that this set is going to contain 'errors' rather than positively balanced forecasts. Kapetanios *et al.* (ibid.) commented that a combination forecast can reduce modelling accuracy if the correctly specified model is identified but the data generating process remains unchanged. Banternghansa and McCracken (ibid, p.65) also added that a combination approach should be used and interpreted with caution whereas '[good] past model performance does not always ensure [good] future model performance'.

Despite this criticism, theoretical and empirical findings (in fields other than commercial property), which date back more than forty years, suggest that Combination Forecasting often outperforms individual forecasts (Bates and Granger, 1969; Makridakis, 1989; Stock and Watson, 2004; Wallis, 2011). Combination Forecasting has been successfully applied within various fields of research, including business, economics and management (Bates and Granger, 1969; Stock and Watson, 2004; Kapetanios *et al.*, 2008; Pesaran and Pick, 2011), psychology (Einhorn and Hogarth, 1975; Libby and Blashfield, 1978; Langlois and Roggman, 1990).

Crane and Crotty (1967) combined Exponential Smoothing and Multiple Regression models, which subsequently increased the accuracy of their forecasts. The accuracy of correctly predicting the future trajectory of time-series increased from 55 percent to 79 percent.

Bates and Granger (1969) combined forecasts derived from Brown's Exponential Smoothing and ARIMA methods. The outcomes of the study resulted in a significant drop in variance of errors (from 170 to 122).

Deutsch *et al.* (1994) combined Switching Regression Models (Regime-Switching Models) and Smooth Transition Regression Models (STAR Models). Accordingly, this Combination Forecasting reduced forecasting error. In case of Model 1 in-sample MSE for the UK inflation rate was 7.03, while out-of-sample MSE dropped to 0.44.

Zou and Yang (2004) combined different ARIMA specifications. The cumulative model reduced error by 38 percent from that of Bayesian Information Criterion (BIC), and 49 percent from that of Akaike Information Criterion (AIC).

Assenmacher-Wesche and Pesaran (2008) averaged different Vector Error Correction with exogenous variables (VECX) model specifications. The results of the study suggested greater predictive accuracy of averaged forecasts over the best single VECX (2,2) model specification.

More recently, Pesaran and Pick (2011) assessed combination forecasts generated from a Time-Varying Regression Model over different estimation windows. The researchers concluded that averaging forecasts lowers Root Mean Square Forecasting Error (RMSFE). The RMSFE for rolling average forecast was 2 point lower than base-line post-break forecast.

In a following paper, Pesaran *et al.* (2011, p.36) estimated that Exponential Smoothing based forecasting combination for GDP growth improves forecasting accuracy. For example, the Mean Square Forecasting Error (MSFE) for equal weight forecasting for USA was 1.533, while it was 0.857 for Exponential Smoothing Forecasting Combination over a h=2 forecasting horizon.

Despite advantages of Combination Forecasting in producing greater modelling estimates, the application of this methodology within property has been limited (Fildes, 1991; Rapach and Strauss, 2007; Wang and Nie, 2008). Few studies have been published on the subject, with all of them investigating the residential property market (Bradley *et al.*, 2003; Pagourtzi *et al.*, 2005; Fleming and Kuo, 2007; Drought and McDonald, 2011; Gupta *et al.*, 2011).

Fildes (1991) combined forecasts obtained from the panel of construction industry experts issued in 'Construction Industry Forecasts' (now produced by Construction Products Association) and ex-ante econometric forecasts. The study identified that a combination forecast does improve forecasting performance. The Mean Average Error (MAE) for private commercial sector (0 lags) was 3.73 from a combined model, while it was 4.18 (0 lags) from the expert predictions.

Bradley *et al.* (2003) developed a house price forecasting combination system. The system combined Repeated Sales model, Hedonic model, and Neural Network based model. First, the system computed estimates for each individual model. It then combined these models into one equation. As the authors claimed, this technique increased forecasting accuracy, whereas it is 'free of human biases and inconsistency inherent in manual appraisals' (ibid., p.10).

Pagourtzi *et al.* (2005) proposed a so called 'theta model' to forecast quarterly and monthly UK House Price Index values. The basic principle behind this methodology is that it divides an initial time-series into components, known as θ-lines. There, the θ-line, as the authors suggested, is 'local curvature of the time-series' (ibid., p.80). Subsequently, the model forecasts each of these θ-lines separately. A final forecast is obtained by simply combining θ-line forecasts into one. To forecast quarterly figures the commentators employed four modelling techniques, including Fixed Level Exponential Smoothing (Simple), Linear Trend Exponential Smoothing (HOLT), Damped Trend Exponential Smoothing (DAMPED) and a combination of HOLT and naïve methods. As this forecasting exercise suggested, the 'theta model' produced the most accurate forecast for quarterly figures.

Rapach and Strauss (2007) assessed whether a combination of individual forecasting models improves forecasting accuracy of US house price growth. The authors employed an Autoregressive Distributed Lag (ARDL) forecasting approach. Forecasts were produced for eight individual US District states for four and eight quarters ahead. The predictive ability of each model was assessed by comparing them against AR specification, which served as a benchmark. Subsequently, individual ARDL models were combined using three types of combination methods. The first was simple combination approach. Second method used weighting principle. The final combination method was based on ‘clustering’, where forecasts were grouped on the basis of their Mean Squared Forecast Error (MSFE). The study estimated that ‘the combining method forecast is more accurate than the AR benchmark forecast in terms of MSFE’, with the cluster combining method being the most accurate (ibid., p.41). Their cluster forecasts were on average fifteen percent more accurate compared with the AR benchmark at the four quarters horizon, and thirty percent more accurate compared with the AR benchmark for eight quarters horizon.

Fleming and Kuo (2007) developed an algorithm to predict the US real estate values. The algorithm was primarily based on weighted values of at least two different forecasting models’ outcomes. Forecasting methods which this algorithm comprised included Hedonic Method, the Repeat Sales method, the Tax Assessment method, and the Neural Network method. As the results of the study indicated, the combined model contained lower Proportional Prediction Error (PPE). The PPE for the four model combination was 0.0124, while it was 0.0347 for a single Neural Network model.

Wang and Nie (2008) combined Grey Dynamic (GD), BP Neural Networks, and Support Vector Machines (SVM) models, to forecast the Shanghai Real Estate Index. The authors compared individual performance of each model against an optimally weighted linear combination of all three models. The findings of the research indicated that the average forecast effectiveness of the combined method is greater than that of any single method. Forecast effectiveness of the combined model was 96.8 percent, against 66.2 percent of that of SVM-based model.

Drought and McDonald (2011) forecasted New Zealand house price inflation. The authors employed Equal Weights and Mean Squared Error Weights combination approaches. Combination Forecasts for house prices were compared against both individual model outputs and the Reserve Bank of New Zealand’s (RBNZ) house price forecasts. Surprisingly, as the results of the study suggested, forecasts from the best-performing model were more accurate than Combination Forecasts. On the other hand, the researchers suggested that Combination Forecasts had better predictive potential. It was noted that Root Mean Squared Errors (RMSE) of the Combination Forecasts and individual models were very similar and that Combination Forecasts were less biased as well as more resilient to structural breaks and misspecification biases than individual model forecasts. The subsequent comparison of the forecasting accuracy of MSE-weighted combination forecasts and the RBNZ forecasts suggested Combination Forecasts as being more accurate. For the year 2006, RMSE of the Combination Forecast was 1.99 while it was 2.79 from RBNZ's model outputs. For 2010 Combination Forecast's RMSE was 2.18, RBNZ's – 2.41. Drought and McDonald (ibid.) therefore suggested that a combination approach produces more accurate house price forecasts and it should be considered in any forecasting process.

Cabrera *et al.* (2011) employed a number of econometric specifications to forecast international securitised real estate returns. The models under study were the Autoregressive model (AR), Exponential Generalized Autoregressive Conditional Heteroscedasticity model (EGARCH), Functional Coefficient model (FC), Feedforward Artificial Neural Network (NN), and Nonparametric Regression model (NP). The authors also employed two simple combination forecasts of AR (1), NN (1,5), FC (1,200), and NP (200, 400) models, and AR (1), EGARCH (1,1), NN (1,5), FC (1,200), and NP (200, 400) models. As the empirical results suggested, Combination Forecasting improved forecasting performance for international securitised real estate returns, although an improvement was not significant. For example, Mean Squared Forecast Error (MSFE) for the UK series was 1.007 for AR (1), while it was 0.998 for both Combination I and Combination II.

In their empirical study, Gupta *et al.* (2011) assessed forecasting accuracy of alternative time-series models in predicting the dynamics of the US real house price index. The researchers employed a Dynamic Stochastic

General Equilibrium (DSGE) model and alternative time-series specifications, including VAR model, benchmark univariate BVAR model (UBVAR), small-scale BVAR model (SBVAR), large-scale BVAR (LBVAR), single-equation model (UFAVAR), multiple-equation model (MFAVAR), Bayesian single-equation VAR (BUFAVAR), and Bayesian multiple-equation VAR (BMFAVAR) model. The authors also used two Combination Forecasts. The first was based on 10 best models. Second Combination Forecast contained 10 best models and DSGE specification. The Combination Forecasts were computed simply averaging all model outcomes. As the modelling results indicated, the Combination Forecast came as the 'best forecasting method, based on the RMSE' (ibid., p.2020).

Therefore, the current research assesses whether combination forecasts from different forecasting techniques are better than single model outputs. It examines which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts best.

3.2.2 The key methods of combination

Combination Forecasting can be produced by simply averaging different forecasts or employing more complex techniques (Makridakis, 1989; De Gooijer and Hyndman, 2006; Goodwin, 2009; Pesaran and Pick, 2011). The major principle of forecast averaging is simply by computing the average of two forecasts for the forecasting period (Mahmoud, 1984). Here, each variable carries equal weight, i.e. if two variables are combined, both get 50 percent, if three variables – each gets 33 percent, if four – 25 percent, et cetera. The criticism behind so called Simple Averaging, however, is that this approach disregards the historic accuracy of the models, as well as the possible relationship between forecasts (Stock and Watson, 2004; De Gooijer and Hyndman, 2006).

An alternative model combination approach is Weighted Combination Forecasting (Makridakis *et al.*, 1998; Yaffee and McGee, 2000; Armstrong, 2001). The weighting technique has two basic alternatives. One is historical weighting, which gives weights to the forecasts based on their historic fit. In many cases, each forecast is weighted according to its Mean Squared Error (MSE). The second approach is subjective weighting, which is also known as Bayesian approach. Using this approach, weights to the forecasts are assigned by forecasters themselves based upon their personal experience and judgements as to which model fits and represents the historic data best (Mahmoud, 1984).

Despite the fact that a Weighted Combination approach appears to be popular, Armstrong (2001) highly criticised it. As he noted, one should use equal weights unless there is evidence suggesting unequal weighting of forecasts. In other words, he favoured Simple Averaging. The effectiveness of Simple Averaging over weighting was also advocated by Chan *et al.* (1999) and Kapetanios *et al.* (2008). Chan *et al.* (1999) suggested that simple Combination Forecasting worked especially well in their study. According to Kapetanios *et al.* (2008), Simple Average Combination Forecasting was more accurate in forecasting the UK GDP growth over the Weighted Combination Forecasting.

The regression, also known as Ordinary Least Squares (OLS), based combination approach, is a more advanced combination technique (Yaffee and McGee, 2000). Using this combination approach, weights to competing specifications are computed from regression (OLS) estimates. Model estimates are regressed against the dependent variable. The obtained coefficients then become weights for each specification which is to be combined.

However, as Chan *et al.* (1999) suggested, the difficulty with OLS combination is that it is not applicable when more than two forecasts are combined. Similar findings were presented by Swanson and Zeng (2001). As the researchers identified, when more than two forecasting models are combined using a regression combination approach, it increases the level of colinearity among competing forecasts which subsequently reduces the significance of the combination. De Gooijer and Hyndman (2006) also noted that simple OLS based combination methods often perform quite poorly due to the possible presence of the serial correlation between forecasts. Goodwin (2009) also added that this approach is sensitive to extreme forecasts, which can negatively affect the combination.

Regardless of this criticism, the OLS combination technique proved to be useful. The study of Diebold and Pauly (1990, p.504) suggested that regression-based combination or as in their case ‘flexible unconstrained regression-based forecast combination framework’ yielded improvements for US GDP forecasting. Yaffee and McGee (2000) demonstrated the usefulness of Regression Combination forecasts in predicting the US Defence and Space Gross Product Value Index. Empirical evidences from Bunn and Oliver (1989), Weinberg (1986), Miller *et al.* (1992), and Rapach and Strauss (2007) were also in favour of OLS combination.

As such, the research adopts the principle of Combination Forecasting as a robust methodology helping to improve the accuracy of commercial property market modelling and forecasting. It examines which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts best.

The following section comments on the model implementation using PASW 18 (known as SPSS) statistical package. It covers key modelling functions, as well as presents with some additional information on auxiliary functions of this statistical package. The section also covers difficulties associated with spread-sheets when employed for time-series modelling purpose.

3.3 Model implementation

3.3.1 Modelling process using PASW (SPSS) 18

The modelling is performed using the forecasting module of IBM SPSS Statistical Product ‘PASW18’. PASW 18 is statistical analysis software which helps with data collation and mining. It also contains a module of advanced statistical analysis for predictive solutions (IBM Corporation, 2010).

The forecasting module of PASW 18 provides two major tools. One is ‘Time-Series Modeller’, which creates time-series models and produces forecasts. Second is ‘Apply Time-Series Models’, which applies existing time-series models onto selected datasets. The ‘Time-Series Modeller’ predicts future values of the dependent variable based on its past estimates. Unlike regression, it measures a single variable over time and uses its statistical properties (average, mode, trend, seasonality, etc.) to derive forecasts. There, time itself is a predictor. The forecasting module also allows for the incorporation of explanatory variable(s) if needed (PASW, 2010a).

Time-series modeller creates ARIMA, multivariate ARIMA, i.e. ARIMAX, and Exponential Smoothing time-series models. It also assesses models’ major statistical properties. It measures their goodness-of-fit, Autocorrelation and Partial Autocorrelation.

The modelling procedure starts with the selection of the dependent variable. Then, the forecasting method, whether it is Exponential Smoothing or ARIMA, is defined. Subsequently, the forecasting period is specified and modelling details are indicated.

For ARIMA modelling, there are several model specification options. This involves defining of Autoregressive (AR) and Moving Average (MA) components, as well as degree of differencing. Following PASW (2010a), ARIMA modelling starts with a specification of a structure for the model. The Autoregressive order (p) specifies which previous values from the series are used to model current values. The Differencing order (d) can be used to remove trend if it is present. Moving Average (q) order uses deviations from the series average of previous values to predict current values. The ‘Dependent Variable Transformation’ can be specified before dependent variables are used in modelling.

The ‘Statistics and Forecast Tables’ option allows displaying model fit measures. These measures are R-square, Stationary R-square, Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and Mean Absolute Error (MAE). This option also computes comparison statistics, including Goodness of fit, Residual Autocorrelation Function (ACF) and Residual Partial Autocorrelation Function (PACF), as well as statistics for individual models (Parameter estimates).

The ‘Plots’ tab provides an option to display the modelling results and all the above noted characteristics. The ‘Output Filter’ tab gives the option to choose output results according to the criteria selected (Best-fitting models or Poorest-fitting models). The ‘Save’ tab allows to save model specifications, confidence intervals and residuals. Finally, the ‘Option’ tab makes possible to set the forecasting period, specify the handling of missing values, set the confidence intervals, and set the number of lags shown for autocorrelations.

Simple Regression, Multiple Regression and VAR specifications are produced using PASW 18 Regression function (PASW, 2010b). As a standard regression module, it allows for the selection of the dependent and independent variables. It also provides an option for the modeller to introduce Weighted Least Squares (WLS) which allows estimating regression models with different weights for different cases. Functions such as ‘Save’ and ‘Option’ are the same as for the Time-Series modelling module (PASW, 2010b).

3.3.2 Difficulties working with spread-sheets

Although PASW 18 is a comprehensive software package, it is nevertheless considered a generalised statistical tool with built-in data mining and data management algorithms. For time-series analysis it is recommended to use more specialised econometric software packages such as Eviews or OxMetrics. These specialised econometric packages offer more scope for time-series analysis, as well as power to create new econometric, statistical and mathematical forms (Timberlake, 2013).

The non-availability of specialised computer packages had an effect on the capacity of the current research. The research employs all except one real estate modelling technique indicated in Figure 2.3 (Section 2.2.1). The research does not estimate an Econometric model. As the Econometric model incorporates a system of equations and combines multiple relationships and interactions within the system, it therefore becomes difficult to compute using available software. In the case of MS Excel, the input X Range (number of explanatory variables) cannot contain more than sixteen variables (Microsoft Excel, 2010). In case of PASW 18, the system finds it difficult to deal with more than fifty regressors. What is more, some equations, which are part of an Econometric system, may not be recursive. According to Brooks and Tsolacos (2010), these equations therefore cannot be estimated using Ordinary Least Squares (OLS). The commentators subsequently recommend using Indirect Least Squares (ILS), Two-Stage Least Squares (2SLS or TSLS), and Instrumental Variables as alternative approaches. PASW 18, however, does not allow for any of these options. In addition to that, PASW 18 does not estimate model fit statistics such as Mean Error (ME), Mean Squared Error (MSE), and Mean Percentage Error (MPE), as well as Akaike and Bayesian Information criteria.

Moreover, there are a number of other difficulties associated with PASW 18 as with any other spread-sheet. Koop (2006) presents a good discussion on the subject. According to the commentator, spread-sheets are somewhat awkward in obtaining empirical results, e.g. creating lagged variables requires constant copying and pasting of data. In situations when one is working with several equations, it becomes even more difficult. Certain statistical measures and procedures such as variance decomposition, impulse response and spectral analysis are difficult to produce using spread-sheets. Accordingly, Koop recommended using more specialised statistical packages if one plans to work extensively with financial time-series.

Considering unavailability of these specialised software packages, the research continues with PASW algorithm which is used to compute five univariate time-series methods including Single Exponential Smoothing, Holt's Linear Trend, Brown's Linear Trend, ARIMA and ARIMAX, as well as three regression based models including Simple Regression, Multiple Regression and Vector Autoregression (VAR).

The next section of this Chapter presents formulae of modelling technique used for this research. It also covers statistical difficulties which are encountered when building a real estate model, including issues of autocorrelation and heteroscedasticity, and Information Criteria.

3.4 Formulation of real estate models

3.4.1 Single Exponential Smoothing model

As it was noted earlier in Section 2.2.1, the advantage of Single Exponential Smoothing is that it requires little storage of historical data and fewer computations. The principle equation of this specification which is used for the research is as follows (Makridakis *et al.*, 1998):

$$F_{t+1} = \alpha Y_t + (1 - \alpha) F_t \tag{1}$$

Where F_t is the forecast from a previous period, F_{t+1} is the forecast for the next period, Y_t is the most recent observation and α is a constant between 0 and 1. In econometrics α is also known as weighting factor. Forecasts using this formula are produced by adding a forecast from a previous period to the most recent observation with an adjustment for the error that occurred in the last forecast. This adjustment is achieved by using a geometrically declining weighting approach.

3.4.2 Brown's Linear Trend model

Brown's Linear Trend (BLT) model is similar to SES specification. However, it is rewritten in such a form that it minimises the effect of the weighting factor α. In this case, Brown's Linear forecast is the old forecast plus an adjustment for the error that occurred in the last forecast. The principle equation of BLT, which is used for the current research, is as follows:

$$F_{t+1} = F_t + \alpha (Y_t - F_t) \tag{2}$$

As it is seen from Equation 2, the weighting factor accounts for the most recent observation of the series being modelled, as well as forecast from a previous period.

3.4.3 Holt's Linear Trend model

According to PASW 18 (PASW, 2010a), Holt's Linear Trend (BLT) model, also known as Double Exponential Smoothing, is a special case of BLT. It uses two smoothing constants α and β (both being between 0 and 1) and a three-set-equation. The three-set-equation which is adopted for the research is as follows:

$$L_t = \alpha Y_t + (1 - \alpha)(L_{t-1} + b_{t-1}) \quad (3a)$$

$$b_t = \beta(L_t - L_{t-1}) + (1 - \beta)b_{t-1} \quad (3b)$$

$$F_{t+m} = L_t + b_{tm} \quad (3c)$$

Where L_t is an estimate of the level of the series at a time period *t*, and b_t is an estimate of the slope of the series at the same time period *t*.

The Equation 3a adjusts L_t to the trend of the previous period by adding b_{t-1} to the least smoothed value L_{t-1}. The Equation 3b updates this trend which is equal to the difference between two last values smoothed by β plus the trend multiplier (1 - β). Equation 3c subsequently forecasts ahead.

3.4.4 ARIMA model

Autoregressive Integrated Moving Average (ARIMA) specification, as it has been noted in Section 2.2.1, is the combination of the autoregressive operator AR of order *p*, and the moving average MA operator of order *q*. The basic representation of Autogression (AR) is as follows (Makridakis *et al.*, 1998; Brooks and Tsolacos, 2010):

$$Y_t = \mu + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + u_t \quad (4)$$

Where Y_t is the current value of dependent variable, y_{t-p} is past values of the variable itself, μ is constant term, ϕ_j is *j*th order autoregressive parameter, and u_t is the error term at a time period *t*.

The principal representation of Moving Average (MA) process is presented in the following equation:

$$\mathrm{Y_t} = \mu + b_1 u_{t-1} + b_2 u_{t-2} + \cdots + b_q u_{t-q} + u_t \qquad (5)$$

Where μ is a constant term, b_j is *j*th moving average parameter, and $u_t$is the error term at a time *t*.

It is important to note that the Moving Average within the ARIMA framework differs from the conventional Moving Average concept. Here it is defined as a Moving Average of errors and not as an average of past values of Y_t (Johnson, 1992; Makridakis *et al.*, 1998).

Subsequently, both AR and MA processes are paired together, creating a class of time-series models ARIMA (Box *et al.*, 1994; Makridakis *et al.*, 1998; Brooks and Tsolacos, 2010). The full model specification which is adopted for this research is formulated as follows:

$$Y_t = \mu + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + b_1 u_{t-1} + b_2 u_{t-2} + \cdots + b_q u_{t-q} + u_t \qquad (6)$$

As the empirical studies on the subject suggested, ARIMA models can have any AR and MA orders (Makridakis *et al.*, 1998; McGough and Tsolacos, 2010). However, the current research uses maximum of the order 4. This comes from the discussion on property cycles which suggested the existence of a minor property cycle of 4 years duration (RICS, 1999; Barras, 2009). For annual time-series it is assumed that a greater order is not relevant as fifth and subsequent orders are likely to capture dynamics of the previous business/property cycle.

Information Criteria

The ARIMA model flexibility creates a difficulty in deciding which model specification is the most appropriate. As such, measures known as 'Information Criteria' are recommended in selecting the best ARIMA model specification. As it was identified in Section 2.2.1, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are two common ones used by property market researchers. Whereas AIC and BIC are two competing specifications and each has its strengths and weaknesses, the current study therefore employs both specifications for the research.

According to Akaike (1973), AIC formulation chooses the correct dimensionality of a model amongst *n*th order models. The AIC is computed following Burnham and Anderson (2002):

$$AIC = n * \ln(\hat{\theta}) + 2 * K \qquad (7)$$

Where *K* is the number of free parameters in the model, *n* is the length of the time-series, and $\hat{\theta}$ is likelihood. Likelihood is subsequently estimated using the following equation:

$$\hat{\theta} = RSS/n \qquad (8)$$

Where *RSS* is Residual Sum of Squares obtained from the regression.

In situations when sample size is relatively small, i.e. $n/K<40$, AIC requires a bias-adjustment. In this case, the size of the data set *n* increases in weight in comparison to the number of parameters *K*. Accordingly, the bias adjustment term becomes less important (Burnham and Anderson, 2002):

$$AICc = AIC + 2K(K+1)/(n-K-1) \qquad (9)$$

The principle equation of the Bayesian Information Criterion (BIC) is as follows:

$$BIC = n * \ln(\hat{\theta}) + (K+1) * ln(n) \qquad (10)$$

Where *n* and *K* are the same estimates as for AIC.

3.4.5 ARIMAX model

The formulae for an Integrated Autoregressive Moving Average model with an Exogenous Explanatory Variable(s), also known as ARIMAX specification, is expressed as follows:

$$Y_t = \mu + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + \sum_{i=0}^{n} \gamma_i X_{t-i} + b_1 u_{t-1} + b_2 u_{t-2} + \cdots + b_q u_{t-q} + u_t \quad (11)$$

Where Y_t is the current value of dependent variable, μ is constant term, y_{t-p} is past values of the variable itself, ϕ_j is *j*th order autoregressive parameter, b_j is *j*th moving average parameter, u_t is the error term at a time *t* and X_t is a vector of explanatory variable(s).

3.4.6 Simple Regression model

The fundamental equation which describes Simple Regression presented in the equation below (Koop, 2006; Brooks and Tsolacos, 2010):

$$y = \alpha + \beta x \quad (12)$$

Where *y* is the dependent variable, *x* is an explanatory variable, α is intercept and β is the slope.

As was suggested in Section 2.2.1, the principle of Simple Regression is that an increase/decline in *x* will lead to an increase/decline in *y*. However, evidence suggests that this model may be difficult to apply in reality. It is impossible to determine with certainty that given any value *x*, value of *y* will be estimated accurately. To make it more realistic, a random disturbance term, or so called 'error' e is added into the equation. Subsequently, the model becomes (Brooks and Tsolacos, 2010):

$$y = \alpha + \beta x + e \quad (13)$$

However, even with an 'error' element, a linear regression model is only an approximation of reality (Koop, 2006). Therefore, in order to fit the model, it is recommended using an Ordinary Least Squares (OLS) approach (Brooks and Tsolacos, 2010). Here, the actual value of y_t at a period *t* is denoted with a fitted value $\hat{y}_t$, which is predicted by the model. Accordingly, α and β are replaced by OLS fitted estimates $\hat{\alpha}$ and $\hat{\beta}$:

$$\hat{y} = \hat{\alpha} + \hat{\beta}x + e \tag{14}$$

For the purpose of the current research, the model is rewritten as follows:

$$\hat{y_t} = \hat{\alpha} + \hat{\beta}x_t + e_t \tag{15}$$

The Equation 15 accounts for time-series data, where $\hat{y_t}$ is a dependent variable at a period *t*, x_t is an explanatory variable at a period *t*, and e_t is an error term at the same period *t*.

3.4.7 Multiple Regression model

In many cases the situation that the dependent variable is influenced by only one explanatory variable is unrealistic. In property, business and economics, dependent variables are often influenced by more than one independent variable. This relationship is at the core of the Multiple Regression. Accordingly, a model with *k* number of regressors becomes:

$$y = \alpha + \beta_1 x_1 + \beta_2 x_3 + \cdots + \beta_n x_k + e \tag{16}$$

For the purpose of the research, time-series Multiple Regression becomes:

$$y_t = \alpha + \beta_1 x_{1t} + \beta_2 x_{3t} + \cdots + \beta_n x_{kt} + e_t \tag{17}$$

Where set of $x_{1t}, x_{2t}, \dots, x_{kt}$ represent group of explanatory variables, and set of $\beta_1, \beta_2, \dots, \beta_n$ is a group of regression coefficients at the time period *t*.

In this case, however, each coefficient represents only a limited impact the explanatory variable has on the dependent variable. It means that a certain regression coefficient measures the effect a corresponding variable has on the dependent variable, after eliminating the effects of the remaining variables. The advantage of multiple regression is that it makes the most of the interdependence of the explanatory variables to model a dependent variable (Makridakis *et al.*, 1998).

Durbin-Watson test

As it was noted in Section 2.2.1, when building any regression specification, there is always a need to assess whether Autocorrelated disturbances are present within the model. It was suggested that Durbin-Watson (DW) test is a standard in testing for Autocorrelation. Following Stevenson and McGarth (2003), the DW specification is expressed as:

$$DW = \frac{\sum_{t=2}^{n}(\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^{n}\varepsilon_t{}^2} \qquad (18)$$

Where e_t is an error of at the period *t*.

Gujarati (2005) suggests that the Durbin-Watson statistics ranges from 0 to 4 with a value around 2 indicating non-autocorrelation. In case of modelling with PASW 18, if Durbin-Watson value is between 1.5 and 2.5, it indicates that values are independent (PASW, 2010b).

White's test for heteroscedasticity

The discussion in Section 2.2.1 also suggested a need to test for the presence of heteroscedasticity. It was identified that White's test (WT) is one of the most popular checks in assessing whether errors are constant across the sample. The difficulty with PASW, however, is that it does not test directly for heteroscedasticity. Therefore, White's test using PASW package is performed following a particular algorithm: first, squares of regression residuals (unstandardised) and explanatory variables are computed. Then, cross product of the explanatory variables is created by multiplying all explanatory variables. Following on from this, regression is performed with squares of residuals being the dependent variable and squares of explanatory variables and the cross product being independent variables:

$$R^2 = \beta_1 + \beta_2 x_{1t} + \cdots + \beta_k x_{kt} + \beta_{k+1}(x_{1t})^2 + \cdots + \beta_{k+n}(x_{kt})^2 + \beta_{k+n+1}(x_{1t} * \ldots * x_{kt}) \tag{19}$$

Here β_k is regression estimates and x_{kt} is explanatory variables. Subsequently, WT value is calculated by multiplying *n*, which is the number of observations, and R^2 obtained from the regression. Finally, the obtained value is compared with χ^2(chi-square):

$$WT = n * R^2 < \chi^2 \tag{20}$$

Accordingly, if χ^2 is greater than the WT value, then the hypothesis is rejected. It implies that the test did not find a problem (Gupta, 1999).

3.4.8 Vector Autoregression model

The simplest case of this method is VAR with two variables (Koop, 2006; Brooks and Tsolacos, 2010). There one variable depends on *p* lags of itself and *q* lags of the other variable. The mathematical representation of this interdependence is as follows:

$$y_t = \alpha_1 + \delta_1 t + \phi_{11} y_{t-1} + \cdots + \phi_{1p} y_{t-p} + \beta_{11} x_{t-1} + \cdots + \beta_{1p} x_{t-p} + e_{1t} \tag{21a}$$

$$x_t = \alpha_1 + \delta_1 t + \phi_{11} x_{t-1} + \cdots + \phi_{1p} x_{t-p} + \beta_{11} y_{t-1} + \cdots + \beta_{1p} y_{t-p} + e_{1t} \tag{21b}$$

This set of equations results in a model known as VAR (*p*). The model has two variables, intercept, deterministic trend and *p* lags of each of the variables. VAR (*p*) models with more variables are obtained in the comparable way (Koop, 2006).

As Koop (ibid.) maintains, once all variables selected for the model are stationary, modelling, model estimation and testing is performed in the standard way. Estimates for each equation are then obtained using OLS. Acquired figures for P-values and *t*-statistics indicate whether variables are significant.

3.4.9 Combination Forecasting

As it was established in Section 3.1, the current research adopts the principle of Combination Forecasting as a robust methodology helping to improve the accuracy of commercial property market modelling and forecasting. It uses two combination approaches, i.e. Simple and Regression (OLS) based averaging. These two particular combination techniques have proved to be useful in improving the accuracy of modelling and forecasting within business and economics (Makridakis, 1989; Pesaran and Pick, 2011; Wallis, 2011).

The difficulty with OLS based Combination Forecasting, however, is that previous empirical studies estimated that it is not applicable when more than two forecasts are combined. Findings presented by Swanson and Zeng (2001), De Gooijer and Hyndman (2006) and Goodwin (2009) suggested that a combination of more than two models reduces the significance of the combination, it results in the presence of serial correlation between forecasts, as well as the combination becomes sensitive to extreme forecasts. Therefore, the current study combines only two competing forecasts at a time.

Considering a **Simple Combination** forecast, a combination of two forecasts is formulated as follows (Yaffee and McGee, 2000):

$$CF_t = (F_{1t} + F_{2t})/2 \tag{22}$$

Where CF_t is Combination Forecasting, F_{1t} is first model outcome and F_{2t} is second model outcome.

In case of **Regression Combination**, the function comprises intercept and two regression coefficients plus an error term (Yaffee and McGee, ibid.; Landram *et al.*, 2009):

$$CF_t = \beta_0 + \beta_1 F_{1t} + \beta_2 F_{2t} + e_t \qquad (23)$$

Where β_0 is intercept, β_1 and β_2 are regression coefficients, and e_t is an error term (Yaffee and McGee, ibid.).

3.4.10 Further steps in formulating a real estate models

Stationarity and Unit-Root testing

In order to proceed with time-series modelling, there is a need to transform non-stationary data into stationary. The concept of stationarity is important for time-series analysis (Koop, 2006; Brooks and Tsolacos, 2010). In general, the term 'stationarity' implies that data does not exhibit growth or decline, i.e. time-series fluctuate around its constant mean through the whole period (Makridakis *et al.*, 1998). As Box *et al.* (1994, p.23) explains, 'stationary processes is based on the assumption that the process is in a particular state of statistical equilibrium'.

Non-stationarity, on the other hand, results in a positive autocorrelation, which, according to Koop (2006, p.143), means that time-series is highly correlated with past values of itself, i.e. it 'remembers the past'. As Koop suggests, non-stationary or unit-root variables should not be included into any regression model. According to the author, 'if Y and X have unit roots then all the usual regression results might be misleading and incorrect' (ibid., p.167). He also adds that most of the statistical packages like Excel implicitly assume that all selected variables are stationary when they calculate P-values. If the explanatory variables are non-stationary, the regression results become automatically invalid. Brooks and Tsolacos (2010) also add that non-stationary data can generate spurious regressions. Accordingly, if non-stationary variables are used for the regression modelling, then standard assumptions for asymptotic analysis become violated. Subsequently, Koop (ibid., p.167) suggests that one ‘should never run a regression of Y on X if variables have unit roots’.

In order to proceed with time-series modelling, non-stationary data must be converted into stationary. Non-stationarity in a time-series is achieved through ‘differencing’. The differenced series is defined as a change between current and previous values of time-series itself. Accordingly, this arithmetic transforms data into stationary series. However, in some cases there might be a necessity to difference the series a second time (Makridakis *et al.*, 1998). The major notation of differencing is as follows (Makridakis *et al.*, 1998):

$$y'_t = y_t - y_{t-1} \tag{24}$$

Accordingly, this simple calculus transforms data into stationary series. However, in some cases there might be a necessity to difference the series a second time. If the mean of the series wanders and the variance is not reasonably constant over time, then series is differences one more time. Second-level differencing is performed as follows (Makridakis *et al.*, 1998):

$$\begin{aligned} y''_t &= y'_t - y'_{t-1} = (y_t - y_{t-1}) - (y_{t-1} - y_{t-2}) \\ &= y_t - 2y_{t-1} + y_{t-2} \end{aligned} \tag{25}$$

One way of assessing stationarity is by looking at the time-series itself. As Makridakis *et al.* (1998) suggest, if the time-series shows no evidence of change in its mean and change in the variance over time, then it all indicates that the series is stationary. Both Autocorrelation (ACF) and Partial Autocorrelation (PACF) plots can aid additional information as to whether the time-series is stationary or not. According to Makridakis *et al.* (ibid.), if Autocorrelations drop to zero relatively quickly, it indicates that series are stationary. If, however, Autocorrelations decrease slowly, it is a clear sign of non-stationarity. If Partial Autocorrelation graph spikes in a first lag and is outside 95 percent limits, it indicates that series are non-stationary.

A more robust way for examining stationarity is by testing for a unit root. The most widely-used is Dickey-Fuller test (Brooks and Tsolacos, 2010). Using PASW 18 statistical package, this test is performed following the algorithm suggested by Koop (2006). First, AR(1) specification is created to examine ϕ value of series. Then, first difference Δy_t values are computed. Following on from this, Δy_t is then regressed on lagged values of time-series itself, i.e. y_{t-1}. Accordingly, regression estimates of *t*-statistics and ρ are compared against Dickey-Fuller critical values.

Testing for Granger causality

Another important step in formulating a real estate model is testing for Granger causality. The principle of Granger causality is in the way explanatory variables influence dependent variables. Here, if past values of an explanatory variable affect current values of the dependent variable, then it means that the explanatory variable Granger causes dependent variable.

In his original paper, Granger (1969, p.428) identified causality as 'the relationship between two (or more) variables when one is causing the other(s)'. According to Kirchgassner and Wolters (2007, p.100) this assumption is at the core of the general equilibrium theory which assumes that 'everything depends on everything else'.

As Koop (2006, p.184) suggests, the principle of Granger causality implies that 'events in the past can cause events to happen today'. More specifically, if past values of variable X explains variable Y, it then suggests that X Granger causes Y. Certainly, this relationship does not constitute an ultimate causality, this is why it is called 'Granger causality'. Nevertheless, the hypothesis is that if past values of an explanatory variable influence current values of a dependent variable, then the explanatory variable can cause the dependent variable.

Hendry and Mizon (1999) suggest that Granger causality is pervasive and highly important for econometric modelling. The authors identified ten aspects of econometric modelling in which Granger causality plays an important role. One of these aspects is so called ‘model marginalising with respect to unwanted variables’, which states that certain variables can be excluded from the equation based on the statistics of their lagged values (ibid., p.103).

The current study adopts a two-step algorithm to test for Granger causality suggested by Koop (2006). Koop’s algorithm is universally applicable and easy to adopt. First, the maximum possible lag length q_{max} is selected. Then, Distributed Lag Model (DLM) is estimated. The major representation of the model is as follows:

$$Y_t = \alpha + \beta_1 X_{t-1} + \cdots + \beta_{q_{max}} X_{t-q_{max}} + e_t \quad (26)$$

If P-value for variable(s) is less than significance level chosen, then this lag should be selected. Otherwise, a further regression analysis is performed with Distributed Lag Model estimated for lag q_{max-1}.

$$Y_t = \alpha + \beta_1 X_{t-1} + \cdots + \beta_{q_{max-1}} X_{t-q_{max-1}} + e_t \quad (27)$$

If P-value of this equation is significant, this lag length is chosen. Otherwise, flag length is shortened by one.

In general, Koop (2006) proposed a simple rule in determining whether a variable is significant or not. According to the author, ‘if you find any or all of the coefficients $\beta_1 ... \beta_q$ to be significant using *t*-statistics or the P-values of individual coefficients, you may safely conclude that *X* Granger causes *Y*. If none of these coefficients is significant, it is probably the case that *X* does not Granger cause *Y*’ (ibid., p.186).

Measuring model accuracy

Following Makridakis *et al.* (1998) and Brooks and Tsolacos (2010), accuracy measurement is an important issue in modelling property market.

According to Makridakis *et al.* (ibid.) in many instances, 'accuracy' is referred to 'goodness of fit', with both terms indicating how well the model is able to reproduce the data that is already known. As Brooks and Tsolacos (ibid., p.115) suggest, these measures assess 'how well does the model…that was proposed actually explain variations in the dependent variable?'.

The issue here, however, is, as De Gooijer and Hyndman (2006, pp.457) comment, 'a bewildering array of accuracy measures [which] have been used to evaluate the performance of forecasting methods'. Mahmoud's (1984) survey of relevant literature identified a number of accuracy measures available, including Mean Error (ME), Mean Absolute Deviation (MAD), Mean Squared Error (MSE), Mean Percentage Error (MPE), Mean Absolute Percentage Error (MAPE), Adjusted Mean Absolute Percentage Error (AMAPE), Theil's U-statistics (U), Root Mean Squared Error (RMSE), the Coefficient of Variation (CV), the Coefficient of Determination (CD), R-Squared, Adjusted R-Squared, Turning Points (TP's), and Hits and Misses (HM). Tsolacos (2006) added few more accuracy measures including Bias Proportion, Variance Proportion, Covariance Proportion, and Gain in Forecast. De Gooijer and Hyndman (2006) suggested using as they call 'a novel alternative measure of accuracy' which is 'Time Distance' developed by Granger and Jeon (2003a; 2003b). Alternative approaches in testing accuracy of competing forecasts are Diebold and Mariano's (1995) test, Clements and Hendry's (2003) 'Generalised Forecast Error Second Moment' (GFESM) criterion, as well as 'Tracking Signal' method, also known as 'Trigg's technique' (Trigg, 1964; Cembrowski *et al.*, 1975).

Although there is no universally accepted forecasting accuracy measure, it is nevertheless possible to identify those which are coming before all others in importance. As the literature on the subject suggests, there are three components which help in selecting the accuracy measures. One accounts for modelling technique which has been employed. Following Mahmoud (1984), for the linear structure the most applicable are Mean Error (ME), Mean Absolute Error (MAE), Mean Absolute Percentage Error

(MPAE), Mean Squared Error (MSE) and similar accuracy measures, as they measure model deviations from a stationary time-series. According Mahmoud (ibid.), if used in different settings, e.g. with non-linear structures, these accuracy measures will produce inappropriate results. The second component suggests using so called ‘Standard Statistical Measures’. According to Makridakis *et al.* (1998), Mean Error (ME), Mean Absolute Error (MAE), and Mean Squared Error (MSE) are all standard statistical measures with Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MPAE) being relative but frequently used measures. The third factor recommends looking across the literature on the subject and selecting the most frequently used accuracy measures. An analysis of publications on property market modelling, including Tsolacos (1995), Chaplin (1998; 1999), D'Arcy *et al.* (1999), Brooks and Tsolacos (2000; 2001), Stevenson and McGarth (2003), Karakozova (2004), Pekdemir (2009), to name a few, suggests that Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Mean Squared Error (MSE) are the most frequently used accuracy measures within the field.

However, Makridakis *et al.* (1998) argued that these accuracy measures assess only the goodness of fit of the model to historical data. Although this statistic is important in estimating the model behaviour, as well as its goodness to fit, it does not necessarily imply good forecasting performance. The authors therefore suggested that the series being modelled should be divided into two time periods normally called ‘initialisation’ set and ‘holdout’ set. The model should then be parameterised and tested on the initialisation set and forecasts made on the holdout set. It is suggested that whereas model is not parameterised on holdout set, forecasts produced on this period can be considered as being genuine. Accordingly, accuracy measures computed from the holdout sample indicate actual forecasting performance of the model. In the property literature, initialisation and holdout sets are sometimes called ‘ex-ante’ and ‘ex-post’ periods respectively (Chaplin, 1998; 1999; Tsolacos, 2006).

Following Chaplin (1998; 1999) and Makridakis *et al.* (1998), the out-of-sample forecasts can successfully be assessed using Theil's second inequality coefficient *U*. This statistical measure also allows for a relative comparison of selected forecasting methods with naïve approach. Naïve modelling approach means no-change or forecast obtained by guessing. As both Makridakis *et al.* (ibid.) and Chaplin (1999) identify, if *U* is equal to zero, then predictions are perfect. If it is equal to one, then the forecasts are the same as those that would be obtained using naïve forecasting approach. If, however, *U* is greater than 1, then there is no point in using formal forecasting method. In such a case a naïve approach would produce better results.

Accuracy measurement starts first by estimated forecasting error e_t. Here, it is simply calculated by subtracting forecast F_t at the period t from the actual observation Y_t of the same period. The formula for this equation is as follows:

$$e_t = Y_t - F_t \tag{28}$$

The Mean Absolute Error (MAE) and Mean Squared Error (MSE) are then obtained from the following equations:

$$MAE = \frac{1}{n}\sum_{t=1}^{n} |e_t| \tag{29}$$

$$MSE = \frac{1}{n}\sum_{t=1}^{n} e_t^2 \tag{30}$$

To compute MAPE, however, there is a need to additionally estimate Percentage (sometimes called Relative) Error (PE). The formula for PE_t is as follows:

$$PE_t = \left(\frac{Y_t - F_t}{Y_t}\right) x100 \quad (31)$$

Once Percentage Error is estimated, MAPE is computed as follows:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n} |PE_t| \quad (32)$$

However, as it was noted above, these accuracy measures assess only the goodness of fit of the model to historical data. The recommendation was to split time-series into 'initialisation' and 'holdout' sets and compute Theil's second inequality coefficient 'U_2'. The literature concerning modelling and forecasting commented that this particular accuracy measure indicates actual forecasting performance of the model. Mathematically Theil's U-statistics is expressed as follows:

$$U = \sqrt{\frac{\sum_{t=1}^{n-1}(FPE_{t+1} - APE_{t+1})^2}{\sum_{t=1}^{n-1}(APE_{t+1})^2}} \quad (33)$$

Where FPE_{t+1} is forecast relative change and APE_{t+1} is actual relative change. There:

$$FPE_{t+1} = \frac{F_{t+1} - Y_t}{Y_t} \quad (34)$$

and

$$APE_{t+1} = \frac{Y_{t+1} - Y_t}{Y_t} \quad (35)$$

Here F_t is forecast and Y_t is observation at the time period *t*.

3.5 Summary

The chapter discussed the difficulty in using different forecasting methods. It was established that, as a standard procedure, property market researchers are selecting the single best model based on its accuracy or statistical complexity. However, this model selection process has been criticised as being unproductive, whereas rejected models may contain useful independent information.

Accordingly, the chapter introduced the principle of Combination Forecasting. This methodology has been successfully employed by economists to improve the overall forecasting accuracy. Even though research on Combination Forecasting has been marginal within property research with most of the studies being produced for residential property, the existing empirical results indicated a benefit of this procedure. Various authors used different forecasting techniques which produced Combination Forecasting using a range of combination principles. However, Simple and OLS based averaging were established as being the key combination techniques. The overall conclusion supported the usefulness of Combination Forecasting and suggested further research in this area. Given the gap in the UK commercial property market cycle modelling and forecasting knowledge, the current research project employs Simple Averaging (SA) and Regression (OLS) based combination to achieve greater predictive outcomes. The research subsequently assesses whether combination forecasts from different forecasting techniques are better than single model outputs. It examines which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts best.

Following on, this chapter presented the modelling process of the current study. It first covered the general principles of model implementation using statistical software package PASW 18. It also assessed the issue of modelling using spread-sheets. Following on from this, the chapter presented each modelling technique used for the research, including

Single Exponential Smoothing (SES), Holt's Linear Trend (HLT), Brown's Linear Trend (BLT), ARIMA, ARIMAX, Simple Regression (SR), Multiple Regression (MR), and Vector Autregression (VAR). It presented the principal formulae for Simple Averaging and OLS based Combination Forecasting (CF). Subsequently, the chapter addressed statistical difficulties related to the construction of real estate models, including autocorrelation, heteroscedasticity, as well as the issue of Information Criteria, and Granger causality.

Statistical package PASW 18 is commonly known as SPPS. There are two modelling functions within the system, which were used for the research. One is 'Time-Series Modeller', which allows computing time-series models. The other one is 'Regression' function which is used to compute regression specifications. PASW 18 is a popular software package commonly used within business and academia. However, it is considered as being less useful than specialised econometric packages, as its scope in creating econometric, statistical and mathematical forms is very limited.

As the discussion above suggested, Exponential Smoothing, whether it is Single Exponential Smoothing, Holt's Linear Trend, and/or Holt's Linear Trend, are all univariate models which require little storage of historical data and few computations. Both Single Exponential Smoothing and Holt's Linear Trend are expressed as single equations requiring only most recent observations of the dependent variable, a forecast and a constant. Brown's Linear Trend is a more complex smoothing algorithm expressed as a three-set-equation incorporating two smoothing constants, as well as estimates of the level of the series at a certain period of time.

Both ARIMA and ARIMAX models were identified as being more advanced modelling structures. The principle behind this approach is that it incorporates an autoregressive operator AR of order p, and the moving average MA operator of order q. In case of ARIMAX, it also contains a vector of an explanatory variable(s) X.

The study however encountered two difficulties with ARIMA(X) models which come from their flexibility. Issue one is that AR and MA components can have any order. They can range from 0 to any number. It was therefore decided to use a maximum order of 4 as for the annual series as greater order may capture dynamics of an earlier business/property cycle (Section 3.4.4). Issue two is in deciding which model specification is the most appropriate. The econometric literature suggests using techniques known as 'Information Criteria' helping to assess the best specified ARIMA structure. Two of the most common information criteria are Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Whereas these measures have their own strengths and weaknesses, it is decided to use them both.

Simple Regression, Multiple Regression and VAR models were estimated using PASW 18 'Regression' function. In the case of Simple Regression, the dependent variable is modelled with only one explanatory variable. In the case of Multiple Regression, the dependent variable is modelled with more than one explanatory variable. VAR model is constructed using p lags of the dependent variable and q lags of explanatory variables. All specifications are estimated using OLS approach.

As with univariate models, the study identified two issues related to the regression model building. One is presence of Autocorrelation, and another is presence of Heteroscedasticity. In the case of Autocorrelation, it was decided to use Durbin-Watson (DW) test to assess whether Autocorrelated disturbances are present within the models. To check for Heteroscedasticity, White's test was selected.

The study also employed Granger causality to assess the significance of the explanatory variables. The study adopted the algorithm proposed by Koop (2006), which suggested estimating the maximum possible lag length of an explanatory variable and checking for its significance. In case the variable is insignificant, lag length is shortened by one period and the test is performed again. In case neither of the lags is significant, the explanatory variable is indicated as being irrelevant.

Finally, the chapter presented accuracy measures used for the research. To estimate in-sample accuracy, the study selected Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Mean Squared Error (MSE) accuracy measures. To assess an ex-post accuracy of each modelling structure, Theil's U-statistics is computed.

Having presented the methodology for the current research, the next chapter will discuss the data needed for building a forecasting model for the commercial property market.

CHAPTER 4 DATA AND ITS ACQUISITION

This chapter presents the data which was acquired for the research and examines its inherent characteristics. It is divided into four sections. Section 1 discusses the importance of historic data for the analysis of the commercial property market. It establishes that long-term series are necessary to build robust and reliable statistical models.

Section 2 assesses difficulties related to UK property data and its acquisition. The UK and especially London commercial property market data is considered as probably the best documented in Europe. However, as the evidences presented in this section suggest, it is not without criticism.

Section 3 presents the principle of Chain-linking as the statistically robust solution for time-series combination. This method is considered as being an effective time-series combination approach which is used by major organisations.

Section 4 evaluates properties of the dependent and explanatory variables. The research uses IPD All Property Rental Value Growth Index for the UK as the dependent variable. The subsequent analysis of the data-sets of seventeen organisations and thirteen publications enables to collect data on twenty-seven of explanatory variables. The chapter then presents five variable reduction techniques used for the research to determine the key variables. These variable reduction techniques are 'What Others Do', 'What Experts Advise', Stepwise Regression (Forward), Stepwise Regression (Backward), and Granger Causality. This combination of variable reduction techniques enables to produce the final 'Short List' of explanatory variables, which are Bank Rate, Construction Costs, Construction Orders, Construction Output, Construction Starts, Employment, and GDP. Accordingly, the latter seven variables are further used for the modelling.

4.1 The importance of historic data

In order to create a robust and reliable property market model, it is of great importance to use historic data. As noted by Solomou (1998), an historical perspective is essential in order to assess what generates cycles and how they have evolved. The long-term time-series analysis helps to understand important changes over time.

As Yaffee and McGee (2000, p.3) suggest, for proper parameter estimation and model building, time-series should contain ‘enough observations’. Although there is no general agreement as to what ‘enough observations’ is, Yaffee and McGee recommend that if a series is cyclical or seasonal, then it should be long enough to cover several cycles or seasons to allow researchers to specify them. In the literature (Section 2.1.2, Chapter 2), it was commented that there are a few types of property cycles. These are so called ‘short cycles’ of 4 to 5 years of duration, and ‘major cycles’ of 7 to 9 years of length. Following this classification and Yaffee and McGee’s (2000) recommendation that series should cover several cycles, it can therefore be suggested that selected time-series should contain more than 20 data-points (years) in order to successfully capture the cyclical nature of the dependent variable.

What is more, long time-series are necessary for mathematical reasons. Yaffee and McGee (2000) and Brooks and Tsolacos (2010) also noted the importance of statistical methods being used in determining the sample size. For univariate time-series models, authors, including Holden *et al.* (1991), McGough and Tsolacos (1995b) and Tse (1997) argued the need for at least 50 sample observations to produce a well parameterised ARIMA model. Although, Weiss and Andersen (1984) suggested that 30 observation are enough. The property studies, which were using univariate time-series modelling techniques (e.g. McGough and Tsolacos, 1995; 2001; Wilson *et al.*, 2000; Brooks and Tsolacos, 2001; Crawford and Fratantoni, 2003; Stevenson, 2007) employed more than 50 observations. However, in cases where such a large sample was not available (e.g.

Stevenson and McGarth, 2003; Karakozova, 2004), the univariate models were still able to capture the dynamics of the dependent variable.

In the case of regression model building, the length of time-series being used varied significantly. Hekman (1985) used only 5 observations. Tsolacos (1995) estimated his structural equation using 69 data points. D'Arcy's *et al.* (1999) study covered 28 years' data. Brooks and Tsolacos' (2000) sample period included 88 data points. White *et al.* (2000) used 29 observations. Stevenson and McGarth (2003) employed 39 observations. Mouzakis and Richards' (2004) data was of 22 observations. Qun and Hua (2009) used 10 observations only. As it is seen, various authors used different data sets of differing lengths, with some of the studies employing ten and less data points. However, Mouzakis and Richards' (2004) study estimated that at least 20 observations are required to build a reliable regression based model.

The following section discusses difficulties related to the UK property data and its acquisition. As it shows, although the UK and especially London commercial property market data is considered as probably the best documented in Europe, it is however not without criticism.

4.2 The UK property data

The UK and especially London commercial property market data is considered as probably the best documented in Europe (Barras, 1984; Ball and Tsolacos, 2002; McGough and Tsolacos, 2002; Lizieri, 2009a; Devaney, 2010). As McGough and Tsolacos (2002, p.35) observed, ‘in some senses, researchers seem spoilt for choice’. According to the commentators, the UK property data goes back for several decades. It is available at national and local levels, as well as in various frequencies. All that makes it possible to produce detailed and robust property market analytics.

However, as the publications on the subject suggest, UK data is not without criticism. Crosby (1988a; 1988b) reflected on the issue by identifying difficulties associated with the quality and quantity of the UK data. According to Crosby (1988a), the non-availability of data is partly related to the barriers within the public domain. As he observed, institutions such as the Valuation Office (now Valuation Office Agency) and Inland Revenue (now HM Revenue and Customs) deposit large amounts of the property data which could be analysed and successfully used for research. However, there is limited access to it. The other difficulty which Crosby identified is associated with substantial costs involved in collecting property data. What is more, data which could be obtained from private sources is often restricted by confidentiality and secrecy. Therefore, as Crosby (1988b) observed, the likelihood in obtaining the details off all property market transactions is very unlikely.

More recently, Ball and Grilli (1997) identified that commercial property market data is too ‘soft’ for robust statistical analysis. What the researchers meant was that ‘the aggregate data on commercial property output are relatively smooth compared to housing and to many other goods’ (ibid., p.282).

Similarly, Ball and Tsolacos (2002) stressed the issues with the way UK construction data is drawn up. As the researchers identified, the length of project implementation, index deflation, and missing information do affect the data. The authors therefore commented that forecasting errors may occur if too much reliance is placed on the data. Accordingly, in agreement with Crosby (1988a), they called for the Government to play a greater role in producing more accurate data.

RICS (1999) also addressed this issue. As the research identified, historic data is often highly aggregate and inaccessible. What is more, it is difficult to assess its reliability whereas there are almost no other independent sources of information against which the data could be cross-referenced.

Gruneberg and Hughes' (2005) assessment of the consistency between different construction data sources identified lack of uniformity amongst data sources. The researchers used correlation analysis as a measure of consistency. As their findings suggested, correlation coefficient of only two series was greater than 0.5. Accordingly, Gruneberg and Hughes hypothesised that this inconsistency arises from the way data is collected, what it contains, and what it measures. It therefore led them to conclude that 'it is not practically possible to develop a consistent predictive model of construction output using construction statistics gathered at different stages in the development process' (ibid., p.83). It was therefore suggested that historic data should be treated with caution.

In their modelling study, McGough and Tsolacos (2002) suggested that property related data is specific and thus hard to obtain. The non-availability of and difficulty to obtain property data was also commented on by Brown and Matysiak (1995), Wyatt (1996), Dunse *et al.* (1998), Knight *et al.* (1998), Ge and Harfield (2007) and Francesca *et al.* (2010). An early observations of Brown and Matysiak's (1995) suggested that historical property data is relatively short because there was no need for it. As the authors indicated, property was considered as a long term investment with minimum management required. What is more, it was anticipated that its financial value will always be growing. Therefore, there has been no perceived need to keep long-term series. According to Wyatt (1996, p.67) reliable property data is not available ‘because of legislative restrictions on data release to the public, confidentiality constraints and conservative attitudes’. Similar suggestions were presented by Dunse *et al.* (1998), who commented that historical property data is somewhere of 30 years of length and access to the information is restricted by the confidentiality clauses. What is more, private-sector organisations are usually reluctant to openly publish the information they collect. As Knight *et al.* (1998) observed, although virtually all areas of empirical research faces data availability problems, real estate research encounters this issue in particular. Francesca *et al.* (2010) discussed the issue of costs involved in obtaining primary property data from specialised organisations.

The current study encountered the same issues as noted in the literature. Estimates for floor-space, take-up, and vacancy rate are collected by major property consultancies (e.g. CBRE, JLL, DTZ) and published in their reports (e.g. McCauley, 2009; JLL, 2010a; Clarke, 2011). However, this data is somewhat fragmented and are not available over a long period of time. In situations when data is available, a special subscription is required. Datastream International (2012), which is a global financial and macro-economic data-base, Building Cost Information Service (BCIS, 2012), which provides cost information for the built environment, Global Financial Data (2012), which is a provider of historical financial data, and organisations such as Cambridge Econometrics (2012), Lombard Street Research (2012), Oxford Economics (2012), Capital Economics (2012) as well as specialised property information providers including EGi (2012), Experian Goad (2012), and Landmark Information Group (2010), all charge for access to their data-sets and reports.

Certainly, the UK property market data is rich and diverse. It is considered as being particularly well documented with some of the indicators going back for several decades. However, it is not without criticism. Difficulties with data, which Crosby indicated in 1988, still do exist in 2014.

The next section of this Chapter presents the principle of Chain-linking. Chain-linking has been commented as being a statistically robust method for time-series combination especially in situations when available data-sets are of short duration.

4.3 Annual Chain-Linking

Availability of a long-term series, as noted above, is an important issue for commercial property market modelling and analysis. In situations when time-series are of limited length, a possible solution is a combination of several data-sets. The difficulty is, however, on deciding how the various series should be combined.

The simplest solution came from Liesner (1989). In her study, Liesner (ibid., p.271) 'used simple average estimates as the central point to construct national accounts'. A more robust approach was employed by Gruneberg and Hughes (2005) and Vivian (2007), who used correlation analysis to detect which of the series had greater statistical relationship. For Vivian correlation analysis helped to check validity of the data and select time-series which were subsequently combined to produce longer-term indicators.

As theoretical and empirical findings suggest, however, the technique, known as 'Chain-Linking' is considered as a better series combination approach (OECD, 2007). According to the OECD (ibid., p.97), an advantage of chain linking is that it is 'joining together two indices that overlap in one period by rescaling one of them to make its value equal to that of the other in the same period, thus combining them into a single time-series'. This time-series combination technique has been used by major organisations, including the Scottish Government (2007), ONS (2011) and the World Bank (2011b). McKenzie (2006) indicated that in year 2006, 14 out of 29 OECD countries used some sort of linking methodology for index combination.

Following Tuke (2002) and Robjohns (2006), there are two major principles of a chain-linking methodology: fixed base year chain-linking and annual chain-linking. Fixed base year chain-linking uses a set of weights which are applied on each component to produce an aggregate measure. This method revises weights every 5 years. However, in a changing economy, it may not be adequate, as this approach does not reflect the current state of the market. Therefore, annual chain-linking is recommended to measure aggregate figures more frequently. As the name suggests, rebasing is performed every year.

The annual chain-linking process is expressed in the equation below:

$$CLV_t = BYA_{t+1}/1 + \left(\frac{BYR_{t+1} - BYR_t}{BYR_t}\right) \tag{40}$$

Where CLV_t is chain-linked value, BYA_t is actual base year value, BYR_t is base year which is to be rebased value, and *t* is time period. The Equation 40 is used when the most recent time-series is established as being the base with, an older data-set being that which is to be rebased.

If, however, the base series is that from the past and most recent series is to be rebased, then formula is as follows:

$$CLV_t = BYR_{t-1} * (1 + \frac{BYA_t - BYA_{t-1}}{BYA_{t-1}}) \tag{41}$$

Equation 41 allows the chain-linking of a time-series based on older data-set, which is then extended by rebasing the newer time-series.

The following section presents dependent and explanatory variables which were used for modelling. The section discusses rationale behind these variables and their significance to property market. It also presents key properties of selected series.

4.4 Method of selecting variables

4.4.1 The dependent variable

The literature has shown (Section 2.2) that the use of the dependent variable within the field of commercial property market modelling and forecasting varied. McGough and Tsolacos (1995b) examined retail, office and industrial rents. Tsolacos (1995) assess retail rents determination factors. D'Arcy *et al.* (1999) investigated dynamics of Dublin office rental market. Karakozova (2004) appreciated office returns in Helsinki. Brooks and Tsolacos (2010) developed an econometric model to assess future value of office yields.

The research, however, employs a rental series as the dependent variable. This comes from Barras (1984), Scott (1996), Ball *et al.* (1998), and Baum and Crosby (2008) who argued that rent is of particular importance for investors and analysts. Following Barras (1984), rent level determines the profitability for developers and investors which as a result affects the level of supply of new developments. Ball *et al.* (1998) documents that in the user market, rent is a payment an organisation makes in order to use commercial property. In the capital market, rent is used to estimate the value of the property. Subsequently, rent plays a very important role in bringing four inter-related property markets (user, financial, development and land market) into simultaneous equilibrium. In mathematical terms, rent constitutes actually income stream that an asset generates. What is more, it is used to derive value of the commercial property. Here the value is estimated by dividing rent, which is a rental income received from letting an asset to occupiers, from capitalisation rate.

Accordingly, Hendershott *et al.* (2002a, p.165) suggested that rent, the price of space, is ‘the most important variable in property economics’. As such, rent determination has been an object of empirical studies over the last few decades.

Following on from this, the current research uses IPD All Property Rental Value Growth Index for the UK as the dependent variable (IPD, 2011). Certainly, IPD is not the only UK property index provider. Property consultancies including JLL (2010) and CBRE (2011) also produce UK commercial property benchmarks. Nevertheless, IPD indices are considered as being reliable property market benchmarks in the UK. They are well regarded within the UK property investment community, as well as being regularly used by property researchers (Baum, 2001; Ball, 2003; McAllister et al., 2005a; 2005b).

IPD provides real estate benchmarking and portfolio analysis services internationally. According to its recent press release (IPD, 2014), IPD's database incorporated more than 1,500 funds containing nearly 77,000 assets, with a total capital value of over USD 1.9 trillion. Each year, IPD produces more than 120 indexes and around 600 benchmarks for client portfolios, making it one of the best property information providers. In terms of UK Annual Property Rental Index, the benchmark tracks performance of 21,175 property investments, with a total capital value of over £152.7 billion as at December 2013. The market coverage is estimated to be around 60% - 70% with results dating back to 1980 (IPD, 2011), which is greater than JLL, CBRE or any other competing dataset in the UK.

Regarding time-series frequency, all data is annual. There may be a suggestion to use quarterly or monthly figures. Certainly, in both cases, series will be longer. Rather than having only 47 annual data point over the 1963-2010 period, quarterly figures would give 188 data-points and monthly figures would provide with 564 data-points. This would therefore be an improvement for modelling purposes. However, it should be remembered that real estate is a long-term asset (Ball et al., 1998; Shiller, 2014). An annual data is more important whereas an impact of exogenous factors such as business cycle can only be detected at annual intervals (Baum, 2009). Therefore, yearly data represent market better than the higher frequency series. What is more, Denton (1971) commented on difficulty in adjusting monthly or quarterly series to annual totals. More recently, EUROSTAT (n.d.) observed issues related to quarterly national accounts. In addition to that, series dating back several decades are available only in annual figures. As such, series in annual numbers are selected for the current research.

The original IPD series is available from 1976, which up to year 2010 gives 35 data-points only (IPD, 2011). Section 4.1. considered the issue of the minimum number of observations required to produce time-series and regression based models. It was suggested, that for an ARIMA model at least 50 sample observations are needed. For the regression specification, it should be more than 20. As such, for the purpose of this study, the IPD index is extended by chain-linking it with Scott's (1996) rental series. Scot's rental series has been chosen following study of the RICS (1999) and statistical estimates. RICS (1999) reported that IPD's rent series can be extended by combining it with Scott's (1996) dataset. RICS (ibid.) study successfully combined two series which extended the dependent variable for several decades. The subsequent visual and statistical analysis suggests high compatibility between the two time-series (Figure 4.1; Figure 4.2). The correlation coefficient over the period 1976-1993, when the two series overlap, is 0.999 (it is 0.997 for 1st.dif. series) which indicates almost perfect positive correlation. It therefore suggests that both series can be successfully linked together.

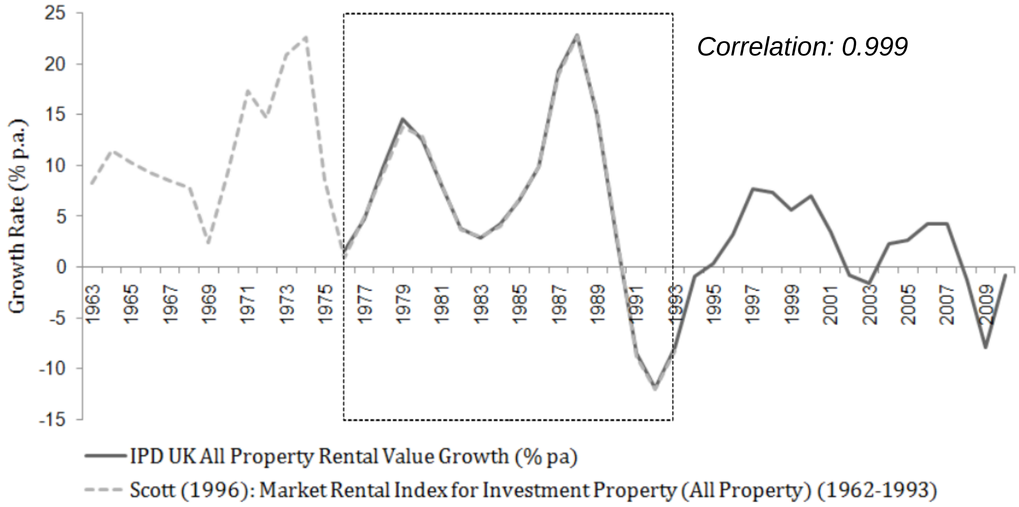

Figure 4.1 Chain-linked UK All Property Rent Index
Source: Scott (1996); IPD (2011)

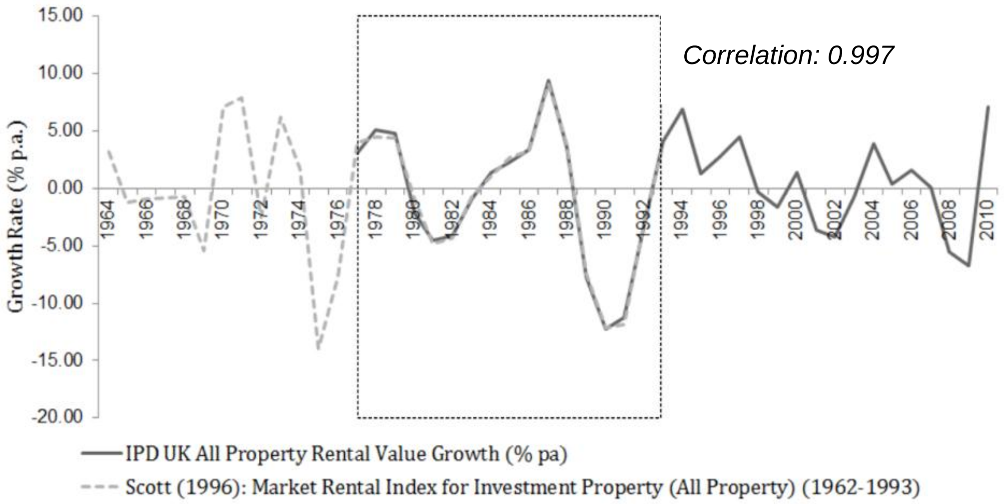

Figure 4.2 Chain-linked UK All Property Rent Index (1st.dif)
Source: Scott (1996); IPD (2011)

The subsequent combination of both IPD and Scott's series extends the rental series for an extra 13 years. As a result it gives 48 data points which is considered to be substantial for both univariate and regression time-series modelling. The study therefore continues with the extended time-series with year 1963 being a starting point. Accordingly, data on all explanatory variables is collected for the same time period (see Section 4.4.2, Chapter 4). What is more, all explanatory variables are acquired following Arthur's (2003) recommendations, i.e. time-series are regular, representative, homogenous (comparable), continuous (unchanging description), and of the same length and frequency.

Following on from this, the time-series are divided into initialisation and hold-out periods. As it was noted in Section 2.2.2., all models must be parameterised and tested on initialisation set and forecasts made on holdout set. The issue here, however, is that the literature does not suggests the length of initialisation and hold-out periods. Various authors within property forecasting used different ex-ante and ex-post periods. Chaplin (1998) tested his models by producing one step ahead predictions for five years. In a subsequent paper, Chaplin (1999) estimated model fit and produced one-step ahead forecasts for ten years (from 1985 to 1994). D'Arcy *et al.* (1999) used time-series over the 1970-1997 period. Then, forecasting adequacy of the estimated rent model was assessed by producing sample forecast for 1996 and 1997. Hendershott *et al.* (1999) in their empirical study employed a series for the period 1977-1996 with model being dynamically simulated yearly from 1986 to 1996. Matysiak and Tsolacos (2003) employed a monthly series for the December 1986 – April 2001 period and produced out-of-sample forecasts for two three-month time horizons, i.e. February 2001 - April 2001 and February 2000 - April 2000. Stevenson and McGarth (2003) used bi-annual data from May 1977 to May 1996 for model construction and the following three years for out-of-sample performance assessment. Similarly, Orr and Jones (2003) employed a bi-annual series for the 1979-2000 period. Accordingly, the authors produced four 1-step ahead forecasts for 1998 (half 1 and half 2) and 1999 (half 1 and half 2). Mouzakis and Richards's (2004) data was available from 1980 to 2001 annually with two final years being the test years. Tsolacos (2006) generated ex-ante forecasts for one- and two-year horizons on a rolling basis over the period from 1999 to 2004.

As can be seen from the discussion above, there is no general agreement as to how long the holdout period should be. The findings suggest that it can range from two (as in Mouzakis and Richards, 2004) to ten periods (as in Chaplin, 1999). In this research it was therefore decided to divide the data set into initialisation period from 1964 to 2000 and holdout period from 2001 to 2010. The ten year ex-post forecasting accuracy period will be sufficient to assess the forecasting performance of each model, as well as to examine the existence of two short 4-5 years property cycles driven by the classical business cycle (Barras, 1994; RICS, 1994; Ball *et al.*, 1998) and one longer 9-10 years major property cycle (Barras, 1994). It will also allow assessing the forecasting accuracy of each model for short- and long-run horizons.

An examination of the general trends in commercial rental values over the sample period produces observations, which corroborate those of Fraser (1984), Scott (1996), RICS (1999; 1994) and Barras (2009). As it is seen from Figure 4.3, over the 1963-2010 period, there were five major corrections in the series, i.e. early 1970s, mid-1980s, early 1990s, early 2000s and that of 2008. It also suggests high volatility of the rental index over 1974-1977, 1988-1992 and 2008-2010 periods in particular.

The subsequent analysis of HP cycle of the combined rental property index (Figure 4.4) suggests that the average period of UK rental cycle is 9 years. The average period between turning points is 4.5 years. It is also apparent that cycles are getting shorter and more volatile over time.

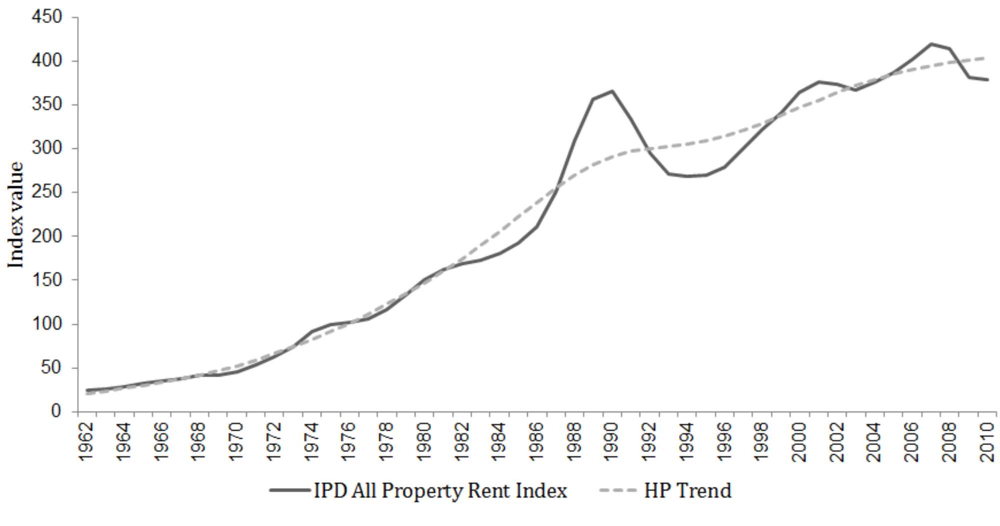

Figure 4.3 Chain-linked UK All Property Rent Index and HP Trend

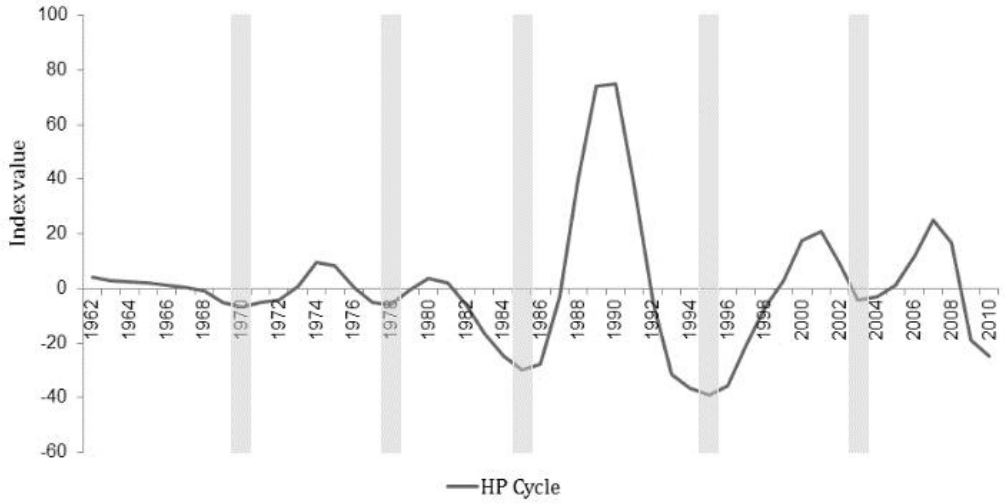

Figure 4.4 The HP Cycle for Chain-linked UK All Property Rent Index

4.4.2 Explanatory variables

The examination of the literature on the subject[3] enabled the identification of thirty-six variables which were used by various property researchers to model commercial property rents. However, not all series indentified were available for the 1963-2010 research period. Business Orders, Consumer Confidence, Floor-space, Index of Services, Retail Sales, Take-up, Business Turnover, Risk Premium and Vacancy Rate were variables for which data was not available for such a long period of time. In most of the cases, data on these variables was not collected before late 1980s/early 1990s. Other variables, which were used within studies on commercial property market rent determination, were subject specific. Table 4.1 provides details on all explanatory variables, their availability, original name and code where applicable, as well as sources of information where they were obtained.

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[3] Publications include Hekman (1985), Frew and Jud (1988), Glascock *et al.* (1993), RICS (1994), Tsolacos (1995; 2006), Hendershott (1996), Wheaton *et al.* (1997), Chaplin (1998; 1999; 2000), Hendershott *et al.* (1996; 1999; 2002a; 2002b; 2008), D'Arcy *et al.* (1999), Mueller (1999), Robertson and Jones (1999), Wheaton (1999), Brooks and Tsolacos (2000), White *et al.* (2000), McDonald (2002), Matysiak and Tsolacos (2003), Orr and Jones (2003), Stevenson and Mcgarth (2003), Mouzakis and Richards (2004), and Qun and Hua (2009).

The data on explanatory variables was obtained from various sources. The author’s intention was to collect as many explanatory variables as possible so that so called ‘omitted variable bias’ could be controlled for. However, a number of important limitations were in play during this process. The most notable one was access to data. As noted in Section 4.2., the UK commercial property market is well documented; series go back for several decades. Unfortunately, it is not without criticism, with the inaccessibility of property specific series being the key limitation. As such, the data for this research project was compiled from web-based data sources such as ONS, World Bank, OECD, as well as from print-copies of various statistical tables available in the archives of the National Library of Scotland.

Analysis of the data-sets of seventeen organisations and thirteen publications made it possible to collect statistical data on only twenty-seven of these variables. Organisations whose datasets were used include the Bank of England (2011), Corporation of London (2011), the UK Debt Management Office (2011), the Department for Communities and Local Government (2011), Department for Transport (2011), Global Financial Data (GFD) (2012), HM Revenue & Customs (HMRC) (2011), Ingleby Trice (2011), Investment Property Databank (IPD) (2011), London Stock Exchange (LSE) (2011), Nationwide Building Society (2011), the NHS Information Centre (IS.NHS) (2011), the Office for National Statistics (ONS) (2010), the Office of the Deputy Prime Minister (ODPM) (2006), the Organisation for Economic Co-operation and Development (OECD) (2011), the University of Groningen (Maddison-Project) (2008), and the World Bank (2011a).

Publications which were used to support, cross-reference and extend existing time-series include Feinstein (1972), London & Cambridge Economic Services (LCES) (1973), Building Societies Association (1982), Liesner (1989), Mitchell (1992), Council of Mortgage Lenders (1995), Scott (1996), Hicks and Allen (1999), Twigger (1999), Bond *et al.* (2001), O‘Donoghue *et al.* (2004), and Holmans (2005).

Variables	Availability	Name and code	Source
Bank Rate	1963-2010	Annual average rate of discount, 3 month Treasury bills, Sterling (IUAAAJNB)	Bank of England (2011) / Liesner (1989)
Business Output	1963-2010	Financial intermediation and real estate, renting and business activities (EWAY)	ONS (2010)
Business Orders	1998-2010	Turnover and Orders in Production and Services Industries - TOPSI: Manufacturing and Services Turnover (JT)	ONS (2010)
Car Registrations	1963-2010	Motor vehicles registered for the first time by tax class	Department for Transport (2011)
Construction Orders	1964-2010	Value of construction new orders by contractors (£ mill)	ONS (2010)
Construction Completions	1963-2010	Volume of construction output by contractors	ONS (2010)
	1963-2010	House building completions	Council of Mortgage Lenders (1995) / the Department for Communities and Local Government (2011) / Building Societies Association (1982)
Construction Cost	1963-2009	Price of construction output	Holmans (2005) / ONS (2010)
Construction Starts	1963-2009	Building starts	Council of Mortgage Lenders (1995) / the Department for Communities and Local Government (2011) / Hicks and Allen (1999) / Building Societies Association (1982)
Consumer Confidence	1974-2010	Consumer survey	OECD (2011)
Consumer Expenditure	1963-2010	Household final consumption expenditure (national concept) (ABPB)	ONS (2010)
Depreciation Rate	1963-2010	Total real estate, renting & business activities (GRRD)	ONS (2010)
Disposable Income	1963-2010	Real household disposable income per head	ONS (2010) / IS.NHS (2011)
Employment	1963-2010	Employment (services) (JWT8)	Liesner (1989) / ONS (2010) / Feinstein (1972)
Floor-Space	1986-2010	Office (use classes order B1) stock estimates	Corporation of London (2011) / Ingleby Trice (2011) / ODPM (2006)
Foreign Funds	1964-2010	Foreign direct investment (net inflows) (BX.KLT.DINV.CD.WD)	World Bank (2011a) / ONS (2010)
FTSE All Share Index	1963-2010	FTSE All-Share Index value	LSE (2011) / Global Financial Data (2012) /Bond *et al.* (2001)/ London & Cambridge Economic Services (1973)
GDP	1963-2010	Gross Domestic Product (ABMI)	ONS (2010) / Maddison-Project (2008) / Liesner (1989) / Hicks and Allen (1999)
ONS Leading Indicator	1996-2010	Index of services (total) (D8ZW)	ONS (2010)
	1963-2010	Index of production (total) (CKYW)	

Variables	Availability	Name and code	Source
Inflation	1963-2010	The value of the pound (CZBH)	ONS (2010) / Twigger (1999) / O'Donoghue *et al.* (2004) / Hicks and Allen (1999)
Lagged Dependent Variable	1964-2010	IPD All Property Rental Value growth series	IPD (2011) / Scott (1996)
Money Supply	1963-2010	Money stock (M4 - end period) (ATTD)	ONS (2010) / Bank of England (2011) / Mitchell (1992)
	1969-2010	Money stock (M0 - end period) (ATTC)	
Number of Property Transactions	1963-2010	Number of property transactions -England and Wales (FTAP)	ONS (2010) / HM Revenue & Customs (2011)
Profitability	1965-2010	Rates of return of service sector (BGYK)	ONS (2010) / Liesner (1989) / Feinstein (1972)
Property Value	1963-2010	UK House Price Index	Nationwide (2011)
Retail Sales	1988-2010	Retail sales (all business index) (J3UU)	ONS (2010)
Risk Premium	1967-2009	Risk premium on lending (prime rate minus treasury bill rate, %)	World Bank (2011a)
Take-Up	1997-2010	Take-up floor-space in the city of London	ONS (2010) / Corporation of London (2011)
Turnover	2000-2010	Turnover and orders in production and services Industries - rental & leasing services (JT3M)	ONS (2010)
Unemployment	1963-2010	Unemployment (LF2Q)	ONS (2010) / Liesner (1989) / Hicks and Allen (1999)
Vacancy Rate	2001-2010	Vacancy rate	Corporation of London (2011) / ONS (2010)
Yields on Government Securities	1963-2010	2.5% Consolidated Stock Average Yield	UK Debt Management Office (2011)
	1963-2010	Par yield on long-dated British Government Securities (20 years - percent per annum) (AJLX)	ONS (2010) / Bank of England (2011)
Capital Formation	1963-2010	Gross fixed capital formation: business investment (NPEK)	ONS (2010) / World Bank (2011a)
Job Vacancies	1963-2010	UK Employee Jobs - total (thousands) (BCAJ)	ONS (2010)
Land Value	1963-2010	Index of land prices	Holmans (1995) / the Department for Communities and Local Government (2011)
Net Investment	1963-2010	Investment by insurance companies, pension funds and trusts: UK buildings, property, land & new construction work (RLKD)	ONS (2010)
Total Returns	1963-2010	IPD Total Returns	IPD (2011) / Scott (1996)

Table 4.1 Time-series employed to model commercial property rents

Bank Rate

The use of interest rates to model the commercial property market was argued by RICS (1994), Wheaton *et al.* (1997), Chaplin (1998), Orr and Jones (2003), Stevenson and McGarth (2003), and Qun and Hua (2009). According to researchers, interest rates do affect the commercial property, with higher interest rates depressing rental levels and *vice-versa*.

The 'Annual Average Rate of Discount, 3 Month Treasury Bills, Sterling' (IUAAAJNB) is selected for the research. The series was obtained from the Bank of England database. Whereas Bank of England's series is available only from 1976, it was extended by chain-linking with Liesner's (1989) 'Treasury bills ave.3months tender rate (%)' series. The latter is available from 1900 to 1988. The correlation analysis over the 1976-1988 period when both series overlap indicate almost perfect positive correlation with correlation coefficient being 0.999. From the statistical and visual analysis (Figure 4.5) it is seen that both datasets are almost identical. Accordingly, by chain-linking both series, the original Bank of England's series were extended for the period needed (Figure 4.6).

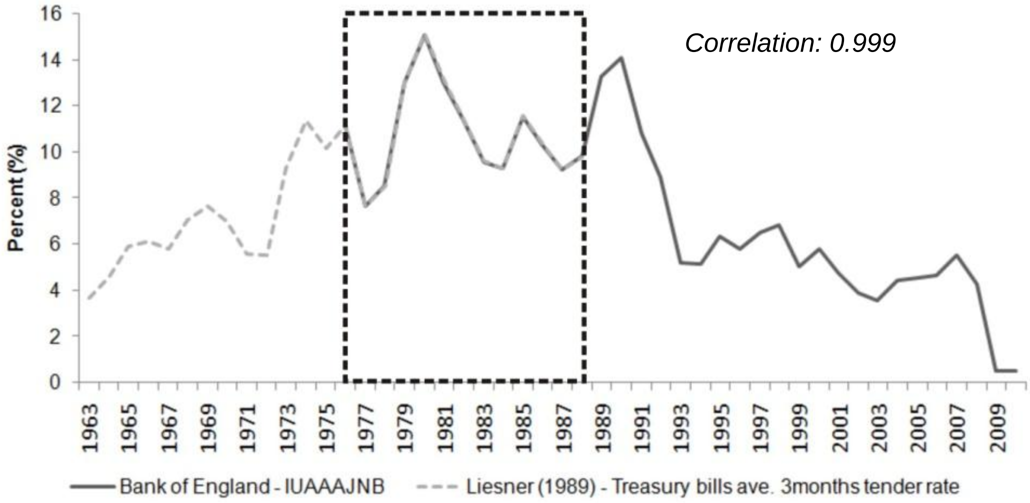

Figure 4.5 Liesner's and BOE's Annual Average Rate of Discount
Source: Liesner(1989); Bank of England (2011)

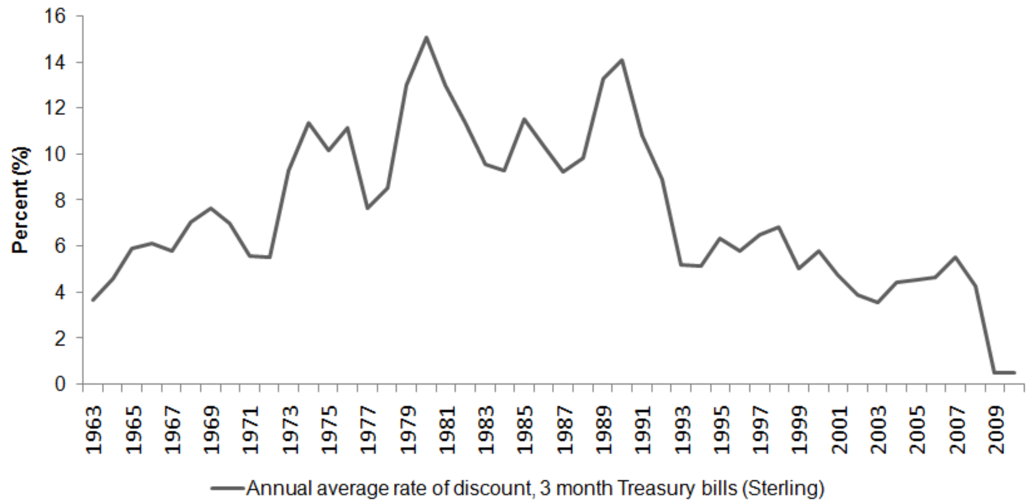

Figure 4.6 Chain-linked Annual Average Rate of Discount

Business Output

The use of business output as an explanatory variable was argued by Chaplin (1999). In his research Chaplin first referred to McGough and Tsolacos (1994, cited in Chaplin, 1999) paper where researchers employed change in Real Output of Business Services and change in Real Output of Financial and Business Services for their Vector Autoregressive (VAR) framework. McGough and Tsolacos' (ibid.) statistical modelling results suggested Business Output to be of particular importance to model the property market. Subsequently, Chaplin (ibid.) selected Output of the Financial and Business Service Sector as an explanatory variable to model the UK real office rents.

The EWAY series, which is one of GVA's Detailed Output Indices, is selected for the research. The full specification of this data-set is ESA95 Output Index: SIC92 Section J & K (excluding Div 79), which contains data on Financial Intermediation and Real Estate, Renting and Business Activities. The series is available from 1948 in yearly and quarterly figures from the ONS.

Car Registrations

The use of this data-set comes from Matysiak and Tsolacos (2003). The authors employed Car Registrations as a real economy variable. They estimated that Car Registrations is a leading indicator for the commercial property market.

The transport statistics series, i.e. 'Motor Vehicles Registered For the First Time' (thousands), is obtained from the Department for Transport (2011). The series is available from 1954 in annual figures.

Construction Orders

The use of Construction Orders as an explanatory variable was argued by Wheaton *et al.* (1997) and Matysiak and Tsolacos (2003). For the current research, Value of Construction New Orders by Contractors (by sector) (£ Million) is obtained from the ONS. The selected series is for 'Private Commercial', which excludes infrastructure and housing. The series is available from 1964 annually.

Construction Completions

The use of construction completions as an explanatory variable was argued within various studies. D'Arcy *et al.* (1999) employed New Office Completions in their econometric analysis of the office rental cycle in the Dublin area. Wheaton (1999) argued importance of Completion Rate in his analytical paper. Orr and Jones (2003) used Construction Completions to analyse and predict urban office rents. Hendershott *et al.* (2008) employed Completions for Office Space to model London office market. Qun and Hua (2009) also selected Office New Completions as a determinant of the office rents in China.

Although Construction Completions as an explanatory variable was used by numerous researchers, long-span historic data for this particular variable is not available. D'Arcy's *et al.* (1999) series went back to 1970. Wheaton's (1999) data was from 1968. Orr and Jones' (2003) series was from 1979. Hendershott's *et al.* (2008) data-set was only from 1987. Qun and Hua (2009) use data from 1998 only. It was therefore decided to use 'Volume of construction output in Great Britain' (index numbers) as a proxy for Construction Completions. This variable is available from the ONS starting from 1955 in annual and quarterly figures. The series is for 'other new work' which excludes infrastructure works and new house building. It is also for 'private commercial' which eliminates public and private industrial elements.

An alternative variable selected for the research is 'House building completions'. Certainly this particular series is for residential property and may not be applicable for the analysis of the commercial real estate market dynamics. Nevertheless, it is decided to employ this data-set as a representative variable of the UK construction activity. The 'House Building: Permanent Dwellings Completed' (nominal numbers) series is available from the Department for Communities and Local Government from 1949 annually. This data-set was also cross-referenced with Council of Mortgage Lenders' (1995) 'Building Completions for Great Britain' series. The correlation coefficient over 1955-1994 period when both series overlap is 0.993, which indicates that both series are highly compatible.

Construction Cost

The importance of Construction Costs for commercial property rents modelling was empirically proven by Wheaton *et al.* (1997) and Orr and Jones (2003). However, as with Construction Completions, Construction Costs long time-series is not publically available. One of the major construction costs data providers in the UK is Building Cost Information Service (BCIS) and the ONS. The ONS' data is available from 1997 only. In the case of BCIS, a special subscription is required.

An alternative to Construction Costs series is Holmans' (2005) Price Index of Construction Output. The researcher compiled long series for the general construction price level for 1861-2001 period. However, this

Holmans' series is for all construction only. It therefore can serve only as a proxy for Construction Costs series.

The visual and correlation analysis of Holmans' (2005) and ONS' series indicate close relationship between two series, despite the difference in their levels (Figure 4.7). As it is seen, both series follow the same trajectory. Correlation coefficient over the 1997-2001 period, when two series overlap, is 0.995. It thus suggests that both series can be successfully chain-linked together in order to produce a long-term Construction Costs Index. Figure 4.8 shows final chain-linked Construction Costs Index series.

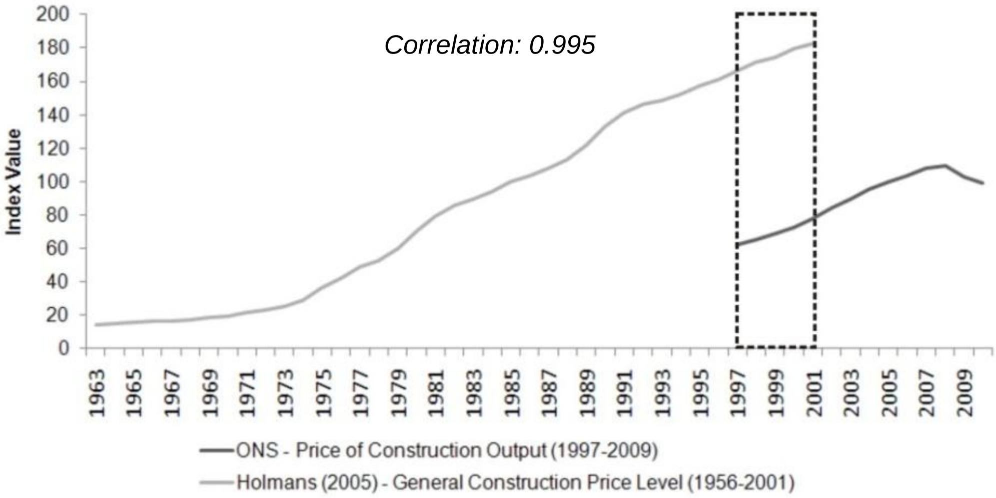

Figure 4.7 ONS' and Holmans' (2005) Construction Costs series
Source: Holmans (2005); ONS (2010)

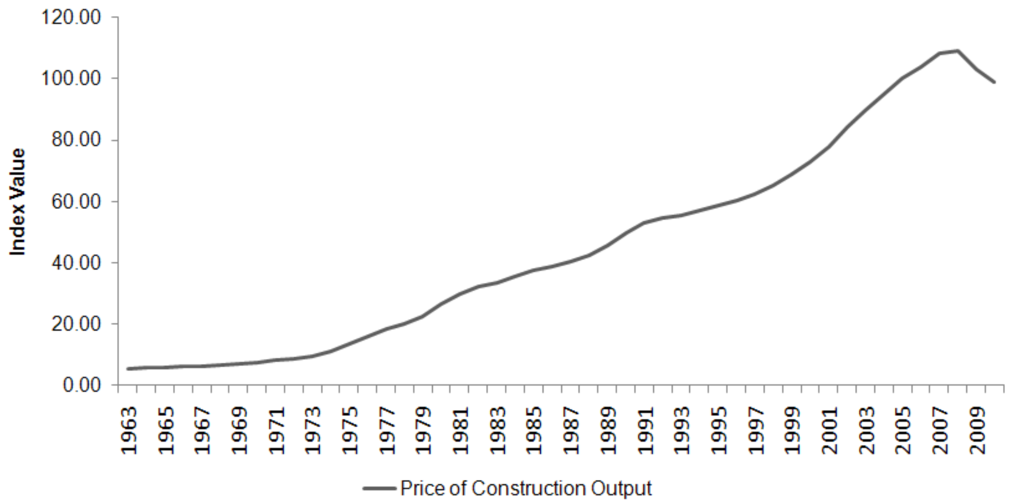

Figure 4.8 Chain-linked Construction Costs series
Source: Holmans (2005); ONS (2010)

Construction Starts

The importance of Construction Starts was noted by the RICS (1994) and Hendershott *et al.* (2008). However, as with Construction Costs and Completions, the data for this series is not available over the long period of time. The alternative here is to use chain-linked House-Building Starts series those of Council of Mortgage Lenders (1995) and the Department for Communities and Local Government as a proxy, whereas direct measure of commercial property Construction Starts is publically not available. The Council of Mortgage Lenders' (1995) data for House-Building Starts (Total - Private and Public) (Nominal Numbers) is for 1955-1994 period. The Department for Communities and Local Government's data is for 1990-2010 period. Visual and correlation analysis indicate that both series are highly compatible. Correlation coefficient is 0.999 which suggests almost perfect positive correlation. Figure 4.9 shows the primary series and a period where both series overlap. Figure 4.10 shows chain-linked Building Starts series for 1963-2010 period.

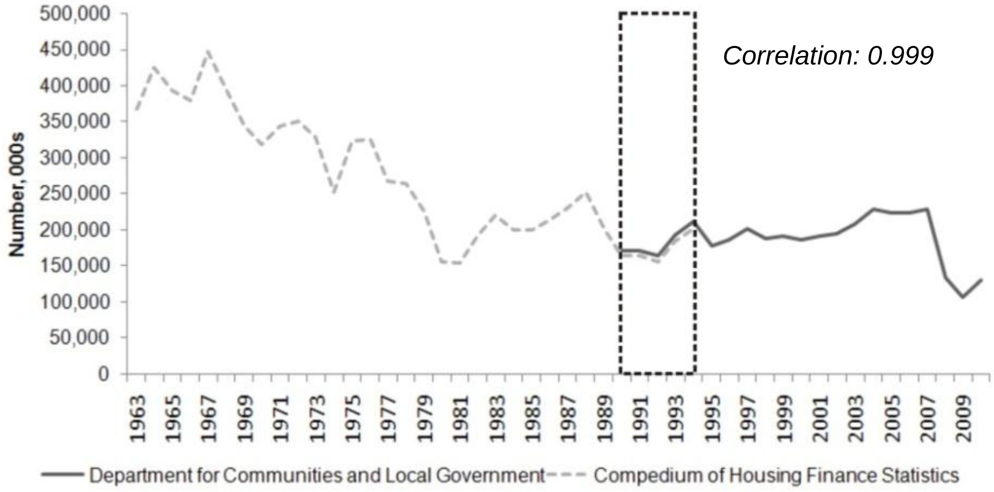

Figure 4.9 The CML's and DCLG's House Building Starts series
Source: The Council of Mortgage Lenders(1995); the Department for Communities and Local Government (2011)

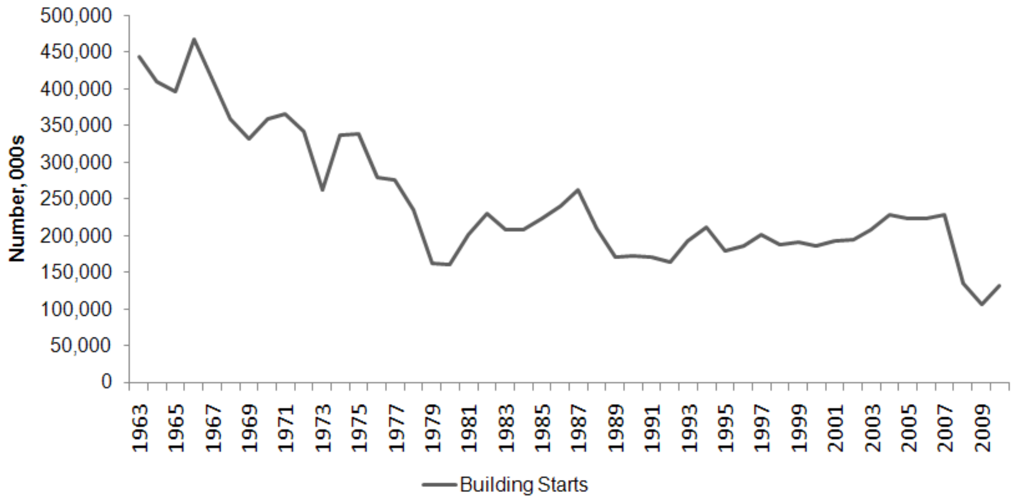

Figure 4.10 Chain-linked House Building Starts series
Source: The Council of Mortgage Lenders (1995); the Department for Communities and Local Government (2011)

Consumer Expenditure

The need to incorporate Consumer Expenditure into the property market modelling was argued by the RICS (1994), Tsolacos (1995), Hendershott (1996), Brooks and Tsolacos (2000), and Hendershott *et al.* (2002a; 2002b). The significance of this variable was particularly emphasised within retail property studies. ONS' database contains 'Household Final

Consumption Expenditure' (HFCE) series (£ thousand). It is available from 1948 in annual figures. Additional information about this variable is available from the OECD (2011) and the World Bank (2011a).

Depreciation Rate

Depreciation Rate or Consumption of Fixed Capital and its effect on the property market was discussed by Hendershott (1996), McDonald (2002) and Orr and Jones (2003). The time-series, which is selected for the current research, is Consumption of Fixed Capital for 'Total Real Estate, Renting & Business Activities' (GRRD) (£ million). The series is available from 1948 in annual figures from the ONS. It is considered that this particular dataset suits the current study better than general depreciation rate series for 'Consumption of Fixed Capital: All Fixed Assets: Whole Economy' (NQAE). The GRRD series is subject specific. What is more, tracks the dynamics of the property market better.

Disposable Income

The use of Disposable Income as an explanatory variable was suggested by Tsolacos (1995) and Brooks and Tsolacos (2000). According to the ONS, 'Real Household Disposable Income' is the amount of money people have available to spend after taxes and other deductions. In the UK, this indicator is often compared against GDP, what commonly indicates the state of the living standards. The ONS database contains Disposable Income index series which is available from 1948 annualy. The selected data-set was cross-referenced with that of the Health and Social Care Information Centre (2011). The correlation analysis indicated almost perfect positive correlation between two series (0.999).

Employment

The importance of employment has been argued by a number of researchers. Employment figures were used in various studies starting from an early publication of Hekman (1985) to those published more recently, e.g. Hendershott *et al.* (2008) and Qun and Hua (2009). In his research, Wheaton *et al.* (1997, p.78) identified employment as 'the primary instrument driving office space demand'.

It is important to note, however, that property researchers were not using employment figures *per-se*, but narrower and more specific measures of the employment, such as Service Sector Employment (D'Arcy *et al.*, 1999; Orr and Jones, 2003), Employment in Banking, Finance and Insurance (Chaplin, 1998; Stevenson and McGarth, 2003), or Financial and Business Services Employment (Hendershott *et al.*, 2002a; 2002b; 2008). It was considered that these specific series capture activity within the property sector better (Stevenson and McGarth, 2003).

The ONS produces Employment figures for the Total Service Sector Employment (JWT8), Financial & Insurance Activities (K) (JWS7) as well as Real Estate Activities (L) (JWS8). However, all three employment series are available from 1978 only. Alternative Employment data sources are those of Feinstein (1972) and Liesner (1989). Feinstein produced data for Total Employment as well as for Employment in Insurance, Banking and Finance. The former series is for 1855-1965 period, while the latter is for 1920-1965 period with a gap in series over the 1939-1947 period. Liesner produced Total and Service Sector Employment figures for 1890-1987 period with the same data gap as in Feinstein (ibid.). A correlation analysis of both Feinstein's and Liesner's total employment figures indicates a strong interdependence between the two series with the correlation coefficient being 0.997. Subsequently, Liesner's longer Service Sector Employment time-series are combined with that of ONS. The correlation analysis over the 1978-1988 period, when both series overlap, indicate almost perfect positive correlation (0.969). Figure 4.11 shows the primary series. Figure 4.12 presents the final chain-linked Service Sector Employment figures for period 1963-2010.

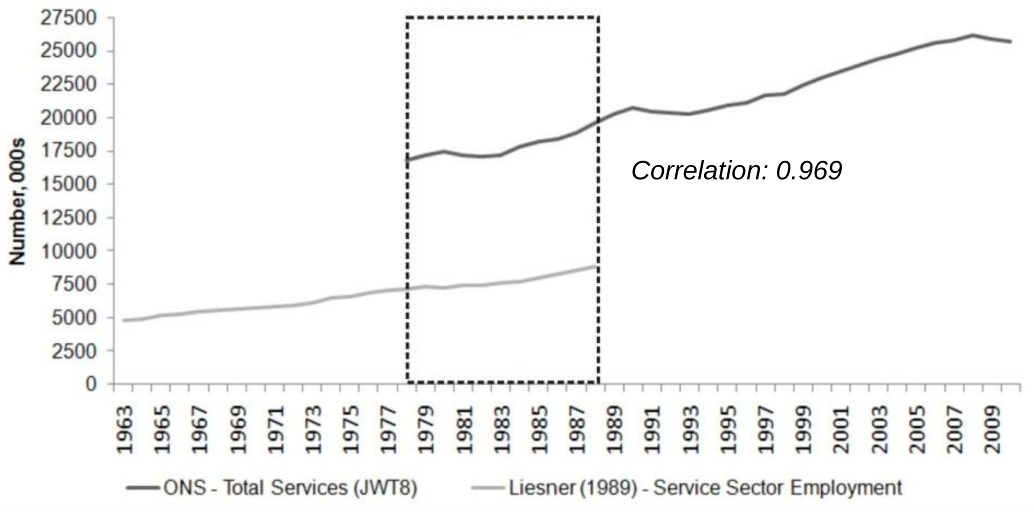

Figure 4.11 Liesner's (1989) and ONS' Service Sector Employment series
Source: Liesner (1989); ONS (2010)

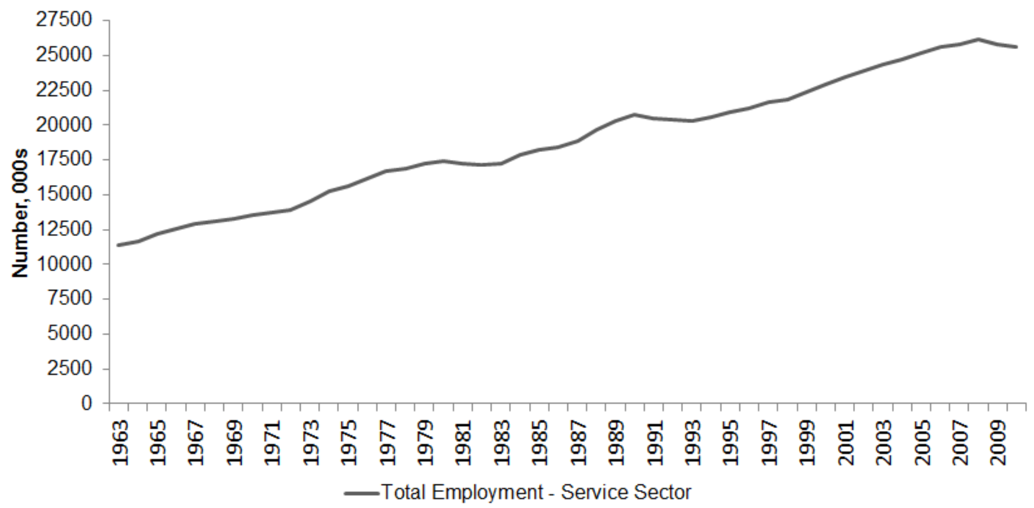

Figure 4.12 Chain-linked Total Service Sector Employment series
Source: Liesner (1989); ONS (2010)

Foreign Funds

In their empirical study, Qun and Hua (2009) identified that an increase in the use of Foreign Funds has a positive effect on the office rents in China. The authors identified that 'use of foreign funds' is a demand side variable which translates into office rents via its effect on the general economy and demand for office space. The high demand for office space comes from foreign companies establishing their presence in Mainland China.

In the UK a comparable variable is Foreign Direct Investment (FDI) series. The FDI for the UK is available from the ONS with 'Total Net Investment' (HJYU) (£ million) series starting from 1964. The ONS' series was also cross-referenced with that of the World Bank (BX.KLT.DINV.CD.WD). Correlation coefficient over the 1971-2008 period, when both series overlap, indicated almost perfect positive correlation (0.996). It therefore suggested high compatibility between two series with that of ONS thus being selected for the research.

FTSE All Share Index (FTAS)

The empirical evidences suggest that stock market data can be successfully used for commercial property market modelling. McGough and Tsolacos (1995a) included a share price index in their model to assess property cycles in the UK. Tsolacos (1995) used stock market data as an explanatory variable for industrial building investment. Chandrashekaran and Young (2000) employed S&P 500 index as a proxy for the rate of return on equities. Brooks and Tsolacos (2001) employed dividend yield data of the FTSE 100 for their comparative study. Karakozova (2004) selected stock market total returns as one of the explanatory variables to forecast office returns in the Helsinki area. Krystalogianni *et al.* (2004) used FTSE All-Share Index as a leading indicator to forecast UK commercial property cycle phases. According to McGough and Tsolacos (1995a, p.48), 'share price movements reflect the investors' expectations as well as conveying information about future economic conditions' which subsequently translate into the property market. Although, as Tsolacos (1995) noted, stock market price information can be misleading due to its medium-term volatility.

For the current research, however, the FTSE All-Share Index (FTAS) rather than FTSE 100 Index is selected. There are few major reasons why this particular index is chosen. First, FTAS is considered as the best performance measure of the London equity market since 1962 (FTSE, 2010). The Index represents 98-99 percent of UK market capitalisation with the vast majority of UK-focused money, an increase from 93.9 percent in 2002 as indicated in Brealey (2002). What is more, this index is preferred over the FTSE 100 index, because FTSE 100 index comprises only the 100 most highly capitalised companies listed on the London Stock Exchange. FTSE 100 index represents approximately 81% of the UK market, far less than FTAS. It is also suggested that most of the companies from FTSE 100 derive a large part of their earnings from overseas investment activities rather than UK (MacGorian and Thompson, 2002; Hussain, 2010). It is therefore considered that FTSE All-Share Index represents sentiments of the UK business environment better.

Data on the FTSE All-Share Index was obtained from the Global Financial Data (GDF) (2012) and London Stock Exchange (2011). The series were then cross-referenced with those of Liesner (1989), the London and Cambridge Economic Service (1973), and Bond *et al.* (2001). An initial data analysis (visual inspection and correlation analysis) suggests that both Barclays Equity Price Index and FTSE All-Share Index are identical, i.e. the correlation coefficient over the 1963-2000 period when both series overlap equals 1. What is more, both series have a positive perfect correlation with GDF's data. Correlation coefficient is 1 over the same period. In addition to that, the correlation estimates suggest perfect positive correlation between GDF and Bond *et al.* (2001), i.e. correlation coefficient equals 1 for 1899-2000 period when both series overlap. These findings therefore allow concluding that historic series those of Bond *et al.* (2001) and GDF are reasonable representations of FTAS index. Whereas GDF data goes back farther than that of Bond *et al.* (2001) and with both series being perfectly correlated, GDF's series is subsequently used to extend FTAS series. Figure 4.13 and Figure 4.14 present the original and chain-linked FTSE All Share Index Growth series.

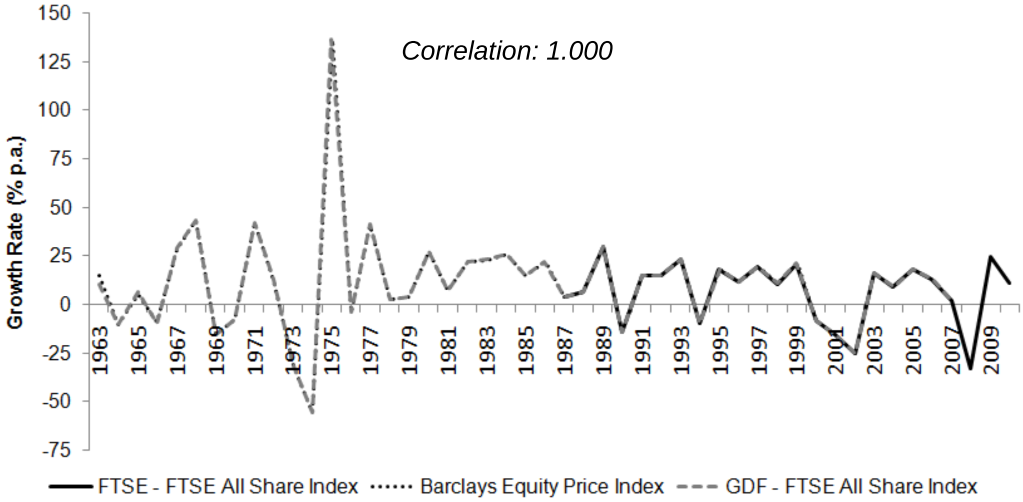

Figure 4.13 FTSE All Share Index Growth series
Source: Bond *et al.* (2001); GDF (2010); LSE (2011)

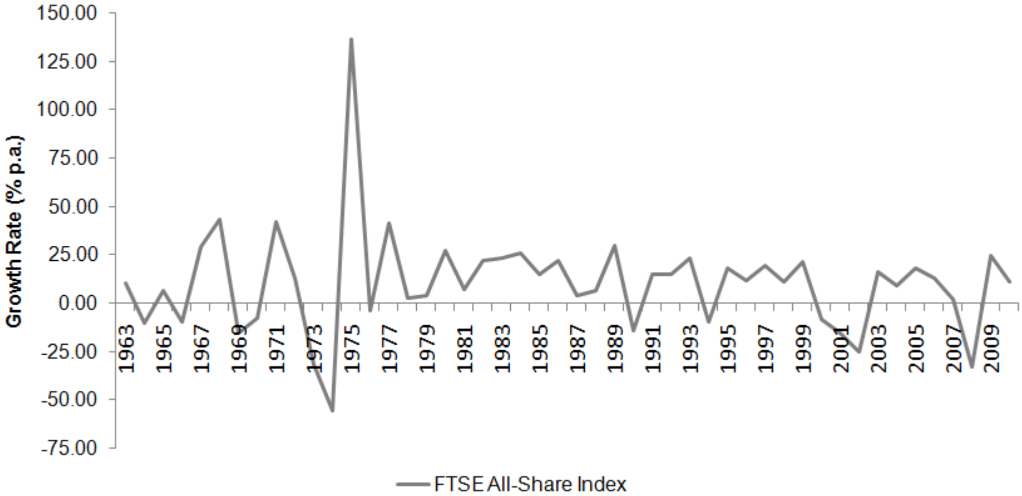

Figure 4.14 Chain-linked FTSE All Share Index Growth series
Source: Bond *et al.* (2001); GDF (2010); LSE (2011)

GDP

Gross Domestic Product was used in the number of studies, including Tsolacos (1995), Chaplin (1998), and Stevenson and McGarth(2003), as a measure of economic activity. As Stevenson and McGarth (2003) noted, GDP embodies economic growth in the whole economy which has a direct effect on the property market.

The GDP growth series is obtained from the ONS (2010), which is available from 1948 annually (ABMI).The series was also cross-referenced with Liesner (1989) and the University of Groningen (Maddison-Project) data-sets. The correlation analysis was performed for 1961-1987 period where all three datasets overlap. The statistics indicated almost perfect positive correlation between ONS's and Maddison's series (0.999). Liesner's GDP figures were least correlated with those of the ONS (0.821).

ONS leading indicators

The Central Statistics Office (CSO) (now ONS) Leading Indicators (both Longer and Shorter) were used by Stevenson and McGarth (2003) to model the London office market. According to the authors, these two series contain a set of independent variables, which capture the dynamics of the UK business and economic conditions.

The difficulty with both series, however, is that they are no longer available. What ONS produces now is a set of Economic Indicators, which fall into five major categories, including 'Prices and Inflation', 'Labour Market', 'National Accounts Economic Activity', 'Balance of Payments and Trade', and 'Short Term Indicators'. The latter group of variables comprises Retail Sales, Index of Production, Labour Productivity, and Index of Services.

Retail Sales Index contains average sales of British retailers. However, the index is available from 1989 only. Index of Production goes back as far as 1948. However, it comprises output of production industries including, mining & quarrying, manufacturing, electricity, gas & water supply, food, drink & tobacco, machinery & equipment, and other manufacturing industries. This information is be useful in assessing the trajectory of the general economy. However, its usefulness for the property market analysis is questionable. Index of Labour Productivity, i.e. 'Output per Filled Job (Whole Economy)' (LNNP) is available from 1961. More specific 'Output per Filled Job (Services)' (GG5J) indicator, which suits the current research better, unfortunately is available from 1979 only. Finally, Index of Services, i.e. 'Total Services' (D8ZW), or more specific 'J&K Business

Services and Finance' (D92P), which shows movements in Gross Value Added for the service industries is available from 1996 only.

Inflation

Property, as equities (ordinary shares), represent ownership of tangible assets. It means that both investment types are performing well during inflationary times (Baum and Crosby, 2008). Various studies (Limmack and Ward, 1988; Matysiak *et al.*, 1996; Miles, 1996; Tarbert, 1996; Barber *et al.*, 1997; Bond and Seiler, 1998; Hoesli *et al.*, 2008) investigated this issue with most of them providing evidence that property could be a hedge against inflation. If to follow Collin (2007, pp.112) it implies that property investment 'will rise in value faster than the increase in the rate of inflation'. As Collin (ibid., p.112) also noted (author has borrowed this quotation from Investors Chronicle) 'during the 1970s commercial property was regarded by investors as an alternative to equities, with many of the same inflation-hedge qualities'. The same is argued by Baum and Crosby (2008). The authors identified that the period from 1950s to 1990s, when significant inflation was witnessed in the UK, it was a major cause of a rise in property prices. Accordingly, Inflation, or Retail Price Index (RPI), was used as one of the explanatory variables in property rent modelling studies, including Chaplin (1998), Chandrashekaran and Young (2000), and Stevenson and McGarth (2003).

Data on RPI is obtained from the ONS (CZBH). The series is available from 1949 to-date in annual figures. To check the significance of the selected series, it was cross-referenced with that of Twigger (1999) and O'Donoghue *et al.* (2004). The correlation coefficient between ONS and O'Donoghue *et al.* (ibid.) over the 1949-1998 period is 1, and between ONS and Twigger (1999) is 0.992. It indicates that both ONS and O'Donoghue *et al.* (ibid.) series are identical. It thus suggests that ONS' data is reliable.

Lagged Dependent Variable

Studies, including Chaplin (1998; 1999; 2000) and White *et al.* (2000), just to name a few, suggested that past values of the dependent variable may contain useful information which could be utilised in predicting its future behaviour. Accordingly, lagged values of UK All Property Rent series are employed in the current research.

Money Supply

In their paper, Matysiak and Tsolacos (2003) identified Broad Money Supply (M4) and Narrow Money Supply (M0) as prospective financial leading indicators to forecast property market rents. The cycles of these two indicators were expected to positively affect rental series.

For the current research, both money supply series are obtained from the ONS. Money Stock M4 (ATTD) (£ billion) is available from 1963 annually. However, Money Stock M0 (ATTC) (£ billion) is available from 1969 only. Accordingly, M0 series were chain-linked with Mitchell's (1992) 'Banknote Circulation' series. The visual inspection (Figure 4.15) and statistical analysis (correlation coefficient over the 1969-1988 period is 0.996) indicate that ONS' data is highly correlated with that of Mitchell (ibid.).

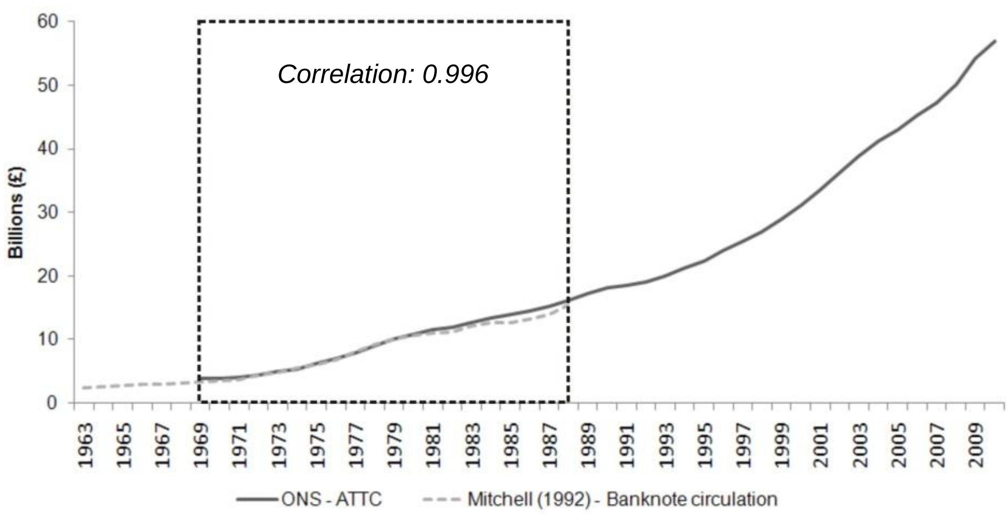

Figure 4.15 ONS' and Mitchell' (1992) Narrow Money Supply (M0) series
Source: Mitchell (1992); ONS (2010)

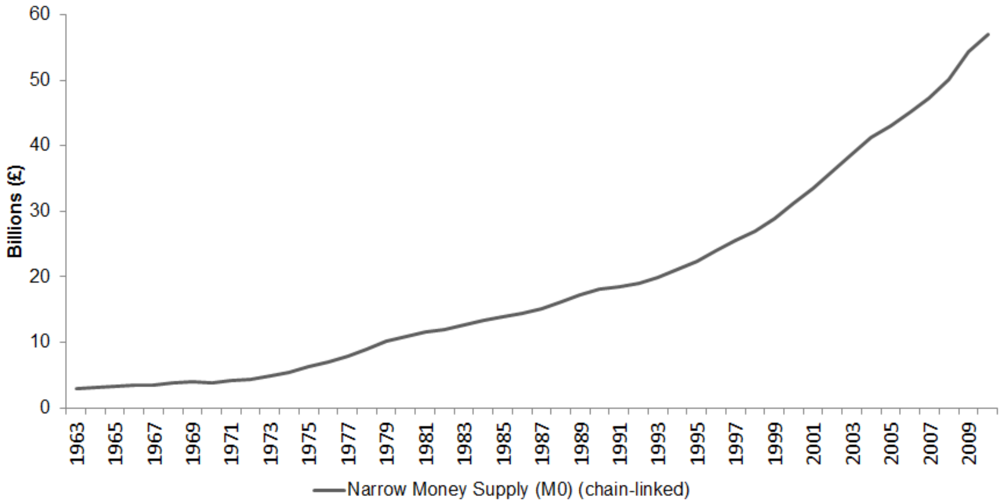

Figure 4.16 Chain-linked Narrow Money Supply (M0) series
Source: Mitchell (1992); ONS (2010)

Number of Property Transactions

According to Stevenson and McGarth (2003), the Property Transactions variable is positively correlated with the market sentiment. As the authors observed, the growing market sentiment turns property transactions upwards, while decreasing market sentiments turns property transactions downward.

The difficulty with this variable, however, is its availability. The publically available series for ‘Number of Property Transactions’ (thousands), those from the ONS and HMRC, are available for England and Wales from 1959 and for England, Wales and Northern Ireland from 1978 only. Long-term series, however, are not available for the whole of the UK. What is more, both series are for all (both residential and non-residential) property market. Neither ONS, nor HMRC produce separate long term commercial and residential transaction series.

Nevertheless, it is decided to select ‘Number of Property Transactions for England and Wales’ series as a proxy variable. The complete series for 1963-2010 period was compiled from ONS’s FTPA series for 1963-2005 period and HMRC’s ‘UK Monthly, Quarterly and Annual Property Transactions Count’ for 2006-2010 period (Figure 7.17 and Figure 7.18).

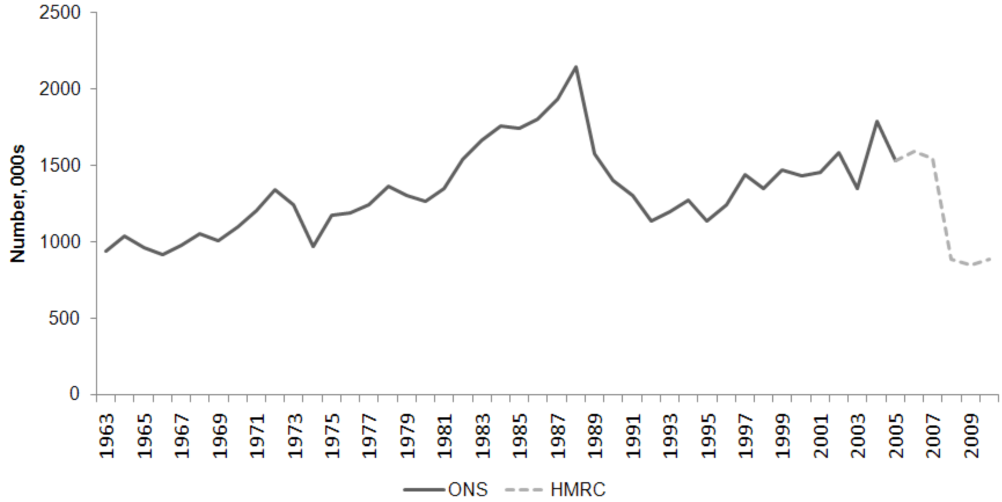

Figure 4.17 ONS' and HMRCs Number of Property Transactions series
Source: ONS (2010); HMRC (2011)

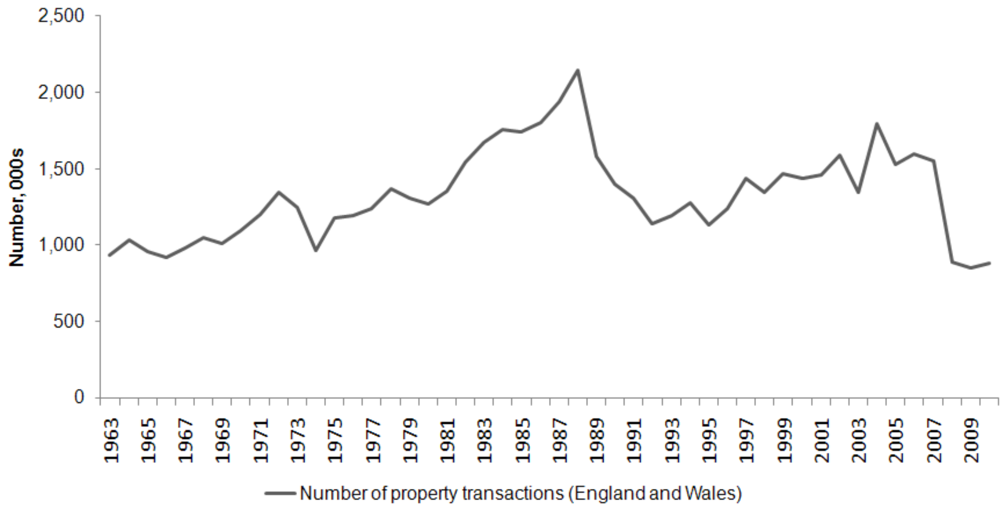

Figure 4.18 Chain-linked Number of Property Transactions series
Source: ONS (2010); HMRC (2011)

Profitability

According to Stevenson and McGarth (2003), Profitability, or Profits of the UK Companies, is a useful indicator which captures demand side effects of the commercial property market. Chaplin (1998) earlier identified it as one of the major explanatory variables to model office rents. Profitability measures were particularly used within retail property research. As RICS (1994) and Tsolacos (1995) suggested, retail profits can be used as an alternative measure for the demand for retail space.

The statistics of the Rate of Return of UK companies is available from the ONS. In its statistical bulletin ONS supplies figures for Manufacturing companies' Net Rate of Return, Service Sector companies' Net Rate of Return, the Net Rate of Return of companies other than United Kingdom Continental Shelf (UKCS), and the Net Rate of Return of United Kingdom Continental Shelf (UKCS) companies. The Service Sector data, which is the most applicable for the current research, however is available from 1989 only. A compatible longer data-set is the Annual Rate of Return of Private Non-Financial Corporations (PNFC) (percent), which is available from 1965 annually. According to the ONS, this series represents Gross trading profits of PNFC from United Kingdom operations plus rentals received less inventory holding gains. PNFC comprises UK Continental Shelf, manufacturing, non-financial service sector and other companies, including construction, electricity and gas supply, agriculture, mining and quarrying. Although this series is not property market specific, it nevertheless contains relevant statistical properties.

Property Values

In his empirical study Chaplin (1998) identified House Prices as one of the major explanatory variables to model the property market. For the UK, there are a number of house price information providers, including commercial companies such as Nationwide (2011) and Halifax (Lloyds Banking Group, 2012), as well as public organisations such as the ONS (2010), Communities and Local Government (2011), the Office of the Deputy Prime Minister (ODPM) (2006), and the Land Registry (2012). As Thwaites and Wood (2003) observed, the list of house price information providers increased with the housing web sites Hometrack (2012) and Rightmove (2012) introducing their Housing Indices. In addition to that, the RICS (2011) and the House Builders Federation (2011) also monitor the housing market.

However, as the comparative analysis suggests, different sources provide information in different formats and of different duration. ONS supplies

‘Average Property Prices’ (£ thousand) which are available from 1982. Communities and Local Government provides ‘Average Dwelling Prices’ (£ thousand) from 1970. Halifax (now part of Lloyds Banking Group) produces House Price Index for the whole country going back to 1983. Nationwide Building Society’s database contains housing data for the UK since 1952 both in nominal (£ values) and index numbers.

Regardless of the number and availability of house price indices, the study uses Nationwide’s House Price Index. First, it spans over the whole research period. Second, empirical evidences those of Thwaites and Wood (2003) suggest that this index tracks the typical house prices more closely than other indices. The index is volume-weighted, which means it is less sensitive to price movements in certain region. It uses a definition of a typical house that changes periodically, usually each year, to reflect for changing market conditions.

Unemployment

The local Unemployment rate was used by Hekman (1985) to model office rental values. Hekman’s two-stage investment model identified Unemployment as one of exogenous demand for property measures. Hekman’s regression analysis established Unemployment as significant (although negatively related) variable.

The Total Unemployment series for the UK is available from the ONS (LF2Q). However, this particular data-set is available from 1971 only. An alternative unemployment series are available from Liesner (1989) and Hicks and Allen (1999). The visual and statistical analysis indicate that both ONS’ and Liesner’s series are highly compatible. The correlation coefficient over the 1971-1987 period when both series overlap is 0.997, which indicates almost perfect positive correlation. Accordingly, both series were chain linked, which enabled to extend ONS’ series over several decades. Figure 4.19 indicates dynamics of both series. Figure 4.20 shows final chain-linked UK Unemployment series.

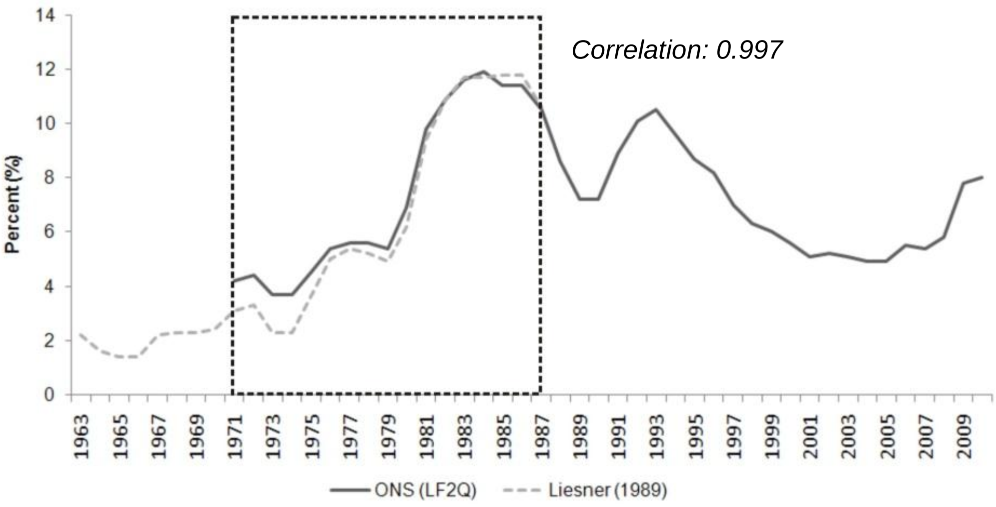

Figure 4.19 ONS' and Liesner's (1989) UK Unemployment series
Source: Liesner (1989); ONS (2010)

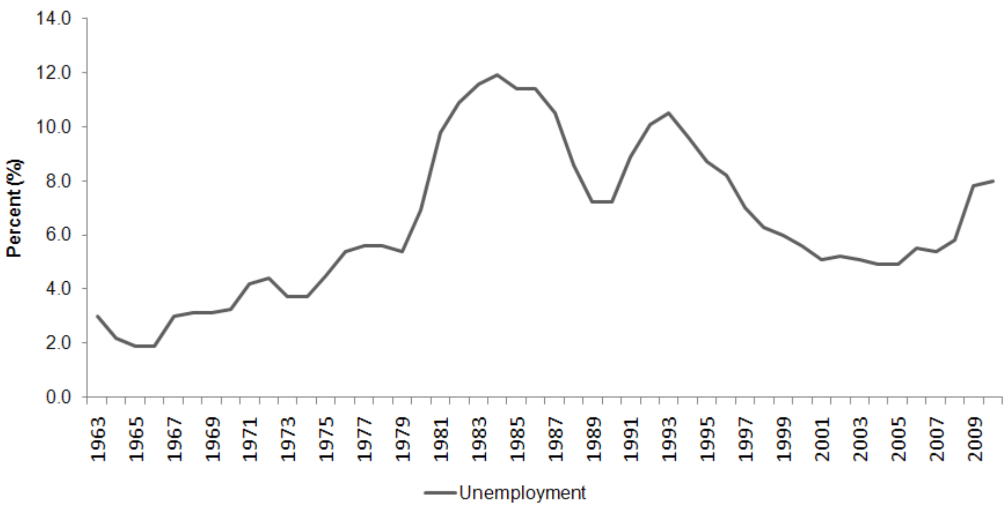

Figure 4.20 Chain-linked UK Unemployment series
Source: Liesner (1989); ONS (2010)

Yields on Government Securities

The performance of UK Government Debt Obligations was acknowledged by Hendershott (1996), Hendershott *et al.* (2002b), and Matysiak and Tsolacos (2003). According to Matysiak and Tsolacos (2003), both the Treasury Bill Rate and the Gilt Yields can be successfully employed to capture anticipated rental movements. The researchers suggested to use these variables as leading indicators for short-term commercial real estate market forecasting.

Two series are collected for the research. One is 2.5% Consolidated Stock Average Yield. The second is Par yield on long-dated British Government Securities (BGS) (20 years). The first series is obtained from the UK Debt Management Office (2011) which is available from 1900 annually. The 20-year British Government Securities (BGS) yield series is obtained from the Bank of England (2011) and the ONS (2010). ONS's series (AJLX) is available for period 1963-2007. The Bank of England (IUMALNZC) produces series for the 1993-2010 period. Visual and statistical analysis (correlation coefficient over the period 1993-2007 is 0.998) indicate that the series are highly compatible and can be linked together (Figure 4.21). The extended BGS (20 years) series are presented in Figure 4.22.

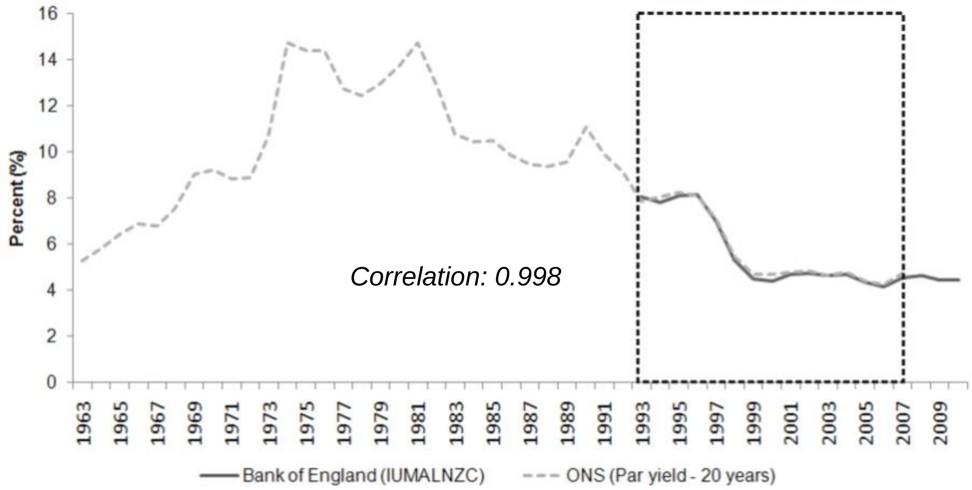

Figure 4.21 ONS' and BOE's 20-year BGS yield series
Source: ONS (2010); Bank of England (2011)

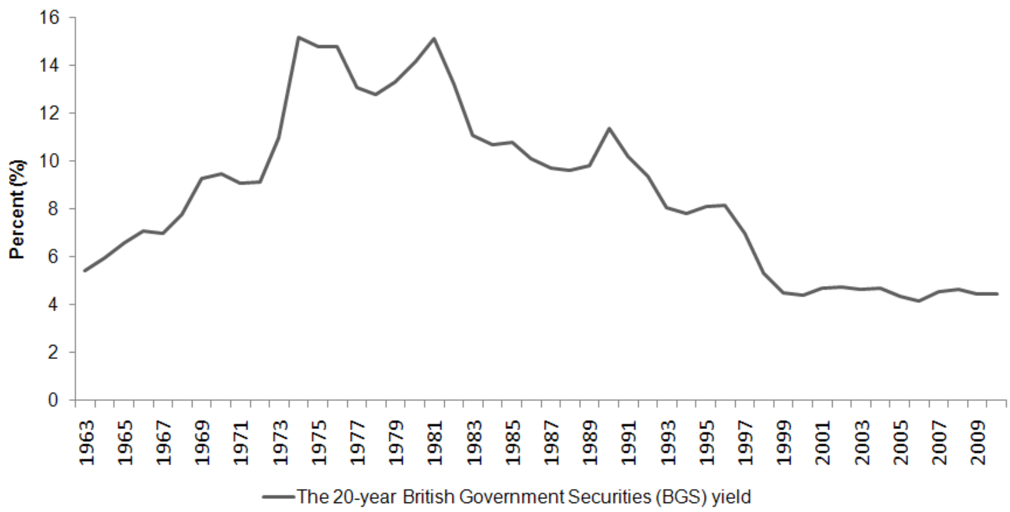

Figure 4.22 Chain-linked 20-year BGS yield series
Source: ONS (2010); Bank of England (2011)

Capital Formation

Capital Formation (CF), as Friedman (2000) defines is a creation (expansion) of capital (buildings, machinery, equipment) through savings that produces other goods and services. According to the World Bank (2010a), it consists of 'outlays on additions to the fixed assets of the economy plus net changes in the level of inventories', where fixed assets consist of land improvements, equipment purchases as well as construction. In general terms, Capital Formation is a component of GDP. This macroeconomic concept is therefore considered to be more useful for property market analysis than broader GDP, whereas it measures (in general terms) the level of investment in the economy, and therefore tracks the dynamics of the property market better.

As Statistics Canada (2008) identifies, capital formation is one of the key variables in any macroeconomic system. What is more, capital formation tends to be cyclical. When economy is growing, businesses expand and thus increase their capacity by building new plants, acquiring new equipment or occupying new space to meet growing demand. However, before new capital can be injected, there is a construction, planning or relocation time lag. Depending on the nature of the business, this lag can vary from a few months to years. This cascading lag, as Statistics Canada suggests, is thus the major element of the cyclical nature of investment, which in turn is a major determinant of the cyclical nature of the whole economy.

The ONS' data-base contains various series for the Gross Fixed Capital Formation (GFCF). The most applicable for the current research are YGPB series, which is for Real Estate, renting and business (£ billion), and YGNG series, which is for financial intermediation. Unfortunately, neither of series is available for a long time-period. YGPB is available from 1989 only. YGNG is available from 1986 only. As such, a more general series is selected for the current research. The ONS structures GFCF series by sector and by asset. Sector-wise GFCF is divided into business investment, general government, dwellings and transfer costs of non-produced assets. Asset-wise GFCF is for transport equipment, other machinery and equipment, dwellings, other building and structures and intangible fixed assets.

Business Investment (NPEK) sector specific GFCF series is considered to be the most applicable for the current research. It represents an element of Total Business Investment within GFCF and is the longest series available, starting from 1965. Its statistical analysis with three GFCF series (NE.GDI.FTOT.ZS; NE.GDI.FTOT.KN; NE.GDI.FTOT.CN) produced by the World Bank (2011a) indicates almost perfect positive correlation with correlation coefficient between NPEK and NE.GDI.FTOT.KN series being 0.992. Accordingly, NPEK series were extended for several years by chain-linking it with World Bank's NE.GDI.FTOT.KN series which is available from 1960 (Figure 4.23 and Figure 4.24).

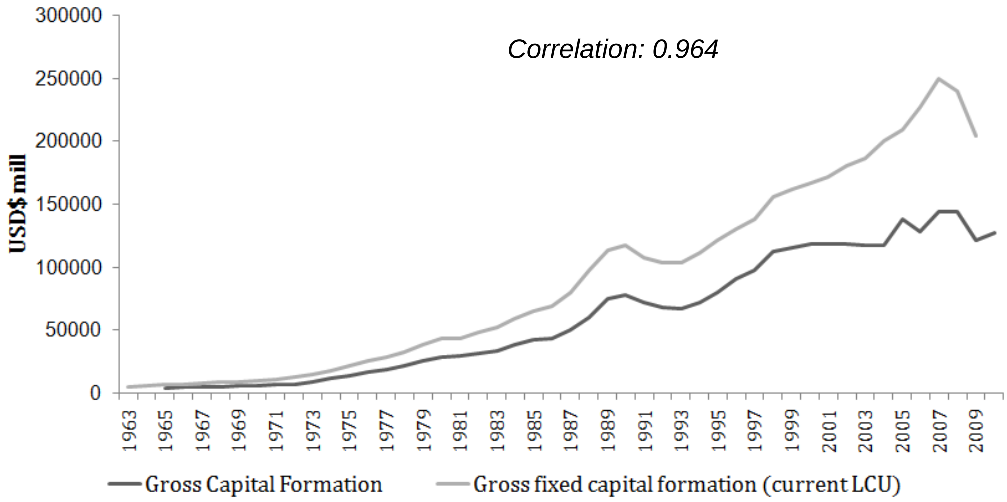

Figure 4.23 ONS' and World Bank Capital Formation series
Source: ONS (2010); World Bank (2011a)

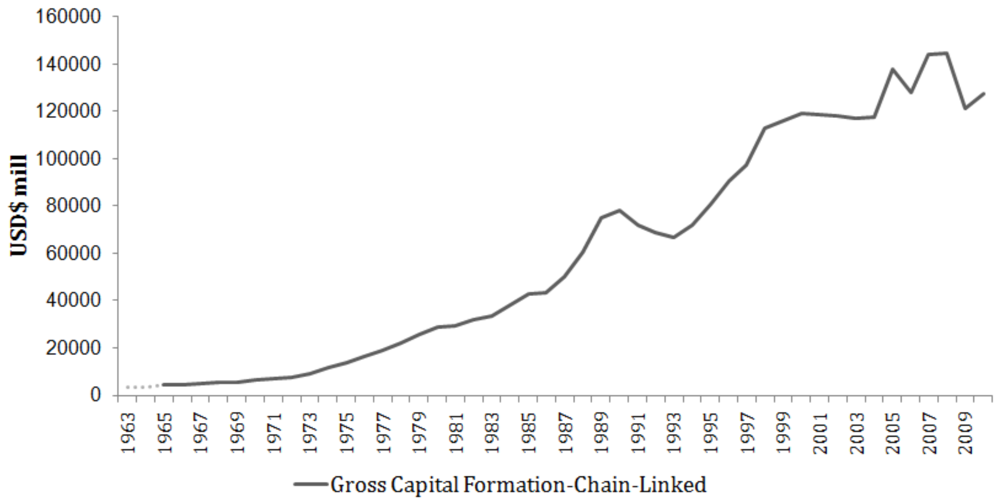

Figure 4.24 Chain-linked Capital Formation series
Source: ONS (2010); World Bank (2011a)

Job Vacancies

The Job Vacancies or more specific 'Number of Employee Workforce' (BCAJ) (thousand) series represents available vacancies in the country. In contrast to Employment and Unemployment, the BCAJ series indicates potential employment opportunities. It implies the possible future employment for unemployed population or for those willing to change their current employment. It also indicates the level of employment businesses are willing to provide. As a result, the growing number of vacancies implies a growing demand for new employees, which as a result translates into a greater demand for space. The longest series is that of ‘All Industries’ (BCAJ), which is available from 1959.

Land Value

The importance of land value was argued by the number of researchers (Fraser, 1984; Capozza and Helsley, 1989; Stone and Ziemba, 1993, Ball *et al.*, 1998). Fraser (1984) regarded land and its fixtures as a single element which constitutes the concept of real estate. Ball *et al.* (1998, p.58) argued that ‘the land market had a key role in determining the equilibrium quantities of commercial property supplied and demanded’. Same as Fraser (ibid.), Ball *et al.* (ibid.) regarded land as a factor input for the production process (economic activity of firms) to commence. What is more, land was identified as being inelastic. According to Ball *et al.*, land market is not fully competitive, whereas each site is unique in terms of its location. Moreover, the number of sites suitable for commercial activity in general is restricted.

Despite the obvious significance of the land for the commercial property market, land variable has not been largely employed to model commercial property rents. Hendershott (1996, p.65) used Land Price series as an indicator ‘of a speculative bubble’ in the Sydney Office market. However, this variable was more of an indicative nature. As the author noted, value of land can generate miss-measurements in replacement-cost ratio. Therefore, in his valuation model, Hendershott did not use Land Value series separately, but incorporated it into the total value of the property. Wheaton *et al.* (1997) estimated that land accounts for around two-thirds of commercial property value in London. However, as the authors noted, ‘little reliable data is available on land prices’ (ibid., p.84).

The Land Value series for the UK are obtained from Holmans (2005) and the Department for Communities and Local Government (2011). Holmans (ibid.) in his publication produced an index of land prices at current and constant prices for the UK for 1963-2002 period. The Department for Communities and Local Government database contains table for ‘Average

Valuations of Residential Building Land With Outline Planning Permission' (table 563) for 1994-2010 period. The correlation analysis over 1994-2002 period when two series overlap indicates almost perfect positive correlation between both Holmans' and Communities' data-sets. Correlation coefficients between Holmans (current prices) and Communities series, and Holmans (constant prices) and Communities are 0.994 and 0.986 respectively. To make series comparable, Communities' nominal land values were converted into index numbers with 1994 being a base rate. Correlation coefficients between all series remained unchanged (Figure 4.25). Accordingly, both series were chain-linked together. Final series is presented in Figure 4.26.

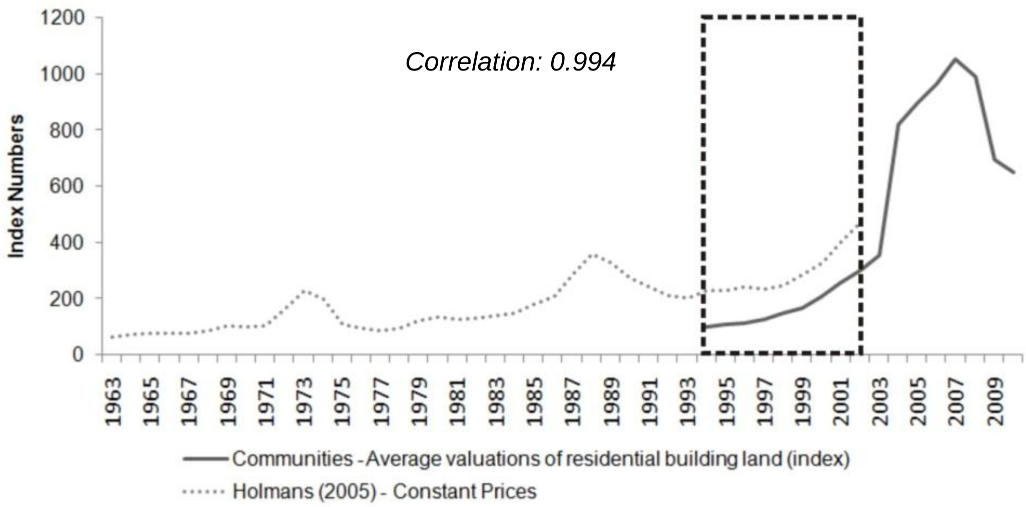

Figure 4.25 Holmans' and Communities' UK Land Value Index series
Source: Holmans (2005); Communities (2011)

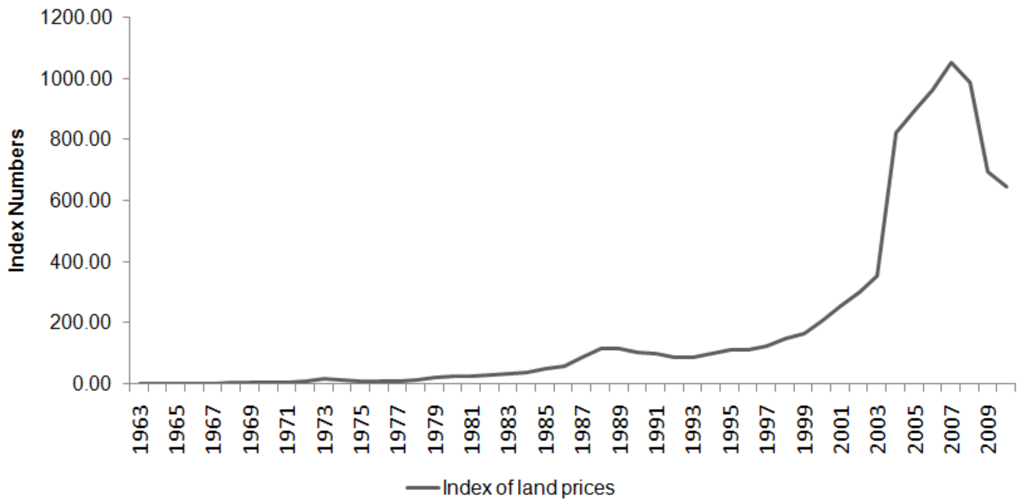

Figure 4.26 Chain-linked UK Land Value Index series
Source: Holmans (2005); Communities (2011)

Net Investment

Net Investment by Insurance Companies, Pension Funds and Trusts (MQ5) series contains important information on the activities of these financial entities. Being an important component of UK's GDP, this series is also of great significance in assessing how key investor groups are investing their funds. It provides information on whether they are buying or selling shares, fixed-income securities, or they are moving into longer-term assets. The value of their holdings at the end of the year is subsequently recorded in the annual ONS' balance sheet survey.

The significance of this variable can also be argued by emphasising the importance of the financial service sector to the UK economy and the property market. Lizieri (2009a) argued that concentration of the financial activity within the City of London leads to the concentration of specialist labour which in turn triggers financial and business service sector employment, which consequently has significant property market implications. His estimates suggest that the City of London financial and business service employment increased by 41 percent over the 1971-2006 period. This significant increase had important ramifications for the City of London office market, as well as for the UK economy as a whole. Earlier hypotheses by Fraser (1984) suggested that changing demand for banking and insurance activities, which are dominant industries within the City of London, explains the changing demand for commercial property.

Haldane's *et al.* (2010) publication stressed the significance of the Financial Sector (FS) to the UK economy. The statistics authors provided indicates that 'growth in financial sector value added has been more than double that of the economy as a whole since 1850' (ibid., p.4). These findings corroborated Turner's *et al.* (2010) observation, that over the previous 20 to 30 years, the financial service sector grew much faster than the general economy. According to Haldane *et al.* (ibid.), the financial intermediation, measured by its real value added, has more than trebled over the 1980-2008 period, while the output of the whole economy doubled over the same period. Their calculations indicated that in 2007 financial intermediation accounted for around 8 percent of the total GVA. Profits gained from this activity (of the whole economy) increased to 15 percent by 2008 from 1.5 percent over 1948-1978 period. Haldane *et al.* (ibid.) therefore suggested that FS industry 'has undergone, at least arithmetically, a 'productivity miracle' over the past few decades' (ibid., p.3).

In their report, PWC (2010) estimated, that FS as a whole made Total Tax Contributions of £53.4 billion for 2010, which is 11.2 percent of total government tax receipts from all taxes for the same year. This led PWC to suggest that FS is 'a major contributor to UK public finance', greater than the oil and gas industry (ibid., p.3). What is more, FS was identified as a major employer in the UK with over a million employees working in the sector, which is around 3.5 percent of the total UK workforce. PWC' employment figures match those of the Financial Services Skills Council (FSSC) (2010). In their report FSSC estimated that there are more than 34,000 FS companies operating in the UK and employing around a million individuals. FSSC also estimated that the insurance sector contribution (net) to UK balance of payments is around £10 billion.

Europe Economics' (2011) report also indicates the great role FS plays for the major European Financial Centres and European Union as a whole. As the report identifies, 17 percent of all global equity trading and 11 percent of global funds management take place in London. It therefore suggests that 'financial services are of enormous social value' for the EU (ibid., 77).

In addition to that, the research published by the Oxford Economics (2011) for the City of London Corporation suggests that in 2009-2010 London financial services contributed £1.4 billion in taxes, which is around 21 percent of the UK's total GVA. The report also expects this contribution to the UK's fiscal position to rise in the forthcoming years.

Seeing the role Financial Services play within the UK economy and its subsequent implications to the property market, it can thus be suggested that introduction of variable, which reflects the dynamics of FS, is of benefit for the current research. The variable considered is 'Investment by insurance companies, pension funds and trusts - UK buildings, property, land & new construction work (RLKD)' (£ million). This particular variable represents a volume of investment by financial institutions into building, property, land and new construction. The series is available for the whole research period annually.

Total Returns

Property Total Returns, as noted, was used by various property researchers as a measure of the dynamics of the property market. However, neither Total Returns were used to model property rents, nor rents were used to model Total Returns. Therefore, the research assesses whether Total Returns has any statistical connections with rents. The Total Returns series comes from IPD data-base and Scott's (1996) statistical tables. Both series were already successfully combined by RICS (1999). As statistical (correlation coefficient is 0.999 for 1971-1993 period) and visual analyses (Figure 4.27) indicate, the two series are highly compatible. Final series are presented in Figure 4.28.

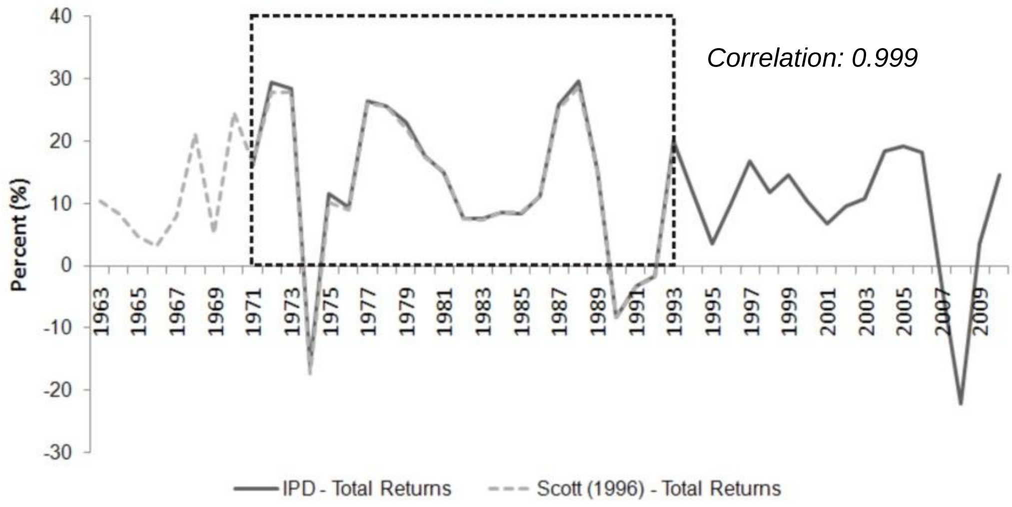

Figure 4.27 Scott's (1996) and IPD's All Property Total Returns series
Source: Scott (1996); IPD (2011)

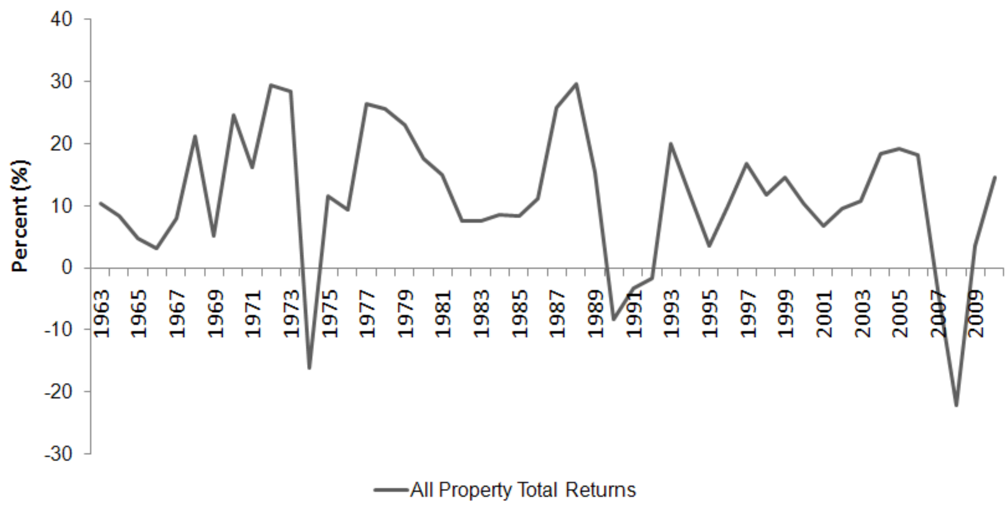

Figure 4.28 Chain-linked All Property Total Returns series
Source: Scott (1996); IPD (2011)

Details of the full time-series of each variable are included as Appendix 1.

4.4.3 Variable reduction

Following Makridakis *et al.* (1998), it would then be desirable to create a model based on all of these explanatory variables whatever their number. However, as the commentators suggest, it is not be feasible to compute a model incorporating all possible variables due to costs involved as well as the level of computation it may require. Koop (2006) also notes statistical issues it may encounter, including omitted variables bias and multicolinearity.

Therefore, a combination of both simple and more complex variable reduction techniques is used to determine which the key variables are. These variable reduction techniques are ‘What Others Do’, ‘What Experts Advise’, Stepwise Regression (Forward), Stepwise Regression (Backward), and Granger Causality.

According to Armstrong (2001, p.365), ‘What Others Do’ approach means that variables are selected based on findings from a similar study on the subject. Following Ball *et al.* (1998) and Barras (2010), variables which came as being significant to model commercial property rents were Bank Rate, Construction Orders, Employment, GDP, and Inflation.

What ‘experts advise’ approach employs expertise from a given subject area (Armstrong, 1980). Following this procedure and examining studies on commercial property rent determination, including McGough and Tsolacos (1995b), Tsolacos (1995), D'Arcy’s *et al.* (1999), Chaplin (1998; 1999), Brooks and Tsolacos (2000) and Füss *et al.* (2012), it was established that Bank Rate, Construction Costs, Construction Orders, Employment and GDP were amongst the key explanatory variables.

Stepwise Regression, according to Draper and Smith (1998), Makridakis *et al.* (1998) and PASW 18 (PASW, 2010b), is a statistical tool which sorts out the relevant explanatory variables from a large set of candidate variables. Backward elimination removes variables with the largest probability of F-test value at each step. Forward entry adds variables with the smallest probability of F-test value to the equation one at a time. The Forward elimination estimated that only Construction Output and GDP are the key variables. The Backward elimination suggested that Construction Costs, Construction Orders, Construction Output and GDP are significant in explaining the dependent variable.

Granger Causality, as Koop (2006) suggests, uses t-statistics and P-values of individual coefficients to determine whether a variable is significant. In this case, only Bank Rate and Construction Costs had any relevant statistical properties to model the dependent variable.

This combination of variable reduction methods enabled the production of the final ‘Short List’ of explanatory variables. These variables are as follows: Bank Rate, Construction Costs, Construction Orders, Construction Output, Construction Starts, Employment, and GDP (Table 4.2). Accordingly, these seven variables were further used for the research.

One interesting observation arises from this exercise – a prominence of construction based series. While GDP and Employment series were well document in the commercial property modelling literature, construction based variables were less discussed. A good account of that presented GVA (2009) in their report. According to GVA, rental growth (decline) is linked not only to economic growth (decline), but also to the development situation. Certainly, strength of the economy has a dominant effect on the need for property. However, the consultants also suggest that interplay between demand and supply for property and a lag in bringing new projects into the market is now becoming even more significant. Their suggestion is that if supply side of the equation does not correspond to customer needs, it will make customers look for alternatives, thus having effect on property development market and subsequently on rents. Which is why construction related series should be incorporated into the modelling process of the commercial property market.

Variable	**‘What Others Do’**	**‘What Experts Advise’**	**Stepwise Regression (Forward)**	**Stepwise Regression (Backward)**	**Granger Causality**
Bank Rate (BR)	X	X			X
Construction Costs (CCs)		X		X	X
Construction Orders (COr)	X	X		X	
Construction Output (COu)			X	X	
Construction Starts (CSt)					
Employment (E)	X	X			
Gross Domestic Product (GDP)	X	X	X	X	

Table 4.2 The summary table of variable importance

Before that, all variables were tested for stationarity following the methodology discussed in Section 3.4.10. Unit-root test results are presented in Table 4.3.

Variables		**t-stat (y_t)**	**t-stat (y'_t)**	**t-stat (y''_t)**
Bank Rate		1.393	-5.890	
		(0.170)	(0.000)	
Business Output		2.446	-3.623	
		(0.018)	(0.001)	
Car Registrations		-1.795	-4.886	
		(0.079)	(0.000)	
Construction Orders		-1.623	-4.243	
		(0.112)	(0.000)	
Construction Completions	Construction Output	-0.856	-4.533	
		(0.397)	(0.000)	
	Building Completions	-0.541	-6.229	
		(0.591)	(0.000)	
Construction Cost		1.165	-1.616	-5.845
		(0.250)	(0.113)	(0.000)
Construction Starts		-2.081	-6.683	
		(0.043)	(0.000)	
Consumer Confidence		-3.241		
		(0.003)		
Consumer Expenditure		6.115	-2.243	-9.747
		(0.000)	(0.002)	(0.000)
Depreciation Rate		6.662	-2.153	-7.134
		(0.000)	(0.037)	(0.000)
Disposable Income		0.646	-4.289	
		(0.522)	(0.000)	
Employment		-0.904	-3.734	
		(0.371)	(0.001)	
Foreign Funds		-6.481		
		(0.000)		
FTSE All Share Index		-0.300	-6.384	
		(0.766)	(0.000)	
GDP		-4.613		
		(0.000)		
ONS Leading Indicator	Index of Production	-2.268	-5.331	
		(0.028)	(0.000)	
Inflation		-2.303	-6.772	
		(0.026)	(0.000)	

Variables		t-stat (y_t)	t-stat (y'_t)	t-stat (y''_t)
Lagged Dependent Variable		-2.019	-4.0945	
		(0.050)	(0.000)	
Money Supply	M4	10.984	-1.817	-9.257
		(0.000)	(0.076)	(0.000)
	M0	-2.199	-7.460	
		(0.033)	(0.000)	
Number of Property Transactions		-2.199	-7.460	
		(0.033)	(0.000)	
Profitability		-1.618	-4.951	
		(0.113)	(0.000)	
Property Value		1.744	-3.533	
		(0.088)	(0.001)	
Risk Premium		-4.206		
		(0.000)		
Unemployment		-1.431	-3.793	
		(0.159)	(0.001)	
Yields of Government Securities	Short	-0.955	-4.859	
		(0.345)	(0.000)	
	Long	-0.887	-4.708	
		(0.380)	(0.000)	
Capital Formation		-0.131	-6.914	
		(0.897)	(0.000)	
Job Vacancies		-0.362	-3.621	
		(0.719)	(0.001)	
Land Value		-0.471	-4.832	
		(0.640)	(0.000)	
Net Investment		-0.914	-5.136	
		(0.366)	(0.000)	
Total Returns		-4.851		
		(0.000)		

Table 4.3 OLS estimation results for AR(p) model in testing for a unit-root
(P-values in parentheses)
NB: Model Estimated for $\Delta y_t = \alpha + \rho y_{t-1} + e_t$, $\rho = 0$; Critical Value at 5% is -2.89

The following table reports estimates for persistence and cross correlation. The low values of AR(1) term suggests that series do not contain memory. It implies that time-series values at a certain period of time are not related to their previous estimates. In other words, high (low) volatility in the past will not translate into high (low) volatility in the future. This low level of autoregression is evident within all explanatory variables. The largest AR (1) value is 0.552 which is for Construction Costs (Table 4.4).

Variable	Cross correlations with HP Cycle (Rents) at time *t*							Persistence
	t-3	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**AR (1)**
HP Cycle (Rents)								**0.663**
HP Cycle (BR)	-0.182	-0.029	0.236	0.471	0.446	0.148	-0.182	0.219
HP Cycle (CCs)	-0.378	-0.301	-0.099	0.185	0.403	0.416	0.249	0.552
HP Cycle (COr)	0.418	**0.760**	**0.810**	0.551	0.101	-0.353	-0.543	0.401
HP Cycle (COu)	-0.091	0.307	0.717	**0.902**	**0.737**	0.244	-0.257	0.371
HP Cycle (CSt)	0.421	0.246	0.019	-0.147	-0.274	-0.241	-0.080	0.140
HP Cycle (E)	0.244	0.581	0.731	**0.731**	0.627	0.308	-0.046	0.547
HP Cycle (GDP)	0.400	**0.734**	**0.835**	0.633	0.261	-0.179	-0.379	0.348

Table 4.4 Cross correlation and persistence estimates for HP cycles

The subsequent statistical analysis suggests that Construction Output and Employment cycles coincide with the Rental cycle. This is evident from the large value of correlation coefficients between dependent and the explanatory variables. The correlation coefficient between Rental cycle and Construction Output and Employment is 0.902 and 0.731 respectively.

Construction Orders and GDP cycles lead by one and two periods. However, neither of explanatory variables lead at the three period level. The only variable which lags the Rental cycle is Construction Output.

The high level of cross-correlation between HP Rental Cycles and Construction Orders (0.810) and GDP (0.835) series is seen from Figure 4.29 and Figure 4.30. Certainly, there are periods when series exhibit different dynamics especially in early 1970s and during late 2000s. However, the general pattern suggests that series follow the same trajectory. Interestingly, property consultancies, including GVA (2009), also related New Construction Orders and GDP growth to the dynamics of the commercial property rental cycle.

The following section summarises the key findings of the Chapter 4.

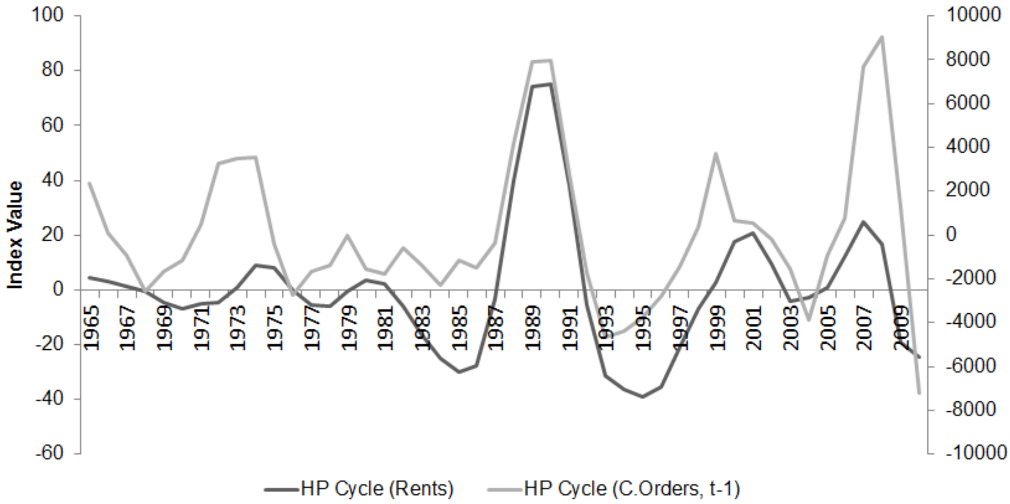

Figure 4.29 Cross-correlation of HP cycles for Rent Index and C.Orders

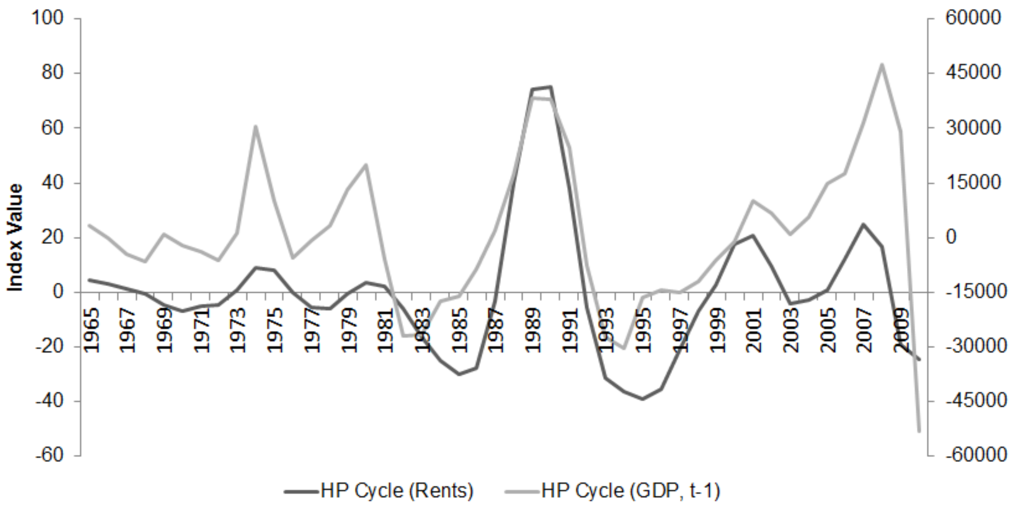

Figure 4.30 Cross-correlation of HP cycles for Rent Index and GDP

4.5 Summary

This chapter discussed the importance of long-term series in analysing property cycles. It assessed difficulties related to UK property data and its acquisition. It then presented the principle of chain-linking as the statistically robust solution for time-series combination. Following on from this, it evaluated the properties of the dependent and explanatory variables, as well as presented five variable reduction methods which were employed to estimate the key variables to model the dependent variable. These variable reduction techniques were 'What Others Do', 'What Experts Advise', Stepwise Regression (Forward), Stepwise Regression (Backward), and Granger Causality. Explanatory variables, which were selected for further modelling, are Bank Rate, Construction Costs, Construction Orders, Construction Output, Construction Starts, Employment, and GDP.

The importance of long-term series, as the research suggests, comes from two main reasons. First, it allows researchers to assess what generated cycles and how they have evolved. The long-term series analysis helps to appreciate important changes which occurred over time. Second, long term-series are necessary for model building purposes. In the literature it was identified that the longer the series, the better the model estimates can be obtained. Previous research has suggested that for a univariate time-series model there is a need for at least 50 observations. To build a reliable regression based model, at least 20 observations are required.

The discussion above suggested that the UK data is probably the best documented in Europe. The commentators commented that it goes back for several decades, it is available at national and local levels, as well as in various frequencies. It therefore makes it possible to produce sound market analytics. However, as the prior studies on the subject have noted, the UK data is not without criticism. The difficulties related to the UK data, which were discussed almost a quarter century ago, were also commented on within more recent publications. Certainly, researchers appreciate that the UK market data is rich and diverse. However, it was suggested that there are many challenges related to data quality and quantity, access to it, as well as the costs involved in obtaining the data, with all that limiting the scope of any research.

Subsequently, the principle of chain-linking was presented as an alternative time-series combination tool. It was suggested that chain-linking is a robust series combination approach which is used by major organisations.

For the dependent variable, the study employed IPD All Property Rental Value Growth Index. It was suggested that IPD provides the most reliable property market benchmarks in the UK. Regarding rental series, the discussion noted that rent is an important variable in analysing the property market. It was commented that rent brings the occupier, lender, developer, and land markets into one equilibrium state. As such, some commentators noted that rent is the most important variable in property economics.

The current study subsequently extended the original IPD series by chain-linking it with an alternative rental series following previous empirical studies. It then assessed cyclical properties of the dependent variable. The estimates suggested that an average period of UK rental cycle is 9 years of length and that cycles are getting shorter and more volatile over time.

Following on from this, the current study acquired series on twenty-seven explanatory variables by analysing data-sets of seventeen organisations and thirteen publications. It also employed twelve alternative sources of data to support, cross-reference and extend selected time-series. Accordingly, simple and more complex variable reduction techniques were employed to determine the key explanatory variables. It estimated that Bank Rate, Construction Costs, Construction Orders, Construction Output, Construction Starts, Employment, and GDP are the main variables to model rental series. The subsequent cross-correlation analysis supported these findings.

These estimates were in line with the literature on the subject. GDP, Employment and construction related series in particular were estimated as being significant for commercial property market analysis. The significance of Construction Orders, for example, was commented by the major property consultancy. It related dynamics in construction orders to the commercial property rental cycle. As such, it heighted the importance of selected variables and their use for the current research study.

Having identified variables that will be used to model the commercial property market in the UK, the next chapter presents modelling estimates, together with the analysis of results.

CHAPTER 5 EMPIRICAL RESULTS

Previous chapters have introduced the objectives and scope of the present research. Chapter 2 discussed the subject of property market modelling and forecasting. Chapter 3 presented Combination Forecasting as an alternative forecasting accuracy improvement technique. Chapter 4 dealt with dependent and explanatory variables used for the research.

This chapter presents modelling estimates. It details the statistical analysis carried out with respect to the stated aims of the research. It then analyses and interprets results. The chapter transforms the modelling estimates obtained into credible evidence about UK commercial property market modelling and forecasting, and its accuracy improvement through Combination Forecasting. Although a number of research constrains played a role in the research process, the estimates obtained confirmed the usefulness of Combination Forecasting.

Chapter 5 is divided into six key sections. Section 1 explains in-sample modelling results obtained from Exponential Smoothing, ARIMA/ARIMAX, Simple and Multiple Regression specifications, and VAR specifications. Section 2 assesses out-of-sample accuracy of these models. Section 3 presents estimates of the Combination Forecasting. Section 4 comments on forecasting accuracy. Section 5 analyses the usefulness of Combination Forecasting. Section 6 summarises the main findings.

5.1 In-sample forecasting estimates

5.1.1 Exponential Smoothing model estimates

Single exponential smoothing, Holt's Linear Trend and Brown's Linear Trend modelling is performed using PASW 18 'Time Series Modeller' algorithm. For Single exponential smoothing, algorithm uses Equation 1 explained in Section 3.4.1. Holt's Linear Trend model is computed from Equation 2, which was presented in Section 3.4.2. Brown's Linear Trend model is estimated using three-set equation established in Section 3.4.3.

As both statistical (Table 5.1) and visual (Figure 5.1; Figure 5.2; Figure 5.3) analyses suggest, none of the Exponential Smoothing models fit the stationary rental series. The R-squared of each of the specifications is less than 0. Other statistical measures, including MSE and AIC, are also insignificant.

Model Specification	Model Fit statistics					
	R-squared	**MAE**	**MAPE**	**MSE**	**AICc**	**BIC**
Single exponential smoothing	-0.027	4.399	109.271	31.078	130.87	134.97
Holt's Linear Trend	-0.027	4.390	110.324	31.101	131.15	135.26
Brown's Linear Trend	-0.001	4.358	100.327	30.289	131.23	135.33

Table 5.1 SES, HLT and BLT model fit statistics

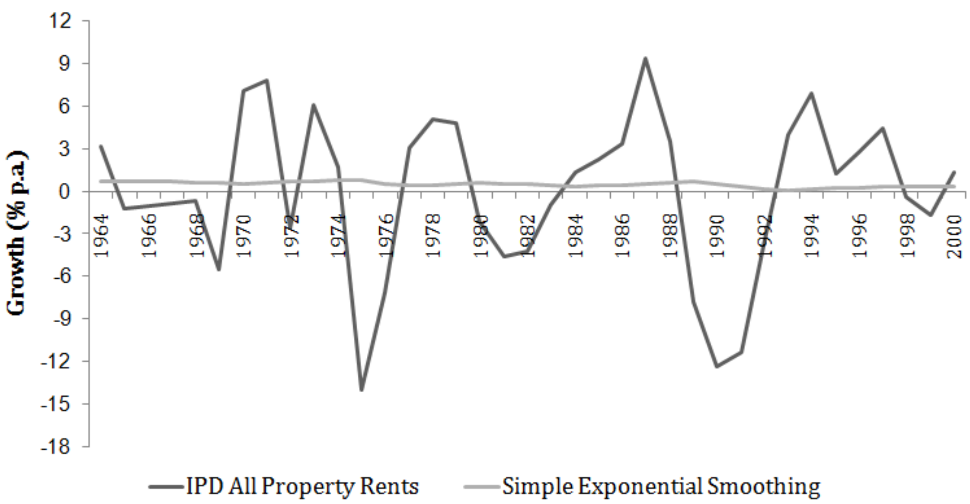

Figure 5.1 Single exponential smoothing (model fit)

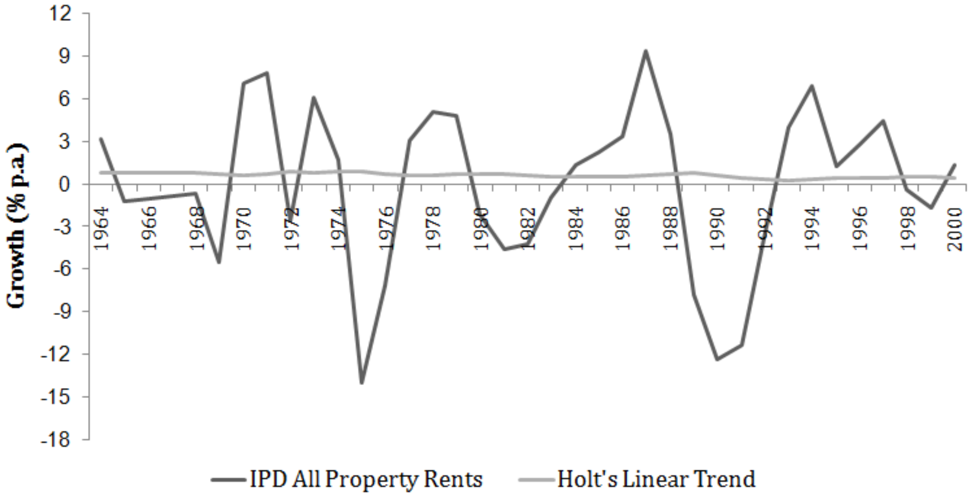

Figure 5.2 Holt's Linear Trend (model fit)

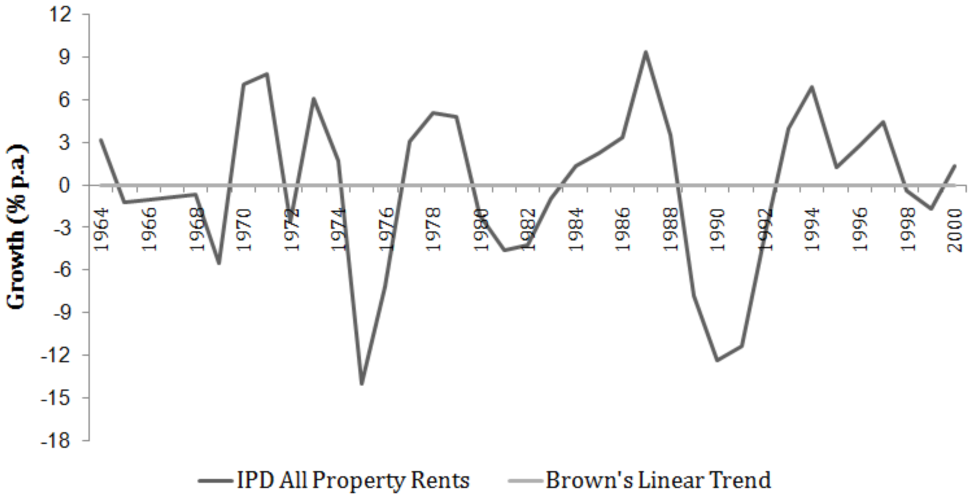

Figure 5.3 Brown's Linear Trend (model fit)

5.1.2 ARIMA/ARIMAX model estimates

To create both ARIMA and ARIMAX specifications, the same PASW 18 'Time Series Modeller' algorithm is employed. The study computes twenty ARIMA specifications ranging from ARIMA (1,0,0) to ARIMA (4,0,4) . As it was commented in Section 3.4.4, ARIMA(X) models can have any AR and MA orders. However, it was decided to select 4th as the largest ARIMA order as greater number would contain the dynamics of the previous business/property cycle.

Table 5.2 provides the ARIMA modelling estimates. As it is seen, there is no consensus between model accuracy measures which ARIMA specification fits the dependent variable best. The R-squared and MSE values indicate that ARIMA (4,0,4) is the best fitting specification. While MAE selects ARIMA (4,0,3) and MAPE selects ARIMA (1,0,2) as the most accurate models. However, AICc and BIC values suggest that ARIMA (1,0,2) is the best parameterised ARIMA specification. What is more, this specification has the lowest MAPE value. It all therefore allows to suggest that ARIMA (1,0,2) is the most accurate model amongst competing ARIMA specifications. The second most accurate is ARIMA (4,0,4) model. The least accurate is ARIMA (1,0,0) specification.

Order of ARIMA	**Model Fit statistics**					
terms	**R-squared**	**MAE**	**MAPE**	**MSE**	**AICc**	**BIC**
1,0,0	0.174	3.873	108.985	25.016	125.84	129.95
1,0,1	0.412	3.137	87.215	17.791	115.64	120.83
1,0,2	0.517	2.601	66.035	14.612	109.85	115.97
1,0,3	0.527	2.605	68.624	14.308	112.91	119.77
1,0,4	0.529	2.582	69.369	14.266	115.62	123.03
2,0,0	0.333	3.280	94.895	20.188	120.43	125.63
2,0,1	0.425	3.068	83.969	17.417	117.65	123.77
2,0,2	0.533	2.615	71.205	14.128	112.66	119.52
2,0,3	0.560	2.563	82.892	13.317	112.30	119.71
2,0,4	0.576	2.549	79.082	12.842	115.16	122.91
3,0,0	0.333	3.279	94.891	20.188	123.12	129.24
3,0,1	0.455	2.965	88.829	16.505	118.33	125.19
3,0,2	0.549	2.529	73.182	13.648	114.28	121.69
3,0,3	0.564	2.510	75.860	13.202	116.33	124.07
3,0,4	0.559	2.567	72.258	13.349	119.00	126.84
4,0,0	0.529	2.794	100.710	14.266	113.08	119.95
4,0,1	0.529	2.796	99.968	14.259	116.13	123.55
4,0,2	0.574	2.542	81.733	12.893	115.28	123.02
4,0,3	0.578	2.470	79.555	12.783	118.51	126.34
4,0,4	0.589	2.521	80.768	12.451	121.49	129.14

Table 5.2 ARIMA model fit statistics

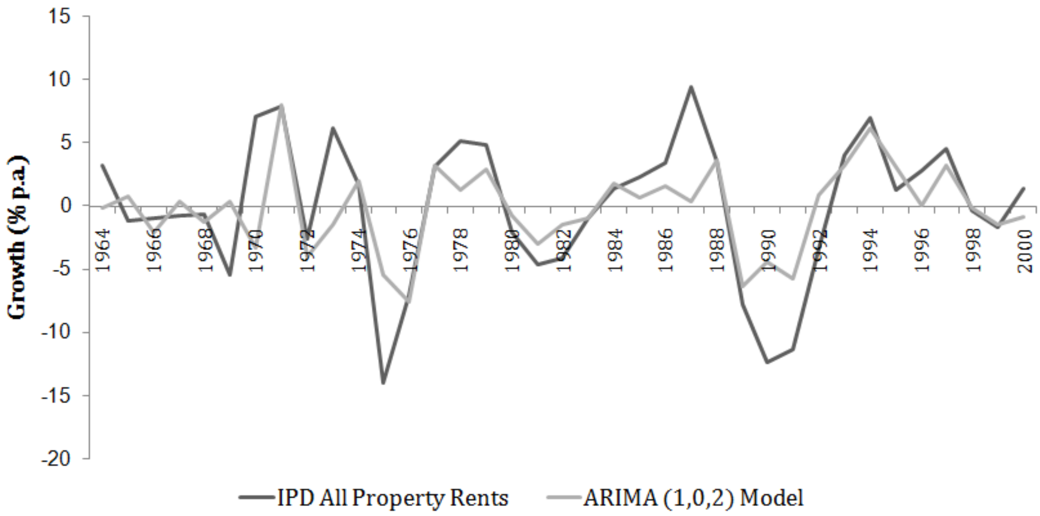

Figure 5.4 ARIMA (1,2) (model fit)

Figure 5.4 illustrates that ARIMA (1,0,2) model fits rental series. It does pick up upturn/downturn in the 1970's, property slump in the early 1990s and market correction in late 1990's. Certainly, model under-estimate decline in 1970s, 1990s and increase in late 1980's. It therefore indicates that the model is optimistic and avoids high deviations in the series. However, considering that the dependent variable is in the state of stationarity, the R-squared of 0.517 suggests that model explains more than half of the deviations in the series.

The subsequent statistics presented in Table 5.3 and Table 5.4 indicates that of all one hundred and forty ARIMAX specifications, the ARIMAX GDP (4,0,0) model has the best statistical properties. The model has the smallest AICc and BIC values. It also fits the historic series best. The second best is ARIMA (1,0,2) model with Construction Orders as an explanatory variable. The least accurate in fitting the dependent variable is ARIMA (1,0,2) specification with Employment as an explanatory variable. Although this specification performed the lest in comparison to other ARIMAX models, its in-sample fit is greater than half ARIMA specifications and of all Exponential Smoothing models.

Explanatory Variable	ARIMAX Order	Model Fit statistics					
		R-squared	MAE	MAPE	MSE	AICc	BIC
Bank Rate	(1,0,2)	0.521	2.582	66.398	14.503	112.32	119.19
Construction Costs	(1,0,2)	0.520	2.612	66.688	14.534	112.46	119.33
Construction Orders	(1,0,2)	0.604	2.608	80.827	12.208	103.24	109.85
Construction Output	(1,0,2)	0.517	2.597	65.486	14.610	112.66	119.52
Construction Starts	(1,0,2)	0.523	2.602	67.448	14.454	112.27	119.14
Employment	(1,0,2)	0.515	2.597	66.645	14.679	112.90	119.77
GDP	(4,0,0)	0.690	2.261	69.831	9.387	99.09	106.50

Table 5.3 ARIMAX model fit statistic

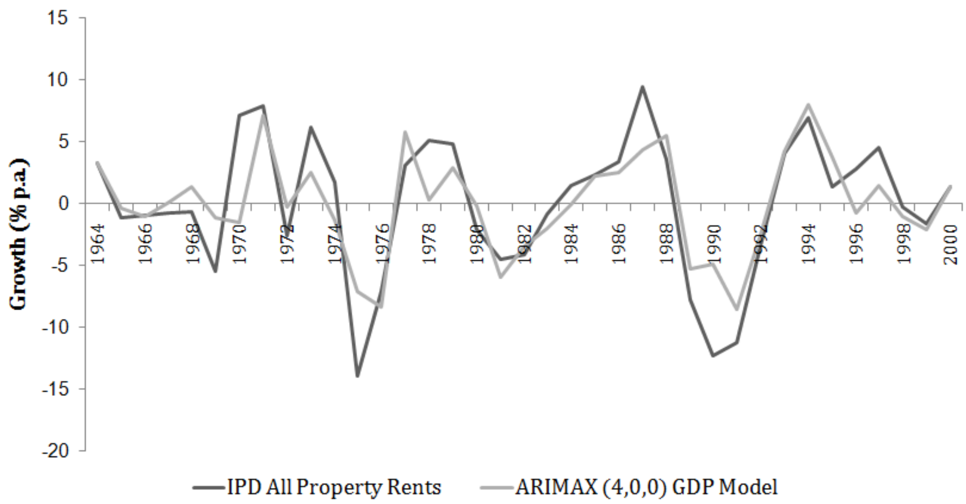

Figure 5.5 ARIMAX (4,0,0) GDP (model fit)

As both statistical and visual analysis suggest, ARIMAX (4,0,0) GDP specification fits rental series better than ARIMA (1,0,2) model. The ARIMAX (4,0,0) GDP model has greater R-squared, smaller MAPE, MSE and AIC values. As can be seen from Figure 5.5, the model tracks the dynamics of the dependent variable. It fits market correction in the 1970's, property slump in the early 1990s and that in late 1990's. It overestimates market rise in the 1978 and underestimates market decline in the 1990. However, it does perform better than the best ARIMA specification.

ARIMAX Order	Model Fit statistics													
	Bank Rate		Construction Orders		Construction Costs		Construction Output		Construction Starts		Employment		GDP	
	AICc	**BIC**	**AICc**	**BIC**	**AICc**	**BIC**	**AICc**	**BIC**	**AICc**	**BIC**	**AICc**	**BIC**	**AICc**	**BIC**
1,0,0	128.17	133.37	115.83	120.88	128.32	133.51	128.12	133.31	128.26	133.45	126.53	131.72	117.95	123.14
1,0,1	118.16	124.27	108.06	113.98	117.91	124.03	118.03	124.15	117.66	123.78	117.95	124.06	107.88	114.00
1,0,2	112.32	119.19	103.24	109.85	112.46	119.33	112.66	119.52	112.27	119.14	112.90	119.76	100.73	107.60
1,0,3	115.68	123.09	106.29	113.37	115.74	123.15	115.95	123.37	115.55	122.96	116.97	124.38	111.33	118.75
1,0,4	118.52	126.27	109.33	116.67	118.74	126.48	118.93	126.68	118.47	126.22	119.10	126.84	103.50	111.25
2,0,0	121.61	127.73	112.14	118.05	123.00	129.12	122.60	128.72	122.82	128.93	121.24	127.36	111.54	117.66
2,0,1	120.20	127.07	110.17	116.77	118.05	124.92	118.14	125.01	118.08	124.94	115.81	122.67	107.36	114.23
2,0,2	114.35	121.76	106.61	113.70	115.27	122.68	116.76	124.18	115.18	122.59	116.44	123.86	105.53	112.95
2,0,3	116.12	123.87	109.68	117.01	119.39	127.14	113.30	121.04	118.84	126.59	116.05	123.80	110.01	117.76
2,0,4	118.20	126.03	111.50	118.83	118.57	126.40	118.59	126.42	118.32	126.15	118.62	126.45	103.68	111.51
3,0,0	124.43	131.30	115.01	121.61	125.86	132.73	125.46	132.32	125.67	132.54	124.05	130.91	113.22	120.09
3,0,1	119.99	127.40	112.64	119.73	122.81	130.22	121.30	128.71	121.20	128.61	118.82	126.24	110.33	117.74
3,0,2	116.73	124.47	109.54	116.88	117.63	125.37	117.38	125.13	117.06	124.80	118.49	126.24	106.97	114.71
3,0,3	119.81	127.64	114.22	121.55	119.46	127.29	119.12	126.95	119.47	127.31	123.04	130.87	104.49	112.32
3,0,4	122.40	130.05	115.49	122.53	122.71	130.36	124.46	132.10	121.65	129.30	123.37	131.02	110.36	118.00
4,0,0	114.78	122.20	106.24	113.33	116.14	123.55	115.94	123.36	115.58	122.99	116.06	123.48	99.09	106.50
4,0,1	118.06	125.80	109.42	116.75	119.41	127.15	119.22	126.97	118.31	126.05	119.34	127.09	101.32	109.06
4,0,2	116.30	124.13	111.56	118.89	118.56	126.39	118.08	125.91	118.25	126.08	118.80	126.63	104.21	112.04
4,0,3	119.90	127.55	116.29	123.32	122.12	129.77	121.94	129.59	121.61	129.25	122.54	130.19	108.94	116.59
4,0,4	123.84	131.00	120.70	127.12	124.75	131.91	124.62	131.78	124.74	131.90	125.78	132.94	111.70	118.86

Table 5.4 AICc estimates for ARIMAX models

5.1.3 Simple Regression model estimates

The Simple Regression specifications are computed using PASW 'Regression' algorithm. The modelling is performed using Equation 15 as indicated in Section 3.4.6. Seven simple regression specifications are estimated using seven explanatory variables.

As the statistical analysis suggests (Table 5.5), Construction Orders is the best explanatory variable for simple regression framework. Although a GDP based model has the smallest MAE value, the Construction Orders based model has the smallest AICc and BIC values amongst competing specifications. The model also has the smallest MSE and the greatest R-squared values. What is more, Durbin-Watson statistics for the Construction Orders specification is 1.543 which indicates positive statistical outcomes. The White's test value WT is 2.005 which is less than χ^2 (5.991)[4]. Therefore, the hypothesis of Heteroskedasticity is rejected. It implies that test did not find a problem with Construction Orders based Simple Regression model.

Explanatory Variable	**Model Fit statistics**					
	R-squared	**MAE**	**MAPE**	**MSE**	**AICc**	**BIC**
Bank Rate	0.001	4.333	98.261	30.246	130.47	134.47
Construction Costs	0.000	4.362	98.859	30.259	130.49	134.49
Construction Orders	0.339	3.737	142.379	20.374	115.26	119.27
Construction Output	0.015	4.526	108.083	33.662	129.94	133.94
Construction Starts	0.001	4.346	97.929	30.237	130.46	134.46
Employment	0.031	4.092	87.638	29.329	129.36	133.37
GDP	0.322	3.631	120.185	20.516	118.50	122.61

Table 5.5 Simple Regression model fit statistics

The principle equation for Simple Regression model with Construction Orders as an explanatory variable is as follows:

$$R_t = \alpha + \beta COr_t + e_t \qquad (47)$$

[4] χ^2 values are obtained from the University of North Carolina at Chapel Hill (2012)

Where R_t is All Property Rental Index at a time t and COr_t is the Construction Orders series at the period time *t*. The estimated regression equation between dependent and explanatory variables over the sample period is:

$$R_t = \hat{\alpha} + \hat{\beta} COr_t = -0.471 + 0.001 COr_t \tag{48}$$

(0.549) (0.0002)

The coefficients α and β are OLS estimates.

The equation above indicates coefficient β to be positive. It implies that when COr_t is growing, rents are also expected to grow. However, from the visual analysis (Figure 5.6) it is seen that there are periods of inverse relationship between the two series (e.g. 1981). It thus suggests that the positive relationship between dependent and explanatory variables is expected to proceed for most of the time; however, not necessarily through all the period. The value of the coefficient β can be interpreted as following: change in COr_t by 1 will make R_t change positively by 0.001 percentage points, *ceteris paribus*. The equation also implies that when COr_t remains 0, R_t will fall by 0.471 percent, *ceteris paribus*. However, in reality when COr_t increases by 1, R_t will not always increase by 0.001 percent, and when COr_t remain flat, R_t will not necessarily decline by 0.471. This is because other factors, which are defined as e, do not remain constant over time.

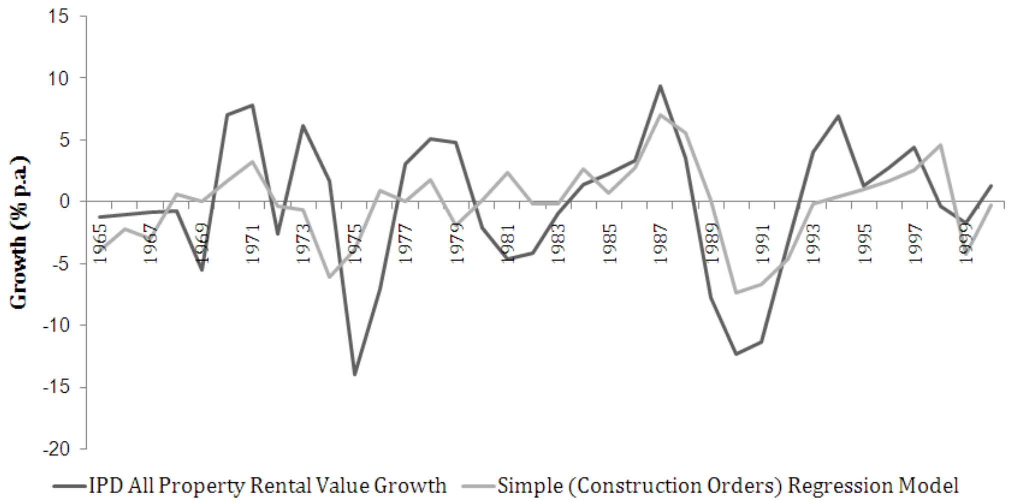

Figure 5.6 Simple Regression (Construction Orders) (model fit)

The subsequent analysis of the dynamics of the Simple Regression model with Construction Orders as an explanatory variable (Figure 5.6) suggests that the model does not track the dependent variable well. This can be explained by the low value of its R-squared (0.339). Certainly, there are periods when the model captures the deviations in the dependent variable. However, overall, its explanatory power is low. The model under-estimates the dependent variable when rents are rising and it avoids high values during when rents are declining.

5.1.4 Multiple Regression model estimates

The subsequent regression analysis (based on P-values and t-statistics) suggests Construction Output (COu_t), Construction Starts (CSt_t), Construction Orders (COr_t), and Gross Domestic Product (GDP_t) to be significant in modelling property rents (Table 5.6). Neither Employment, nor Bank Rate came up as being useful in modelling Real Estate rents within Multiple Regression Framework. It was therefore decided to drop the latter two variables out of the equation as they convey irrelevant information.

Explanatory variables	Coefficient	t-Stat	P-value
Constant	-4.399	-2.989	0.006
Construction Output	-0.001	-2.177	0.038
Construction Costs	0.228	0.161	0.073
Construction Starts	0.000	2.552	0.016
Construction Orders	0.001	3.003	0.006
GDP	1.560	2.935	0.007
Employment	0.003	0.824	0.417
Bank Rate	0.310	0.630	0.534

Table 5.6 Regression estimates for MR equation

Accordingly, Multiple Regression equation derived from the relationship between dependent and explanatory variables is as follows:

$$R_t = \alpha + \beta_1 COu_t + \beta_2 CCs_t + \beta_3 CSt_t + \beta_4 COr_t + \beta_5 GDP_t e_t \quad (49)$$

$$R_t = -4.144 - 0.001COu_t + 1.211CCs_t + 0.0010CSt_t + \quad (50)$$

(0.002) (0.047) (0.270) (0.016)

$$+0.001COr_t + 1.8134GDP_t + e_t$$

(0.008) (0.001)

As the statistical results suggest, the model tracks property rents. Given the fact that changes of the rental series are modelled, the R-squared of 0.553 indicates that the model explains more than half of the deviations in the dependent variable. The model captures market upturn and downturn in late 1980s/early 1990s, as well as tracks subsequent market movements (Figure 5.7).

The DW statistical value for Multiple Regression is 1.709. It suggests that autocorrelated disturbances are not present within the model, i.e. that values are independent**.** White's test for this specification is computed following the same algorithm as that for Simple Regression models. The WT value (5.04) is less than χ^2(18.307). Therefore, the hypothesis of Heteroskedasticity can be rejected.

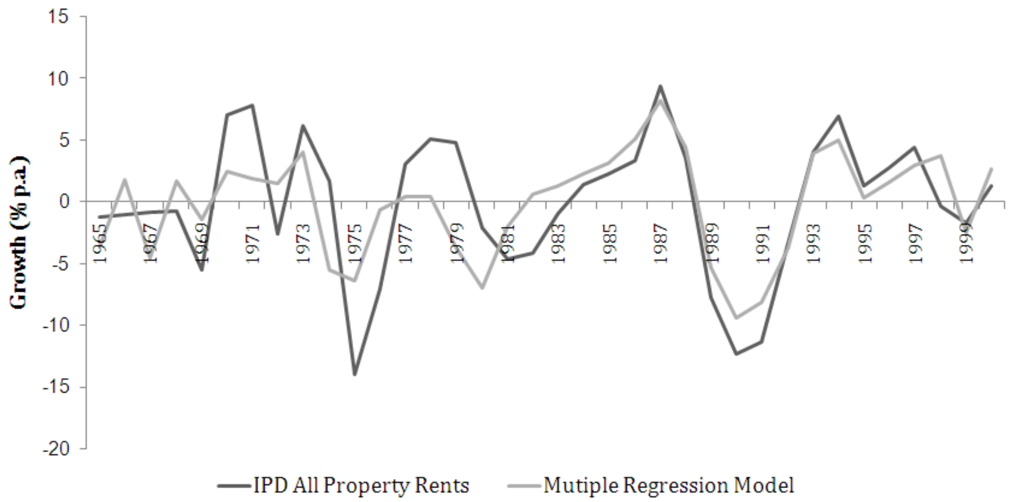

Figure 5.7 Multiple Regression (model fit)

5.1.5 Vector Autoregression model estimates

The Vector Autoregression modelling is performed following Equation 21 presented in Section 3.4.8. In this framework, the same lag length is used for every variable in every equation, i.e. *p*=*q*, subsequently creating VAR (*p*) model. Since all variables selected for the model are stationary, model estimation and testing are performed in the standard way. Estimates for each equation are obtained using OLS (Table 5.7). Acquired figures for P-values and t-statistics then indicate whether variables are significant. Lag length is selected from AICc for each system as suggested by Brooks and Tsolacos (2010). Accordingly, the best VAR specification is VAR (1)[5]:

$$R_t = -2.578 + 0.055R_{t-1} - 0.001COu_{t-1} - 2.349CCs_{t-1} + \quad (51)$$

(0.154) (0.807) (0.097) (0.085)

$$+0.00003CSt_{t-1} + 0.001COr_{t-1} + 1.336GDP_{t-1} + e_t$$

(0.436) (0.249) (0.078)

[5] *AICc* for VAR (3) is 102.60, VAR (2) is 103.58 and VAR (1) is 85.180

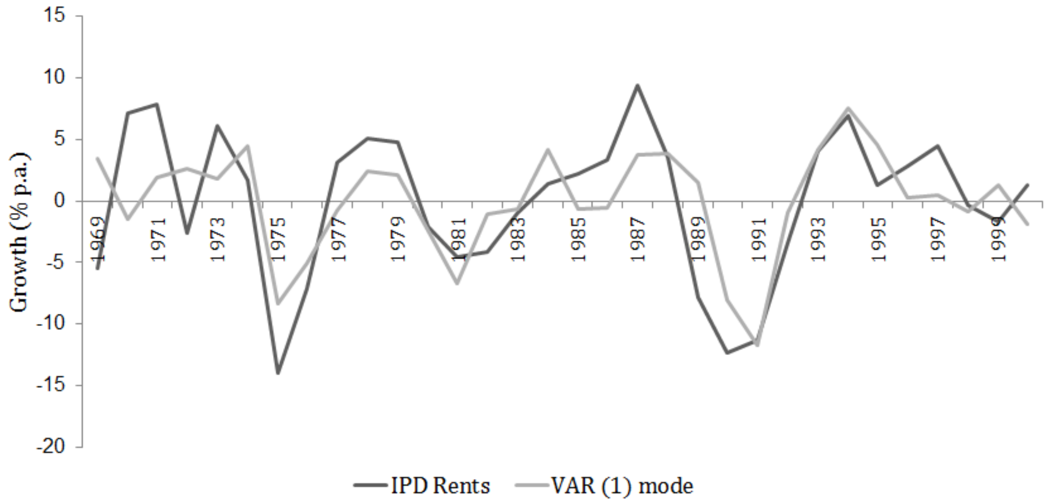

Figure 5.8 Vector Autoregression (model fit)

As it is seen from Figure 5.8 above, the model tracks historic rent series with its R-square being 0.793. The model picks up the main ups and downs in the dependent variable. However, there are periods when the model underestimates the dynamics of the dependent variable. The model does not pick up market rise in early-1970s and late-1980s. It also produces inverse estimates during a three year period from 1984 to 1886.

Regardless of these limitations, model is well parameterised. Its DW statistics is 1.545. White's test indicates that there are no difficulties associated with the specification. Its n is 32, R-squared is 1, with WT being equal to 32, which is less than χ^2 (53.384).

The following section presents out-of-sample accuracy of these models.

	Equation in VAR							
	R_t	COu_t	CCs_t	CSt_t	COr_t	GDP_t	E_t	BR_t
Constant	-7.094	-274.5	-0.352	28147	454.7	0.196	-72.93	-1.361
	(0.183)	(0.669)	(0.616)	(0.349)	(0.785)	(0.888)	(0.683)	(0.326)
R_{t-1}	-0.358	-51.67	0.094	2434	-45.85	-0.282	2.723	-0.055
	(0.528)	(0.479)	(0.254)	(0.465)	(0.807)	(0.103)	(0.891)	(0.717)
R_{t-2}	-0.504	-28.11	0.027	-3722	135.2	0.166	-10.16	0.318
	(0.457)	(0.742)	(0.775)	(0.353)	(0.549)	(0.385)	(0.670)	(0.108)
R_{t-3}	-0.772	79.00	0.225	2541	-231.9	-0.241	47.19	0.075
	(0.380)	(0.478)	(0.092)	(0.614)	(0.428)	(0.330)	(0.152)	(0.745)
COu_{t-1}	-0.002	0.041	0.000	14.91	0.788	-0.001	-0.048	0.000
	(0.410)	(0.912)	(0.945)	(0.386)	(0.422)	(0.417)	(0.643)	(0.709)
COu_{t-2}	-0.003	0.066	0.000	-14.03	0.625	0.000	-0.005	0.000
	(0.269)	(0.843)	(0.336)	(0.368)	(0.479)	(0.659)	(0.960)	(0.936)
COu_{t-3}	-0.001	-0.231	0.000	15.16	-0.781	0.000	-0.010	0.000
	(0.619)	(0.327)	(0.841)	(0.173)	(0.215)	(0.795)	(0.876)	(0.753)
CCs_{t-1}	-0.688	-527.7	-0.490	-11542	-1832	0.043	-69.29	-0.855
	(0.830)	(0.225)	(0.295)	(0.544)	(0.120)	(0.962)	(0.550)	(0.338)
CCs_{t-2}	3.972	-911.4	-0.964	6763	-1553	1.121	-202.6	-0.467
	(0.396)	(0.150)	(0.161)	(0.800)	(0.327)	(0.392)	(0.238)	(0.704)
CCs_{t-3}	1.580	-604.0	-0.629	-11545	-1431	0.718	-113.9	0.895
	(0.709)	(0.285)	(0.306)	(0.642)	(0.328)	(0.548)	(0.459)	(0.441)
CSt_{t-1}	0.000	0.001	0.000	-0.071	0.013	0.000	-0.002	0.000
	(0.397)	(0.921)	(0.483)	(0.862)	(0.575)	(0.047)	(0.500)	(0.264)
CSt_{t-2}	0.000	-0.001	0.000	0.017	-0.011	0.000	0.004	0.000
	(0.956)	(0.943)	(0.852)	(0.968)	(0.653)	(0.870)	(0.180)	(0.158)
CSt_{t-3}	0.000	0.009	0.000	-0.049	0.024	0.000	-0.001	0.000
	(0.630)	(0.356)	(0.220)	(0.910)	(0.344)	(0.343)	(0.592)	(0.318)
COr_{t-1}	0.002	0.345	0.000	-0.993	0.413	0.001	-0.052	0.000
	(0.154)	(0.106)	(0.469)	(0.910)	(0.424)	(0.213)	(0.351)	(0.565)
COr_{t-2}	0.001	0.495	0.000	0.173	0.233	0.000	0.034	0.000
	(0.592)	(0.058)	(0.675)	(0.987)	(0.695)	(0.761)	(0.589)	(0.314)
COr_{t-3}	0.001	-0.173	0.000	-6.172	-0.567	0.000	-0.016	0.000
	(0.465)	(0.504)	(0.430)	(0.599)	(0.407)	(0.652)	(0.817)	(0.538)
GDP_{t-1}	1.618	-72.70	-0.122	-3724	340.5	0.854	54.095	0.399
	(0.350)	(0.736)	(0.607)	(0.705)	(0.549)	(0.101)	(0.380)	(0.390)
GDP_{t-2}	-0.343	-62.44	0.228	2900	-1389	-0.320	128.4	-0.182
	(0.872)	(0.819)	(0.453)	(0.816)	(0.083)	(0.594)	(0.124)	(0.752)
GDP_{t-3}	2.846	112.7	-0.390	-1743	858.7	0.534	-78.03	-0.163
	(0.207)	(0.681)	(0.216)	(0.888)	(0.251)	(0.382)	(0.321)	(0.776)
E_{t-1}	0.000	0.570	0.001	-27.87	5.284	0.001	0.022	0.003
	(0.971)	(0.691)	(0.519)	(0.670)	(0.185)	(0.738)	(0.955)	(0.404)
E_{t-2}	-0.020	0.952	0.002	-19.33	-8.096	-0.003	0.765	0.003
	(0.137)	(0.560)	(0.256)	(0.793)	(0.087)	(0.451)	(0.121)	(0.386)
E_{t-3}	0.012	0.736	0.001	-52.59	4.692	0.001	-0.077	-0.002
	(0.285)	(0.582)	(0.475)	(0.396)	(0.202)	(0.671)	(0.836)	(0.396)
BR_{t-1}	0.735	-184.7	-0.291	8847	0.327	-0.103	-82.44	-0.491
	(0.652)	(0.386)	(0.224)	(0.364)	(1.000)	(0.821)	(0.183)	(0.280)
BR_{t-2}	0.735	341.6	-0.160	7847	1800	-0.160	0.124	-0.648
	(0.636)	(0.116)	(0.466)	(0.396)	(0.009)	(0.711)	(0.998)	(0.149)
BR_{t-3}	-1.917	-55.49	0.059	113.7	-261.5	-0.255	81.88	-1.361
	(0.300)	(0.808)	(0.813)	(0.991)	(0.663)	(0.611)	(0.223)	(0.932)
R^2	0.880	0.976	0.866	0.869	0.922	0.922	0.927	0.926

Table 5.7 Estimates from VAR (*p*) specification
(P-values in parentheses)

5.2 Out-of-sample forecasting estimates

As the statistical results indicate (Table 5.8), the VAR (1) specification is the best fitting model. Its R-squared is the greatest of all sample models. The AICc also indicate it to be the best parameterised model. In the in-sample, VAR model outperforms all one hundred and seventy one specification computed for the current research. However, these results do not come as a surprise. The VAR model comprises a number of explanatory variables (i.e. Construction Output, Construction Costs, Construction Starts, Construction Orders and GDP), their lagged values as well as past values of dependent variable itself. It therefore justifies its goodness to fit to the historic data.

Model Specification	**Model Fit statistics**						
	R-squared	**MAE**	**MAPE**	**MSE**	**AICc**	**BIC**	**U**
Exponential Smoothing							
Single exponential smoothing	-0.027	4.399	109.261	18.143	130.87	134.97	0.940
Holt's Linear Trend	-0.027	4.390	110.323	18.351	131.15	135.26	0.928
Brown's Linear Trend	-0.001	4.358	100.240	17.486	131.23	135.33	0.999
Simple Regression							
Bank Rate	0.001	4.333	98.261	16.824	130.47	134.47	0.953
Construction Costs	0.000	4.362	98.859	19.821	130.49	134.49	0.968
Construction Orders	0.339	3.737	142.379	19.280	115.26	119.27	0.405
Construction Output	0.015	4.526	108.083	31.531	129.94	133.94	0.879
Construction Starts	0.001	4.346	97.929	16.550	130.46	134.46	0.934
Employment	0.031	4.092	87.638	18.689	129.36	133.37	0.824
GDP	0.322	3.631	120.185	14.812	118.50	122.61	0.466
Multiple Regression	0.553	3.061	141.647	30.962	109.35	115.95	0.461
Vector Autoregression	0.793	2.474	91.845	12.230	85.180	122.06	0.481
ARIMA (1,0,2)	0.517	2.601	66.035	17.433	109.85	115.97	0.848
ARIMAX							
Bank Rate (1,0,2)	0.521	2.582	66.398	16.363	112.32	119.19	0.822
Construction Costs (1,0,2)	0.520	2.612	66.688	14.584	112.46	119.33	0.736
Construction Orders (1,0,2)	0.604	2.608	80.827	6.770	103.24	109.85	0.328
Construction Output (1,0,2)	0.517	2.597	65.486	17.273	112.66	119.52	0.839
Construction Starts (1,0,2)	0.523	2.602	67.448	16.229	112.27	119.14	0.828
Employment (1,0,2)	0.515	2.597	66.645	17.183	112.90	119.77	0.836
GDP (4,0,0)	0.690	2.261	69.831	10.050	99.09	106.50	0.433

Table 5.8 Summary model fit statistics

However, when it comes to out-of-sample forecasting performance, VAR's accuracy is not so impressive. Its Theil's U value is poorer than that of some less complex ARIMAX and Simple Regression models.

Regarding Exponential Smoothing specifications, their accuracy remained low in and out-of-sample. All three specifications had their U values close to one. Interestingly, similar estimates were obtained for ARIMA models. Theil's U value for the best fitting ARIMA (1,0,2) model was also close to one.

Table 5.9 reports that ARIMAXCOr (1,0,2) specification has the lowest Theil's U value of all the candidate models. This subsequently makes it the best performing specification. Interestingly, in both cases (in- and out-of-sample) simple models and ARIMAX specifications in particular generated better results than more complex Multiple Regression and VAR specifications.

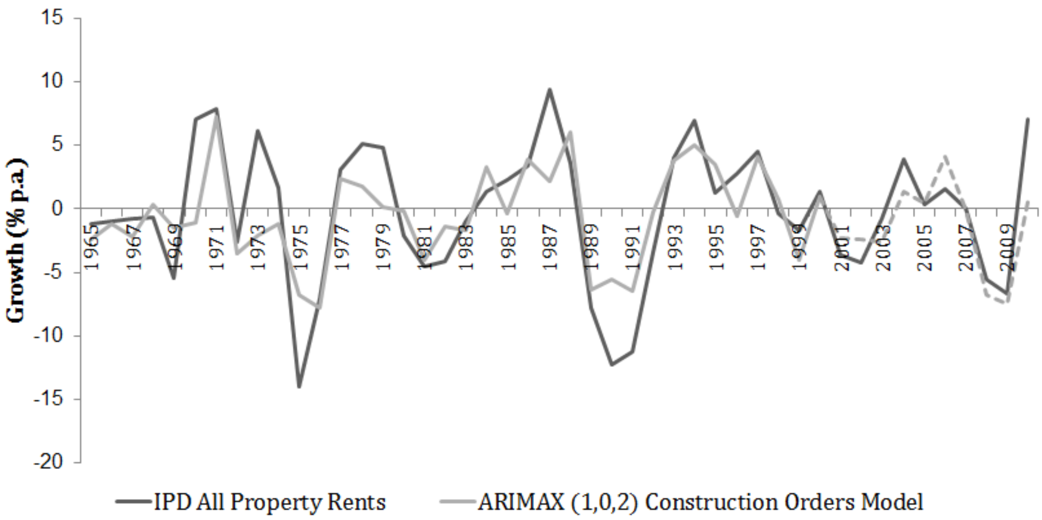

Figure 5.9 ARIMAX (1,0,2) Construction Orders (fit and accuracy)

The second most accurate of all sample models is Simple Regression specification with Construction Orders (SRCOr) as an explanatory variable, following ARIMAX GDP (4,0,0) (ARIMAXGDP) models. ARIMAXGPD model is effective within in-sample and out-of-sample forecasting. Although ARIMAXCOr, ARIMAXGDP or SRCOr models do not fit the historic series with the same degree of accuracy as it does VAR or Multiple Regression specifications, their out-of-sample performance is better. These estimates also suggest that past values of rents itself, as well as change in Construction Orders and GDP are the most important explanatory variables to model IPD All Property Rent Index. These findings reinforce arguments presented in Section 4.4.3, where it was commented that the latter explanatory variables relate to the dynamics of the commercial property rental cycle.

Having discusses in- and out-of-sample modelling accuracy, the next section presents estimates of the Combination Forecasting.

5.3 Combination Forecasting estimates

The Combination Forecasting is produced using two principle techniques, i.e. Simple Averaging (SA) and Regression (OLS) combination. Simple Averaging is computed using Equation 22. The Regression based Combination Forecasting is estimated using Equation 23 (Section 3.4.9). The combination forecasts are produced for the 2001-2010 period with 380 combination forecasts computed in total, i.e. 190 Simple and 190 OLS. The accuracy of each combination is assessed by computing their Theil's U statistical values.

As the modelling results indicate (Table 5.9 below), the best SA Combination Forecasts are obtained from the combination of Simple Regression and ARIMAX models, which were based on construction and GDP based series. Theil's U statistic for these particular combinations is 0.35 which indicates good forecasting ability. The best OLS Combination Forecasts are obtained by combining ARIMAX and Simple Regression specifications which were computed using Construction related, Employment, and Bank Rate series. Theil's U statistic of these specifications is 0.32.

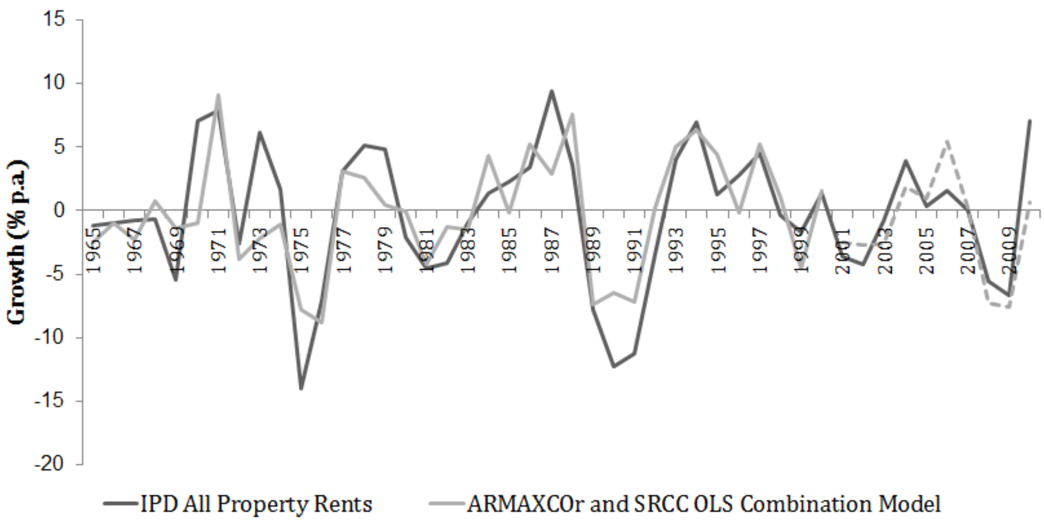

Figure 5.10 ARIMAXCOr and SRCCs OLS Combination (fit and accuracy)

Figure 5.10 above presents ARIMAXCOr and SRCCs OLS Combination model. As it is seen, this specification accurately tracks series in the out-of-sample.

Certainly, model over-estimates rental growth in 2006. Nevertheless, it pick-ups market decline in 2008 and subsequent correction in 2009 and 2010 well. Overall, model tracks dynamics of the dependent variable which subsequently makes it the best performing specification.

The following section comments on forecasting (in)accuracy in more details. It then discusses issues related to model fit, forecasting performance and increased model complexity and how it all relates to overall modelling results.

	SES	HES	BES	ARIMA	ARIMAX (BR)	ARIMAX (CCs)	ARIMAX (COr)	ARIMAX (COu)	ARIMAX (CSt)	ARIMAX (E)	ARIMAX (GDP)	SR (BR)	SR (CCs)	SR (COr)	SR (COu)	SR (CSt)	SR (E)	SR (GDP)	MR	VAR
SES	-																			
HES	0.93	-																		
	0.72																			
BES	0.97	0.96	-																	
	0.67	0.89																		
ARIMA	0.93	0.94	0.91	-																
	0.84	0.83	0.84																	
ARIMAX(BR)	0.92	0.93	0.90	0.84	-															
	0.81	0.80	0.81	0.81																
ARIMAX(CCs)	0.87	0.87	0.85	0.80	0.78	-														
	0.71	0.70	0.70	0.65	0.78															
ARIMAX(COr)	0.49	0.49	0.49	0.48	0.47	0.44	-													
	0.32	0.33	0.34	0.32	0.32	0.32														
ARIMAX(COu)	0.93	0.93	0.91	0.84	0.83	0.79	0.48	-												
	0.83	0.83	0.83	0.78	0.82	0.67	0.32													
ARIMAX(CSt)	0.92	0.92	0.90	0.84	0.83	0.78	0.47	0.83	-											
	0.81	0.80	0.80	0.82	0.82	0.78	0.32	0.83												
ARIMAX(E)	0.92	0.93	0.91	0.84	0.83	0.79	0.48	0.84	0.83	-										
	0.83	0.83	0.83	0.85	0.75	0.70	0.32	0.84	0.82											
ARIMAX(GDP)	0.59	0.60	0.59	0.58	0.56	0.53	0.36	0.57	0.56	0.57	-									
	0.42	0.42	0.42	0.42	0.42	0.42	0.36	0.42	0.42	0.42										
SR(BR)	0.97	0.96	0.98	0.90	0.88	0.83	0.48	0.90	0.89	0.89	0.58	-								
	0.80	0.80	0.77	0.80	0.78	0.67	0.32	0.79	0.77	0.80	0.42									
SR(CCs)	0.97	0.97	0.98	0.93	0.92	0.89	0.51	0.93	0.93	0.93	0.62	0.98	-							
	0.66	0.71	0.72	0.90	0.88	0.89	0.32	0.89	0.89	0.90	0.67	0.93								
SR(COr)	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.36	0.35	0.36	0.35	0.36	0.37	-						
	0.39	0.39	0.39	0.35	0.34	0.35	0.36	0.35	0.35	0.35	0.38	0.43	0.39							
SR(COu)	0.91	0.91	0.91	0.90	0.89	0.89	0.61	0.90	0.89	0.90	0.73	0.91	0.91	0.41	-					
	0.64	0.66	0.67	0.66	0.62	0.56	0.33	0.65	0.62	0.65	0.42	0.70	0.86	0.40						
SR(CSt)	0.95	0.95	0.97	0.90	0.88	0.83	0.47	0.89	0.88	0.89	0.57	0.95	0.98	0.36	0.91	-				
	0.87	0.86	0.83	0.86	0.83	0.74	0.32	0.86	0.87	0.86	0.40	0.87	0.96	0.42	0.66					
SR(E)	0.90	0.90	0.90	0.87	0.85	0.80	0.49	0.87	0.86	0.86	0.58	0.88	0.93	0.39	0.94	0.88	-			
	0.79	0.79	0.79	0.81	0.78	0.69	0.37	0.81	0.79	0.80	0.43	0.85	0.92	0.44	0.76	0.77				
SR(GDP)	0.56	0.56	0.56	0.55	0.54	0.52	0.38	0.55	0.54	0.55	0.45	0.55	0.58	0.38	0.69	0.55	0.56	-		
	0.47	0.47	0.47	0.49	0.48	0.46	0.38	0.49	0.47	0.49	0.42	0.48	0.48	0.43	0.48	0.45	0.46			
MR	0.36	0.36	0.36	0.36	0.36	0.36	0.37	0.36	0.36	0.37	0.38	0.36	0.37	0.43	0.40	0.36	0.40	0.41	-	
	0.46	0.46	0.46	0.39	0.38	0.40	0.41	0.38	0.39	0.39	0.41	0.48	0.53	0.46	0.46	0.46	0.49	0.46		
VAR	0.56	0.72	0.70	0.68	0.67	0.63	0.40	0.68	0.67	0.68	0.48	0.69	0.75	0.36	0.83	0.69	0.68	0.48	0.39	-
	0.58	0.58	0.59	0.66	0.64	0.59	0.34	0.66	0.64	0.66	0.42	0.59	0.88	0.39	0.57	0.49	0.54	0.47	0.44	

Table 5.9 Theil's U statistics for SA and OLS Combination Forecasts

NB: the top number indicates Theil's U value for SA combination; the bottom number indicates Theil's U value for OLS combination

5.4 Overall forecasting accuracy

The current research employed a number of modelling and forecasting techniques to forecast UK commercial property market. As both statistical and visual analyses suggested, none of the Exponential Smoothing models fitted the stationary rental series. The R-squared of each of the specifications was less than 0. Other statistical measures, including MSE and AIC, were also insignificant.

The analysis of ARIMA and ARIMAX model accuracy suggested that ARIMA (1,0,2) was the best fitting specification. There was no consensus between model accuracy measures which ARIMA specification fits the dependent variable best. However, ARIMA (1,0,2) model had the best properties amongst competing specifications and it tracked more than half of the deviations of the dependent variable. The least accurate was ARIMA (1,0,0) specification. Its accuracy was close to that of Exponential Smoothing models. ARIMAX GDP (4,0,0) model was the best performing specification amongst one-hundred-and-forty ARIMAX specification. The model had the highest accuracy estimates and it tracked dependent variable best. The second best specification was ARIMA (1,0,2) model with Construction Orders as an explanatory variable. The least accurate in fitting the dependent variable was ARIMAX (1,0,2) specification with Employment as an explanatory variable. These estimates corroborated earlier observations (see Section 4.4.3) that Construction Orders and GDP are significant in explaining changes in commercial property rents.

In an out-of-sample, the performance of Exponential Smoothing specifications as measured from their U value are as good as guessing or obtained using no change forecast method. Interestingly, similar estimates were obtained for ARIMA models. Theil's U valued for the best fitting ARIMA (1,0,2) model was also close to one. It all therefore adds to the observations noted in Section 2.2.3, that model fit does not guarantee forecasting performance. Regardless that ARIMA (1,0,2) model successfully tracked around fifty percent of the dynamics of the dependent variable, its application in an out-of-sample forecasting.

In section 2.2.1 it was identified that Exponential Smoothing and ARIMA(X) models are pure time-series specifications. These models are not based upon any underlying economic or financial theory and produce forecasts only capturing empirically relevant properties of selected series. Although they come from the same class of models, their performance in tracking UK commercial property rental index was different. In case of Exponential Smoothing, neither of models performed in capturing dynamics of the dependent variable. The implications are that neither Single Exponential Smoothing, nor Holt's Linear Trend, or Brown's Linear Trend specifications, which isolate trend and seasonality from irregular variations, are applicable for stationary time-series modelling.

The ARIMA and ARIMAX models performed differently. In case of ARIMA models, the estimates advocate for this modelling technique being unsuitable for long-term forecasting purposes. These findings corroborate those noted in the literature on commercial property market modelling and forecasting (Section 2.2.2). However, ARIMAX modelling out-of-sample estimates were different. The ARIMAX specifications, which contained Construction Orders and GDP as explanatory variables, performed well by tracking around seventy percent of dynamics of the dependent variable. These two specifications also performed well in out-of-sample. As it was reported in Section 5.1.2, ARIMAXCOr (1,0,2) specification had the lowest Theil's U value of all the candidate models, what made it the best performing specification.

Although it was noted in Section 2.2.2 and current estimates confirmed that ARIMA specifications are applicable only for short-term forecasting purposes only, an introduction of explanatory variable(s) into the framework significantly improved model performance both in- and out-of-sample. In the current research, ARIMA (1,0,2) specification with Construction Orders and GDP as explanatory variables improved ARIMA

(1,0,2) model performance in sample from 0.517 to 0.690 as measured by its R-squared. The out-of-sample model accuracy improved from 0.848 to 0.382 as measured by its U-coefficient. This therefore suggests that econometric specifications which incorporate past estimates of the dependent variable with a vector of key explanatory variable(s) are applicable for UK commercial property rental values forecasting.

In case of regression models, results were not uniform. Seven different Simple Regression specifications were computed using seven explanatory variables including Bank Rate, Construction Costs, Construction Orders, Construction Output, Construction Starts, Employment and GDP. The statistical analysis suggested that Construction Orders based specification was the best fitting model. The second best was GDP based model. There we no issues with the way models were parameterised and hypotheses of Heteroskedasticity were rejected. The subsequent analysis of the Construction Orders base Simple Regression model suggested positive interrelationship between dependent and explanatory variables. The equation derived from the regression estimates implied that a rise in Construction Orders by 1 generates 0.001 percentage point increase in Rents with everything else being equal.

However, regardless of the positive interrelationship between dependent and explanatory variables within Simple Regression framework, the general estimates suggested low explanatory power of this type of econometric specifications. The highest fitting Simple Regression specification was able to explain less than forty percent of the dynamics of the dependent variable.

In the out-of-sample, only two Simple Regression specifications were able to track the dependent variable. These models were Simple Regression specification with Construction Orders (SRCOr) and Simple Regression specification with GDP (SRGDP) as explanatory variable. Both models produced 60 percent greater accuracy than estimates obtained by chance. However, other five specifications generated out-of-sample results close to those of no-change strategy. As afore noted, Construction Orders and GDP were both significant in explaining UK commercial property rental series. However, one variable, regardless of how significant, is not enough to explain deviations in the dependent variable.

The Multiple Regression specification was formulated using five explanatory variables including Construction Output, Construction Costs, Construction Starts, Construction Orders and GDP. The overall performance of the Multiple Regression based model was adequate both in- and out-of-sample. The model explained more than fifty percent of deviations in the dependent variable and produced twice better out-of-sample estimates than the no-change strategy. There were no issues in the way model is parameterised, i.e. autocorrelated disturbances were not present within the model and hypothesis of Heteroskedasticity was rejected.

The comparative analysis of the Multiple Regression model with Exponential Smoothing, Simple Regression and ARIMA(X) specifications suggests that the Multiple Regression model is better than any Exponential Smoothing or Simple Regression specification in explaining UK commercial property rents. The Multiple Regression model has greater in-sample accuracy. However, its statistical estimates are poorer than of some ARIMA and ARIMAX specifications. The Multiple Regression model fit, as expressed by its R-squared value (0.553), is lower than that of ARIMA (4,0,4) model (0.589) and ARIMAX (4,0,0) GDP model (0.690). Nevertheless, the Multiple Regression framework in general proves to be useful in modelling stationary time-series.

The VAR model was the most complex specification of all computed for the current research. It was also the best fitting one. The model explained around eighty percent of the deviations of the dependent variable as expressed by its R-squared. It picked-up the main turning points in the series. Model was also successful in out-of-sample by producing more than twice greater estimates than no-change strategy. However, this out-of-sample performance was less accurate than estimates obtained from less complex specifications, such as Simple Regression model with Construction Orders as an explanatory variable, ARIMAX specification with a vector of Construction Orders and Multiple Regression equation. All this adds to the earlier suggestions that good fit does not imply good forecasting performance (Section 2.2.3), and that increased model complexity does not necessarily yield greater forecasting accuracy (Section 3.1).

The following section analyses the usefulness of Combination Forecasting. It assesses which sets of combinations generated increased modelling accuracy. It then comments the key reasons as to why certain combinations did not produce better modelling estimates.

5.5 Overall Combination Forecasting accuracy

The Chapter 3 of this thesis discussed the difficulty in using different forecasting methods. As it was indicated, as a standard procedure, property market researchers are selecting the single best model based on its accuracy or statistical complexity. However, this model selection process has been criticised as being unproductive, whereas rejected models may contain important independent information. What is more, analyst are facing dilemma in deciding which model to choose when different specifications suggest different results.

It was then commented that an alternative solution to this issue is to use improved, which mostly means more complex, modelling techniques. However, the idea of creating a more complex specification has been widely criticised. The argument that complexity does not necessarily improve modelling accuracy was presented in Section 3.1.

Accordingly, the principle of Combination Forecasting has been introduced as a useful methodology in achieving greater modelling accuracy. Various authors produced Combination Forecasting using a range of combination principles. However, it was decided to adopt a Simple and OLS based averaging for the current research. These two combination methods were established as being the key in achieving greater modelling estimates.

Following on from this, 380 combination forecasts were computed in total using Simple and OLS based combination approaches. As the modelling estimates suggested, Combination Forecasting improves overall UK commercial property forecasting accuracy. Comparing the best performing individual model (ARIMAXCOr) out-of-sample fit with the best performing combination accuracy, it is seen that the combination forecast has better statistical properties. Theil's U value for ARIMAXCOr+SRCCs OLS combination forecast is 0.32, while it is 0.33 for ARIMAXCOr (the best single model).

Accuracy of combination forecasting, however, was not uniform. Neither Simple Average (SA) combinations generated better out-of-sample estimates than the best parameterised model. The most accurate SA Combination Specification (0.35) was few points less accurate than the most accurate individual model (0.33). Not all OLS based combinations generated forecasting improvement either.

There are two main reasons why SA Combination Forecasting was not more accurate than the best performing model. Firstly, this type of combination does not account for historic accuracy of each model being combined. The SA combination combines two competing forecasts together disregarding their consequential dynamics. This particular specification estimates an average (central point) of two forecasts, which, in the current setting, does not improve modelling accuracy. Secondly, SA Combination Forecasting does not relate to the possible relationship between forecasts. The combination mechanically sums two competing forecasts disregarding interconnections between different models and variables these models contain. These estimates are in line with the criticism of Combination Forecasting discussed in Section 3.2

In case of OLS combination, accuracy improvement came from ARIMAX model combinations. As it is seen from the Table 5.9, a combination of ARIMA models with Construction Orders, Bank Rate and Construction Costs as explanatory variables is more accurate than that of any single model. The OLS Combination Forecasting appreciates the historic accuracy of competing forecasts by regressing them against the dependent variable. This therefore suggests that OLS based combination of models, which incorporate autoregressive component with an effect of key explanatory variables, such as GDP and Construction Orders, improve the overall UK commercial property cycle forecasting accuracy.

The following section summarises Chapter 5.

5.6 Summary

This chapter has presented the empirical results obtained using modelling techniques specified in Chapter 3. Modelling accuracy has been evaluated within in- and out-of-sample periods.

The results obtained using Exponential Smoothing models suggested that none of the Exponential Smoothing specifications fitted the dependent variable. The poor model fit was visually observed. All three models had their R-squared values lower than zero. Exponential smoothing modelling approach therefore proved to be unsuitable for stationary time-series modelling. The out-of-sample performance of Exponential Smoothing did not improve either. All three specifications had their Theil's U values close to one.

Subsequent analysis examined modelling and forecasting accuracy of twenty ARIMA and one-hundred and forty ARIMAX specifications. The results of the study suggested that there was no consensus between modelling accuracy measures as to which ARIMA specification fitted the dependent variable best. However, following the AICc and BIC estimates, it was then commented that ARIMA (1,0,2) was the best parameterised ARIMA specification, which also had the lowest MAPE value. The model fit, as expressed by its R-squared value, suggested that this particular specification fitted the dependent variable. Certainly, there were periods when it under- or over-estimated the dynamics of the series being modelling. Nevertheless, the model was able to explain more than half of the deviations in the series. However, In the out-of-sample, ARIMA (1,0,2) model accuracy was low. Its U value approximated to one. Following on from this, the study estimated that ARIMAX GDP (4,0,0) model had the best statistical properties amongst competing ARIMAX specifications. This particular specification had the smallest AICc and BIC values, and it fitted the historic series best.

Subsequently, seven Simple Regression specifications were computed using seven explanatory variables. The statistical analysis suggested that

Construction Orders and GDP were the best explanatory variables for Simple Regression framework. However, explanatory power of these specifications was low. The R-squared value of the Construction Orders model was 0.339, and it was 0.322 of the GDP based model. In the out-of-sample, the latter two specifications performed better. The GDP based model U value was 0.466 and the Construction Orders based model U value was 0.405. Theil's U valued for other Simple Regression specifications was close to one.

The accuracy of Multiple Regression model was not impressive neither in-sample nor out-of-sample, regardless the fact that it contained five explanatory variables. Certainly, Multiple Regression specification captured the dynamics of the dependent variable and its out-of-sample performance was better than of any Simple Regression specifications. Nevertheless, its performance was lower than that of ARIMA and ARIMAX specifications.

Vector Autoregression specification provided with the best model fit. VAR specification had the largest R-squared value amongst all competing models. However, when it came to out-of-sample forecasting, VAR model performance was not so impressive. Its Theils U value was higher than that of less complex ARIMAX and Simple Regression models.

The Combination Forecasting was produced using two principle techniques. One was Simple Averaging (SA) and second was Regression (OLS) based combination. There were 380 combination forecasts computed in total, i.e. 190 Simple and 190 OLS. The accuracy of each combination was assessed by computing their Theil's U statistical values. The modelling results suggested that Combination Forecasting improves overall forecasting accuracy. Theil's U statistics for ARIMAXCOr+SRCCs OLS combination forecasting accuracy was greater than that of the best single model.

CHAPTER 6 CONCLUSIONS

This chapter concludes the current research. A discussion of limitations and plausible explanations for unexpected results also are presented. Finally, this chapter highlights practical implications for property market participants and some avenues for further research.

6.1 Summary of the main findings

After the Global financial and property crisis of 2007-2008, it became difficult to ignore the existence of cycles in the general business sector, as well as in building and property. The issue has grown to have significant importance in the UK, as the UK property market has been characterized by boom and bust cycles with a negative impact on the overall British economy. Therefore, this research was set out to determine ways to improve forecasting accuracy of commercial property cycles in the UK.

The literature review of the thesis provided a chronological analysis of property cycle research over a one hundred year period. The particular emphasis was on research methods, data and data analysis techniques employed, and outcomes of these studies. As the review suggested, property cycles have been debated over a long period of time. Subsequently, there has been a shift in understanding on the subject. This shift was from more building/construction and population oriented explanation towards business/economic commentary. Early property cycle researchers considered property/building cycles as a local phenomenon, mostly independent from the wider economy. It was suggested that the sudden increase in population, or migration within certain areas with greater industrial opportunities, was a major driver for property/building cycles to occur. However, later studies considered property cycles as an element of the broader economy. Nowadays, analysts and investors investigate the dynamics of the property market on a global scale.

The subsequent developments in the field of property cycles research led to the construction of various mathematical models helping to explain the behaviour of the real property market. The area of property market modelling and forecasting, which was primarily developed within academia, has been quickly adopted by practitioners. Property practitioners started to employ both quantitative and qualitative research methods to arrive at the final decision. Accordingly, it has resulted in the development of forecasting models, ranging from simple single-equation methods to more advanced multi-equation with stationary data techniques.

As the research suggested, property forecasting models fall into three major categories: judgemental, univariate and multivariate. The judgemental methods are based on subjective judgement, experience, intuition and any other relevant qualitative information. Univariate methods, also known as decomposition, extrapolative or time-series methods, produce forecasts solely based on current and past values of the series being forecasted. Multivariate methods, known as explanatory or regression methods, forecast any given variable from values of one or more variables that relate to the series of interest. The key time-series models are Moving Average, Exponential Smoothing and ARIMA. The key regression models are Simple Regression, Multiple Regression, VAR and Econometric (Simultaneous Equation). However, as the discussion suggested, despite increased complexity within commercial property market modelling and forecasting, the forecasting adequacy of these specifications can be improved.

The study discussed the difficulty in using different forecasting methods. It was established that, as a standard procedure, property market researchers are selecting the single best model based on its accuracy or statistical complexity. This model selection process has been criticised as being unproductive. First of all, rejected models may contain useful independent information. It was commented that when the aim of the research is to obtain the most accurate forecast, discarding alternative models is unproductive. What is more, researchers are facing difficulty in deciding on the outcomes of research when competing specifications produce different results. The suggestion came to use improved, which mostly means more complex, modelling techniques. However, this proposition has been strongly criticised, i.e. it would require more resources, greater skills and/or additional training to those already at work. The empirical evidences from various fields of research were also not in favour of complex models.

Accordingly, the research presented the principle of Combination Forecasting as a medium helping to achieve greater predictive outcomes. This modelling approach was originally developed by economists and business researchers who were motivated that a combination of forecasts from different methods and sources generates greater predictive results. It was even recommended that Combination Forecasting should become a standard practice within forecasting. Certainly, some researchers argued that Combination Forecasting does not necessarily lead to a better forecasting performance. Nevertheless, theoretical and empirical findings, which date back more than forty years, suggested that Combination Forecasting often outperforms individual forecasts. The Combination Forecasting has been successfully applied within various fields of research, including business, economics and management, psychology, and real estate. Although application of this methodology for commercial property modelling and forecasting has been limited to residential property only.

The study established that Combination Forecasting can be produced simply by averaging different forecasts or employing more complex methods, including weighting or regression estimates. The major principle of forecast averaging is simply by computing the average of two forecasts for the forecasting period. Weighting techniques have two basic principle alternatives. One is historical weighting, which gives weights to the forecasts based on their historic fit. In many cases, each forecast is weighted according to its Mean Squared Error (MSE). Second approach is subjective weighting, which is also known as Bayesian approach. Using this approach, weights to the forecasts are assigned by forecasters themselves based upon their personal experience and judgements as to which model fits and represents the historic data best. The regression, also known as the Ordinary Least Squares (OLS), based combination approach is considered to be a more advanced combination technique.

The research adopted the principle of Combination Forecasting as a means of improving forecasting accuracy of commercial property cycles in the UK. Two combination techniques, Simple and Regression averaging, were then selected to combine univariate and regression forecasting models. The Univariate (Time-series) methods employed for the research were Exponential Smoothing (Single, Holt's Linear Trend and Brown's Linear Trend), ARIMA and ARIMAX. The Regression based models estimated for the study were Simple Regression, Multiple Regression, and Vector Autoregression.

Following on from this, the study assessed dependent and explanatory variables. The IPD All Property Rents index was chosen as a dependent variable. This index was selected since it is well regarded within UK property investment community and is regularly used by property researchers. The use of rental series as a dependent variable was governed by the suggestions that it is the most important variable for property economics.

The analysis of the data-sets of seventeen organisations and thirteen publications made it possible to collect statistical data on twenty-seven explanatory variables for the 1963-2010 period. The study employed annual chain-linking principle in situations when time-series were of limited length. All time-series were then tested for stationarity. Subsequently, a combination of variable reduction techniques enabled to select seven key explanatory variables which were then used for modelling. These variables were Bank Rate, Construction Costs, Construction Orders, Construction Output, Construction Starts, Employment, and GDP.

All time-series were divided into initialisation and hold-out periods accordingly. Initialisation period was for 1963-2000. The hold-out periods was for 2001-2010. Modelling accuracy was assessed by computing Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Mean Squared Error (MSE), as well as Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The out-of-sample modelling accuracy was examined by estimating Theil's second inequality coefficient 'U_2'. These accuracy measures were established as being the most commonly used within commercial real estate research and applicable for the current study.

Following on from this, the study assessed whether combination forecasts from different forecasting techniques are more accurate than single model outputs. It investigated which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts more accurately.

The study compared the forecasting ability of eight alternative modelling techniques and a Combination Forecasting to forecast the UK commercial property market rents. The best fitting individual model proved to be VAR specification. Its R-squared was the greatest of all sample models. The AICc also indicate it to be the best parameterised model. However, these results did not come as a surprise. The VAR model comprised key explanatory variables, including Construction Starts, Construction Output, Construction Orders, Construction Costs and GDP, their lagged values as well as past values of the dependent variable itself.

However, despite its goodness of fit, this specification did not produce accurate forecasts. It therefore suggested that goodness of fit does not imply good forecasting performance. The best individual model forecast was obtained from the ARIMAX (1,0,2) specification with Construction Orders as an explanatory variable (ARIMAXCOr). Subsequently, Combination Forecasts were produced using two principle techniques, i.e. Simple Averaging (SA) and Regression (OLS) combination. As results of the study suggested, the ARIMAXCOr+SRCCs OLS combination forecast had better statistical properties than the best single model. It therefore suggested that combination approach and OLS combination in particular is used for commercial property cycle forecasting accuracy improvement.

These findings extend to a practical application of the Combination Forecasting in UK commercial property market modelling field. Often analysts/researchers have access to few competing modelling estimates. It is likely, that these estimates diverge. Therefore, a standard procedure in econometrics, when a single best model is selected based on its accuracy or its statistical complexity/sophistication, is ineffective. As it was commented throughout the current study, rejected methods may contain useful independent information. What is more, model complexity does not necessarily yield greater modelling results. In that case, when a few alternative models are available, the best approach is to combine them.

The following section present limitations which were unavoidable while conducting this research project.

6.2 Limitations of the research

Although this research was carefully executed, there were some unavoidable limitations. First of all, the modelling was conducted using PASW 18 (SPSS) statistical package. As the discussion in Section 3.3.1 suggested, PASW 18 is a comprehensive software package allowing for time-series modelling. However, it is considered to be a generalised statistical package and that research would benefit if all modelling was done with more specialised software. Hence, it would allow computing Structural econometric specification. This would therefore allow for the employment of all real estate forecasting methods indicated in Figure 2.3 (Section 2.2.1).

The research employed twenty-seven explanatory variables which were obtained from statistical tables of seventeen organisations and thirteen publications. However, there was a small number of key variables for which data was not available. These particular variables were Business Orders, Consumer Confidence, Floor-space, Index of Services, Retail Sales, Take-up, Business Turnover, Risk Premium and Vacancy Rate. The introduction of these variables would certainly enable obtaining additional insights into the dynamics of the UK commercial property market.

Additionally, the study used annual time series over the 1963-2010 period. This gave thirty-seven data points. Although it was established that this length is enough to build a reliable and well parameterised model, the study would benefit from a longer series. This would allow for the estimation of a greater interdependence between dependent and explanatory variables as well as obtaining more accurate autoregressive component.

The next section discusses the practical implications of this research for property market participants.

6.3 Implications for property market participants

After the global financial and property crisis of 2007-2013, neither the general business sector nor building and property sectors ignore the existence of cycles. The cycle issue has grown to have significant importance in the UK, as the UK property market has been characterized by boom and bust cycles with a negative impact on the overall UK economy. Property participants realised that a sound grasp of property cycles is a key determinant of financial success or failure.

The current research examined the UK commercial property market cycle forecasting accuracy and its improvement through Combination Forecasting. Firstly, a chronological analysis of property cycle research over a one hundred year period was presented. The particular emphasis was on research methods, data and data analysis techniques employed, and outcomes of these studies. As the review suggested, property cycles have been debated over a long period of time. Subsequently, there has been a shift in understanding on the subject. This shift was from a more building/construction and population oriented explanation towards business/economic commentary. Secondly, the study discussed developments in the field of property cycles research and various cycle theories. Following on from this, the research commented on the application of econometrics in assessing cycle duration. Finally, it assessed whether Combination Forecasts from different forecasting techniques are better than single model outputs. It examined which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts best. As the results of the study suggested, Combination Forecasting is useful in improving UK commercial property cycle forecasting accuracy.

The results of the current research inform real estate market participants. A greater awareness of cycles and the ability to forecast them more accurately could be useful for both the private and public sectors in examining economic issues. The existence of business cycles implies that the economy has its rhythm and dynamic behaviour. Analysts, who can recognise short and long property cycles, determine their repetitive nature, and subsequently estimate future direction, are well positioned to anticipate changes in the economy and property market better.

For investors and portfolio managers, this updated knowledge of forecasting accuracy improvement through Combination Forecasting allows making better investment decisions. A greater understanding of the length of the cycles and improved forecasting accuracy can enrich their strategies. A better appreciation of market timing allows them to allocate funds more effectively. For property developers, an increased market timing knowledge is even more crucial. Considering, that property market lags the general economy by around 2 years (as mentioned above, construction lag depends on the nature of the project as well as its complexity and location), having a greater appreciation of the property market cycle and the existing situation, allows developers to plan projects with a greater accuracy. Knowing where they are in the cycle and having obtained more accurate forecasting estimates, developers can subsequently either build new projects in the anticipation that once projects are completed, the general economy will be in the upturn and therefore there will be a demand for property, or they can acquire new sites when economy and property market is in correction, so that when the economy recovers, they can start building. Additionally, policy makers, wary of future crashes, could bring real estate cycle insights to bear on future policy design to guide the general economy towards stability.

This research has thrown up many questions in need of further investigation. The following section presents some possible future research avenues.

6.4 Further related work

The study was not able to explore all the issues that have come up during the course of the research and the author is aware that more exists to be researched in this field. The further related work could assess alternative combination techniques, examine whether combination of more than two forecasting models further improves the accuracy of commercial property forecasting, assess effectiveness of Combination Forecasting within shorter/longer out-of-sample period, as well as establish whether Combination Forecasting is applicable in forecasting alternative real estate indicators.

As it was discussed in section 3.2.2, there is a number of forecasting combination techniques available to researches. One of them is the weighting approach. It was suggested that weighting is computed using model historic fit which is mostly derived from Mean Squared Error (MSE) estimates of each competing forecast, or it can be assigned by modellers themselves based on their experience and judgement. Certainly, weighting combination was an object of some heavy criticism. Nevertheless, further research in this direction can yield additional insights into the accuracy improvement through Weighting Combination.

The research employed a combination of two competing forecasts within its framework. The combination of two models came up from the literature review where it was established that in case of OLS Combination Forecasting, a combination of more than two models can yield negative results. However, a further research could assess whether combination of three and more models does improve the accuracy of commercial property forecasting.

A future study investigating effectiveness of Combination Forecasting within shorter/longer out-of-sample periods could also be very interesting. The current study adopted 10-year out-of-sample period. However, considering different properties of univariate and multivariate modelling techniques, which were discussed in Section 2.2.1, it would be useful to assess the forecasting accuracy of each model and their combination within different time scale.

Further, research could assess whether the principle of Combination Forecasting is applicable in modelling real estate indicators. The current research employed rental index as the dependent variable. The use of this particular variable came from the suggestions that rent dynamics is of particular importance for investors and analysts. It was commented that rent acts as an agent which brings four inter-related property markets, i.e. user, financial, development and land market into simultaneous equilibrium. However, further studies could examine the applicability of Combination Forecasting to model real estate returns, yields and other property market indicators.

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APPENDIX A. Time-series used for the research

Year	IPD Rents	Bank Rate	Business Output	Car Registrations	Construction Orders
	% p.a.	% p.a.	index	000's	£ mill
1963	8.33	4.00	11	1,466	
1964	11.54	6.00	11.6	1,711.2	14,612.59
1965	10.34	6.00	12.2	1,600.7	12,088.61
1966	9.38	7.00	12.5	1,493.6	10,819.20
1967	8.57	6.42	13.7	1,575.2	8,982.52
1968	7.89	7.25	13.8	1,561.9	9,781.19
1969	2.44	8.00	14.3	1,401.8	10,187.07
1970	9.52	7.25	15.2	1,524.9	11,778.61
1971	17.39	5.50	15.9	1,741.6	14,505.69
1972	14.81	6.00	16.6	2,183.7	14,603.43
1973	20.97	9.23	17.6	2,230.3	14,479.09
1974	22.67	12.13	18.2	1,750.40	10,341.50
1975	8.70	10.85	18.8	1,749.90	7,869.93
1976	1.60	11.68	19.6	1,838.00	8,934.07
1977	4.70	8.96	20.3	1,862.00	9,352.23
1978	9.80	9.04	21.5	2,151.40	11,067.05
1979	14.60	14.00	22.9	2,369.90	10,040.59
1980	12.50	15.00	23.7	2,155.80	10,481.20
1981	7.92	12.00	24.7	2,030.30	12,592.29
1982	3.77	11.89	26.3	2,103.90	12,823.37
1983	2.84	9.93	28.4	2,307.50	13,086.93
1984	4.23	10.02	30.6	2,238.90	15,447.97
1985	6.49	12.52	32.4	2,309.30	16,366.69
1986	9.86	10.94	36	2,333.70	18,735.94
1987	19.27	9.38	38	2,473.90	24,284.44
1988	22.84	9.46	41.5	2,723.50	28,786.56
1989	15.07	10.00	42.2	2,828.90	29,260.90
1990	2.77	13.88	43.8	2,438.70	24,219.92
1991	-8.53	11.88	43.1	1,921.50	19,684.24
1992	-11.93	8.38	41.9	1,901.80	16,620.22
1993	-7.87	5.63	43.1	2,073.90	16,867.12
1994	-0.94	5.63	46.7	2,249.00	17,545.45
1995	0.38	6.50	49.1	2,306.54	18,676.86
1996	3.19	5.92	52.7	2,410.12	20,310.51
1997	7.68	6.75	57.1	2,597.71	22,537.09
1998	7.33	6.94	63.2	2,740.00	26,267.90
1999	5.68	5.42	67.8	2,766.00	23,552.22
2000	7.01	5.88	73.5	2,871.00	23,745.69
2001	3.40	4.96	77.8	3,138.00	23,214.21
2002	-0.85	4.00	78.9	3,229.00	22,076.48
2003	-1.58	3.67	83.1	3,231.90	19,836.03
2004	2.29	4.38	87.9	3,185.44	22,790.70
2005	2.69	4.50	93.6	3,021.37	24,319.16
2006	4.24	4.88	100	2,913.58	30,886.63
2007	4.30	5.50	106.9	2,996.91	31,587.63
2008	-1.20	3.95	109.3	2,672.19	22,922.01
2009	-7.90	1.00	102.6	2,371.21	13,289.57
2010	-0.80	0.50	103.5	2,400.00	14,755.00

Year	Construction Completions		Construction Starts	Consumer Confidence	Consumer Expenditure
	Construction Output	**House building Completions**			
	£ mill	numbers	numbers	index	£
				444,647	
1963	8147.69	307,710		409,593	19,547
1964	8685.53	383,190		395,717	20,865
1965	9301.38	391,230		466,973	22,149
1966	9311.81	396,010		411,366	23,386
1967	9738.58	415,460		358,263	24,566
1968	9247.58	425,830		332,703	26,455
1969	9446.82	378,330		359,202	28,054
1970	9751.99	362,230		366,297	30,541
1971	10549.92	364,480		342,823	34,226
1972	10250.20	330,940		262,907	38,787
1973	10467.79	304,640	97.71	336,876	44,511
1974	9615.23	279,630	95.70	339,484	51,356
1975	8765.71	322,000	98.44	278,556	63,038
1976	7745.16	324,840	101.05	276,157	73,243
1977	7704.11	314,160	104.81	234,843	83,823
1978	8499.01	288,690	101.60	161,813	96,656
1979	8088.24	251,820	96.83	160,874	114,693
1980	8098.97	242,000	96.60	202,084	133,174
1981	8208.42	206,630	99.76	230,252	148,052
1982	9255.73	182,850	102.47	207,718	162,228
1983	9454.04	209,030	101.32	208,552	178,027
1984	10205.03	220,410	98.05	222,950	191,390
1985	11072.08	207,470	98.68	240,581	209,382
1986	12226.87	216,540	102.35	262,699	232,095
1987	14599.25	226,230	102.32	209,387	255,361
1988	16690.29	242,360	99.61	171,203	288,346
1989	21252.29	221,460	96.82	171,620	315,822
1990	23821.30	203,230	97.93	170,690	343,041
1991	20874.32	191,450	98.05	164,150	364,586
1992	17168.49	179,690	97.70	193,380	384,131
1993	14411.28	186,070	98.26	211,420	406,813
1994	14364.03	193,970	99.85	178,390	426,710
1995	14774.00	199,930	101.20	185,850	448,720
1996	16329.08	189,270	103.58	200,820	482,041
1997	18285.60	191,110	102.24	187,930	512,482
1998	19867.94	181,020	101.72	191,120	546,887
1999	22386.69	181,990	101.69	186,190	582,371
2000	22461.23	176,850	101.43	192,070	616,558
2001	22320.95	174,080	101.66	194,370	647,777
2002	22887.13	181,960	101.05	208,570	680,964
2003	22253.74	190,490	101.97	227,990	714,605
2004	23560.97	203,490	102.19	223,900	749,867
2005	23672.56	209,580	101.34	223,970	784,140
2006	26462.61	212,800	101.55	228,650	819,610
2007	29429.60	225,330	97.21	134,500	861,695
2008	30006.73	182,960	97.64	106,820	892,194
2009	22947.12	152,630	99.41	130840	874,380
2010	23025.56	134080			919,310

Year	Depreciation	Real household disposable income	Employment	Foreign Direct Investment	GDP Growth
	£ mill	index	000's	$ mill	% p.a.
1963	59	143.8	11406.08		4.30
1964	67	148.9	11682.38	-24.90	5.48
1965	68	150.8	12199.55	29.02	2.23
1966	75	153.4	12579.75	24.10	1.93
1967	77	154.8	12933.98	14.56	2.47
1968	83	156.9	13059.14	41.53	4.20
1969	86	157.7	13266.95	-10.98	2.07
1970	96	163.0	13545.61	39.24	2.24
1971	109	164.1	13701.47	17.55	2.09
1972	130	177.2	13956.51	-33.97	3.66
1973	165	188.0	14509.11	130.91	7.20
1974	226	186.1	15257.70	69.45	-1.31
1975	293	187.5	15619.02	-19.35	-0.62
1976	362	186.5	16202.31	8.94	2.64
1977	458	182.5	16665.16	53.95	2.38
1978	568	195.9	16847.00	-22.89	3.23
1979	732	207.2	17259.00	54.40	2.69
1980	946	210.2	17465.00	43.73	-2.03
1981	1145	209.2	17210.00	-32.67	-1.22
1982	1319	209.2	17165.00	3.23	2.20
1983	1438	213.6	17211.00	11.83	3.69
1984	1620	221.3	17859.00	-105.33	2.69
1985	1866	228.4	18217.00	-2593.92	3.62
1986	2191	237.6	18424.00	29.60	4.01
1987	2655	241.0	18909.00	64.02	4.56
1988	3075	254.0	19666.00	31.89	5.03
1989	3817	265.5	20283.00	51.94	2.28
1990	4813	276.8	20733.00	-0.50	0.78
1991	5643	281.2	20459.00	-51.93	-1.39
1992	5928	288.1	20408.00	2.38	0.15
1993	6104	296.1	20313.00	16.22	2.22
1994	6234	299.5	20532.00	-35.13	4.28
1995	6574	306.5	20908.00	94.83	3.05
1996	7129	315.1	21170.00	26.99	2.89
1997	7098	327.5	21679.00	30.38	3.31
1998	7843	333.4	21824.00	96.74	3.61
1999	8787	341.7	22403.00	22.22	3.47
2000	9391	354.9	22959.00	46.31	3.92
2001	9817	369.2	23497.00	-53.64	2.46
2002	10558	375.4	23886.00	-55.07	2.10
2003	11325	385.1	24361.00	-0.04	2.81
2004	12022	387.3	24762.00	86.03	2.95
2005	12809	392.5	25205.00	213.53	2.17
2006	13138	393.1	25602.00	-13.24	2.79
2007	13377	392.3	25822.00	18.21	2.68
2008	14390	397.9	26152.00	-50.40	-0.07
2009	15522	399.0	25843.00	-22.01	-4.87
2010		395.9	25662.00	-41.58	1.40

Year	FTSE All-Share Index	Lagged Dependent Variable	Gilts-Treasury Bills-Yields	
			2.5% Consolidated Stock Average Yield	Par yield (20 years)
	index	% p.a.	%	%
1963	107.86		5.59	5.44
1964	97.07	8.33	6.03	5.96
1965	103.6	11.54	6.42	6.60
1966	93.95	10.34	6.81	7.10
1967	121.18	9.38	6.70	6.98
1968	173.72	8.57	7.40	7.75
1969	147.34	7.89	8.89	9.29
1970	136.26	2.44	9.17	9.47
1971	193.39	9.52	9.07	9.09
1972	218.18	17.39	9.13	9.14
1973	149.76	14.81	10.85	11.00
1974	66.89	20.97	14.95	15.17
1975	158.08	22.67	14.68	14.78
1976	151.96	8.70	14.25	14.82
1977	214.53	1.60	12.31	13.07
1978	220.22	4.70	11.92	12.81
1979	229.79	9.80	11.38	13.34
1980	291.99	14.60	11.86	14.15
1981	313.12	12.50	12.99	15.14
1982	382.22	7.92	11.90	13.23
1983	470.50	3.77	10.24	11.09
1984	592.94	2.84	10.15	10.71
1985	682.94	4.23	10.11	10.78
1986	835.48	6.49	9.47	10.13
1987	870.22	9.86	9.31	9.73
1988	926.59	19.27	9.12	9.61
1989	1204.70	22.84	9.26	9.84
1990	1032.25	15.07	10.88	11.38
1991	1187.70	2.77	9.99	10.19
1992	1363.79	-8.53	9.16	9.37
1993	1682.15	-11.93	7.69	8.07
1994	1521.44	-7.87	8.18	7.81
1995	1803.09	-0.94	8.24	8.09
1996	2013.66	0.38	8.03	8.16
1997	2411.00	3.19	7.15	6.99
1998	2673.92	7.68	5.59	5.34
1999	3242.06	7.33	4.87	4.51
2000	2983.81	5.68	4.93	4.42
2001	2523.88	7.01	4.99	4.67
2002	1893.73	3.40	5.04	4.75
2003	2207.38	-0.85	4.87	4.64
2004	2410.75	-1.58	4.79	4.69
2005	2847.02	2.29	4.45	4.34
2006	3221.42	2.69	4.24	4.17
2007	3286.67	4.24	4.62	4.56
2008	2209.29	4.30	4.60	4.66
2009	2761.00	-1.20	4.54	4.45
2010	3063.00	-7.90	4.66	4.47

Year	Money Supply		Profitability	UK House Price Index	Inflation
	Broad (M4)	Narrow (M0)			
	£ bn	£ bn	£ bn	index	% p.a.
1963	14.80	2.40	936	150.20	2
1964	15.90	2.56	1036	164.20	3.3
1965	17.40	2.73	959	177.30	4.8
1966	18.50	2.89	915	187.30	3.9
1967	20.90	2.87	977	197.50	2.5
1968	22.70	3.12	1050	212.10	4.7
1969	23.80	3.90	1009	223.30	5.4
1970	26.60	3.80	1095	236.90	6.4
1971	31.00	4.10	1201	270.10	9.4
1972	38.20	4.40	1343	368.10	7.1
1973	46.60	4.90	1244	478.40	9.2
1974	51.70	5.40	968	533.00	16
1975	57.80	6.20	1174	573.60	24.2
1976	64.40	7.00	1190	627.60	16.5
1977	74.00	7.80	1239	677.20	15.8
1978	85.20	8.90	1365	807.20	8.3
1979	97.50	10.10	1306	1048.80	13.4
1980	114.30	10.90	1267	1231.70	18
1981	137.80	11.50	1351	1266.90	11.9
1982	153.90	11.90	1542	1314.40	8.6
1983	174.20	12.60	1669	1461.00	4.6
1984	198.20	13.30	1760	1643.60	5
1985	224.10	13.90	1743	1818.20	6.1
1986	258.00	14.50	1801	1990.00	3.4
1987	304.50	15.20	1937	2282.90	4.2
1988	357.30	16.20	2148	2718.80	4.9
1989	425.70	17.20	1580	3253.40	7.8
1990	477.40	18.10	1398	3050.80	9.5
1991	504.60	18.50	1306	2889.10	5.9
1992	518.20	19.00	1136	2740.50	3.7
1993	543.40	19.90	1196	2708.50	1.6
1994	566.30	21.20	1274	2730.90	2.4
1995	622.40	22.40	1135	2710.30	3.5
1996	681.60	24.00	1242	2824.00	2.4
1997	719.90	25.50	1440	3131.00	3.1
1998	782.00	27.00	1347	3448.40	3.4
1999	813.70	28.90	1469	3761.60	1.5
2000	881.60	31.20	1433	4250.50	3
2001	940.00	33.50	1457	4696.50	1.8
2002	1006.10	36.20	1586	5627.80	1.7
2003	1077.90	38.80	1345	6730.00	2.9
2004	1174.50	41.20	1792	7862.40	3
2005	1322.90	43.00	1529	8267.90	2.8
2006	1493.30	45.20	1594	8804.50	3.2
2007	1671.00	47.30	1548	9592.20	4.3
2008	1933.90	50.20	889	8936.90	4
2009	2038.50	54.30	847	8277.80	-0.5
2010	2152.70	57.00	883	8752.30	4.6

Year	ONS leading indicators		Unemployment	Vacancy Rate	Job Vacancies
	Index of Services	Index of Production			
	index	index	% p.a.	%	000's
1963		52.6	2.2		23,914
1964		57.00	1.6		24,241
1965		58.60	1.4		24,531
1966		59.50	1.4		24,720
1967		59.90	2.2		24,254
1968		64.50	2.3		24,084
1969		66.70	2.3		24,051
1970		67.00	2.4		23,897
1971		66.70	4.2		23,543
1972		67.90	4.4		23,547
1973		74.00	3.7		24,132
1974		72.50	3.7		24,271
1975		68.60	4.5		24,186
1976		70.80	5.4		23,990
1977		74.50	5.6		24,079
1978		76.60	5.6		24,244
1979		79.50	5.4		24,663
1980		74.30	6.9		24,470
1981		72.00	9.8		23,308
1982		73.40	10.9		22,799
1983		76.00	11.6		22,421
1984		76.10	11.9		22,613
1985		80.30	11.4		22,812
1986		82.20	11.4		22,776
1987		85.50	10.5		22,989
1988		89.70	8.6		23,708
1989		91.50	7.2		24,149
1990		91.30	7.2		24,450
1991		88.20	8.9		23,774
1992		88.50	10.1		23,392
1993		90.40	10.5		23,014
1994		95.30	9.6		23,095
1995		97.00	8.7		23,475
1996	3.60	98.30	8.2		23,789
1997	4.20	99.70	7.0		24,401
1998	5.20	100.70	6.3		24,775
1999	4.60	102.20	6.0		25,168
2000	4.80	104.10	5.6		25,744
2001	3.60	102.50	5.1	6.80	26,100
2002	2.40	100.80	5.2	9.50	26,244
2003	3.50	100.20	5.1	14.50	26,324
2004	3.50	101.20	4.9	15.30	26,566
2005	3.10	100.00	4.9	12.00	26,970
2006	4.00	100.00	5.5	8.70	27,287
2007	3.50	100.10	5.4	5.10	27,426
2008	0.50	97.00	5.8	5.70	27,645
2009	-3.20	87.20	7.8	9.70	27,048
2010	1.10	89.10	8.0	8.10	26,615

Year	Goss Capital Formation	Total Returns	Index of Land Prices	Risk Premium	Construction Costs
	£ mill	% p.a.	index	%	index
1963	3,484,779,541	10.30	40		5.42
1964	3,655,323,394	8.30	56		5.61
1965	4,351,000,000	4.70	63		5.87
1966	4,608,000,000	3.20	67		6.10
1967	4,921,000,000	7.90	68		6.25
1968	5,296,000,000	21.30	79	-0.32	6.55
1969	5,571,000,000	5.20	98	-0.96	6.88
1970	6,367,000,000	24.60	100	-1.01	7.33
1971	6,963,000,000	16.10	114	0.23	8.01
1972	7,394,000,000	29.50	192	1.92	8.60
1973	9,087,000,000	28.50	298	2.00	9.39
1974	11,504,000,000	-16.20	296	-1.29	10.89
1975	13,965,000,000	11.50	204	-2.37	13.50
1976	16,535,000,000	9.40	204	0.20	15.75
1977	19,092,000,000	26.50	216	0.11	18.26
1978	22,012,000,000	25.70	263	0.97	19.75
1979	25,912,000,000	23.00	373	0.74	22.41
1980	29,003,000,000	17.50	492	0.92	26.45
1981	29,300,000,000	15.00	512	1.05	29.59
1982	31,712,000,000	7.50	576	0.26	32.13
1983	33,469,000,000	7.60	649	0.42	33.59
1984	38,202,000,000	8.60	733	0.20	35.28
1985	42,899,000,000	8.30	952	0.38	37.41
1986	43,137,000,000	11.10	1,101	0.73	38.68
1987	50,257,000,000	25.80	1,600	0.50	40.29
1988	60,555,000,000	29.70	2,091	0.39	42.27
1989	74,981,000,000	15.40	2,063	0.49	45.56
1990	78,284,000,000	-8.40	1,869	0.64	49.87
1991	72,073,000,000	-3.20	1,776	0.66	52.78
1992	68,560,000,000	-1.70	1,591	0.72	54.65
1993	66,807,000,000	20.00	1,554	0.48	55.51
1994	72,069,000,000	12.00	1,785	0.70	56.86
1995	80,447,000,000	3.50	1,878	0.32	58.84
1996	90,414,000,000	10.00	2,026	0.36	60.27
1997	97,487,000,000	16.80	2,035	0.18	62.14
1998	112,796,000,000	11.80	2,192	0.10	65.31
1999	115,795,000,000	14.50	2,590	0.38	69.01
2000	118,917,000,000	10.40	3,053	0.30	72.80
2001	118,334,000,000	6.79	3,793	0.18	77.66
2002	118,172,000,000	9.64	4,505	0.32	84.38
2003	117,167,000,000	10.85	5,322	0.14	89.48
2004	117,736,000,000	18.33	12,247	0.13	95.10
2005	137,984,000,000	19.10	13,378	-0.03	100.00
2006	127,938,000,000	18.10	14,382	0.09	103.82
2007	143,848,000,000	-3.40	15,704	0.00	108.25
2008	144,518,000,000	-22.10	14,748	0.00	109.14
2009	121,282,000,000	3.50	10,356	0.32	103.02
2010	127,184,000,000	14.50	9,667	0.10	99.13

Year	Floor-space	Number of property transactions	Turnover	Retail Sales	Net Investment
	mill., sq.m.	000's	£ mill	% p.a.	£ mill
1963					920
1964					1016
1965		11.40			1151
1966		10.30			1658
1967		10.40			1873
1968		10.50			2152
1969		10.50			2518
1970		9.60			2917
1971		9.90			3429
1972		10.20			3839
1973		10.00			5353
1974		7.30			6196
1975		6.50			7499
1976		6.90			9042
1977		8.70			12097
1978		9.20			15013
1979		8.90			18467
1980		8.50			22977
1981		8.30			26878
1982		9.40			29419
1983		10.60			31306
1984		11.30			34432
1985		11.60			36523
1986	6.61	10.70			40093
1987	6.63	11.10			47792
1988	6.54	11.70			61216
1989	6.71	11.30		2.70	70727
1990	6.96	10.40		1.30	66068
1991	7.41	9.80		-2.10	61038
1992	7.76	9.70		0.20	53836
1993	7.82	10.50		2.50	59779
1994	7.8	11.40		3.20	64675
1995	7.66	11.50		0.50	60957
1996	7.65	12.10		2.90	62740
1997	7.67	12.30		4.20	73126
1998	7.42	12.30		2.20	74202
1999	7.46	12.00		2.60	85376
2000	7.71	11.90	9881.20	4.00	87523
2001	7.82	11.50	18026.10	5.50	87656
2002	7.95	11.70	18717.00	6.40	89679
2003	8.24	12.10	19067.10	3.20	94275
2004	8.23	12.50	18867.30	6.20	97895
2005	7.91	12.60	18941.10	2.50	103860
2006	7.64	13.20	20537.30	3.00	107914
2007	7.54	13.60	21463.00	3.50	110977
2008	7.91	13.30	21359.40	2.20	79910
2009	8.23	11.30	17624.50	1.60	75109
2010	8.22	11.50	20643.40	1.50	

APPENDIX B. Model estimates

B.1 In-sample

Year	IPD Rents (1st.dif)	ARIMA Order				
		100	101	102	103	104
1964	3.21	0.048	0.123	-0.167	-0.175	-0.169
1965	-1.19	1.342	1.483	0.792	0.855	0.994
1966	-0.97	-0.461	-1.575	-2.130	-2.350	-2.324
1967	-0.80	-0.370	0.709	0.333	0.364	0.163
1968	-0.68	-0.302	-0.988	-1.242	-1.335	-1.240
1969	-5.46	-0.249	0.474	0.301	0.318	0.228
1970	7.08	-2.209	-4.303	-3.357	-3.694	-3.676
1971	7.87	2.933	9.229	8.012	8.988	8.503
1972	-2.58	3.253	-1.965	-4.072	-4.713	-3.532
1973	6.15	-1.028	-0.112	-1.455	-1.601	-2.050
1974	1.70	2.551	5.058	2.012	2.295	2.276
1975	-13.97	0.725	-3.095	-5.512	-6.300	-5.484
1976	-7.10	-5.700	-8.149	-7.618	-8.295	-8.764
1977	3.10	-2.881	1.911	3.197	3.694	2.956
1978	5.10	1.299	0.871	1.233	1.349	1.830
1979	4.80	2.119	3.440	2.872	3.144	3.151
1980	-2.10	1.996	0.840	-0.815	-0.933	-0.668
1981	-4.58	-0.833	-2.339	-2.977	-3.339	-3.243
1982	-4.16	-1.849	-1.411	-1.502	-1.564	-1.831
1983	-0.93	-1.676	-1.932	-0.970	-1.085	-1.060
1984	1.39	-0.352	1.176	1.821	2.094	1.883
1985	2.26	0.599	0.178	0.683	0.688	0.900
1986	3.37	0.954	1.815	1.598	1.804	1.712
1987	9.41	1.411	1.201	0.388	0.355	0.576
1988	3.56	3.886	6.712	3.596	3.995	3.985
1989	-7.77	1.490	-3.207	-6.390	-7.250	-6.393
1990	-12.30	-3.157	-3.231	-4.456	-4.792	-5.291
1991	-11.30	-5.013	-6.921	-5.753	-6.349	-6.362
1992	-3.40	-4.604	-2.659	0.851	1.109	0.482
1993	4.05	-1.365	-0.165	3.193	3.513	3.466
1994	6.94	1.690	3.616	6.217	6.890	6.751
1995	1.31	2.873	2.450	3.065	3.261	3.601
1996	2.81	0.566	-1.077	0.000	-0.021	0.014
1997	4.49	1.180	3.452	3.168	3.493	3.302
1998	-0.34	1.868	0.593	-0.177	-0.263	0.116
1999	-1.65	-0.113	-0.701	-1.515	-1.708	-1.668
2000	1.33	-0.649	-0.563	-0.853	-0.915	-1.019

Year	ARIMA Order					
	200	201	202	203	204	300
1964	0.029	0.118	-0.184	-0.295	-0.215	0.029
1965	1.357	1.415	0.944	1.050	1.150	1.357
1966	-2.051	-1.736	-2.555	-2.536	-2.203	-2.051
1967	-0.046	0.875	0.302	-0.005	-0.478	-0.046
1968	-0.042	-1.049	-1.398	-1.705	-1.834	-0.042
1969	-0.037	0.564	0.294	-0.073	-0.025	-0.037
1970	-2.940	-4.546	-3.925	-4.199	-2.961	-2.939
1971	6.570	10.247	9.625	8.672	7.200	6.569
1972	1.698	-3.158	-4.936	-4.595	-2.850	1.699
1973	-4.859	0.149	-1.982	-2.439	-1.672	-4.860
1974	4.788	5.370	2.402	0.919	-0.054	4.787
1975	-1.582	-3.885	-6.892	-7.726	-6.726	-1.581
1976	-9.026	-8.308	-9.033	-10.232	-8.934	-9.026
1977	1.741	2.999	3.896	1.794	0.994	1.741
1978	4.892	0.636	1.660	0.372	1.337	4.894
1979	1.745	3.677	3.357	2.287	4.319	1.746
1980	0.715	0.399	-0.945	-1.885	0.627	0.715
1981	-3.270	-2.494	-3.689	-4.344	-2.816	-3.271
1982	-1.811	-1.323	-1.697	-2.827	-2.951	-1.811
1983	-0.504	-1.850	-1.163	-1.816	-2.146	-0.504
1984	1.241	1.447	2.311	1.440	1.464	1.241
1985	1.249	0.067	0.803	0.628	1.745	1.249
1986	0.778	1.946	1.964	1.527	2.586	0.779
1987	1.073	1.061	0.374	0.051	0.914	1.073
1988	4.198	7.170	4.157	2.104	2.544	4.198
1989	-1.856	-4.408	-7.829	-9.290	-6.965	-1.856
1990	-6.124	-2.854	-5.413	-8.020	-6.597	-6.124
1991	-3.999	-7.390	-6.787	-8.651	-7.747	-3.999
1992	-1.477	-1.740	1.171	-0.494	-0.496	-1.476
1993	2.808	-0.224	4.041	3.674	4.326	2.809
1994	3.886	4.279	7.510	7.801	8.949	3.888
1995	2.435	1.857	3.732	5.056	6.485	2.436
1996	-2.146	-1.095	-0.012	2.137	2.197	-2.146
1997	1.140	3.603	3.758	5.158	2.969	1.139
1998	1.505	0.428	-0.300	1.151	-0.850	1.504
1999	-2.091	-0.984	-1.879	-0.693	-2.175	-2.091
2000	-0.813	-0.363	-1.090	-0.447	-1.701	-0.814

Year	ARIMA Order					
	301	**302**	**304**	**304**	**400**	**401**
1964	-0.224	-0.213	-0.223	-0.187	-0.048	-0.044
1965	1.217	1.164	1.162	0.970	1.263	1.270
1966	-2.441	-2.535	-2.475	-2.059	-2.088	-2.090
1967	-1.026	-0.325	-0.315	-0.280	-0.018	-0.018
1968	-0.694	-1.361	-1.566	-1.384	-1.913	-1.913
1969	-0.464	0.040	0.000	0.642	0.370	0.450
1970	-2.399	-3.529	-3.576	-3.251	-2.612	-2.710
1971	5.117	7.925	7.943	6.812	7.940	8.074
1972	1.019	-2.642	-3.207	-2.712	-1.456	-1.504
1973	-5.558	-3.046	-2.608	-0.691	-1.739	-1.651
1974	0.522	1.062	0.587	0.413	4.178	4.187
1975	-4.408	-5.965	-6.690	-5.345	-7.947	-7.958
1976	-9.828	-9.878	-9.863	-6.894	-6.200	-6.078
1977	-0.105	1.869	1.594	1.510	2.346	2.238
1978	4.647	2.486	1.797	0.977	1.149	1.150
1979	2.488	3.535	3.614	4.594	5.797	5.975
1980	0.252	-0.456	-0.440	0.289	4.033	3.879
1981	-3.752	-3.559	-3.397	-4.343	-4.433	-4.619
1982	-2.789	-2.496	-2.449	-3.211	-2.468	-2.421
1983	-0.738	-1.125	-1.291	-0.111	-2.625	-2.626
1984	1.611	1.889	1.884	3.152	1.748	1.843
1985	2.063	1.483	1.445	0.380	2.393	2.368
1986	1.378	1.837	2.060	0.331	2.189	2.153
1987	0.740	0.708	0.738	0.891	1.367	1.342
1988	1.383	3.109	3.001	4.767	3.309	3.417
1989	-4.770	-6.732	-7.286	-5.394	-4.233	-4.203
1990	-8.780	-7.118	-7.113	-6.474	-5.750	-5.724
1991	-5.735	-7.111	-7.659	-7.492	-5.902	-6.006
1992	-0.462	0.073	-0.034	1.071	-2.945	-2.951
1993	5.754	4.677	4.544	4.650	5.432	5.475
1994	7.899	8.125	8.572	6.183	7.271	7.164
1995	6.012	5.266	5.791	2.708	6.072	5.962
1996	1.095	0.903	1.777	0.525	-0.834	-1.015
1997	1.879	3.335	3.934	3.284	0.880	0.900
1998	1.104	0.272	0.341	-0.016	-2.374	-2.311
1999	-2.383	-1.976	-1.814	-1.547	-3.002	-2.848
2000	-1.973	-1.646	-1.659	-1.356	-0.819	-0.775

Year	ARIMA Order			ARIMAX Order		
				Bank Rate		
	402	403	404	100	101	102
1964	-0.249	-0.249	-0.234	0.376	0.129	0.010
1965	1.113	1.124	1.066	1.207	1.480	0.709
1966	-2.304	-2.304	-2.307	-0.305	-1.580	-1.959
1967	-0.138	-0.162	-0.176	-0.554	0.698	0.204
1968	-2.094	-2.186	-2.210	-0.131	-0.989	-1.023
1969	-0.018	0.044	0.376	-0.192	0.471	0.251
1970	-3.687	-3.580	-3.173	-2.427	-4.353	-3.245
1971	8.111	7.845	7.876	2.712	9.323	7.758
1972	-4.080	-3.429	-3.612	3.494	-2.040	-3.952
1973	-1.926	-2.467	-1.177	-0.531	-0.043	-1.353
1974	1.094	1.885	1.517	2.840	5.067	2.136
1975	-8.969	-9.840	-9.246	0.298	-3.137	-5.722
1976	-8.231	-7.378	-7.085	-5.545	-8.238	-7.196
1977	0.572	0.314	1.716	-3.452	1.955	2.803
1978	0.727	0.464	0.030	1.513	0.840	1.702
1979	3.269	3.884	4.557	2.981	3.548	2.921
1980	0.732	0.969	2.703	1.829	0.769	-0.629
1981	-3.927	-4.390	-5.742	-1.439	-2.336	-3.247
1982	-1.635	-1.507	-3.673	-1.686	-1.463	-1.137
1983	-2.375	-2.493	-0.959	-2.032	-1.948	-1.342
1984	2.001	1.889	3.514	-0.211	1.191	2.266
1985	1.090	1.494	0.646	1.018	0.179	0.551
1986	2.261	1.909	1.279	0.510	1.829	1.691
1987	0.780	1.095	1.264	1.261	1.197	0.150
1988	2.295	1.936	3.108	4.049	6.841	3.637
1989	-7.274	-6.790	-6.765	1.585	-3.367	-6.615
1990	-7.334	-7.634	-7.181	-2.579	-3.148	-3.987
1991	-7.262	-6.952	-7.175	-5.703	-7.182	-6.194
1992	-1.705	-2.271	-1.782	-5.128	-2.540	1.204
1993	5.154	5.719	6.016	-1.614	-0.328	2.745
1994	7.561	7.391	8.188	1.897	3.835	6.630
1995	7.322	7.435	6.150	3.050	2.309	2.631
1996	1.946	1.850	0.061	0.402	-0.969	0.263
1997	4.897	4.394	3.450	1.368	3.414	2.823
1998	-0.498	-0.393	-0.557	1.855	0.652	-0.022
1999	-1.610	-1.968	-1.303	-0.398	-0.792	-1.997
2000	-1.700	-1.285	-1.502	-0.479	-0.504	-0.569

Year	ARIMAX Order					
	Bank Rate					
	103	104	200	201	202	203
1964	-0.040	0.003	0.886	0.682	0.576	0.449
1965	0.808	0.928	0.976	1.135	0.776	0.835
1966	-2.187	-2.172	-1.365	-1.454	-1.934	-2.032
1967	0.255	0.025	-0.596	0.331	-0.416	-0.494
1968	-1.153	-1.020	0.679	-0.288	-0.298	-0.602
1969	0.260	0.166	-0.071	0.060	-0.143	-0.109
1970	-3.621	-3.640	-3.452	-4.564	-3.608	-3.607
1971	8.732	8.359	6.481	10.004	8.715	8.630
1972	-4.437	-3.336	2.162	-2.236	-2.773	-3.260
1973	-1.506	-2.000	-4.285	-0.965	-3.223	-2.762
1974	2.474	2.484	5.500	7.367	4.086	2.705
1975	-6.286	-5.655	-2.501	-5.668	-7.902	-8.147
1976	-7.950	-8.478	-8.131	-7.224	-7.727	-8.303
1977	3.241	2.546	0.318	1.357	1.566	1.272
1978	1.724	2.348	6.148	3.102	4.844	4.269
1979	3.125	3.223	3.364	2.779	3.294	3.603
1980	-0.699	-0.500	-0.293	1.213	0.381	0.372
1981	-3.501	-3.516	-4.119	-4.246	-4.783	-4.695
1982	-1.270	-1.480	-0.890	-0.029	-0.238	-0.487
1983	-1.425	-1.457	-1.936	-3.369	-2.386	-2.446
1984	2.399	2.308	1.892	2.747	3.687	3.795
1985	0.536	0.771	1.970	-0.061	1.363	1.187
1986	1.872	1.781	-0.623	1.216	1.305	1.976
1987	0.206	0.388	1.290	1.232	0.888	0.499
1988	4.100	4.146	4.423	6.409	3.197	3.287
1989	-7.201	-6.578	-2.237	-3.615	-6.717	-7.668
1990	-4.396	-4.891	-4.871	-3.175	-5.993	-6.238
1991	-6.682	-6.905	-5.912	-7.112	-7.016	-8.061
1992	1.213	0.744	-1.562	-2.489	0.318	0.507
1993	3.018	2.989	2.420	0.341	4.552	4.429
1994	7.038	7.136	4.114	3.723	7.374	8.475
1995	2.894	3.168	2.255	2.390	4.421	4.905
1996	0.138	0.207	-2.895	-2.203	-0.871	0.263
1997	3.195	2.979	1.844	4.236	3.781	3.829
1998	-0.107	0.288	1.217	0.041	-0.662	-0.582
1999	-2.028	-2.163	-2.852	-1.546	-2.984	-2.946
2000	-0.694	-0.752	-0.206	0.117	-1.135	-1.592

Year	ARIMAX Order					
	Bank Rate					
	204	300	301	302	303	304
1964	0.010	0.904	0.671	0.085	0.126	-0.001
1965	1.079	0.970	0.857	1.046	1.003	0.887
1966	-2.055	-1.353	-1.734	-2.299	-2.221	-1.876
1967	-0.615	-0.534	-1.328	-0.547	-0.545	-0.409
1968	-1.550	0.679	0.184	-0.998	-1.000	-1.167
1969	-0.068	-0.119	-0.223	-0.012	-0.002	0.596
1970	-3.007	-3.543	-2.784	-3.470	-3.430	-3.178
1971	7.153	6.675	5.326	7.787	7.774	6.518
1972	-2.727	1.982	1.598	-2.384	-2.641	-2.443
1973	-1.574	-4.260	-4.912	-2.964	-2.703	-0.521
1974	0.277	5.902	1.628	1.290	1.174	0.453
1975	-7.092	-2.687	-5.011	-6.411	-6.695	-5.524
1976	-8.741	-8.178	-8.714	-9.423	-9.185	-6.371
1977	0.590	0.453	-0.689	1.317	1.251	1.036
1978	1.955	5.981	6.275	3.367	3.257	1.342
1979	4.516	3.161	4.648	3.892	3.970	4.786
1980	0.834	-0.242	-0.080	-0.217	-0.169	0.564
1981	-3.160	-4.068	-4.241	-3.981	-3.987	-4.727
1982	-2.381	-0.791	-1.302	-1.874	-1.721	-2.899
1983	-2.458	-2.039	-1.367	-1.654	-1.777	-0.337
1984	2.017	1.889	2.544	2.623	2.782	3.573
1985	1.549	1.882	3.171	1.441	1.362	0.166
1986	2.630	-0.660	0.348	1.930	2.056	0.342
1987	0.683	1.377	1.018	0.469	0.377	0.801
1988	2.893	4.535	1.965	3.330	3.355	4.895
1989	-7.260	-2.265	-4.977	-7.167	-7.452	-5.566
1990	-6.184	-4.729	-7.514	-6.614	-6.356	-6.123
1991	-8.570	-5.896	-7.261	-8.072	-8.339	-7.887
1992	-0.284	-1.683	-0.595	0.492	0.675	1.301
1993	3.747	2.166	5.521	4.173	3.981	4.214
1994	9.495	3.921	7.986	8.867	9.124	6.440
1995	6.040	2.199	5.465	4.739	4.645	2.388
1996	2.471	-2.869	-0.302	1.115	1.395	0.719
1997	2.737	2.097	1.941	2.872	2.868	2.931
1998	-0.618	1.242	0.431	0.376	0.368	0.065
1999	-2.887	-2.858	-3.696	-2.828	-2.945	-1.916
2000	-1.574	-0.074	-1.942	-1.386	-1.296	-1.125

Year	ARIMAX Order					
	Bank Rate					**Construction Orders**
	400	**401**	**402**	**403**	**404**	**100**
1964	0.651	0.649	0.567	0.604	0.596	-3.526
1965	0.983	0.986	0.799	0.790	0.799	-1.428
1966	-1.555	-1.557	-1.657	-1.628	-1.657	-2.441
1967	-0.402	-0.400	-0.623	-0.684	-0.698	1.020
1968	-0.883	-0.886	-0.942	-0.932	-0.968	-0.200
1969	0.123	0.150	-0.314	-0.196	-0.097	0.258
1970	-2.859	-2.903	-3.311	-3.263	-3.154	4.260
1971	8.137	8.199	7.796	7.717	7.757	0.865
1972	-1.363	-1.392	-3.289	-2.767	-2.562	-1.098
1973	-1.366	-1.318	-1.855	-2.062	-1.705	-3.945
1974	5.487	5.485	2.852	3.451	3.424	-1.767
1975	-9.043	-9.059	-10.409	-11.040	-10.730	-1.557
1976	-5.764	-5.686	-6.981	-6.135	-6.145	-1.768
1977	1.752	1.698	-0.194	-0.205	0.579	2.414
1978	2.797	2.785	2.743	2.465	2.235	-0.880
1979	6.174	6.238	4.173	5.300	5.423	1.657
1980	3.711	3.642	1.795	1.660	2.642	1.677
1981	-5.193	-5.294	-4.281	-4.836	-5.865	-1.712
1982	-2.065	-2.035	-0.436	-0.468	-1.239	-1.028
1983	-3.280	-3.274	-2.772	-2.719	-2.038	2.313
1984	2.798	2.838	3.465	3.381	3.524	0.466
1985	2.149	2.120	1.776	2.143	1.780	2.880
1986	1.237	1.235	1.883	1.464	1.565	6.650
1987	1.484	1.472	1.243	1.551	1.384	5.852
1988	3.278	3.334	1.955	1.740	2.060	-0.194
1989	-4.177	-4.153	-7.065	-6.498	-6.242	-8.501
1990	-4.814	-4.807	-6.530	-6.622	-6.253	-7.340
1991	-7.567	-7.615	-8.458	-8.472	-8.718	-5.434
1992	-2.787	-2.776	-1.685	-1.886	-1.926	0.085
1993	4.408	4.424	4.207	4.766	5.150	1.406
1994	7.858	7.813	8.416	8.365	8.716	2.518
1995	5.598	5.524	6.860	6.795	6.133	1.688
1996	-1.829	-1.913	1.505	0.878	0.119	2.626
1997	1.353	1.373	4.674	4.232	3.681	4.707
1998	-2.678	-2.643	-1.280	-1.400	-1.440	-4.830
1999	-3.377	-3.289	-3.074	-3.163	-2.924	0.328
2000	-0.357	-0.335	-1.841	-1.479	-1.276	-3.526

Year	ARIMAX Order					
	Construction Orders					
	101	102	103	104	200	201
1964	-2.827	-2.355	-2.449	-2.394	-3.250	-2.858
1965	-1.050	-1.163	-1.191	-1.138	-1.331	-1.170
1966	-2.302	-2.228	-2.317	-2.213	-2.957	-2.461
1967	1.157	0.334	0.360	0.335	0.704	1.113
1968	-1.190	-1.500	-1.557	-1.473	-1.021	-1.282
1969	-0.811	-1.074	-1.031	-1.170	-0.154	-0.492
1970	7.311	7.326	7.282	7.041	6.694	7.500
1971	-1.534	-3.512	-3.439	-2.796	-0.671	-2.476
1972	-0.740	-2.128	-2.154	-2.287	-3.368	-0.558
1973	-0.182	-1.122	-1.241	-1.361	-1.834	-0.264
1974	-2.931	-6.721	-6.671	-6.168	-3.388	-3.766
1975	-6.087	-7.745	-7.714	-7.857	-5.596	-5.847
1976	1.468	2.355	2.219	1.533	1.379	2.631
1977	1.840	1.783	1.823	2.004	5.531	1.624
1978	0.493	0.196	0.020	0.348	-1.479	0.230
1979	2.183	-0.179	-0.097	-0.056	0.908	1.847
1980	-1.731	-3.993	-3.986	-3.778	-1.269	-2.089
1981	-0.938	-1.407	-1.421	-1.809	-1.637	-0.278
1982	-1.957	-1.653	-1.665	-1.716	0.931	-1.784
1983	3.120	3.337	3.318	3.211	3.429	3.413
1984	-0.994	-0.391	-0.378	-0.255	0.602	-1.162
1985	4.469	3.953	3.930	3.877	3.090	4.620
1986	3.469	2.154	2.372	2.406	5.514	3.134
1987	8.295	6.085	6.023	6.060	5.415	8.326
1988	-4.354	-6.383	-6.047	-5.958	-1.660	-4.841
1989	-6.127	-5.592	-5.863	-5.954	-8.422	-5.544
1990	-8.546	-6.456	-6.210	-6.735	-4.689	-8.071
1991	-3.991	-0.210	-0.584	-0.479	-3.511	-3.560
1992	0.439	3.843	4.033	3.649	2.204	0.761
1993	2.467	5.078	4.712	5.264	1.622	2.046
1994	2.977	3.513	3.715	3.622	1.538	2.727
1995	-0.610	-0.539	-0.712	-0.239	-0.966	-1.148
1996	4.582	4.142	4.257	3.843	2.354	4.938
1997	2.286	0.729	0.742	1.103	4.031	1.735
1998	-4.469	-4.040	-4.051	-4.185	-5.817	-4.216
1999	2.120	0.989	0.957	0.909	1.956	2.207
2000	-2.827	-2.355	-2.449	-2.394	-3.250	-2.858

Year	ARIMAX Order					
	Construction Orders					
	202	203	204	300	301	302
1964	-2.323	-2.375	-1.914			
1965	-1.149	-1.171	-0.958	-3.244	-3.014	-2.080
1966	-2.208	-2.247	-1.708	-1.327	-1.240	-1.017
1967	0.320	0.336	0.179	-2.951	-2.739	-1.919
1968	-1.525	-1.509	-1.215	0.768	1.004	0.230
1969	-1.159	-1.051	-1.600	-1.024	-1.364	-1.358
1970	7.532	7.286	6.774	-0.161	-0.310	-1.594
1971	-3.664	-3.492	-2.322	6.779	7.534	7.384
1972	-2.205	-2.130	-2.022	-0.808	-2.152	-2.680
1973	-1.019	-1.179	-1.528	-3.294	-1.782	-2.831
1974	-6.933	-6.707	-6.836	-1.592	-0.657	-1.038
1975	-8.022	-7.725	-8.324	-3.432	-3.900	-6.646
1976	2.478	2.329	0.454	-5.605	-6.257	-8.852
1977	1.814	1.776	1.584	1.574	2.815	1.306
1978	0.275	0.172	1.756	5.359	3.251	2.317
1979	-0.233	-0.187	0.610	-1.668	-0.432	0.774
1980	-4.186	-3.973	-3.825	1.023	1.401	-0.160
1981	-1.449	-1.418	-2.816	-1.261	-2.204	-4.208
1982	-1.695	-1.651	-2.522	-1.520	-0.643	-2.283
1983	3.393	3.337	2.876	0.893	-0.658	-1.760
1984	-0.410	-0.398	0.638	3.287	3.622	3.074
1985	4.004	3.967	3.939	0.499	-0.604	0.098
1986	2.022	2.171	2.049	3.093	4.223	3.660
1987	6.124	6.113	5.028	5.484	3.763	2.124
1988	-6.698	-6.376	-6.425	5.484	7.416	5.426
1989	-5.607	-5.573	-6.450	-1.676	-4.153	-6.471
1990	-6.580	-6.492	-7.486	-8.397	-6.521	-6.587
1991	-0.027	-0.196	-0.418	-4.703	-6.703	-6.815
1992	3.954	3.792	4.423	-3.713	-3.266	-0.098
1993	5.326	5.093	7.163	2.105	1.598	4.440
1994	3.547	3.469	5.046	1.516	1.915	6.376
1995	-0.562	-0.502	0.656	1.583	2.253	4.290
1996	4.163	4.113	3.223	-0.915	-1.505	0.066
1997	0.627	0.770	0.304	2.536	4.184	3.702
1998	-4.111	-4.077	-3.873	4.053	2.334	0.880
1999	0.975	1.022	0.036	-5.841	-4.914	-4.220
2000	-2.323	-2.375	-1.914	2.076	2.369	0.364

Year	ARIMAX Order					
	Construction Orders					
	303	304	400	401	402	403
1964						
1965	-2.638	-2.141	-2.329	-2.312	-1.428	-2.436
1966	-0.935	-1.062	-1.024	-1.018	-0.866	-0.967
1967	-2.280	-1.944	-2.096	-2.077	-1.277	-2.166
1968	0.830	0.238	0.563	0.556	0.055	0.792
1969	-1.382	-1.301	-1.578	-1.573	-0.968	-1.496
1970	-0.848	-1.213	-0.970	-1.080	-2.232	-0.730
1971	7.277	6.942	7.287	7.612	8.084	7.676
1972	-0.709	-2.553	-2.428	-2.517	-3.707	-2.420
1973	-0.880	-1.721	-1.084	-0.875	-1.425	0.043
1974	-1.490	-1.781	-0.551	-0.522	-0.116	-1.040
1975	-3.922	-6.188	-7.737	-7.539	-8.708	-5.559
1976	-6.254	-6.787	-5.385	-5.169	-8.172	-5.992
1977	1.509	1.185	2.025	1.782	0.594	3.079
1978	3.518	1.018	1.464	1.486	0.512	2.289
1979	2.490	1.705	2.529	3.067	1.815	2.415
1980	2.710	0.690	4.652	4.301	0.699	2.958
1981	-1.908	-4.546	-3.956	-4.576	-4.495	-1.894
1982	-2.660	-2.729	-2.040	-1.787	-1.760	-1.437
1983	-2.850	-1.095	-1.798	-1.908	-2.912	-3.486
1984	2.952	4.097	3.093	3.346	2.497	2.486
1985	0.830	-0.461	2.632	2.451	0.379	0.406
1986	5.799	2.716	4.141	3.898	3.260	6.486
1987	4.895	2.388	3.927	3.698	1.737	4.840
1988	7.126	6.575	4.949	5.177	3.972	7.383
1989	-5.013	-6.076	-3.744	-3.868	-6.918	-6.050
1990	-7.504	-6.557	-7.623	-7.582	-7.258	-6.852
1991	-8.034	-7.047	-5.243	-5.461	-7.013	-7.803
1992	-2.281	0.389	-3.343	-3.457	-1.771	-1.947
1993	2.997	4.020	5.953	5.993	5.531	3.884
1994	4.169	4.957	4.523	4.079	6.465	4.332
1995	2.714	3.363	4.432	4.347	6.871	3.472
1996	-2.197	0.270	-1.610	-2.007	0.827	-2.593
1997	1.223	3.739	1.409	1.654	5.061	1.615
1998	0.243	0.444	-0.431	-0.301	-0.519	-1.824
1999	-4.256	-3.658	-5.682	-5.314	-3.096	-4.170
2000	3.450	0.837	1.847	2.002	-0.868	3.262

Year	ARIMAX Order					
	Construction Orders	Construction Costs				
	404	**100**	**101**	**102**	**103**	**104**
1964		0.053	0.124	-0.165	-0.171	-0.165
1965	-2.290	1.350	1.548	0.778	0.878	0.998
1966	-0.937	-0.439	-1.675	-2.152	-2.413	-2.384
1967	-2.016	-0.348	0.709	0.311	0.355	0.155
1968	0.793	-0.326	-1.012	-1.216	-1.331	-1.215
1969	-1.436	-0.234	0.459	0.273	0.280	0.183
1970	-0.916	-2.225	-4.535	-3.282	-3.755	-3.668
1971	7.626	2.922	9.826	7.964	9.226	8.644
1972	-2.022	3.310	-2.236	-4.135	-4.856	-3.685
1973	-0.484	-1.063	0.043	-1.427	-1.503	-1.984
1974	0.705	2.449	5.368	2.041	2.554	2.503
1975	-7.271	0.578	-3.128	-5.342	-6.156	-5.306
1976	-4.019	-5.549	-8.907	-7.708	-8.617	-9.045
1977	2.033	-2.962	2.386	3.507	4.156	3.499
1978	1.840	1.533	0.338	0.852	0.806	1.256
1979	2.598	1.833	4.428	3.489	4.079	4.107
1980	3.856	1.840	0.417	-1.030	-1.263	-0.974
1981	-2.801	-0.540	-2.272	-2.806	-3.093	-3.057
1982	-0.913	-1.800	-1.865	-1.685	-1.842	-2.050
1983	-3.554	-1.508	-1.987	-0.962	-1.125	-1.088
1984	1.101	-0.472	1.227	1.848	2.130	1.951
1985	2.196	0.543	0.268	0.745	0.713	0.947
1986	4.054	1.172	1.674	1.337	1.529	1.352
1987	6.598	1.294	1.547	0.594	0.668	0.923
1988	5.390	3.867	7.039	3.306	3.864	3.731
1989	-3.741	1.283	-3.208	-5.988	-6.756	-5.853
1990	-8.292	-3.250	-3.451	-4.598	-5.024	-5.509
1991	-5.816	-4.673	-7.761	-5.729	-6.493	-6.456
1992	-4.361	-4.519	-2.690	0.751	0.857	0.309
1993	5.110	-1.247	-0.543	3.141	3.317	3.318
1994	3.135	1.533	4.345	6.324	7.031	6.907
1995	3.810	2.811	2.248	3.030	3.164	3.502
1996	-1.505	0.740	-0.999	-0.133	-0.243	-0.251
1997	0.228	1.064	3.686	3.279	3.720	3.546
1998	-0.175	1.670	0.843	-0.107	-0.192	0.209
1999	-6.148	-0.098	-0.880	-1.467	-1.657	-1.639
2000	4.577	-0.618	-0.479	-0.824	-0.871	-0.960

Year	ARIMAX Order					
	Construction Costs					
	200	**201**	**202**	**203**	**204**	**300**
1964	0.022	-0.236	-0.186	-0.161	-0.213	0.022
1965	1.349	1.160	0.969	0.776	1.117	1.347
1966	-2.122	-2.136	-2.644	-2.248	-2.175	-2.121
1967	-0.071	-1.344	0.265	0.354	-0.501	-0.068
1968	-0.003	-0.792	-1.388	-1.269	-1.831	-0.002
1969	-0.087	-0.578	0.224	0.314	-0.074	-0.088
1970	-2.918	-1.915	-3.969	-3.461	-2.770	-2.914
1971	6.656	3.910	9.839	8.643	6.991	6.654
1972	1.575	1.056	-5.083	-4.890	-2.888	1.559
1973	-4.843	-4.720	-1.900	-0.985	-1.557	-4.835
1974	4.981	-0.915	2.646	2.104	-0.131	4.991
1975	-1.394	-4.246	-6.668	-5.503	-6.597	-1.394
1976	-9.335	-9.193	-9.494	-8.133	-8.856	-9.328
1977	2.137	-1.017	4.537	4.248	1.241	2.160
1978	4.484	3.577	0.914	0.219	0.971	4.457
1979	2.329	3.490	4.684	4.601	4.934	2.335
1980	0.740	0.827	-1.491	-1.620	0.679	0.740
1981	-3.746	-3.582	-3.297	-2.507	-2.573	-3.754
1982	-1.649	-2.715	-2.112	-2.059	-3.133	-1.635
1983	-0.874	-1.123	-1.159	-0.951	-2.243	-0.884
1984	1.450	1.675	2.324	1.991	1.459	1.453
1985	1.180	2.178	0.850	0.693	1.884	1.173
1986	0.400	1.090	1.532	1.318	2.408	0.387
1987	1.383	0.879	0.812	0.716	1.096	1.390
1988	4.094	0.421	3.842	3.626	2.100	4.085
1989	-1.540	-4.476	-7.163	-6.281	-6.640	-1.531
1990	-6.061	-8.479	-5.825	-4.450	-6.657	-6.045
1991	-4.458	-6.694	-6.980	-6.456	-7.675	-4.457
1992	-1.352	-0.717	0.886	1.066	-0.584	-1.345
1993	2.537	5.366	3.769	2.714	4.319	2.521
1994	4.106	8.475	7.759	7.020	9.103	4.099
1995	2.358	6.746	3.524	2.633	6.562	2.346
1996	-2.469	1.902	-0.272	-0.090	2.088	-2.477
1997	1.461	2.073	3.980	3.479	2.875	1.475
1998	1.729	1.209	-0.209	-0.090	-0.995	1.733
1999	-2.178	-2.152	-1.892	-1.493	-2.223	-2.177
2000	-0.721	-2.209	-1.029	-0.778	-1.665	-0.712

Year	ARIMAX Order					
	Construction Costs					
	301	**302**	**303**	**304**	**400**	**401**
1964	0.088	-0.206	-0.228	-0.183	-0.047	-0.044
1965	1.394	1.172	1.049	0.966	1.263	1.270
1966	-2.107	-2.495	-2.450	-2.061	-2.079	-2.082
1967	0.713	-0.405	-0.207	-0.286	-0.016	-0.016
1968	-0.789	-1.294	-1.509	-1.367	-1.918	-1.918
1969	0.471	-0.028	-0.040	0.623	0.376	0.453
1970	-4.362	-3.388	-3.483	-3.222	-2.610	-2.707
1971	10.250	7.571	7.923	6.798	7.925	8.058
1972	-2.664	-2.308	-3.713	-2.729	-1.442	-1.489
1973	-1.272	-2.992	-2.317	-0.630	-1.732	-1.650
1974	5.639	1.071	0.859	0.480	4.145	4.159
1975	-3.567	-5.394	-6.388	-5.188	-7.973	-7.983
1976	-9.355	-9.935	-9.723	-6.950	-6.156	-6.044
1977	4.019	1.944	2.511	1.694	2.288	2.187
1978	1.354	2.123	0.837	0.703	1.193	1.195
1979	4.158	4.286	4.639	5.036	5.715	5.889
1980	-0.262	-0.450	-0.898	0.208	4.053	3.906
1981	-2.854	-3.340	-3.025	-4.281	-4.404	-4.587
1982	-1.725	-2.606	-2.488	-3.319	-2.466	-2.421
1983	-1.404	-1.108	-1.194	-0.046	-2.584	-2.588
1984	1.651	1.884	1.977	3.175	1.694	1.788
1985	0.471	1.591	1.361	0.333	2.422	2.400
1986	1.331	1.447	1.426	0.129	2.230	2.193
1987	1.421	1.039	0.997	1.139	1.353	1.329
1988	6.372	2.775	2.473	4.685	3.323	3.429
1989	-3.945	-5.885	-6.657	-5.178	-4.285	-4.255
1990	-4.215	-7.206	-7.003	-6.567	-5.736	-5.711
1991	-6.679	-7.123	-7.487	-7.436	-5.868	-5.970
1992	-1.335	-0.198	-0.085	1.035	-2.958	-2.966
1993	0.904	4.456	4.125	4.488	5.463	5.504
1994	4.720	8.099	8.336	6.139	7.226	7.126
1995	1.832	5.226	5.178	2.723	6.109	6.004
1996	-1.924	0.705	1.182	0.502	-0.789	-0.966
1997	3.459	3.357	4.069	3.328	0.859	0.879
1998	0.615	0.466	0.296	-0.009	-2.400	-2.337
1999	-1.462	-1.913	-1.782	-1.483	-3.012	-2.863
2000	-0.460	-1.616	-1.558	-1.263	-0.825	-0.782

Year	ARIMAX Order					
	Construction Costs			Construction Output		
	402	**403**	**404**	**100**	**101**	**102**
1964	-0.245	-0.248	-0.222	0.092	0.079	-0.179
1965	1.106	1.111	0.980	1.374	1.474	0.771
1966	-2.386	-2.357	-2.317	-0.600	-1.547	-2.145
1967	-0.184	-0.178	-0.150	-0.305	0.650	0.322
1968	-2.036	-2.145	-2.032	-0.574	-0.835	-1.261
1969	-0.036	-0.015	0.533	-0.195	0.360	0.292
1970	-3.672	-3.520	-3.292	-2.180	-4.333	-3.344
1971	8.305	7.894	8.332	3.028	9.363	7.955
1972	-4.394	-3.652	-4.771	2.943	-1.891	-4.131
1973	-1.717	-2.382	-0.044	-0.980	-0.207	-1.489
1974	1.079	1.890	0.900	2.152	5.499	1.905
1975	-8.511	-9.543	-8.036	0.486	-3.311	-5.565
1976	-8.643	-7.683	-7.927	-5.900	-8.081	-7.623
1977	1.344	0.860	3.039	-2.797	1.828	3.198
1978	0.193	0.095	-0.417	1.460	0.933	1.203
1979	4.738	4.691	5.824	1.791	3.637	2.823
1980	0.387	0.906	0.974	1.950	0.807	-0.884
1981	-3.660	-4.258	-4.592	-0.860	-2.366	-3.014
1982	-1.785	-1.489	-4.609	-1.584	-1.629	-1.532
1983	-2.505	-2.697	-0.674	-1.793	-1.849	-0.984
1984	2.579	2.397	4.340	-0.211	1.025	1.797
1985	0.898	1.260	0.561	0.693	0.240	0.654
1986	2.086	1.792	0.029	1.118	1.681	1.556
1987	0.805	1.127	1.083	1.908	1.053	0.340
1988	2.173	1.698	5.155	4.109	6.864	3.486
1989	-6.915	-6.468	-6.907	2.546	-4.125	-6.449
1990	-7.396	-7.749	-7.451	-2.960	-3.045	-4.510
1991	-7.739	-7.202	-8.805	-6.246	-7.038	-5.756
1992	-1.495	-2.140	0.946	-5.388	-2.127	0.864
1993	4.793	5.405	4.891	-1.807	-0.181	3.205
1994	8.185	7.856	8.040	1.924	3.919	6.205
1995	6.883	7.171	3.960	2.893	2.344	3.020
1996	1.569	1.634	0.853	0.916	-1.206	-0.021
1997	4.838	4.463	3.328	1.502	3.436	3.106
1998	-0.443	-0.370	-0.745	2.015	0.463	-0.237
1999	-1.616	-1.949	-1.204	0.398	-1.007	-1.570
2000	-1.769	-1.358	-1.140	-1.003	-0.329	-0.914

Year	ARIMAX Order					
	Construction Output					
	103	104	200	201	202	203
1964	-0.202	-0.188	0.108	-0.242	-0.165	-0.424
1965	0.850	0.991	1.406	1.130	1.092	1.064
1966	-2.301	-2.340	-2.257	-2.040	-2.661	-2.378
1967	0.310	0.147	0.146	-1.283	0.177	-0.352
1968	-1.158	-1.192	-0.484	-0.842	-1.462	-1.106
1969	0.221	0.183	0.141	-0.532	0.120	-0.574
1970	-3.637	-3.707	-3.021	-1.917	-3.734	-3.939
1971	9.000	8.611	6.727	3.774	8.518	8.459
1972	-4.440	-3.524	1.129	1.110	-3.038	-3.554
1973	-1.728	-2.136	-4.718	-4.701	-3.695	-3.133
1974	2.860	2.524	4.123	-1.133	2.891	2.483
1975	-6.355	-5.595	-1.909	-4.516	-6.822	-8.197
1976	-7.926	-8.733	-9.427	-8.884	-9.206	-8.930
1977	3.581	2.994	1.903	-1.438	2.548	1.406
1978	1.665	1.925	4.962	3.708	2.645	1.827
1979	3.281	3.196	1.130	2.645	1.914	3.206
1980	-0.628	-0.595	0.743	0.354	0.032	-0.302
1981	-3.256	-3.269	-3.465	-3.243	-4.526	-3.319
1982	-1.475	-1.822	-1.439	-2.916	-1.449	-1.684
1983	-0.947	-1.035	-0.712	-0.990	-1.614	-0.202
1984	2.092	1.882	1.640	1.330	2.126	2.602
1985	0.806	0.910	1.336	2.043	0.934	2.340
1986	1.749	1.682	1.037	1.482	1.589	2.570
1987	0.259	0.506	1.797	0.659	0.858	0.739
1988	4.005	4.006	4.463	0.464	3.127	2.456
1989	-7.880	-6.742	-0.189	-4.697	-5.292	-11.507
1990	-4.874	-5.384	-5.855	-8.514	-6.851	-8.963
1991	-6.394	-6.425	-5.016	-6.136	-5.254	-9.435
1992	1.198	0.501	-1.750	-0.769	-0.521	-1.047
1993	3.634	3.502	1.995	5.441	5.019	3.411
1994	6.862	6.751	3.722	8.114	6.352	7.118
1995	3.463	3.638	1.849	6.657	4.672	5.470
1996	-0.256	-0.123	-1.792	2.321	-0.301	1.344
1997	3.604	3.334	1.504	1.908	3.492	5.392
1998	-0.481	-0.001	1.787	0.921	0.243	0.295
1999	-1.886	-1.808	-1.186	-2.049	-1.797	-1.730
2000	-0.883	-1.037	-1.242	-2.246	-1.196	-0.954

Year	ARIMAX Order					
	Construction Output					
	204	300	301	302	303	304
1964	-0.247	0.108	-0.197	-0.245	-0.302	-0.215
1965	1.073	1.405	1.218	1.160	1.145	1.070
1966	-2.065	-2.257	-2.471	-2.526	-2.381	-2.164
1967	-0.482	0.110	-0.950	-0.374	-0.513	-0.479
1968	-1.614	-0.476	-0.848	-1.227	-1.344	-1.330
1969	-0.071	0.146	-0.423	-0.039	-0.236	0.416
1970	-2.852	-2.990	-2.410	-3.548	-3.427	-3.154
1971	7.000	6.660	5.050	8.100	7.631	7.181
1972	-2.544	1.190	0.783	-2.537	-2.734	-2.353
1973	-1.682	-4.730	-5.476	-3.142	-2.866	-1.591
1974	0.433	3.992	0.213	1.573	1.025	0.676
1975	-6.458	-1.858	-4.564	-6.073	-6.887	-5.394
1976	-8.263	-9.415	-9.968	-9.660	-9.296	-7.755
1977	1.008	1.822	-0.268	1.955	1.255	1.302
1978	1.602	5.042	4.402	2.757	2.222	2.012
1979	4.445	1.190	2.024	3.804	3.977	4.750
1980	0.889	0.716	0.011	-0.205	0.171	0.081
1981	-2.654	-3.474	-3.990	-3.464	-3.015	-3.937
1982	-2.782	-1.482	-2.870	-2.388	-2.198	-2.972
1983	-1.832	-0.702	-1.038	-0.947	-0.868	-0.807
1984	1.574	1.663	1.486	1.970	1.989	2.565
1985	1.866	1.371	1.888	1.593	1.784	1.526
1986	2.448	1.046	1.292	1.853	2.083	1.398
1987	0.690	1.789	0.879	0.592	0.559	0.149
1988	2.410	4.423	1.422	3.189	2.612	3.335
1989	-7.411	-0.164	-4.062	-7.490	-8.646	-6.117
1990	-6.552	-5.876	-8.356	-7.291	-7.831	-6.002
1991	-7.504	-5.054	-5.836	-7.260	-8.031	-7.497
1992	-0.434	-1.694	-0.383	0.060	-0.400	0.050
1993	4.165	2.068	5.587	4.667	4.419	4.610
1994	8.481	3.785	7.817	8.117	8.363	7.937
1995	6.326	1.862	5.708	5.395	6.273	4.433
1996	1.870	-1.805	1.088	0.714	1.797	-0.165
1997	2.937	1.430	1.877	3.433	4.181	2.339
1998	-0.966	1.772	1.117	0.091	0.075	0.045
1999	-2.274	-1.174	-2.029	-2.253	-2.268	-1.181
2000	-1.611	-1.278	-2.018	-1.640	-1.855	-1.454

Year	ARIMAX Order					
	Construction Output					Construction Starts
	400	401	402	403	404	100
1964	-0.002	-0.001	-0.320	-0.299	-0.261	-0.152
1965	1.289	1.292	1.084	1.099	0.970	1.386
1966	-2.174	-2.175	-2.147	-2.198	-2.224	0.126
1967	0.065	0.065	-0.332	-0.312	-0.209	-0.956
1968	-2.105	-2.107	-1.797	-1.939	-1.879	-0.49
1969	0.521	0.556	-0.211	-0.044	0.433	-0.246
1970	-2.696	-2.737	-3.509	-3.554	-3.203	-1.921
1971	8.026	8.085	8.049	8.024	8.270	2.954
1972	-1.756	-1.781	-3.784	-3.466	-4.384	3.113
1973	-1.702	-1.661	-1.715	-2.097	-0.246	-1.511
1974	3.715	3.720	1.647	2.014	1.363	3.373
1975	-7.938	-7.950	-8.986	-9.626	-8.331	0.559
1976	-6.497	-6.444	-7.351	-6.796	-7.302	-6.15
1977	2.420	2.384	0.471	0.120	2.519	-2.701
1978	1.175	1.169	1.238	1.097	0.381	1.046
1979	5.460	5.542	4.244	4.548	5.204	1.757
1980	3.896	3.841	1.360	1.215	1.726	2.251
1981	-4.632	-4.711	-3.130	-3.725	-4.674	-0.504
1982	-2.217	-2.199	-1.453	-1.465	-4.336	-1.747
1983	-2.746	-2.750	-1.647	-1.982	-0.649	-1.901
1984	1.982	2.024	2.206	2.157	4.408	-0.249
1985	2.377	2.369	1.651	1.738	0.832	0.736
1986	2.412	2.399	2.373	2.086	0.243	1.077
1987	1.678	1.664	0.641	0.871	0.582	1.558
1988	3.443	3.484	2.224	1.988	5.384	3.488
1989	-3.336	-3.332	-8.977	-8.097	-7.945	1.413
1990	-5.604	-5.600	-7.712	-7.864	-7.394	-3.026
1991	-6.048	-6.092	-7.868	-7.402	-9.035	-5.019
1992	-2.958	-2.964	-1.746	-2.161	1.103	-4.644
1993	5.262	5.287	4.952	5.662	5.033	-1.109
1994	7.489	7.450	7.178	7.030	7.835	1.775
1995	5.540	5.495	7.809	7.913	4.350	2.628
1996	-0.937	-1.006	1.689	1.471	0.981	0.754
1997	0.698	0.708	5.342	4.797	3.325	1.305
1998	-2.216	-2.191	-1.013	-0.837	-1.200	1.773
1999	-2.562	-2.502	-1.931	-2.145	-1.443	-0.02
2000	-0.958	-0.940	-1.850	-1.436	-0.981	-0.666

Year	ARIMAX Order					
	Construction Starts					
	101	102	103	104	200	201
1964	-0.064	-0.366	-0.35	-0.373	-0.273	-0.391
1965	1.576	0.792	0.866	1.021	1.422	1.173
1966	-1.242	-1.649	-1.954	-1.876	-1.313	-1.658
1967	0.133	-0.269	-0.184	-0.489	-1.116	-1.795
1968	-0.88	-1.086	-1.15	-1.052	0.145	-0.903
1969	0.199	-0.054	-0.024	-0.113	-0.162	-0.56
1970	-4.171	-2.926	-3.339	-3.327	-2.701	-1.818
1971	9.564	7.694	8.752	8.306	6.5	3.725
1972	-2.064	-3.931	-4.591	-3.449	1.597	1.027
1973	-0.601	-2.151	-2.214	-2.751	-5.54	-5.075
1974	6.252	2.956	3.209	3.365	6.128	-0.556
1975	-4.1	-6.342	-7.154	-6.435	-2.373	-4.719
1976	-8.307	-7.184	-7.873	-8.453	-9.399	-9.226
1977	1.751	2.755	3.263	2.609	2.227	-1.329
1978	0.944	1.336	1.474	1.906	4.302	3.463
1979	3.233	2.136	2.497	2.44	1.292	2.326
1980	1.242	-0.441	-0.57	-0.267	1.057	0.39
1981	-2.61	-3.309	-3.722	-3.646	-3.137	-3.237
1982	-1.197	-1.096	-1.195	-1.478	-1.732	-3.029
1983	-2.476	-1.503	-1.619	-1.645	-0.676	-1.231
1984	1.689	2.306	2.571	2.38	1.613	1.368
1985	-0.147	0.313	0.292	0.496	1.374	2.107
1986	2.398	2.12	2.314	2.225	0.952	1.57
1987	0.978	0.145	0.091	0.324	1.34	0.812
1988	7.255	3.598	4.105	4.075	3.666	0.299
1989	-3.897	-6.661	-7.533	-6.699	-1.785	-4.687
1990	-3.023	-4.251	-4.603	-5.111	-6.128	-8.46
1991	-7.895	-5.946	-6.614	-6.668	-4.163	-6.199
1992	-2.351	1.059	1.29	0.637	-1.478	-0.857
1993	-0.444	3.278	3.529	3.502	3.274	5.609
1994	4.323	6.427	7.09	6.947	3.974	8.214
1995	1.994	2.835	3.043	3.34	2.184	6.614
1996	-0.573	0.397	0.335	0.379	-1.732	2.577
1997	3.317	3.037	3.361	3.188	1.175	2.104
1998	0.894	0.052	-0.037	0.323	1.38	1.002
1999	-1.012	-1.543	-1.762	-1.723	-1.866	-1.842
2000	-0.377	-0.657	-0.731	-0.839	-0.892	-2.101

Year	ARIMAX Order					
	Construction Starts					
	202	203	204	300	301	302
1964	-0.507	-0.331	-0.387	-0.279	-0.425	-0.417
1965	1.07	0.779	1.136	1.421	1.257	1.225
1966	-1.941	-1.764	-1.734	-1.303	-1.941	-2.038
1967	-0.854	-0.14	-1.007	-1.185	-1.727	-1.034
1968	-0.946	-1.133	-1.737	0.15	-0.677	-1.195
1969	-0.413	0.027	-0.231	-0.138	-0.525	-0.236
1970	-3.368	-3.043	-2.605	-2.66	-2.268	-3.268
1971	9.175	7.909	6.9	6.41	4.981	7.793
1972	-4.165	-4.186	-2.805	1.68	0.878	-2.566
1973	-3.751	-1.928	-2.229	-5.571	-6.019	-3.611
1974	4.563	2.725	0.794	5.966	1.271	2.299
1975	-8.711	-6.337	-7.151	-2.297	-4.821	-6.748
1976	-8.518	-7.296	-8.572	-9.409	-10.16	-9.69
1977	2.877	2.946	0.696	2.145	0.087	1.571
1978	2.236	1.293	1.363	4.428	4.217	2.42
1979	1.977	2.344	3.651	1.371	2.025	2.876
1980	0.038	-0.584	0.79	1.026	0.278	-0.066
1981	-4.682	-3.295	-3.144	-3.156	-3.797	-3.902
1982	-1.148	-1.16	-2.752	-1.799	-2.929	-2.254
1983	-2.107	-1.444	-2.611	-0.66	-1.04	-1.773
1984	2.968	2.313	1.807	1.662	1.682	2.292
1985	0.453	0.309	1.472	1.429	2.084	1.095
1986	2.451	2.127	2.897	0.963	1.444	2.312
1987	0.382	0.096	0.666	1.32	0.907	0.558
1988	3.585	3.757	2.511	3.591	1.081	3.368
1989	-7.302	-6.917	-7.02	-1.78	-4.704	-6.824
1990	-6.421	-4.163	-6.217	-6.181	-8.694	-6.751
1991	-6.201	-6.152	-7.76	-4.208	-5.833	-7.471
1992	0.193	1.251	-0.377	-1.396	-0.55	0.089
1993	5.353	3.167	4.241	3.393	5.952	4.511
1994	6.857	6.619	8.872	4.092	7.937	8.213
1995	4.625	2.757	6.023	2.217	5.853	4.913
1996	-0.19	0.399	2.313	-1.734	1.397	1.269
1997	4.131	3.047	2.818	1.071	2.021	3.294
1998	-0.303	-0.008	-0.617	1.348	1.117	0.537
1999	-1.573	-1.6	-2.05	-1.865	-2.131	-1.909
2000	-0.377	-0.657	-0.731	-0.949	-1.869	-1.368

Year	ARIMAX Order					
	Construction Starts					
	303	**304**	**400**	**401**	**402**	**403**
1964	-0.424	-0.634	-0.401	-0.525	-0.506	-0.585
1965	1.205	1.114	1.32	1.402	1.181	1.209
1966	-2.003	-1.034	-1.227	-0.861	-1.693	-1.483
1967	-1.034	-1.939	-1.288	-1.863	-1.071	-1.414
1968	-1.394	-1.245	-1.653	-1.459	-1.792	-1.816
1969	-0.282	0.25	-0.242	0.028	-0.404	-0.388
1970	-3.202	-2.418	-1.663	-1.923	-3.253	-3.045
1971	7.629	5.709	7.453	8.122	8.236	7.993
1972	-3.025	-1.976	-1.681	-2.124	-4.351	-3.795
1973	-3.322	-1.977	-2.659	-2.278	-2.358	-3.066
1974	1.592	2.105	5.465	6.138	2.172	3.29
1975	-7.403	-6.716	-8.835	-9.359	-9.486	-10.762
1976	-9.621	-6.594	-6.003	-4.954	-8.291	-6.868
1977	1.208	-0.046	2.02	0.565	0.366	-0.666
1978	1.904	1.633	0.856	1.607	0.892	1.006
1979	2.914	3.839	5.668	6.487	2.873	3.518
1980	-0.122	0.836	3.898	2.293	0.507	0.197
1981	-3.815	-5.582	-4.295	-4.931	-4.172	-4.341
1982	-2.276	-2.685	-2.367	-1.798	-1.689	-1.696
1983	-1.928	-0.763	-3.103	-3.469	-3.03	-3.318
1984	2.243	4.022	2.166	3.312	2.482	2.506
1985	1.078	-0.494	2.719	2.31	0.605	1.065
1986	2.471	1.2	2.704	2.712	2.901	2.381
1987	0.521	0.975	1.545	1.328	0.519	1.152
1988	3.04	4.669	2.535	3.207	2.857	1.93
1989	-7.401	-5.641	-4.055	-3.849	-7.642	-6.548
1990	-6.903	-6.551	-5.806	-5.75	-6.816	-7.624
1991	-7.884	-8.098	-5.779	-6.498	-7.856	-7.028
1992	0.051	0.899	-2.937	-2.874	-1.213	-2.219
1993	4.563	5.159	5.906	6.386	5.025	6.247
1994	8.692	6.635	7.52	6.664	7.857	7.167
1995	5.496	2.525	5.948	5.242	6.783	7.237
1996	2.07	1.104	-0.413	-1.451	1.935	1.548
1997	3.76	3.086	0.805	1.291	5.05	4.66
1998	0.55	0.471	-2.334	-1.882	-0.442	-0.281
1999	-1.813	-1.242	-2.895	-1.866	-1.101	-1.419
2000	-1.446	-1.377	-0.979	-0.957	-1.752	-1.180

Year	ARIMAX Order					
	Construction Starts	Employment				
	404	100	101	102	103	104
1964	-0.646	-0.134	0.197	-0.207	-0.233	-0.209
1965	1.181	2.412	1.465	0.862	1.298	1.135
1966	-1.251	-0.577	-1.599	-2.165	-2.546	-2.386
1967	-1.721	-0.331	0.694	0.375	0.543	0.186
1968	-1.877	-1.28	-0.861	-1.376	-1.625	-1.373
1969	-0.323	-0.384	0.45	0.322	0.265	0.257
1970	-2.318	-2.248	-4.534	-3.367	-3.657	-3.702
1971	7.273	2.365	10.037	7.818	8.139	8.234
1972	-3.573	3.405	-2.188	-4.22	-3.424	-3.469
1973	-2.405	0.164	-0.148	-1.431	-3.129	-2.114
1974	3.009	4.198	5.274	1.934	3.955	2.233
1975	-10.374	0.104	-3.244	-5.636	-7.115	-5.466
1976	-6.684	-4.745	-9.032	-7.312	-6.932	-8.501
1977	0.17	-2.829	2.32	3.211	3.038	2.871
1978	0.318	0.427	0.797	1.316	2.749	2.095
1979	4.17	2.913	3.855	2.874	2.435	3.202
1980	1.628	1.364	0.841	-0.928	0.018	-0.754
1981	-5.85	-3.315	-2.122	-3.226	-4.597	-3.526
1982	-2.396	-2.469	-1.627	-1.558	-1.109	-1.902
1983	-2.405	-2.281	-1.791	-1.169	-1.779	-1.286
1984	2.885	1.726	0.875	2.035	2.767	2.156
1985	0.994	0.158	0.555	0.389	0.268	0.558
1986	2.632	0.396	1.739	1.669	1.641	1.809
1987	0.737	2.47	1.445	0.169	0.624	0.389
1988	2.161	5.755	6.985	3.665	3.448	4.151
1989	-6.343	2.076	-3.52	-6.64	-5.832	-6.533
1990	-6.869	-3.242	-3.524	-4.276	-5.827	-5.145
1991	-7.582	-8.221	-7.177	-6.128	-5.247	-6.838
1992	-1.945	-5.315	-2.864	1.195	0.17	0.86
1993	6.549	-2.607	0.135	2.783	4.224	2.961
1994	8.131	2.115	3.801	6.524	5.999	7.142
1995	6.239	3.452	2.767	2.601	3.932	3.097
1996	0.996	0.216	-1.277	0.204	-0.801	0.252
1997	3.94	2.234	3.864	2.79	3.601	2.841
1998	-0.54	0.753	0.611	-0.231	-0.818	0.142
1999	-0.941	1.454	-0.875	-1.685	-1.334	-1.829
2000	-1.330	-0.071	-0.624	-0.833	-1.142	-1.001

Year	ARIMAX Order					
	Employment					
	200	201	202	203	204	300
1964	-0.096	-0.384	-0.247	-0.345	-0.253	-0.106
1965	2.365	2.457	1.464	1.492	1.269	2.406
1966	-2.407	-2.48	-2.792	-2.66	-2.05	-2.415
1967	0.343	-1.053	0.325	0.06	-0.298	0.18
1968	-0.817	-1.665	-1.64	-2.048	-2.1	-0.779
1969	0.104	-0.383	0.2	-0.047	-0.024	0.133
1970	-3.262	-2.074	-3.776	-4.111	-2.735	-3.126
1971	6.043	3.053	8.324	7.7	6.533	5.716
1972	1.966	1.117	-3.021	-3.73	-3.016	2.223
1973	-4.078	-3.876	-3.791	-3.128	-1.182	-4.059
1974	6.111	0.519	3.603	1.335	-0.07	5.626
1975	-2.073	-4.857	-7.248	-8.187	-6.794	-1.846
1976	-7.527	-6.936	-8.04	-9.072	-7.923	-7.391
1977	1.721	-0.165	2.872	0.983	0.995	1.491
1978	4.599	4.493	3.427	1.527	1.203	4.904
1979	2.923	5.395	2.833	2.138	4.375	3.286
1980	-0.148	1.245	0.091	-0.869	0.981	-0.22
1981	-5.302	-4.615	-4.841	-4.928	-2.619	-5.48
1982	-2.103	-2.873	-1.46	-2.173	-2.839	-2.307
1983	-1.791	-2.005	-1.786	-2.246	-2.723	-1.786
1984	2.758	2.778	2.891	2.423	1.474	2.834
1985	0.122	0.631	0.474	0.199	1.137	0.188
1986	0.898	0.49	1.776	1.795	2.807	0.845
1987	2.266	1.533	0.697	0.049	0.827	2.303
1988	5.678	2.412	3.475	1.884	2.715	5.585
1989	-1.381	-3.667	-6.24	-8.484	-7.013	-1.311
1990	-5.72	-7.487	-6.78	-8.372	-5.82	-5.84
1991	-6.528	-8.204	-5.941	-8.406	-8.077	-6.707
1992	-1.372	-0.356	0.279	-0.729	-0.043	-1.165
1993	0.975	4.21	4.767	3.907	3.329	1.233
1994	4.049	8.03	7.004	7.745	9.216	4.256
1995	2.361	6.204	4.579	5.667	5.856	2.45
1996	-2.708	0.698	-0.545	2.18	2.835	-2.797
1997	2.317	2.017	3.609	5.208	2.29	2.019
1998	0.283	-1.276	-0.669	0.652	-1.293	0.194
1999	-0.163	-1.092	-1.577	-0.349	-2.534	-0.11
2000	-0.806	-2.316	-1.497	-1.051	-1.492	-0.893

Year	ARIMAX Order					
	Employment					
	301	**302**	**303**	**304**	**400**	**401**
1964	-0.358	-0.323	0.204	-0.185	-0.069	-0.073
1965	2.337	1.941	1.731	1.025	1.499	1.511
1966	-2.634	-2.703	-2.067	-2.173	-2.161	-2.165
1967	-0.824	-0.349	-0.164	-0.262	0.056	0.059
1968	-1.496	-1.884	-1.26	-1.332	-2.095	-2.105
1969	-0.322	0.154	0.836	0.652	0.493	0.438
1970	-2.325	-3.323	-3.17	-3.463	-2.673	-2.608
1971	3.773	6.234	9.374	7.172	7.807	7.702
1972	1.017	-1.743	-0.595	-2.764	-1.387	-1.346
1973	-4.387	-3.024	-0.646	-0.886	-1.692	-1.757
1974	1.221	0.829	2.797	0.685	4.452	4.46
1975	-4.759	-5.68	-4.087	-5.34	-7.891	-7.864
1976	-7.376	-8.355	-7.984	-7.248	-5.862	-5.936
1977	0.401	1.357	2.1	1.694	2.338	2.409
1978	4.818	3.52	3.138	1.246	1.461	1.494
1979	4.882	4.675	5.84	4.55	5.974	5.861
1980	0.817	0.024	1.951	0.051	3.812	3.897
1981	-4.823	-4.292	-2.966	-4.374	-4.729	-4.603
1982	-2.758	-2.667	-3.818	-3.016	-2.644	-2.678
1983	-1.874	-1.899	-3.892	-0.171	-2.893	-2.915
1984	2.799	2.82	0.622	3.066	2.142	2.093
1985	0.675	0.37	1.65	0.375	1.914	1.898
1986	0.685	1.799	4.16	0.48	2.172	2.186
1987	1.555	0.597	2.973	0.855	1.402	1.425
1988	2.622	3.629	6.084	4.931	3.755	3.706
1989	-3.822	-6.228	-4.538	-5.506	-3.972	-3.969
1990	-7.56	-6.552	-5.162	-6.489	-5.648	-5.659
1991	-7.67	-8.685	-8.164	-7.648	-6.377	-6.335
1992	-0.046	1.02	-1.457	1.125	-2.676	-2.653
1993	4.312	3.239	2.131	4.671	4.987	4.926
1994	7.824	9.295	7.085	6.297	7.421	7.496
1995	5.741	4.291	3.885	2.535	5.711	5.776
1996	0.217	1.573	-0.93	0.359	-1.061	-0.949
1997	2.126	1.979	-0.226	3.491	0.963	0.962
1998	-0.955	-0.091	-2.701	0.184	-2.652	-2.712
1999	-1.127	-2.01	-2.709	-1.75	-2.449	-2.532
2000	-2.149	-1.669	0.220	-1.508	-0.931	-0.972

Year	ARIMAX Order					
	Employment			**GDP**		
	402	**403**	**404**	**100**	**101**	**102**
1964	-0.277	-0.299	-0.272	4.022	2.964	3.589
1965	1.336	1.545	1.36	-0.701	-0.155	-0.466
1966	-2.367	-2.422	-2.397	-1.092	-1.124	-0.850
1967	-0.062	-0.053	-0.109	-0.164	0.174	0.200
1968	-2.291	-2.528	-2.446	2.067	1.037	1.839
1969	-0.017	0.068	0.36	-1.511	-1.439	-1.029
1970	-3.577	-3.314	-2.98	-1.791	-2.827	-0.595
1971	7.564	6.859	7.131	1.465	7.061	5.881
1972	-3.638	-2.691	-2.891	3.903	0.429	-0.639
1973	-2.334	-2.907	-1.818	5.244	2.601	2.338
1974	1.545	2.451	2.169	-5.428	-0.779	-3.135
1975	-9.203	-9.833	-9.5	-2.417	-1.753	-4.095
1976	-7.709	-6.788	-6.593	-2.599	-9.241	-8.121
1977	0.585	0.765	1.766	-2.285	3.165	4.302
1978	1.023	0.786	0.358	1.866	0.117	1.680
1979	3.381	4.452	4.667	1.339	4.111	3.009
1980	1.059	1.472	3.114	-5.051	-4.630	-6.303
1981	-4.028	-4.631	-6.067	-4.028	-1.686	-4.680
1982	-1.626	-1.642	-3.701	-0.322	-2.860	-3.947
1983	-2.458	-2.596	-0.959	0.523	0.643	-0.482
1984	2.197	2.288	3.504	-0.527	-0.918	-0.732
1985	0.876	1.05	0.266	1.802	3.126	2.123
1986	2.123	1.725	1.338	2.223	0.485	0.443
1987	0.8	1.056	1.511	3.141	4.497	2.884
1988	2.251	2.16	2.868	5.278	5.947	3.395
1989	-6.939	-6.243	-6.34	-0.351	-2.676	-5.626
1990	-7.36	-7.479	-7.176	-4.548	-5.264	-5.729
1991	-7.319	-7.333	-7.256	-8.237	-8.756	-7.336
1992	-1.632	-1.912	-1.897	-4.986	-3.458	-0.118
1993	4.898	5.089	5.717	-0.493	-0.011	3.055
1994	7.805	7.986	8.516	3.641	4.952	7.004
1995	7.12	6.892	5.872	1.957	1.579	2.116
1996	2.105	1.886	0.194	0.619	0.006	0.885
1997	4.645	4.000	3.283	1.688	3.111	2.616
1998	-0.715	-1.074	-0.815	2.412	1.804	1.206
1999	-1.592	-1.635	-1.363	0.749	-0.855	-1.129
2000	-1.804	-1.659	-1.521	1.045	1.103	1.709

Year	ARIMAX Order					
	GDP					
	103	104	200	201	202	203
1964	4.527	3.236	4.028	3.670	4.197	4.569
1965	-0.687	-0.381	-0.647	-0.527	-0.683	-0.790
1966	-0.591	-1.070	-0.797	-0.915	-0.652	-0.530
1967	0.016	0.326	0.185	0.129	0.236	0.216
1968	2.518	1.292	2.050	1.544	2.288	2.609
1969	-1.368	-1.242	-1.527	-1.781	-1.331	-1.373
1970	-0.347	-1.192	-1.119	-1.925	-0.259	0.004
1971	4.121	8.990	4.487	6.972	6.438	5.792
1972	0.040	-2.106	1.859	-0.549	-0.039	0.434
1973	4.388	-0.649	1.140	2.062	2.255	3.032
1974	-4.169	1.444	-3.601	-0.694	-3.680	-4.392
1975	-3.459	-8.174	-1.372	-2.615	-3.821	-3.753
1976	-6.934	-9.571	-6.712	-9.491	-9.073	-8.470
1977	4.393	5.902	0.900	4.830	4.360	4.029
1978	0.834	2.102	5.352	1.593	2.637	2.599
1979	2.732	2.166	0.519	1.548	2.725	2.608
1980	-8.087	-3.300	-6.086	-4.808	-6.580	-7.135
1981	-4.463	-8.188	-5.347	-4.246	-5.673	-5.939
1982	-3.733	-1.248	-1.956	-1.713	-4.260	-4.365
1983	1.151	-4.636	-0.151	-0.171	-1.429	-1.376
1984	-0.820	1.891	0.756	0.865	-0.858	-1.152
1985	3.223	0.634	3.028	2.378	1.874	1.823
1986	0.553	-0.233	1.850	1.364	0.554	0.526
1987	4.390	3.859	3.004	3.637	2.783	2.893
1988	4.144	1.955	5.562	6.499	3.907	3.878
1989	-3.577	-7.253	-3.059	-4.477	-6.370	-6.028
1990	-4.728	-8.712	-5.482	-4.341	-6.248	-6.134
1991	-7.426	-7.388	-6.275	-7.957	-8.057	-8.217
1992	-1.522	-1.162	-1.519	-2.106	-0.004	-0.307
1993	1.077	5.397	2.019	0.585	3.474	3.136
1994	5.350	6.947	4.279	4.590	7.632	7.452
1995	0.485	3.902	0.697	0.807	2.325	2.104
1996	0.381	-0.112	-1.176	-0.631	0.906	0.985
1997	1.908	4.938	1.761	3.134	2.833	2.624
1998	1.520	0.664	1.898	1.449	1.383	1.487
1999	-0.691	-2.303	-0.889	-1.081	-1.232	-1.036
2000	2.482	3.231	1.456	1.938	1.955	2.151

Year	ARIMAX Order					
	GDP					
	204	300	301	302	303	304
1964	3.178	4.313	3.709	3.149	3.428	3.430
1965	-0.344	-0.774	-0.552	-0.334	-0.432	-0.438
1966	-0.979	-0.732	-0.914	-1.113	-0.905	-0.881
1967	0.069	0.021	0.089	0.227	0.255	0.178
1968	1.524	2.015	1.535	1.426	1.524	1.572
1969	-0.525	-1.820	-1.844	-1.051	-1.200	-1.063
1970	0.126	-1.268	-1.985	-1.060	-1.012	-0.835
1971	4.275	4.637	6.918	7.233	7.610	5.956
1972	-0.248	1.130	-0.594	-0.798	-1.721	-1.079
1973	3.942	2.007	2.391	0.790	0.763	2.491
1974	-3.865	-2.466	-0.518	-2.430	0.460	-1.854
1975	-6.967	-1.603	-2.832	-4.385	-7.094	-5.012
1976	-7.258	-7.921	-9.497	-9.408	-8.249	-8.221
1977	2.969	2.190	4.977	4.067	5.373	5.516
1978	0.779	4.495	1.178	2.605	1.753	0.992
1979	3.885	-0.756	1.376	3.071	1.927	1.314
1980	-4.015	-5.997	-4.541	-5.161	-3.518	-3.728
1981	-2.980	-4.899	-4.243	-5.012	-7.672	-4.945
1982	-4.556	-1.523	-1.503	-3.833	-0.649	-4.727
1983	-2.315	0.313	-0.174	-1.388	-3.797	0.346
1984	-3.458	0.941	0.848	-0.317	2.106	0.518
1985	1.509	2.779	2.236	1.834	0.938	0.151
1986	2.041	1.452	1.348	0.722	0.339	1.136
1987	5.195	3.405	3.732	2.331	4.328	3.955
1988	2.178	6.189	6.601	3.626	2.756	2.798
1989	-6.251	-3.360	-4.441	-6.659	-5.434	-6.152
1990	-7.426	-4.888	-4.176	-6.655	-7.056	-3.945
1991	-7.780	-6.731	-8.166	-7.684	-6.785	-7.831
1992	-1.164	-2.639	-2.498	0.220	-1.213	-1.963
1993	3.857	0.604	0.306	4.161	4.196	3.831
1994	8.668	3.655	4.464	7.895	6.109	6.860
1995	5.467	0.612	0.921	3.129	2.946	0.736
1996	3.112	-0.594	-0.487	0.836	-0.455	1.045
1997	1.569	2.677	3.312	3.109	4.219	3.747
1998	-1.780	2.107	1.446	1.111	0.371	-0.130
1999	-1.922	-0.769	-0.987	-1.502	-1.887	-1.367
2000	2.332	2.115	2.036	1.151	2.765	2.846

Year	ARIMAX Order					VAR (1)
	GDP					
	400	401	402	403	404	
1964	3.326	3.457	3.154	3.482	2.957	
1965	-0.378	-0.416	-0.331	-0.369	-0.282	
1966	-1.016	-0.953	-1.072	-0.885	-1.163	
1967	0.187	0.187	0.192	0.231	0.178	
1968	1.359	1.518	1.186	1.514	0.966	
1969	-1.123	-0.958	-1.004	-1.057	-1.016	3.425
1970	-1.453	-0.815	-1.017	-1.067	-1.315	-1.502
1971	7.121	6.346	7.202	6.573	7.241	1.893
1972	-0.217	-0.107	-1.174	-0.889	-1.002	2.665
1973	2.507	2.674	2.402	3.322	2.162	1.766
1974	-1.302	-1.501	-1.433	-0.938	-1.461	4.438
1975	-7.091	-7.361	-7.553	-6.460	-7.749	-8.323
1976	-8.279	-8.634	-8.822	-8.691	-8.782	-5.088
1977	5.800	5.601	4.977	5.910	4.897	-0.721
1978	0.351	1.273	0.415	1.541	0.067	2.442
1979	2.963	1.876	2.984	2.466	2.356	2.089
1980	-0.155	-0.318	-1.474	-1.922	-1.360	-2.433
1981	-5.960	-5.081	-5.208	-4.092	-5.657	-6.667
1982	-3.369	-3.555	-2.732	-3.011	-3.965	-1.036
1983	-1.982	-2.209	-2.250	-2.754	-2.384	-0.627
1984	-0.092	-0.633	-0.459	-0.909	-0.442	4.129
1985	2.238	1.786	1.219	2.103	0.767	-0.701
1986	2.518	2.358	1.639	3.711	0.981	-0.555
1987	4.325	4.487	3.575	5.987	2.523	3.796
1988	5.546	5.372	4.731	6.160	3.302	3.889
1989	-5.231	-5.094	-5.887	-5.518	-7.190	1.474
1990	-4.878	-4.876	-5.077	-5.296	-6.411	-8.031
1991	-8.510	-7.720	-7.928	-8.424	-8.723	-11.748
1992	-2.495	-2.351	-1.318	-2.451	-2.081	-0.961
1993	4.306	4.328	4.657	2.710	4.472	4.156
1994	8.026	8.567	8.757	7.685	8.757	7.516
1995	3.752	4.636	5.318	4.137	5.113	4.577
1996	-0.689	0.310	1.562	-0.055	1.637	0.255
1997	1.453	1.429	3.240	0.150	3.727	0.519
1998	-1.005	-1.399	-0.611	-3.143	0.398	-0.872
1999	-2.046	-2.661	-2.367	-2.727	-1.232	1.258
2000	1.375	1.096	0.496	2.981	1.362	-1.896

Year	VAR (2)	VAR (3)	SES	HLT	BLT	MR
1964			0.688	0.779	0.018	
1965			0.732	0.813	0.020	-3.733
1966			0.699	0.784	0.019	2.662
1967			0.670	0.759	0.018	-5.416
1968			0.645	0.736	0.017	1.376
1969	1.593	-0.423	0.622	0.716	0.017	-1.511
1970	2.000	6.032	0.517	0.628	0.014	2.684
1971	4.246	9.041	0.630	0.719	0.017	1.346
1972	-0.054	-2.706	0.755	0.821	0.020	1.411
1973	-1.243	-0.660	0.697	0.772	0.019	4.666
1974	6.882	4.713	0.791	0.849	0.021	-2.481
1975	-9.219	-11.502	0.807	0.861	0.021	-5.952
1976	-8.070	-6.426	0.553	0.649	0.015	0.793
1977	2.224	0.999	0.421	0.538	0.012	0.374
1978	4.926	4.913	0.467	0.575	0.013	-0.389
1979	-1.021	2.123	0.547	0.639	0.015	-1.884
1980	-2.591	-0.372	0.620	0.698	0.017	-5.865
1981	-4.440	-6.576	0.573	0.658	0.015	-3.640
1982	0.183	0.514	0.485	0.583	0.013	-0.764
1983	1.897	-0.337	0.405	0.515	0.011	-0.577
1984	4.813	2.708	0.382	0.494	0.010	3.682
1985	-0.367	-0.533	0.399	0.507	0.011	3.998
1986	-0.384	-2.201	0.431	0.532	0.011	4.040
1987	4.441	7.829	0.482	0.572	0.012	8.351
1988	3.060	2.809	0.635	0.697	0.016	5.368
1989	-1.397	-0.115	0.686	0.738	0.017	-5.901
1990	-7.532	-8.822	0.540	0.617	0.014	-9.347
1991	-12.782	-10.789	0.320	0.432	0.008	-9.803
1992	-2.997	-3.336	0.120	0.265	0.003	-4.762
1993	4.946	5.270	0.059	0.212	0.001	3.150
1994	6.738	5.609	0.128	0.267	0.003	4.925
1995	5.178	6.413	0.245	0.362	0.006	0.854
1996	-0.720	0.430	0.264	0.375	0.006	0.904
1997	1.250	0.836	0.307	0.409	0.007	3.587
1998	-1.784	-2.682	0.379	0.467	0.008	3.528
1999	0.384	-1.794	0.367	0.455	0.008	-3.660
2000	-1.036	-1.848	0.332	0.425	0.007	3.461

Year	Simple Regression			
	Bank Rate	Construction Costs	Construction Orders	Employment
1964	0.129	-0.032		-0.174
1965	-0.040	-0.032	-3.909	0.754
1966	0.045	-0.015	-2.200	0.226
1967	-0.089	-0.009	-2.973	0.126
1968	0.031	-0.043	0.617	-0.757
1969	0.023	-0.026	0.082	-0.438
1970	-0.103	-0.038	1.696	-0.165
1971	-0.188	-0.055	3.243	-0.638
1972	0.002	-0.009	-0.338	-0.256
1973	0.233	-0.049	-0.641	0.891
1974	0.205	-0.130	-6.106	1.646
1975	-0.148	-0.193	-3.837	0.153
1976	0.030	0.037	0.978	1.009
1977	-0.270	-0.061	0.098	0.545
1978	-0.033	0.135	1.864	-0.538
1979	0.379	-0.198	-1.869	0.349
1980	0.045	-0.233	0.129	-0.445
1981	-0.294	0.117	2.404	-2.222
1982	-0.050	0.071	-0.157	-1.412
1983	-0.205	0.146	-0.112	-1.062
1984	-0.032	-0.055	2.744	1.258
1985	0.171	-0.089	0.780	0.141
1986	-0.173	0.112	2.756	-0.441
1987	-0.173	-0.072	7.086	0.630
1988	-0.033	-0.078	5.660	1.678
1989	0.006	-0.221	0.175	1.139
1990	0.288	-0.175	-7.337	0.495
1991	-0.209	0.192	-6.649	-2.295
1992	-0.336	0.140	-4.644	-1.436
1993	-0.273	0.135	-0.135	-1.605
1994	-0.040	-0.095	0.453	-0.395
1995	0.034	-0.118	1.070	0.210
1996	-0.089	0.066	1.754	-0.229
1997	0.030	-0.089	2.561	0.723
1998	-0.024	-0.221	4.610	-0.680
1999	-0.169	-0.100	-4.170	0.992
2000	-0.001	-0.036	-0.208	0.904

Year	Simple Regression		
	GDP	Construction Output	Construction Starts
1964	4.784	-0.245	-0.184
1965	-0.488	-0.310	-0.072
1966	-0.977	0.197	0.378
1967	-0.100	-0.152	-0.293
1968	2.710	0.617	-0.280
1969	-0.739	0.039	-0.134
1970	-0.460	-0.050	0.141
1971	-0.704	-0.463	0.039
1972	1.828	0.457	-0.123
1973	7.564	0.023	-0.421
1974	-6.225	0.920	0.392
1975	-5.103	0.917	0.015
1976	0.177	1.060	-0.321
1977	-0.240	0.240	-0.011
1978	1.144	-0.460	-0.217
1979	0.254	0.550	-0.385
1980	-7.392	0.197	-0.004
1981	-6.068	0.114	0.219
1982	-0.528	-0.672	0.150
1983	1.885	0.039	-0.118
1984	0.265	-0.423	0.006
1985	1.775	-0.521	0.077
1986	2.408	-0.762	0.094
1987	3.296	-1.782	0.118
1988	4.058	-1.546	-0.281
1989	-0.400	-3.616	-0.201
1990	-2.834	-1.946	0.003
1991	-6.353	2.674	-0.004
1992	-3.859	3.310	-0.033
1993	-0.496	2.515	0.156
1994	2.839	0.245	0.097
1995	0.849	-0.138	-0.173
1996	0.579	-1.097	0.041
1997	1.263	-1.433	0.080
1998	1.748	-1.120	-0.067
1999	1.531	-1.904	0.018
2000	2.248	0.143	-0.025

B.2 Out-of-sample

Year	IPD Rents	ARIMA (1,0,2)	ARIMAX (1,0,2) B.Rate	ARIMAX (1,0,2) C. Orders	ARIMAX (1,0,2) C. Costs
2001	-3.611	0.809	0.218	-2.303	1.069
2002	-4.250	-1.688	-1.807	-2.36	-1.236
2003	-0.734	-1.032	-1.064	-2.647	-1.391
2004	3.876	-0.659	-0.586	1.356	-0.53
2005	0.401	-0.447	-0.430	0.450	-0.607
2006	1.543	-0.326	-0.289	4.151	-0.581
2007	0.063	-0.258	-0.200	-0.056	-0.121
2008	-5.500	-0.218	-0.369	-6.805	-1.051
2009	-6.700	-0.196	-0.481	-7.496	-1.833
2010	7.100	-0.184	-0.239	0.523	0.32

Year	ARIMAX (1,0,2) C. Output	ARIMAX (1,0,2) C. Starts	ARIMAX (1,0,2) Employment	ARIMAX (4,0,0) GDP	SES
2001	0.738	0.859	0.662	-0.844	0.349
2002	-1.797	-1.463	-1.804	-1.077	0.349
2003	-1.095	-0.787	-1.011	2.007	0.349
2004	-0.684	-0.416	-0.641	1.75	0.349
2005	-0.468	-0.393	-0.392	-0.783	0.349
2006	-0.324	-0.257	-0.293	0.158	0.349
2007	-0.253	-0.164	-0.321	-0.014	0.349
2008	-0.229	-0.828	-0.223	-3.827	0.349
2009	-0.259	-0.339	-0.550	-8.577	0.349
2010	-0.198	0.036	-0.469	-0.716	0.349

Year	HLT	BLT	MR	VAR (1)	VAR (2)
2001	0.438	0.007	0.207	1.365	-4.876
2002	0.437	0.007	-1.748	-0.307	-1.792
2003	0.437	0.007	0.034	-1.357	-2.197
2004	0.437	0.006	3.773	0.641	-1.665
2005	0.437	0.006	0.925	-0.076	-0.114
2006	0.436	0.006	4.653	-0.344	-1.028
2007	0.436	0.006	-0.912	-1.385	1.627
2008	0.436	0.005	-17.340	-2.899	-1.107
2009	0.436	0.005	-16.698	-5.668	-10.470
2010	0.435	0.005	1.004	-0.477	-12.420

Year	VAR (3)	Simple Regression			
		Bank Rate	Construction Orders	Construction Costs	Construction Output
2001	-8.723	-0.117	-1.195	-0.183	0.323
2002	-3.219	-0.122	-2.021	-0.307	-0.269
2003	0.305	-0.068	-3.523	0.228	0.736
2004	0.869	0.020	3.553	-0.099	-0.889
2005	-3.273	-0.029	1.610	0.088	0.112
2006	2.060	-0.008	8.473	0.147	-2.131
2007	2.984	0.013	0.484	-0.115	-2.280
2008	-0.494	-0.171	-12.273	0.524	-0.278
2009	-14.590	-0.290	-13.590	1.055	6.119
2010	-18.408	-0.082	1.525	-0.363	0.140

Year	Simple Regression		
	Construction Starts	Employment	GDP
2001	0.032	0.834	-0.108
2002	0.013	0.260	-0.699
2003	0.076	0.592	0.454
2004	0.104	0.306	0.685
2005	-0.020	0.468	-0.576
2006	0.002	0.291	0.421
2007	0.026	-0.391	0.254
2008	-0.497	0.033	-4.203
2009	-0.145	-2.430	-11.997
2010	0.128	-1.937	-1.825

B.3 SA Combination Foresting

Year	SA Combination Forecasting				
	SES/ HES	**SES/BES**	**SES/ARMA**	**SES/ ARMAXBR**	**SES/ ARMAXCC**
2001	0.394	0.178	0.579	0.284	0.709
2002	0.393	0.178	-0.670	-0.729	-0.444
2003	0.393	0.178	-0.342	-0.358	-0.521
2004	0.393	0.178	-0.155	-0.119	-0.091
2005	0.393	0.178	-0.049	-0.041	-0.129
2006	0.393	0.178	0.012	0.030	-0.116
2007	0.393	0.178	0.046	0.075	0.114
2008	0.393	0.177	0.066	-0.010	-0.351
2009	0.393	0.177	0.077	-0.066	-0.742
2010	0.392	0.177	0.083	0.055	0.335
	SES/ ARMAXCOr	**SES/ ARMAXCOu**	**SES/ ARMAXCS**	**SES / ARMAXBR**	**SES/ ARMAXE**
2001	-0.977	0.544	0.604	0.284	0.506
2002	-1.006	-0.724	-0.557	-0.729	-0.728
2003	-1.149	-0.373	-0.219	-0.358	-0.331
2004	0.853	-0.168	-0.034	-0.119	-0.146
2005	0.400	-0.060	-0.022	-0.041	-0.022
2006	2.250	0.013	0.046	0.030	0.028
2007	0.147	0.048	0.093	0.075	0.014
2008	-3.228	0.060	-0.240	-0.010	0.063
2009	-3.574	0.045	0.005	-0.066	-0.101
2010	0.436	0.076	0.193	0.055	-0.060
	SES/ ARMAGDP	**SES/ SRBR**	**SES/ SRCC**	**SES/ SRCOr**	**SES/ ARMAGDP**
2001	-0.248	0.116	0.083	-0.423	-0.248
2002	-0.364	0.114	0.021	-0.836	-0.364
2003	1.178	0.140	0.289	-1.587	1.178
2004	1.050	0.184	0.125	1.951	1.050
2005	-0.217	0.160	0.219	0.980	-0.217
2006	0.254	0.170	0.248	4.411	0.254
2007	0.168	0.181	0.117	0.416	0.168
2008	-1.739	0.089	0.436	-5.962	-1.739
2009	-4.114	0.030	0.702	-6.621	-4.114
2010	-0.184	0.133	-0.007	0.937	-0.184
	SES/ SRCOu	**SES/ SRCS**	**SES/ SRE**	**SES/ SRGDP**	**SES/ MR**
2001	0.336	0.191	0.592	0.120	0.278
2002	0.040	0.181	0.305	-0.175	-0.699
2003	0.543	0.213	0.470	0.402	0.192
2004	-0.270	0.226	0.328	0.517	2.061
2005	0.231	0.164	0.409	-0.113	0.637
2006	-0.891	0.175	0.320	0.385	2.501
2007	-0.965	0.187	-0.021	0.302	-0.281
2008	0.036	-0.074	0.191	-1.927	-8.495
2009	3.234	0.102	-1.040	-5.824	-8.174
2010	0.244	0.239	-0.794	-0.738	0.677

Year	SA Combination Forecasting				
	SES/ VAR	HES/ BES	HES/ ARMA	HES/ ARMAXBR	HES/ ARMAXCC
2001	1.714	0.223	0.624	0.328	0.754
2002	0.042	0.222	-0.626	-0.685	-0.400
2003	-1.008	0.222	-0.298	-0.314	-0.477
2004	0.990	0.222	-0.111	-0.075	-0.047
2005	0.273	0.222	-0.005	0.004	-0.085
2006	0.005	0.221	0.055	0.074	-0.073
2007	-1.036	0.221	0.089	0.118	0.158
2008	-2.550	0.221	0.109	0.034	-0.308
2009	-5.319	0.221	0.120	-0.023	-0.699
2010	-0.128	0.220	0.126	0.098	0.378
	HES/ ARMAXCOr	HES/ ARMAXCOu	HES/ ARMAXCS	HES/ ARMAXE	HES/ ARMAXGDP
2001	-0.933	0.588	0.649	0.550	-0.203
2002	-0.962	-0.680	-0.513	-0.684	-0.320
2003	-1.105	-0.329	-0.175	-0.287	1.222
2004	0.897	-0.124	0.011	-0.102	1.094
2005	0.444	-0.016	0.022	0.023	-0.173
2006	2.294	0.056	0.090	0.072	0.297
2007	0.190	0.092	0.136	0.058	0.211
2008	-3.185	0.104	-0.196	0.107	-1.696
2009	-3.530	0.089	0.049	-0.057	-4.071
2010	0.479	0.119	0.236	-0.017	-0.141
	HES/ SRBR	HES/ SRCC	HES/ SRCOr	HES/ SRCOu	HES/ SRCS
2001	0.160	0.127	-0.379	0.381	0.235
2002	0.158	0.065	-0.792	0.084	0.225
2003	0.184	0.333	-1.543	0.587	0.257
2004	0.228	0.169	1.995	-0.226	0.270
2005	0.204	0.263	1.024	0.275	0.208
2006	0.214	0.291	4.455	-0.848	0.219
2007	0.224	0.160	0.460	-0.922	0.231
2008	0.132	0.480	-5.919	0.079	-0.030
2009	0.073	0.745	-6.577	3.278	0.145
2010	0.176	0.036	0.980	0.287	0.282
	HES/ SRE	HES/ SRGDP	HES/ MR	HES/ VAR	BES/ ARMA
2001	0.636	0.165	0.323	0.902	0.408
2002	0.349	-0.131	-0.655	0.065	-0.841
2003	0.514	0.446	0.236	-0.460	-0.513
2004	0.372	0.561	2.105	0.539	-0.327
2005	0.453	-0.069	0.681	0.181	-0.221
2006	0.363	0.428	2.544	0.046	-0.160
2007	0.022	0.345	-0.238	-0.475	-0.126
2008	0.234	-1.883	-8.452	-1.231	-0.107
2009	-0.997	-5.780	-8.131	-2.616	-0.096
2010	-0.751	-0.695	0.720	-0.021	-0.090

Year	SA Combination Forecasting				
	BES/ ARMAXBR	**BES/ ARMAXCC**	**BES/ ARMAXCOr**	**BES/ ARMAXCOu**	**BES/ ARMAXCS**
2001	0.113	0.538	-1.148	0.373	0.433
2002	-0.900	-0.615	-1.177	-0.895	-0.728
2003	-0.529	-0.692	-1.320	-0.544	-0.390
2004	-0.290	-0.262	0.681	-0.339	-0.205
2005	-0.212	-0.301	0.228	-0.231	-0.194
2006	-0.142	-0.288	2.079	-0.159	-0.126
2007	-0.097	-0.058	-0.025	-0.124	-0.079
2008	-0.182	-0.523	-3.400	-0.112	-0.412
2009	-0.238	-0.914	-3.746	-0.127	-0.167
2010	-0.117	0.163	0.264	-0.097	0.021
	BES/ ARMAXE	**BES/ ARMAXGDP**	**BES/ SRBR**	**BES/ SRCC**	**BES/ SRCOr**
2001	0.335	-0.419	-0.055	-0.088	-0.594
2002	-0.899	-0.535	-0.057	-0.150	-1.007
2003	-0.502	1.007	-0.031	0.118	-1.758
2004	-0.318	0.878	0.013	-0.046	1.779
2005	-0.193	-0.389	-0.012	0.047	0.808
2006	-0.144	0.082	-0.001	0.076	4.240
2007	-0.158	-0.004	0.009	-0.055	0.245
2008	-0.109	-1.911	-0.083	0.264	-6.134
2009	-0.273	-4.286	-0.142	0.530	-6.793
2010	-0.232	-0.356	-0.039	-0.179	0.765
	BES/ SRCOu	**BES/ SRCS**	**BES/ SRE**	**BES/ SRGDP**	**BES/ MR**
2001	0.165	0.020	0.421	-0.051	0.107
2002	-0.131	0.010	0.134	-0.346	-0.870
2003	0.372	0.042	0.299	0.231	0.021
2004	-0.442	0.055	0.156	0.346	1.889
2005	0.059	-0.007	0.237	-0.285	0.466
2006	-1.063	0.004	0.148	0.213	2.329
2007	-1.137	0.016	-0.193	0.130	-0.453
2008	-0.136	-0.246	0.019	-2.099	-8.667
2009	3.062	-0.070	-1.212	-5.996	-8.346
2010	0.072	0.067	-0.966	-0.910	0.505
	BES/ VAR	**ARMA/ ARMAXBR**	**ARMA/ ARMAXCC**	**ARMA/ ARMAXCOr**	**ARMA/ ARMAXCOu**
2001	0.686	0.514	0.939	-0.747	0.774
2002	-0.150	-1.748	-1.462	-2.024	-1.743
2003	-0.675	-1.048	-1.212	-1.840	-1.064
2004	0.323	-0.623	-0.595	0.349	-0.672
2005	-0.035	-0.439	-0.527	0.002	-0.458
2006	-0.169	-0.308	-0.454	1.913	-0.325
2007	-0.690	-0.229	-0.190	-0.157	-0.256
2008	-1.447	-0.294	-0.635	-3.512	-0.224
2009	-2.832	-0.339	-1.015	-3.846	-0.228
2010	-0.236	-0.212	0.068	0.170	-0.191

Year	SA Combination Forecasting				
	ARMA/ ARMAXCS	**ARMA/ ARMAXE**	**ARMA/ ARMAXGDP**	**ARMA/ SRBR**	**ARMA/ SRCC**
2001	0.834	0.736	-0.018	0.346	0.313
2002	-1.576	-1.746	-1.383	-0.905	-0.998
2003	-0.910	-1.022	0.488	-0.550	-0.402
2004	-0.538	-0.650	0.546	-0.320	-0.379
2005	-0.420	-0.420	-0.615	-0.238	-0.179
2006	-0.292	-0.310	-0.084	-0.167	-0.090
2007	-0.211	-0.290	-0.136	-0.123	-0.187
2008	-0.523	-0.221	-2.023	-0.195	0.153
2009	-0.268	-0.373	-4.387	-0.243	0.429
2010	-0.074	-0.327	-0.450	-0.133	-0.273
	ARMA/ SRCOr	**ARMA/ SRCOu**	**ARMA/ SRCS**	**ARMA/ SRE**	**ARMA/ SRGDP**
2001	-0.193	0.566	0.421	0.822	0.350
2002	-1.854	-0.978	-0.837	-0.714	-1.193
2003	-2.277	-0.148	-0.478	-0.220	-0.289
2004	1.447	-0.774	-0.278	-0.176	0.013
2005	0.582	-0.167	-0.234	0.011	-0.511
2006	4.074	-1.229	-0.162	-0.018	0.047
2007	0.113	-1.269	-0.116	-0.325	-0.002
2008	-6.246	-0.248	-0.357	-0.093	-2.210
2009	-6.893	2.962	-0.171	-1.313	-6.096
2010	0.670	-0.022	-0.028	-1.060	-1.005
	ARMA/ MR	**ARMA/ VAR**	**ARMAXBR/ ARMAXCC**	**ARMAXBR/ ARMAXCOr**	**ARMAXBR/ ARMAXCOu**
2001	0.508	1.087	0.644	-1.043	0.478
2002	-1.718	-0.998	-1.522	-2.084	-1.802
2003	-0.499	-1.195	-1.228	-1.856	-1.080
2004	1.557	-0.009	-0.558	0.385	-0.635
2005	0.239	-0.261	-0.519	0.010	-0.449
2006	2.163	-0.335	-0.435	1.931	-0.307
2007	-0.585	-0.822	-0.161	-0.128	-0.227
2008	-8.779	-1.558	-0.710	-3.587	-0.299
2009	-8.447	-2.932	-1.157	-3.989	-0.370
2010	0.410	-0.331	0.041	0.142	-0.219
	ARMAXRB/ ARMAXCS	**ARMAXBR/ ARMAXE**	**ARMAXBR/ ARMAXGDP**	**ARMAXBR/ SRBR**	**ARMAXBR/ SRCC**
2001	0.539	0.440	-0.313	0.050	0.017
2002	-1.635	-1.806	-1.442	-0.964	-1.057
2003	-0.926	-1.038	0.472	-0.566	-0.418
2004	-0.501	-0.614	0.582	-0.283	-0.342
2005	-0.412	-0.411	-0.607	-0.230	-0.171
2006	-0.273	-0.291	-0.066	-0.149	-0.071
2007	-0.182	-0.261	-0.107	-0.094	-0.158
2008	-0.599	-0.296	-2.098	-0.270	0.077
2009	-0.410	-0.516	-4.529	-0.385	0.287
2010	-0.102	-0.354	-0.478	-0.161	-0.301

Year	SA Combination Forecasting				
	ARMAXBR/ SRCOr	**ARMAXBR/ SRCOu**	**ARMAXBR/ SRCS**	**ARMAXBR/ SRE**	**ARMAXBR/ SRGDP**
2001	-0.489	0.271	0.125	0.526	0.055
2002	-1.914	-1.038	-0.897	-0.773	-1.253
2003	-2.293	-0.164	-0.494	-0.236	-0.305
2004	1.483	-0.738	-0.241	-0.140	0.050
2005	0.590	-0.159	-0.225	0.019	-0.503
2006	4.092	-1.210	-0.144	0.001	0.066
2007	0.142	-1.240	-0.087	-0.296	0.027
2008	-6.321	-0.323	-0.433	-0.168	-2.286
2009	-7.036	2.819	-0.313	-1.455	-6.239
2010	0.643	-0.050	-0.055	-1.088	-1.032

	ARMAXBR/ MR	**ARMAXBR/ VAR**	**ARMAXCC/ ARMAXCOr**	**ARMAXCC/ ARMAXCOu**	**ARMAXCC/ ARMAXCS**
2001	0.213	0.792	-0.617	0.904	0.964
2002	-1.777	-1.057	-1.798	-1.517	-1.350
2003	-0.515	-1.211	-2.019	-1.243	-1.089
2004	1.593	0.027	0.413	-0.607	-0.473
2005	0.248	-0.253	-0.079	-0.538	-0.500
2006	2.182	-0.317	1.785	-0.453	-0.419
2007	-0.556	-0.793	-0.089	-0.187	-0.143
2008	-8.854	-1.634	-3.928	-0.640	-0.940
2009	-8.589	-3.075	-4.665	-1.046	-1.086
2010	0.383	-0.358	0.422	0.061	0.178

	ARMAXCC/ ARMAXE	**ARMAXCC/ ARMAXGDP**	**ARMAXCC/ SRBR**	**ARMAXCC/ SRCC**	**ARMAXCC/ SRCOr**
2001	0.866	0.113	0.476	0.443	-0.063
2002	-1.520	-1.157	-0.679	-0.772	-1.628
2003	-1.201	0.308	-0.730	-0.581	-2.457
2004	-0.586	0.610	-0.255	-0.314	1.511
2005	-0.500	-0.695	-0.318	-0.259	0.502
2006	-0.437	-0.212	-0.295	-0.217	3.946
2007	-0.221	-0.068	-0.054	-0.118	0.181
2008	-0.637	-2.439	-0.611	-0.264	-6.662
2009	-1.192	-5.205	-1.061	-0.389	-7.712
2010	-0.075	-0.198	0.119	-0.021	0.922

	ARMAXCC/ SRCOu	**ARMAXCC/ SRCS**	**ARMAXCC/ SRE**	**ARMAXCC/ SRGDP**	**ARMAXCC/ MR**
2001	0.696	0.551	0.952	0.480	0.638
2002	-0.752	-0.611	-0.488	-0.967	-1.492
2003	-0.327	-0.657	-0.400	-0.468	-0.678
2004	-0.710	-0.213	-0.112	0.078	1.621
2005	-0.247	-0.314	-0.069	-0.591	0.159
2006	-1.356	-0.290	-0.145	-0.080	2.036
2007	-1.200	-0.048	-0.256	0.067	-0.516
2008	-0.664	-0.774	-0.509	-2.627	-9.195
2009	2.143	-0.989	-2.131	-6.915	-9.265
2010	0.230	0.224	-0.808	-0.753	0.662

Year	SA Combination Forecasting				
	ARMAXCOr/ SRBR	**ARMAXCOr/ SRCC**	**ARMAXCOr/ SRCOr**	**ARMAXCOr/ SRCOu**	**ARMAXCOr/ SRCS**
2001	-1.210	-1.243	-1.749	-0.990	-1.135
2002	-1.241	-1.334	-2.190	-1.314	-1.173
2003	-1.358	-1.209	-3.085	-0.955	-1.285
2004	0.688	0.629	2.454	0.233	0.730
2005	0.210	0.269	1.030	0.281	0.215
2006	2.071	2.149	6.312	1.010	2.076
2007	-0.022	-0.086	0.214	-1.168	-0.015
2008	-3.488	-3.141	-9.539	-3.541	-3.651
2009	-3.893	-3.221	-10.543	-0.688	-3.821
2010	0.220	0.080	1.024	0.331	0.326
	ARMAXCOr/ SRCE	**ARMAXCOr/ SRGDP**	**ARMAXCOr/ MR**	**ARMAXCOr/ VAR**	**ARMAXCOu/ ARMAXCS**
2001	-0.734	-1.206	-1.048	-0.469	0.799
2002	-1.050	-1.529	-2.054	-1.334	-1.630
2003	-1.028	-1.096	-1.306	-2.002	-0.941
2004	0.831	1.021	2.564	0.998	-0.550
2005	0.459	-0.063	0.688	0.187	-0.431
2006	2.221	2.286	4.402	1.903	-0.291
2007	-0.224	0.099	-0.484	-0.721	-0.209
2008	-3.386	-5.504	-12.072	-4.852	-0.529
2009	-4.963	-9.746	-12.097	-6.582	-0.299
2010	-0.707	-0.651	0.764	0.023	-0.081
	ARMAXCOu/ ARMAXE	**ARMAXCOu/ ARMAXGDP**	**ARMAXCOu/ SRBR**	**ARMAXCOu/ SRCC**	**ARMAXCOu/ SRCOr**
2001	0.700	-0.053	0.310	0.277	-0.229
2002	-1.801	-1.437	-0.959	-1.052	-1.909
2003	-1.053	0.456	-0.582	-0.433	-2.309
2004	-0.663	0.533	-0.332	-0.391	1.434
2005	-0.430	-0.626	-0.249	-0.190	0.571
2006	-0.309	-0.083	-0.166	-0.089	4.075
2007	-0.287	-0.134	-0.120	-0.184	0.115
2008	-0.226	-2.028	-0.200	0.147	-6.251
2009	-0.405	-4.418	-0.274	0.398	-6.925
2010	-0.334	-0.457	-0.140	-0.280	0.663
	ARMAXCOu/ SRCOu	**ARMAXCOu/ SRCS**	**ARMAXCOu/ SRCE**	**ARMAXCOu/ SRGDP**	**ARMAXCOu/ MR**
2001	0.531	0.385	0.786	0.315	0.473
2002	-1.033	-0.892	-0.768	-1.248	-1.772
2003	-0.179	-0.509	-0.252	-0.320	-0.530
2004	-0.787	-0.290	-0.189	0.001	1.544
2005	-0.178	-0.244	0.000	-0.522	0.229
2006	-1.228	-0.161	-0.017	0.048	2.164
2007	-1.266	-0.114	-0.322	0.001	-0.582
2008	-0.253	-0.363	-0.098	-2.216	-8.784
2009	2.930	-0.202	-1.344	-6.128	-8.478
2010	-0.029	-0.035	-1.067	-1.012	0.403

Year	SA Combination Forecasting				
	ARMAXCOu/ VAR	ARMAXCS/ ARMAXE	ARMAXCS/ ARMAXGDP	ARMAXCS/ SRBR	ARMAXCS/ SRCC
2001	1.052	0.761	0.008	0.371	0.338
2002	-1.052	-1.634	-1.270	-0.792	-0.885
2003	-1.226	-0.899	0.610	-0.428	-0.279
2004	-0.022	-0.529	0.667	-0.198	-0.257
2005	-0.272	-0.393	-0.588	-0.211	-0.152
2006	-0.334	-0.275	-0.050	-0.133	-0.055
2007	-0.819	-0.243	-0.089	-0.076	-0.140
2008	-1.564	-0.526	-2.328	-0.500	-0.152
2009	-2.964	-0.445	-4.458	-0.314	0.358
2010	-0.338	-0.217	-0.340	-0.023	-0.163
	ARMAXCS/ SRCOr	ARMAXCS/ SRCOu	ARMAXCS/ SRCS	ARMAXCS/ SRCE	ARMAXCS/ SRGDP
2001	-0.168	0.591	0.446	0.847	0.375
2002	-1.742	-0.866	-0.725	-0.601	-1.081
2003	-2.155	-0.025	-0.355	-0.098	-0.166
2004	1.568	-0.653	-0.156	-0.055	0.135
2005	0.609	-0.140	-0.207	0.038	-0.484
2006	4.108	-1.194	-0.128	0.017	0.082
2007	0.160	-1.222	-0.069	-0.278	0.045
2008	-6.551	-0.553	-0.662	-0.398	-2.515
2009	-6.965	2.890	-0.242	-1.384	-6.168
2010	0.780	0.088	0.082	-0.950	-0.895
	ARMAXCS/ MR	ARMAXCS/ VAR	ARMAXE/ ARMAXGDP	ARMAXE/ SRBR	ARMAXE/ SRCC
2001	0.533	1.112	-0.091	0.272	0.239
2002	-1.605	-0.885	-1.441	-0.963	-1.056
2003	-0.376	-1.072	0.498	-0.540	-0.391
2004	1.678	0.112	0.555	-0.311	-0.370
2005	0.266	-0.234	-0.588	-0.211	-0.152
2006	2.198	-0.301	-0.068	-0.151	-0.073
2007	-0.538	-0.775	-0.168	-0.154	-0.218
2008	-9.084	-1.863	-2.025	-0.197	0.150
2009	-8.518	-3.004	-4.564	-0.420	0.252
2010	0.520	-0.221	-0.593	-0.276	-0.416
	ARMAXE/ SRCOr	ARMAXE/ SRCOu	ARMAXE/ SRCS	ARMAXE/ SRE	ARMAXE/ SRGDP
2001	-0.267	0.493	0.347	0.748	0.277
2002	-1.912	-1.036	-0.895	-0.772	-1.251
2003	-2.267	-0.137	-0.467	-0.210	-0.278
2004	1.456	-0.765	-0.269	-0.167	0.022
2005	0.609	-0.140	-0.206	0.038	-0.484
2006	4.090	-1.212	-0.146	-0.001	0.064
2007	0.081	-1.300	-0.148	-0.356	-0.033
2008	-6.248	-0.250	-0.360	-0.095	-2.213
2009	-7.070	2.785	-0.348	-1.490	-6.273
2010	0.528	-0.165	-0.170	-1.203	-1.147

Year	SA Combination Forecasting				
	ARMAXE/ MR	ARMAXE/ VAR	ARMAXGDP/ SRBR	ARMAXGDP/ SRCC	ARMAXGDP/ SRCOr
2001	0.435	1.014	-0.481	-0.514	-1.195
2002	-1.776	-1.056	-0.599	-0.692	-2.021
2003	-0.488	-1.184	0.969	1.118	-3.523
2004	1.566	0.000	0.885	0.826	3.553
2005	0.267	-0.234	-0.406	-0.347	1.610
2006	2.180	-0.319	0.075	0.152	8.473
2007	-0.616	-0.853	-0.001	-0.065	0.484
2008	-8.781	-1.561	-1.999	-1.652	-12.273
2009	-8.624	-3.109	-4.433	-3.761	-13.590
2010	0.268	-0.473	-0.399	-0.539	1.525
	ARMAXGDP/ SRCOu	ARMAXGDP /SRCS	ARMAXGDP/ SRE	ARMAXGDP/ SRGDP	ARMAXGDP /MR
2001	-0.260	-0.406	-0.005	-0.476	-0.318
2002	-0.673	-0.532	-0.408	-0.888	-1.412
2003	1.372	1.042	1.299	1.231	1.021
2004	0.430	0.927	1.028	1.218	2.761
2005	-0.335	-0.402	-0.157	-0.679	0.071
2006	-0.987	0.080	0.224	0.289	2.405
2007	-1.147	0.006	-0.203	0.120	-0.463
2008	-2.052	-2.162	-1.897	-4.015	-10.583
2009	-1.229	-4.361	-5.503	-10.287	-12.637
2010	-0.288	-0.294	-1.326	-1.271	0.144
	ARMAXGDP/ VAR	SRBR/ SRCC	SRBR/ SRCOr	SRBR/ SRCOu	SRBR/ SRCS
2001	0.261	-0.150	-0.656	0.103	-0.042
2002	-0.692	-0.214	-1.071	-0.195	-0.054
2003	0.325	0.080	-1.795	0.334	0.004
2004	1.195	-0.039	1.786	-0.435	0.062
2005	-0.429	0.029	0.791	0.041	-0.025
2006	-0.093	0.069	4.233	-1.070	-0.003
2007	-0.700	-0.051	0.248	-1.133	0.019
2008	-3.363	0.176	-6.222	-0.224	-0.334
2009	-7.123	0.383	-6.940	2.915	-0.217
2010	-0.597	-0.222	0.721	0.029	0.023
	SRBR/ SRE	SRBR/ SRGDP	SRBR/ MR	SRBR/ VAR	SRCC/ SRCOr
2001	0.359	-0.113	0.045	0.624	-0.689
2002	0.069	-0.410	-0.935	-0.214	-1.164
2003	0.262	0.193	-0.017	-0.713	-1.647
2004	0.163	0.353	1.896	0.330	1.727
2005	0.219	-0.303	0.448	-0.053	0.849
2006	0.141	0.206	2.322	-0.176	4.310
2007	-0.189	0.134	-0.449	-0.686	0.184
2008	-0.069	-2.187	-8.755	-1.535	-5.875
2009	-1.360	-6.143	-8.494	-2.979	-6.268
2010	-1.009	-0.954	0.461	-0.280	0.581

Year	SA Combination Forecasting				
	SRCC/ SRCOu	SRC/ SRCS	SRCC/ SRE	SRCC/ SRGDP	SRCC /MR
2001	0.070	-0.076	0.325	-0.146	0.012
2002	-0.288	-0.147	-0.024	-0.503	-1.028
2003	0.482	0.152	0.410	0.341	0.131
2004	-0.494	0.003	0.104	0.293	1.837
2005	0.100	0.034	0.278	-0.244	0.507
2006	-0.992	0.074	0.219	0.284	2.400
2007	-1.197	-0.045	-0.253	0.069	-0.514
2008	0.123	0.014	0.278	-1.840	-8.408
2009	3.587	0.455	-0.688	-5.471	-7.821
2010	-0.111	-0.117	-1.150	-1.094	0.321
	SRCC/ VAR	SRCOr/ SRCOu	SRCOr/ SRCS	SRCC/ SRGDP	SRCC /MR
2001	0.591	-0.436	-0.581	-0.146	0.012
2002	-0.307	-1.145	-1.004	-0.503	-1.028
2003	-0.564	-1.393	-1.723	0.341	0.131
2004	0.271	1.332	1.828	0.293	1.837
2005	0.006	0.861	0.795	-0.244	0.507
2006	-0.099	3.171	4.238	0.284	2.400
2007	-0.750	-0.898	0.255	0.069	-0.514
2008	-1.188	-6.276	-6.385	-1.840	-8.408
2009	-2.307	-3.736	-6.868	-5.471	-7.821
2010	-0.420	0.832	0.826	-1.094	0.321
	SRCOr/ SRE	SRCOr/ SRGDP	SRCOr/ MR	SRCOr/ VAR	SRCOu/ SRCS
2001	-0.180	-0.652	-0.494	0.085	0.178
2002	-0.880	-1.360	-1.884	-1.164	-0.128
2003	-1.466	-1.534	-1.744	-2.440	0.406
2004	1.930	2.119	3.663	2.097	-0.393
2005	1.039	0.517	1.268	0.767	0.046
2006	4.382	4.447	6.563	4.065	-1.065
2007	0.046	0.369	-0.214	-0.451	-1.127
2008	-6.120	-8.238	-14.807	-7.586	-0.387
2009	-8.010	-12.793	-15.144	-9.629	2.987
2010	-0.206	-0.150	1.264	0.524	0.134
	SRCS/ SRE	SRCS/ SRGDP	SRCS/ MR	SRCS/ VAR	SRE/ SRGDP
2001	0.433	-0.038	1.425	0.699	0.363
2002	0.137	-0.343	-0.631	-0.147	-0.219
2003	0.334	0.265	0.361	-0.640	0.523
2004	0.205	0.395	-1.871	0.372	0.496
2005	0.224	-0.298	-3.005	-0.048	-0.054
2006	0.146	0.211	-4.235	-0.171	0.356
2007	-0.183	0.140	-0.443	-0.680	-0.069
2008	-0.232	-2.350	-8.918	-1.698	-2.085
2009	-1.288	-6.071	-8.421	-2.907	-7.213
2010	-0.904	-0.848	0.566	-0.174	-1.881
	SRE/ MR	SRE/ VAR	SRGDP/ MR	SRGDP/ VAR	MR/ VAR
2001	0.521	1.100	0.049	0.629	0.786
2002	-0.744	-0.023	-1.223	-0.503	-1.027
2003	0.313	-0.383	0.244	-0.452	-0.661
2004	2.040	0.474	2.229	0.663	2.207
2005	0.697	0.196	0.175	-0.326	0.425
2006	2.472	-0.027	2.537	0.038	2.154
2007	-0.651	-0.888	-0.329	-0.565	-1.148
2008	-8.653	-1.433	-10.771	-3.551	-10.119
2009	-9.564	-4.049	-14.347	-8.832	-11.183
2010	-0.466	-1.207	-0.410	-1.151	0.264

B.4 OLS Combination Foresting

Year	OLS Combination Forecasting				
	SES/ HES	**SES/ BES**	**SES/ ARMA**	**SES/ ARMAXBR**	**SES/ ARMAXCC**
2001	-1.580	-1.416	1.130	0.411	1.445
2002	-1.699	-1.416	-1.909	-2.072	-1.369
2003	-1.699	-1.416	-1.111	-1.161	-1.559
2004	-1.699	-2.706	-0.657	-0.575	-0.507
2005	-1.699	-2.706	-0.399	-0.384	-0.601
2006	-1.818	-2.706	-0.251	-0.211	-0.570
2007	-1.818	-2.706	-0.169	-0.102	-0.008
2008	-1.818	-3.995	-0.120	-0.309	-1.144
2009	-1.818	-3.995	-0.093	-0.446	-2.098
2010	-1.936	-3.995	-0.079	-0.149	0.531
	SES/ ARMAXCOr	**SES/ ARMAXCOu**	**SES/ ARMAXCS**	**SES/ ARMAXE**	**SES/ ARMAGDP**
2001	-2.731	1.076	1.153	1.019	-0.760
2002	-2.801	-2.020	-1.695	-1.966	-1.026
2003	-3.154	-1.163	-0.866	-1.006	2.500
2004	1.769	-0.661	-0.411	-0.558	2.206
2005	0.655	-0.397	-0.383	-0.257	-0.690
2006	5.206	-0.221	-0.216	-0.137	0.386
2007	0.032	-0.134	-0.102	-0.171	0.189
2008	-8.267	-0.105	-0.916	-0.052	-4.170
2009	-9.117	-0.142	-0.317	-0.448	-9.601
2010	0.744	-0.067	0.143	-0.350	-0.613
	SES/ SRBR	**SES/ SRCC**	**SES/ SRCOr**	**SES/ SRCOu**	**SES/ SRCS**
2001	0.794	1.550	-0.407	0.782	0.946
2002	0.773	1.966	-1.199	1.259	0.949
2003	1.028	0.169	-2.640	0.450	0.937
2004	1.450	1.266	4.149	1.759	0.931
2005	1.214	0.639	2.285	0.952	0.956
2006	1.315	0.443	8.871	2.760	0.952
2007	1.417	1.322	1.204	2.879	0.947
2008	0.535	-0.822	-11.036	1.266	1.052
2009	-0.032	-2.604	-12.300	-3.886	0.981
2010	0.961	2.152	2.203	0.930	0.926
	SES/ SRE	**SES/ SRGDP**	**SES/ MR**	**SES/ VAR**	**HES/ BES**
2001	2.797	0.652	0.294	1.878	0.312
2002	1.858	0.089	-1.643	0.257	0.339
2003	2.400	1.188	0.122	-0.760	0.339
2004	1.933	1.409	3.827	1.176	-0.278
2005	2.198	0.206	1.005	0.481	-0.278
2006	1.908	1.157	4.699	0.221	-0.252
2007	0.793	0.998	-0.815	-0.787	-0.252
2008	1.486	-3.253	-17.094	-2.253	-0.869
2009	-2.541	-10.688	-16.457	-4.936	-0.869
2010	-1.734	-0.986	1.084	0.093	-0.843

Year	OLS Combination Forecasting				
	HES/ ARMA	**HES/ ARMAXBR**	**HES/ ARMAXCC**	**HES/ ARMAXCOr**	**HES/ ARMAXCOu**
2001	1.089	0.373	1.405	-2.822	1.034
2002	-1.959	-2.116	-1.418	-2.894	-2.069
2003	-1.158	-1.203	-1.607	-3.248	-1.210
2004	-0.703	-0.615	-0.553	1.689	-0.707
2005	-0.444	-0.424	-0.647	0.572	-0.443
2006	-0.298	-0.251	-0.616	5.135	-0.267
2007	-0.215	-0.142	-0.053	-0.055	-0.180
2008	-0.166	-0.349	-1.192	-8.380	-0.151
2009	-0.139	-0.487	-2.149	-9.232	-0.188
2010	-0.125	-0.190	0.486	0.657	-0.114
	HES/ ARMAXCS	**HES/ ARMAXE**	**HES/ ARMAXGDP**	**HES/ SRBR**	**HES/ SRCC**
2001	1.101	0.981	-0.752	0.909	1.498
2002	-1.755	-2.011	-1.017	0.898	1.828
2003	-0.924	-1.049	2.517	1.132	0.431
2004	-0.468	-0.600	2.222	1.520	1.284
2005	-0.439	-0.298	-0.680	1.303	0.796
2006	-0.273	-0.178	0.400	1.404	0.651
2007	-0.159	-0.212	0.203	1.497	1.335
2008	-0.976	-0.093	-4.167	0.688	-0.332
2009	-0.374	-0.490	-9.610	0.168	-1.717
2010	0.086	-0.393	-0.600	1.087	1.987
	HES/ SRCOr	**HES/ SRCOu**	**HES/ SRCS**	**HES/ SRE**	**HES/ SRGDP**
2001	-0.370	0.868	1.025	2.792	0.699
2002	-1.160	1.314	1.034	1.919	0.140
2003	-2.605	0.569	1.027	2.428	1.242
2004	4.204	1.775	1.024	1.990	1.463
2005	2.335	1.032	1.038	2.239	0.257
2006	8.944	2.703	1.043	1.976	1.216
2007	1.255	2.813	1.040	0.927	1.056
2008	-11.020	1.329	1.101	1.579	-3.206
2009	-12.287	-3.414	1.060	-2.209	-10.660
2010	2.263	1.027	1.035	-1.440	-0.927
	HES/ MR	**HES/ VAR**	**BES/ ARMA**	**BES/ ARMAXBR**	**BES/ ARMAXCC**
2001	0.259	1.944	1.098	0.392	1.414
2002	-1.687	0.323	-1.939	-2.088	-1.400
2003	0.087	-0.698	-1.141	-1.178	-1.589
2004	3.809	1.244	-0.704	-0.605	-0.553
2005	0.974	0.547	-0.446	-0.414	-0.647
2006	4.685	0.291	-0.299	-0.241	-0.616
2007	-0.854	-0.721	-0.216	-0.132	-0.054
2008	-17.207	-2.192	-0.185	-0.351	-1.205
2009	-16.568	-4.884	-0.158	-0.488	-2.159
2010	1.054	0.167	-0.143	-0.192	0.469

Year	OLS Combination Forecasting				
	BES/ ARMAXCOr	**BES/ ARMAXCOu**	**BES/ ARMAXCS**	**BES/ ARMAXE**	**BES/ ARMAXGDP**
2001	-2.931	1.047	1.089	0.997	-0.688
2002	-3.002	-2.022	-1.757	-1.985	-0.955
2003	-3.356	-1.173	-0.929	-1.026	2.579
2004	1.507	-0.677	-0.507	-0.593	2.337
2005	0.389	-0.416	-0.479	-0.292	-0.566
2006	4.958	-0.242	-0.312	-0.172	0.512
2007	-0.236	-0.156	-0.198	-0.206	0.315
2008	-8.649	-0.129	-1.045	-0.101	-4.003
2009	-9.502	-0.165	-0.446	-0.497	-9.447
2010	0.400	-0.091	0.014	-0.399	-0.437
	BES/ SRBR	**BES/ SRCC**	**BES/ SRCOr**	**BES/ SRCOu**	**BES/ SRCS**
2001	1.199	1.691	-0.268	1.115	1.252
2002	1.178	1.983	-1.063	1.535	1.254
2003	1.416	0.722	-2.508	0.822	1.247
2004	2.077	1.723	4.455	2.222	1.460
2005	1.857	1.283	2.585	1.510	1.475
2006	1.951	1.145	9.192	3.104	1.472
2007	2.045	1.762	1.500	3.209	1.469
2008	1.492	0.489	-10.628	2.032	1.746
2009	0.964	-0.762	-11.896	-2.513	1.706
2010	1.888	2.575	2.655	1.736	1.675
	BES/ SRE	**BES/ SRGDP**	**BES/ MR**	**BES/ VAR**	**ARMA/ ARMAXBR**
2001	3.066	0.812	0.166	2.080	0.394
2002	2.201	0.249	-1.795	0.450	-2.019
2003	2.700	1.348	-0.008	-0.572	-1.104
2004	2.570	1.729	3.735	1.520	-0.509
2005	2.814	0.526	0.878	0.822	-0.325
2006	2.547	1.477	4.617	0.560	-0.151
2007	1.519	1.318	-0.964	-0.453	-0.040
2008	2.458	-2.772	-17.449	-1.781	-0.271
2009	-1.254	-10.203	-16.805	-4.479	-0.423
2010	-0.510	-0.505	0.950	0.578	-0.101
	ARMA/ ARMAXCC	**ARMA/ ARMAXCOr**	**ARMA/ ARMAXCOu**	**ARMA/ ARMAXCS**	**ARMA/ ARMAXE**
2001	1.645	-1.967	0.749	1.171	1.203
2002	-1.036	-2.431	-2.675	-1.652	-1.818
2003	-1.709	-2.628	-1.411	-0.835	-1.043
2004	-0.373	1.662	-0.573	-0.386	-0.592
2005	-0.639	0.739	-0.275	-0.345	-0.341
2006	-0.665	4.669	0.105	-0.181	-0.192
2007	0.128	0.235	0.218	-0.070	-0.097
2008	-1.580	-6.890	0.105	-0.824	-0.056
2009	-3.010	-7.617	-0.394	-0.265	0.015
2010	0.882	0.858	0.116	0.163	0.021

Year	OLS Combination Forecasting				
	ARMA/ ARMAXGDP	**ARMA/ SRBR**	**ARMA/ SRCC**	**ARMA/ SRCOr**	**ARMA/ SRCOu**
2001	-0.909	0.995	0.823	0.194	0.944
2002	-1.326	-2.050	-2.514	-2.837	-1.744
2003	2.152	-1.120	-0.372	-3.158	-1.515
2004	1.889	-0.447	-0.743	1.815	-0.150
2005	-0.920	-0.313	-0.016	0.764	-0.457
2006	0.136	-0.113	0.278	5.346	0.950
2007	-0.051	0.022	-0.299	0.220	1.116
2008	-4.297	-0.387	1.356	-8.034	0.040
2009	-9.589	-0.655	2.717	-8.868	-3.528
2010	-0.829	-0.125	-0.831	0.970	-0.154
	ARMA/ SRCS	**ARMA/ SRE**	**ARMA/ SRGDP**	**ARMA/ MR**	**ARMA/ VAR**
2001	1.114	1.853	0.934	0.952	1.499
2002	-1.897	-1.578	-2.063	-2.493	-1.383
2003	-1.177	-0.537	-0.576	-0.698	-1.438
2004	-0.757	-0.312	-0.028	2.233	-0.054
2005	-0.347	0.067	-0.693	0.412	-0.278
2006	-0.227	0.074	0.131	3.126	-0.329
2007	-0.174	-0.373	0.084	-0.719	-0.843
2008	0.516	0.003	-2.998	-12.204	-1.637
2009	0.111	-1.880	-8.439	-11.736	-3.131
2010	-0.210	-1.483	-1.297	0.686	-0.289
	ARMAXBR/ ARMAXCC	**ARMAXBR/ ARMAXCOr**	**ARMAXBR/ ARMAXCOu**	**ARMAXRB/ ARMAXCS**	**ARMAXBR/ ARMAXE**
2001	0.866	-2.055	0.466	0.913	-0.597
2002	-1.738	-2.451	-2.004	-1.750	-2.171
2003	-1.253	-2.630	-1.098	-0.891	-1.361
2004	-0.489	1.663	-0.516	-0.382	-0.549
2005	-0.408	0.735	-0.326	-0.282	-0.550
2006	-0.290	4.655	-0.154	-0.113	-0.290
2007	-0.007	0.241	-0.045	-0.003	0.063
2008	-0.571	-6.891	-0.251	-0.541	-0.700
2009	-1.023	-7.637	-0.387	-0.273	-0.391
2010	0.171	0.844	-0.093	0.111	0.241
	ARMAXBR/ ARMAXGDP	**ARMAXBR/ SRBR**	**ARMAXBR/ SRCC**	**ARMAXBR/ SRCOr**	**ARMAXBR/ SRCOu**
2001	-0.914	0.334	0.081	-0.399	0.214
2002	-1.362	-2.146	-2.717	-2.973	-1.922
2003	2.075	-1.153	-0.414	-3.196	-1.586
2004	1.841	-0.427	-0.682	1.862	-0.079
2005	-0.910	-0.316	-0.004	0.763	-0.457
2006	0.131	-0.110	0.321	5.344	0.990
2007	-0.048	0.033	-0.253	0.266	1.183
2008	-4.227	-0.470	1.204	-8.156	-0.161
2009	-9.422	-0.798	2.450	-9.120	-3.934
2010	-0.818	-0.168	-0.944	0.900	-0.240

Year	OLS Combination Forecasting				
	ARMAXBR/ SRCS	**ARMAXBR/ SRE**	**ARMAXBR/ SRGDP**	**ARMAXBR/ MR**	**ARMAXBR/ VAR**
2001	0.393	1.093	0.312	0.454	1.021
2002	-2.066	-1.765	-2.203	-2.601	-1.488
2003	-1.224	-0.629	-0.635	-0.739	-1.464
2004	-0.668	-0.261	0.023	2.266	-0.008
2005	-0.344	0.045	-0.685	0.412	-0.270
2006	-0.195	0.086	0.149	3.127	-0.303
2007	-0.112	-0.305	0.127	-0.675	-0.793
2008	0.244	-0.199	-3.123	-12.262	-1.743
2009	-0.272	-2.130	-8.615	-11.909	-3.324
2010	-0.270	-1.479	-1.348	0.627	-0.334
	ARMAXCC/ ARMAXCOr	**ARMAXCC/ ARMAXCOu**	**ARMAXCC/ ARMAXCS**	**ARMAXCC/ ARMAXE**	**ARMAXCC/ ARMAXGDP**
2001	-1.749	1.513	1.370	1.550	-0.883
2002	-2.326	-1.196	-1.449	-1.220	-1.299
2003	-2.649	-1.704	-1.040	-1.558	2.115
2004	1.569	-0.492	-0.344	-0.436	1.889
2005	0.641	-0.695	-0.366	-0.581	-0.930
2006	4.367	-0.707	-0.255	-0.561	0.117
2007	0.242	-0.004	0.041	0.074	-0.043
2008	-6.753	-1.488	-0.900	-1.216	-4.341
2009	-7.624	-2.717	-0.939	-2.237	-9.670
2010	0.923	0.675	0.405	0.702	-0.792
	ARMAXCC/ SRBR	**ARMAXCC/ SRCC**	**ARMAXCC/ SRCOr**	**ARMAXCC/ SRCOu**	**ARMAXCC/ SRCS**
2001	1.316	1.010	0.448	1.256	1.426
2002	-1.503	-2.219	-2.407	-1.218	-1.364
2003	-1.569	-0.610	-3.541	-1.958	-1.626
2004	-0.317	-0.657	1.934	-0.020	-0.608
2005	-0.524	-0.123	0.591	-0.663	-0.557
2006	-0.444	0.105	5.087	0.600	-0.551
2007	0.166	-0.214	0.346	1.239	-0.018
2008	-1.392	0.796	-8.899	-0.988	-0.543
2009	-2.618	1.624	-10.543	-5.449	-1.907
2010	0.484	-0.506	1.467	0.447	0.400
	ARMAXCC/ SRE	**ARMAXCC/ SRGDP**	**ARMAXCC/ MR**	**ARMAXCC/ VAR**	**ARMAXCOr/ ARMAXCOu**
2001	2.122	1.198	1.168	1.695	-1.959
2002	-1.067	-1.613	-2.137	-1.045	-2.443
2003	-1.007	-0.967	-1.017	-1.736	-2.627
2004	-0.186	0.091	2.329	0.030	1.653
2005	-0.158	-0.873	0.266	-0.419	0.736
2006	-0.258	-0.148	2.904	-0.543	4.654
2007	-0.211	0.214	-0.615	-0.740	0.240
2008	-1.013	-3.876	-12.924	-2.299	-6.857
2009	-3.771	-10.151	-13.129	-4.420	-7.589
2010	-0.824	-0.784	1.099	0.102	0.858

Year	OLS Combination Forecasting				
	ARMAXCOr/ ARMAXCS	ARMAXCOr/ ARMAXE	ARMAXCOr/ ARMAXGDP	ARMAXCOr/ SRBR	ARMAXCOr/ SRCC
2001	-1.998	-1.971	-1.447	-2.725	-2.515
2002	-2.396	-2.441	-1.672	-2.811	-2.689
2003	-2.604	-2.611	0.943	-2.952	-2.569
2004	1.726	1.666	2.114	2.243	1.918
2005	0.762	0.753	-0.433	0.953	1.000
2006	4.736	4.667	1.688	5.521	5.459
2007	0.254	0.232	0.068	0.504	0.221
2008	-7.052	-6.859	-5.646	-8.392	-7.267
2009	-7.720	-7.640	-10.070	-9.690	-7.632
2010	0.902	0.817	-0.348	0.836	0.697
	ARMAXCOr/ SRCOr	ARMAXCOr/ SRCOu	ARMAXCOr/ SRCS	ARMAXCOr/ SRCE	ARMAXCOr/ SRGDP
2001	-2.419	-2.518	-2.487	-1.656	-2.040
2002	-2.742	-2.391	-2.530	-2.196	-2.418
2003	-3.517	-3.061	-2.958	-2.263	-2.085
2004	2.861	2.214	1.806	2.234	2.099
2005	1.308	0.812	0.885	1.296	0.498
2006	7.308	5.932	5.294	5.524	4.789
2007	0.428	0.997	0.216	-0.009	0.434
2008	-10.590	-7.653	-7.184	-7.637	-8.821
2009	-11.722	-10.569	-8.479	-10.480	-13.740
2010	1.356	0.890	0.775	-0.596	-0.105
	ARMAXCOr/ MR	ARMAXCOr/ VAR	ARMAXCOu/ ARMAXCS	ARMAXCOu/ ARMAXE	ARMAXCOu/ ARMAXGDP
2001	-1.464	-1.124	1.247	1.172	-0.905
2002	-2.559	-1.962	-1.619	-1.925	-1.333
2003	-1.832	-2.707	-0.794	-1.113	2.143
2004	3.373	1.715	-0.334	-0.598	1.884
2005	1.121	0.590	-0.259	-0.350	-0.918
2006	6.079	3.681	-0.092	-0.158	0.138
2007	-0.269	-0.468	0.015	-0.031	-0.049
2008	-14.476	-7.049	-0.620	-0.032	-4.286
2009	-14.684	-8.956	-0.155	0.054	-9.570
2010	1.222	0.464	0.222	0.119	-0.825
	ARMAXCOu/ SRBR	ARMAXCOu/ SRCC	ARMAXCOu/ SRCOr	ARMAXCOu/ SRCOu	ARMAXCOu/ SRCS
2001	0.947	0.806	0.160	0.897	1.072
2002	-2.152	-2.559	-2.915	-1.837	-1.990
2003	-1.160	-0.454	-3.189	-1.563	-1.213
2004	-0.432	-0.721	1.826	-0.130	-0.746
2005	-0.296	-0.021	0.778	-0.444	-0.331
2006	-0.066	0.290	5.387	1.021	-0.183
2007	0.074	-0.237	0.260	1.192	-0.126
2008	-0.370	1.287	-8.016	0.070	0.544
2009	-0.712	2.492	-8.902	-3.644	0.076
2010	-0.104	-0.749	0.992	-0.132	-0.185

Year	OLS Combination Forecasting				
	ARMAXCOu/ SRCE	ARMAXCOu/ SRGDP	ARMAXCOu/ MR	ARMAXCOu/ VAR	ARMAXCS/ ARMAXE
2001	1.827	0.898	0.923	1.474	1.278
2002	-1.666	-2.142	-2.554	-1.443	-1.517
2003	-0.562	-0.608	-0.722	-1.460	-0.709
2004	-0.296	-0.020	2.238	-0.046	-0.260
2005	0.091	-0.679	0.423	-0.266	-0.248
2006	0.123	0.168	3.153	-0.298	-0.081
2007	-0.332	0.125	-0.685	-0.809	0.039
2008	0.033	-2.971	-12.171	-1.615	-0.814
2009	-1.955	-8.459	-11.746	-3.149	-0.168
2010	-1.491	-1.274	0.703	-0.271	0.304
	ARMAXCS/ ARMAXGDP	ARMAXCS/ SRBR	ARMAXCS/ SRCC	ARMAXCS/ SRCOr	ARMAXCS/ SRCOu
2001	-0.754	1.080	0.972	0.260	1.016
2002	-1.355	-1.752	-2.088	-2.604	-1.455
2003	1.990	-0.803	-0.190	-2.899	-1.217
2004	1.777	-0.141	-0.400	2.056	0.172
2005	-0.882	-0.231	0.004	0.821	-0.379
2006	0.128	-0.015	0.287	5.403	1.084
2007	-0.039	0.148	-0.129	0.321	1.282
2008	-4.147	-1.099	0.355	-8.608	-0.680
2009	-9.064	-0.789	2.017	-8.971	-3.788
2010	-0.746	0.163	-0.385	1.196	0.125
	ARMAXCS/ SRCS	ARMAXCS/ SRCE	ARMAXCS/ SRGDP	ARMAXCS/ MR	ARMAXCS/ VAR
2001	1.120	1.895	1.010	0.997	1.532
2002	-1.691	-1.303	-1.844	-2.285	-1.195
2003	-1.018	-0.250	-0.307	-0.489	-1.223
2004	-0.631	-0.018	0.248	2.410	0.138
2005	-0.288	0.129	-0.636	0.455	-0.227
2006	-0.176	0.161	0.224	3.151	-0.263
2007	-0.123	-0.232	0.201	-0.628	-0.746
2008	0.383	-0.712	-3.704	-12.563	-2.080
2009	0.095	-1.945	-8.806	-11.712	-3.175
2010	-0.136	-1.133	-1.088	0.866	-0.103
	ARMAXE/ ARMAXGDP	ARMAXE/ SRBR	ARMAXE/ SRCC	ARMAXE/ SRCOr	ARMAXE/ SRCOu
2001	-0.905	0.891	0.723	0.092	0.823
2002	-1.335	-2.098	-2.547	-2.904	-1.809
2003	2.143	-1.017	-0.307	-3.101	-1.429
2004	1.884	-0.366	-0.645	1.913	-0.052
2005	-0.910	-0.180	0.104	0.885	-0.326
2006	0.141	-0.011	0.363	5.490	1.079
2007	-0.052	0.004	-0.299	0.216	1.130
2008	-4.277	-0.303	1.351	-8.063	0.101
2009	-9.571	-0.971	2.230	-9.253	-3.957
2010	-0.841	-0.395	-1.070	0.752	-0.434

Year	OLS Combination Forecasting				
	ARMAXE/ SRCS	ARMAXE/ SRE	ARMAXE/ SRGDP	ARMAXE/ MR	ARMAXE/ VAR
2001	1.011	1.688	0.832	0.872	1.427
2002	-1.947	-1.655	-2.110	-2.540	-1.419
2003	-1.052	-0.474	-0.494	-0.632	-1.371
2004	-0.632	-0.241	0.047	2.303	0.010
2005	-0.209	0.172	-0.575	0.506	-0.186
2006	-0.111	0.162	0.220	3.209	-0.255
2007	-0.169	-0.364	0.075	-0.727	-0.846
2008	0.464	0.059	-2.926	-12.199	-1.596
2009	-0.277	-2.106	-8.685	-12.017	-3.365
2010	-0.448	-1.654	-1.524	0.498	-0.466
	ARMAXGDP/ SRBR	ARMAXGDP/ SRCC	ARMAXGDP/ SRCOr	ARMAXGDP/ SRCOu	ARMAXGDP/ SRCS
2001	-0.944	-2.134	-1.323	-1.063	-0.848
2002	-1.211	-3.331	-1.900	-1.257	-1.167
2003	2.327	4.319	0.576	2.177	2.588
2004	1.954	1.584	3.259	2.088	2.356
2005	-0.947	-0.044	-0.095	-0.966	-0.907
2006	0.129	1.511	3.704	0.408	0.245
2007	-0.089	-0.639	0.210	0.228	0.105
2008	-4.364	-0.438	-8.926	-4.432	-5.641
2009	-9.783	-2.154	-14.249	-10.735	-10.310
2010	-0.825	-3.311	-0.063	-0.892	-0.460
	ARMAXGDP/ SRE	ARMAXGDP/ SRGDP	ARMAXGDP/ MR	ARMAXGDP/ VAR	SRBR/ SRCC
2001	-0.903	-0.946	-0.603	-0.353	-0.586
2002	-1.240	-1.335	-1.733	-1.038	-0.919
2003	2.359	2.184	1.738	1.659	0.589
2004	2.029	1.971	3.300	1.959	-0.088
2005	-0.876	-0.996	-0.210	-0.690	0.301
2006	0.189	0.235	2.366	0.147	0.497
2007	-0.090	0.013	-0.431	-0.306	-0.146
2008	-4.441	-5.077	-11.497	-4.413	1.154
2009	-10.216	-11.966	-15.230	-9.773	2.303
2010	-1.084	-1.231	-0.115	-0.736	-0.985
	SRBR/ SRCOr	SRBR/ SRCOu	SRBR/ SRCS	SRBR/ SRE	SRBR/ SRGDP
2001	-1.557	-0.312	-0.062	1.238	0.120
2002	-2.432	0.017	-0.095	0.552	-0.465
2003	-3.766	-0.574	0.070	0.813	0.528
2004	3.942	0.257	0.239	0.233	0.468
2005	1.721	-0.258	-0.005	0.560	-0.648
2006	8.927	0.961	0.056	0.289	0.294
2007	0.729	1.027	0.121	-0.597	0.053
2008	-13.274	0.057	-0.871	0.407	-3.859
2009	-15.137	-3.377	-0.562	-2.273	-11.382
2010	1.410	-0.236	0.121	-2.223	-1.741

Year	OLS Combination Forecasting				
	SRBR/ MR	**SRBR/ SRCOu**	**SRBR/ SRCS**	**SRBR/ SRE**	**SRBR/ SRGDP**
2001	-0.135	-0.312	-0.062	1.238	0.120
2002	-2.165	0.017	-0.095	0.552	-0.465
2003	-0.089	-0.574	0.070	0.813	0.528
2004	4.156	0.257	0.239	0.233	0.468
2005	1.004	-0.258	-0.005	0.560	-0.648
2006	4.931	0.961	0.056	0.289	0.294
2007	-0.690	1.027	0.121	-0.597	0.053
2008	-18.414	0.057	-0.871	0.407	-3.859
2009	-18.296	-3.377	-0.562	-2.273	-11.382
2010	0.843	-0.236	0.121	-2.223	-1.741
	SRBR/ VAR	**SRCC/ SRCOr**	**SRCC/ SRCOu**	**SRC/ SRCS**	**SRCC/ SRE**
2001	1.620	-1.420	-1.112	-0.093	-0.004
2002	-0.068	-2.434	-1.299	-0.212	-2.121
2003	-1.304	-3.125	0.665	0.287	3.496
2004	0.454	3.461	0.219	0.044	-0.070
2005	-0.121	1.800	0.420	0.081	1.966
2006	-0.461	8.759	2.386	0.149	2.229
2007	-1.587	0.364	1.170	-0.043	-1.374
2008	-2.551	-11.437	2.914	-0.012	5.372
2009	-5.000	-11.950	0.839	0.756	6.353
2010	-0.364	1.031	-1.883	-0.149	-6.255
	SRCC/ SRGDP	**SRCC/ MR**	**SRCC/ VAR**	**SRCOr/ SRCOu**	**SRCOr/ SRCS**
2001	-0.342	1.059	0.411	-1.057	-1.027
2002	-1.084	-0.243	-2.159	-2.246	-1.918
2003	0.750	-1.470	0.414	-3.357	-3.261
2004	0.547	4.241	0.241	3.448	3.992
2005	-0.444	0.246	0.779	1.861	1.667
2006	0.610	3.743	0.901	8.125	8.688
2007	0.103	-0.480	-1.961	-0.563	0.657
2008	-3.428	-21.014	0.839	-13.304	-13.774
2009	-10.374	-23.386	1.607	-11.489	-14.103
2010	-2.261	2.902	-2.712	1.782	2.005
	SRCOr/ SRE	**SRCOr/ SRGDP**	**SRCOr/ MR**	**SRCOr/ VAR**	**SRCOu/ SRCS**
2001	-0.437	-0.847	0.207	0.230	-0.191
2002	-1.746	-1.792	-1.748	-1.613	0.109
2003	-2.944	-2.081	0.034	-3.395	-0.362
2004	3.798	2.916	3.773	2.682	0.563
2005	2.019	0.775	0.925	0.881	-0.143
2006	8.644	6.117	4.653	5.039	1.114
2007	0.167	0.536	-0.912	-0.867	1.226
2008	-12.067	-11.066	-17.340	-10.180	-0.531
2009	-15.484	-16.972	-16.698	-13.199	-3.589
2010	-0.134	-0.086	1.004	0.511	0.030

Year	OLS Combination Forecasting				
	SRCOu/ SRE	SRCS/ SRE	SRCS/ SRGDP	SRCS/ MR	SRCS/ VAR
2001	0.621	1.035	0.552	0.207	1.580
2002	0.251	0.381	-0.399	-1.748	-0.172
2003	0.324	0.864	1.739	0.034	-1.018
2004	0.423	0.614	2.329	3.773	1.091
2005	0.350	0.536	-0.608	0.925	-0.053
2006	0.672	0.390	0.891	4.653	-0.250
2007	0.115	-0.292	0.943	-0.912	-1.217
2008	0.057	-0.896	-10.335	-17.340	-4.516
2009	-3.422	-2.824	-16.418	-16.698	-6.119
2010	-1.730	-1.741	-0.588	1.004	0.046
	SRE/ SRGDP	SRE/ MR	SRE/ VAR	SRGDP/ MR	SRGDP/ VAR
2001	-0.196	0.860	1.049	0.207	1.116
2002	-0.746	-1.508	-0.445	-1.748	-0.499
2003	0.372	0.505	-1.670	0.034	-0.786
2004	0.615	3.986	0.518	3.773	0.917
2005	-0.637	1.293	-0.292	0.925	-0.256
2006	0.355	4.844	-0.496	4.653	0.005
2007	0.228	-1.175	-1.291	-0.912	-0.904
2008	-4.187	-17.099	-3.035	-17.340	-4.236
2009	-11.735	-18.331	-4.881	-16.698	-10.160
2010	-1.738	-0.453	0.291	1.004	-1.172
	MR/ VAR	SRE/ MR	SRE/ VAR	SRGDP/ MR	SRGDP/ VAR
2001	0.915	0.860	1.049	0.207	1.116
2002	-1.483	-1.508	-0.445	-1.748	-0.499
2003	-0.767	0.505	-1.670	0.034	-0.786
2004	3.134	3.986	0.518	3.773	0.917
2005	0.622	1.293	-0.292	0.925	-0.256
2006	3.221	4.844	-0.496	4.653	0.005
2007	-1.481	-1.175	-1.291	-0.912	-0.904
2008	-14.473	-17.099	-3.035	-17.340	-4.236
2009	-15.581	-18.331	-4.881	-16.698	-10.160
2010	0.452	-0.453	0.291	1.004	-1.172