EXAMINATION OF PROPERTY FORECASTING MODELS - ACCURACY AND ITS IMPROVEMENT THROUGH COMBINATION FORECASTING

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This paper investigates property forecasting accuracy and its improvement. The research suggests that despite increased sophistication of property market modelling and forecasting, there still remains a degree of inaccuracy between model outputs and actual property market performance. Subsequently, the paper presents the principle of combination forecasting as a medium helping to achieve greater predictive outcomes. The research implements combination forecasting principle. It then 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 property market better, and which of these options forecasts best.

Keywords: Combination, Commercial Property, Forecasting, UK.

INTRODUCTION

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 exponential smoothing specifications to sophisticated structural with stationary data techniques (Ball et.al., 1998; Tonelli et.al., 2004; Barras, 2009; Brooks and Tsolacos, 2010). In particular, as researchers including Ball et.al. (1998), Dehesh and Pugh (2000), and Barras (2009) observed, the introduction of computer technology triggered the surge in the sophistication of mathematical modelling. However, despite this increase in the sophistication of the property market modelling and forecasting, the forecasting adequacy of alternative specifications, as the research suggests, has still room for improvement (Newell et.al., 2002; Gallimore and McAllister, 2004; 2005; McAllister et.al., 2005a; 2005b; Newell and MacFarlane, 2006; Newell, 2006; McAllister and Kennedy, 2007).

PRINCIPLE OF COMBINATION FORECASTING

Accordingly, researchers including Makridakis (1989), De Gooijer and Hyndman (2006), Goodwin (2009), Pesaran and Pick (2011) and Wallis (2011), just to name a few, suggested using combination forecasting as a means helping to achieve greater predictive outcomes. The researchers were motivated that by combining forecasts from different methods and sources greater predictive results can be achieved. What is more, their theoretical and empirical findings suggested usefulness of this procedure. Accordingly, different models have been developed to design the best combination forecasts. Although, Bates and Granger (1969) and more recently Kapetanios et.al. (2008) observed that the combination forecasting does not necessarily lead to a better forecasting performance. Banternghansa and McCracken (2010, p.65) also added that averaging approach should be used and interpreted with caution whereas "past model performance does not always ensure future model performance".

Combination forecasts can be generated simply by averaging different forecasts or using more sophisticated techniques, including weighting or regression estimates (Makridakis,

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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 forecasted period (Mahmoud, 1984). The criticism behind 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).

Weighting technique has two principle alternatives. One is historical weighting, which gives weights to the forecasts based on their historic fit. In this case, 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 (Mahmoud, 1984).

The regression, also known as Ordinary Least Squares (OLS), combination approach is considered to be a more advanced combination technique. According to De Gooijer and Hyndman (2006) and Rapach and Strauss (2007), however, the OLS based combination methods often perform quite poorly due to possible presence of the serial correlation within combined forecasting errors. Goodwin (2009) also added that this approach is sensitive to extreme forecasts (outliers in the forecast).

What is regarding property market forecasting, the use of the combination forecasting was not widespread within the field (Bradley et.al., 2003). Reasonably few studies have been published on the subject, with the majority of them investigating residential property market. However, the empirical results indicated a benefit of this procedure and suggest further research in this area (Bradley et.al., 2003; Pagourtzi et.al., 2005; Fleming and Kuo, 2007; Drought and McDonald, 2011; Gupta et.al., 2011).

DATA

Dependent Variable

The research uses the 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, it has been suggested that IPD indices are the most reliable property market benchmarks in the UK. They are well regarded within UK property investment community, as well as they are regularly used by property researchers (Baum, 2001; Ball, 2003; McAllister et.al., 2005a; 2005b).

The original IPD All Property Rental Value Growth Index series, which is available from 1976, is extended by combining it with Scott's (1996) dataset. Empirical evidences those of RICS (1999) suggest that IPD's series can be extended by combining it with Scott's time-series. The visual and statistical analysis also indicates high compatibility between two datasets (Figure 1; Figure 2). The correlation coefficient over the period 1976-1993, when two series overlap, is 0.9994 (it is 0.9968 for 1st.dif. series) which indicates almost perfect positive correlation.

The need for a greater sample size comes from Holden et.al. (1991), McGough and Tsolacos (1995) and Tse (1997) who argued the need for at least 50 sample observations to produce an adequate time-series model. Accordingly, the combination of both IPD and Scott's datasets extends rental series for 13 years for 1963-2010 period. As a result it gives 48 data points which is considered to be substantial for both univariate and regression time-series modelling. Subsequently, data on all explanatory variables is collected for the same time period.

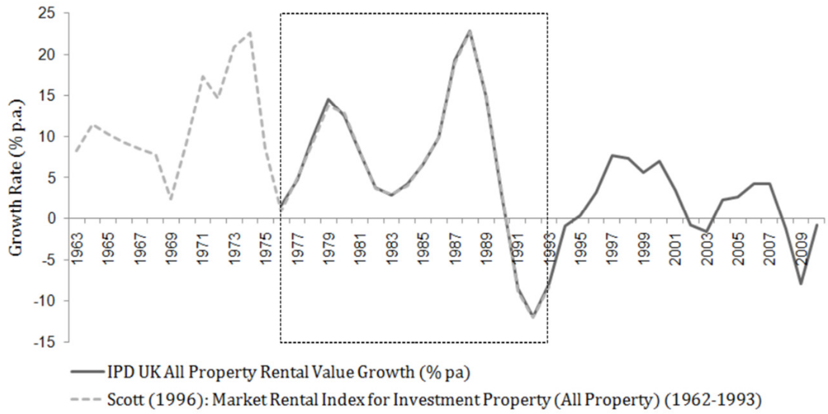

Figure 1. IPD and Scott's (1996) Combined UK Property Rental Series
Source: Scott (1996); IPD (2011)

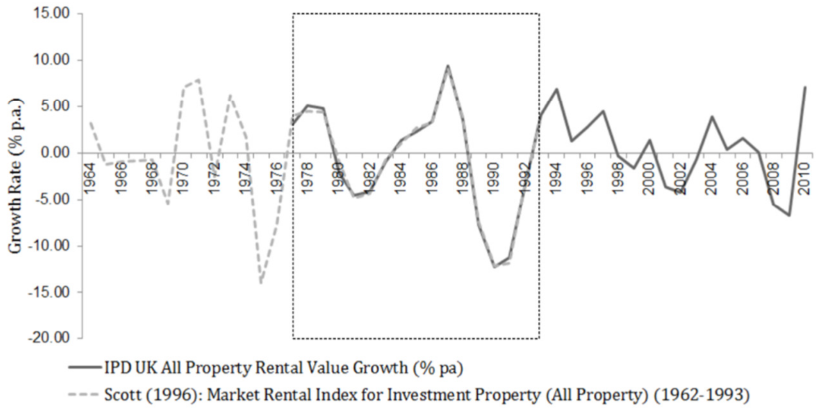

Figure 2. IPD and Scott's (1996) combined UK property rental series (1st.dif.)
Source: Scott (1996); IPD (2011)

Explanatory Variables

The examination of the literature on the subject[2] enabled to identify fifty-two variables which were used by various property researchers to model commercial property rents. However, subsequent analysis of the data-sets of seventeen organisations and thirteen publications made it possible to collect statistical data on only twenty-eight (plus five additional) of these variables for the 1963-2010 research period (Table 1). Business Orders, Consumer Confidence, Floor-space, Index of Services, Retail Sales, Take-up, Business Turnover, and Vacancy Rate were variables for which data was not available for such a long period of time. Time series, which were of limited length, were extended by chain-linking them with the alternatively available data-sets where possible.

The data on explanatory variables was obtained from various sources. Organisations whose data sets 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) (2010), HM Revenue & Customs (HMRC) (2011), Ingleby Trice (2011), Investment Property

[2]The publications are: 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. (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).

Databank (IPD) (2011), London Stock Exchange (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 (2011). 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).

All time-series were also tested for stationarity. The unit root assessment was performed using Autocorrelation Function (ACF) and Partial-Autocorrelation Function (PACF) plots as well as OLS estimates for AR model as suggested by Koop (2006). First, AR(1) specification was created to examine ϕ value of series. Then, first difference Δy_t values were computed. Following on from this, Δy_t was regressed on lagged values of time-series itself, i.e. y_{t-1}. The regression estimates of t-statistics and ρ were then assessed against Dickey-Fuller critical values (Table 2).

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)
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	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	1970-2010	Foreign direct investment (net inflows) (BX.KLT.DINV.CD.WD)	World Bank (2011) / ONS (2010)
FTSE All Share Index	1963-2010	FTSE All-Share Index value	LSE (2011) / Global Financial Data (2010) / Bondet.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)	
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 (2011)
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 of Government	1963-2010	2.5% consolidated stock average yield	UK Debt Management Office (2011)
Securities	1963-2010	Par yield on long-dated British Government Securities (20 years - per cent per annum) (AJLX)	ONS (2010) / Bank of England (2011)
Capital Formation	1963-2010	Gross fixed capital formation: business investment (NPEK)	ONS (2010) / World Bank (2011)
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 1. Time-series employed to model commercial property rents and their availability

Variables		**t-stat (y_t)**	**t-stat (Δy_t)**	**t-stat ($2\Delta y_t$)**
Bank Rate		1.393 (0.170)	-5.890 (0.000)	-
Business Output		2.446 (0.018)	-3.623 (0.001)	-
Car Registrations		-1.795 (0.079)	-4.886 (0.000)	-
Construction Orders		-1.623 (0.112)	-4.243 (0.000)	-
Construction Completions	Construction Output	-0.856 (0.397)	-4.533 (0.000)	-
	Building Completions	-0.541 (0.591)	-6.229 (0.000)	-
Construction Cost		1.165 (0.250)	-1.616 (0.113)	-5.845 (0.000)
Construction Starts		-2.081 (0.043)	-6.683 (0.000)	-
Consumer Confidence		-3.241 (0.003)	-	-
Consumer Expenditure		6.115 (0.000)	-2.243 (0.002)	-9.747 (0.000)
Depreciation Rate		6.662 (0.000)	-2.153 (0.037)	-7.134 (0.000)
Disposable Income		0.646 (0.522)	-4.289 (0.000)	-
Employment		-0.904 (0.371)	-3.734 (0.001)	-
Foreign Funds		-6.481 (0.000)	-	-
FTSE All Share Index		-0.300 (0.766)	-6.384 (0.000)	-
GDP		-4.613 (0.000)	-	-
ONS Leading Indicator	Index of Production	-2.268 (0.028)	-5.331 (0.000)	-
Inflation		-2.303 (0.026)	-6.772 (0.000)	-
Lagged Dependent Variable		-2.019 (0.050)	-4.0945 (0.000)	-
Money Supply	M4	10.984 (0.000)	-1.817 (0.076)	-9.257 (0.000)
	M0	-2.199 (0.033)	-7.460 (0.000)	-
Number of Property Transactions		-2.199 (0.033)	-7.460 (0.000)	-
Profitability		-1.618 (0.113)	-4.951 (0.000)	-
Property Value		1.744 (0.088)	-3.533 (0.001)	-
Risk Premium		-4.206 (0.000)	-	-
Unemployment		-1.431 (0.159)	-3.793 (0.001)	-
Yields of Government Securities	Short	-0.955 (0.345)	-4.859 (0.000)	-
	Long	-0.887 (0.380)	-4.708 (0.000)	-
Capital Formation		-0.131 (0.897)	-6.914 (0.000)	-
Job Vacancies		-0.362 (0.719)	-3.621 (0.001)	-
Land Value		-0.471 (0.640)	-4.832 (0.000)	-
Net Investment		-0.914 (0.366)	-5.136 (0.000)	-
Total Returns		-4.851 (0.000)	-	-

Table 2. The OLS estimation results for AR(1) 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

Variable Reduction

The combination of simple and more sophisticated variable reduction techniques was used in selecting the key variables to model property rental index. 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. “What experts advise” suggests looking across the literature on the subject and picking the main variables used by acknowledged researchers. Stepwise Regression, according to Draper and Smith (1998), Makridakis et.al. (1998) and PASW 18 (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 at each step. Forward entry adds variables with the smallest probability of F to the equation one at a time. Granger causality, as Koop (2006) suggests, uses *t*-statistics and P-values of individual coefficients to determine whether a variable is significant. Accordingly, the combination of all these procedures enabled to produced so called “short list” of explanatory variables, which is as follows: Bank Rate, Construction Costs, Construction Orders, Construction Output, Construction Starts, Employment, GDP, as well as past values of rents itself (Table 3). Subsequently, the latter seven variables are further used for the research.

Variable	“what others do”	“what experts advise”	Stepwise Regression (Forward)	Stepwise Regression (Backward)	Granger Causality
Bank Rate	X	X			X
Construction Costs		X		X	X
Construction Orders	X	X		X	
Construction Output			X	X	
Construction Starts				X	
Employment	X	X			
Gross Domestic Product	X	X	X	X	
Lagged Rents	X	X	X	X	X

Table 3. The summary table of the importance of variables in modelling UK commercial property rents

In- and Out-Of-Sample Accuracy Measurement

The time-series were then divided into “initialisation” and “holdout” periods. All models were parameterised and tested on the initialisation period from 1964 to 2000, and forecasts made on the holdout set from 2001 to 2010. It was hypothesised that ten years ex-post forecasting accuracy assessment period should be substantial to examine forecasting performance of each of the models. It was also anticipated that the ten year hold out period would contain two short 4-5 years property cycles driven by the classical business cycle (Barras, 1994; RICS, 1994; Ball et.al., 1998) and longer 9-10 years property cycle (Barras, 1994), as well as it would allow to assess the forecasting accuracy of each of the forecasting specification for short- and long-run horizons.

The research compares the forecasting ability of six alternative modelling techniques including Exponential Smoothing (Simple, Holt’s and Brown’s), ARIMA/ARIMAX, Simple Regression, Multiple Regression, Vector Autoregression, and Combination Forecasting.

The in-sample accuracy is assessed by computing R-square, Mean Error (ME), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE) accuracy measures. The out-of-sample accuracy is examined from Theil’s second inequality coefficient *“U”*.

In addition to that, technique known as “information criteria” is used in selecting the best parameterised models. The “information criteria” employed for the current research is Akaike Information Criterion (AIC) (Chaplin, 1998; 1999; Makridakis et.al., 1998; Stevenson and McGarth, 2003; Karakozova, 2004; Stevenson, 2007; Brooks and Tsolacos, 2010).

What is more, two supplementary tests are computed, which are Durbin-Watson (DW) test for autocorrelation, and White's test (WT) for heteroscedasticity. The DW assesses whether autocorrelated disturbances are present within the model. Following PASW 18 (2010b) statistical module, if DW value is between 1.5 and 2.5, it indicates that values are independent. The presence of heteroscedasticity is assessed using the popular White's test (WT). White's test using PASW package is performed following a certain algorithm. First, squares of regression residuals (unstandardized) 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. Subsequently, WT value is calculated by multiplying *n*, which is the number of observations, and R-squared obtained from the regression. Finally, the obtained value is compared with χ^2 (chi-square). 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; PASW 18, 2010b).

Empirical Results of the Exponential Smoothing
Simple, Holt's Linear Trend and Brown's Linear Trend modelling is performed using PASW 18 "Time Series Modeller" (PASW 18, 2010a). As the statistical analysis suggests, neither of Exponential Smoothing models fit historic rental series (Table 6). The R-squared of each of the specifications is less than 0, which implies that none of the specifications has a power in explaining the change of the rental growth. Other statistical measures are also insignificant. It all thus suggests that Exponential Smoothing techniques are not applicable for stationary time-series forecasting.

Empirical Results of the ARIMA/ARIMAX Models
As the findings suggest, ARIMA (1,0,2) is the best parameterised ARIMA specification (Table 4) of all twenty ARIMA models, ranging from ARIMA (1,0,0) to ARIMA (4,0,4), produced for the research. This specification has the lowest MAPE, as well as the smallest *AICc* value.

The subsequent statistics indicate that ARIMAX GDP (4,0,0) model has the best statistical properties (Table 6) of all one hundred and forty ARIMAX specifications (ranging from ARIMA (1,0,0) to ARIMA (4,0,4) and which include all seven explanatory variables).

ARIMA Order	Model Fit statistics				
	R-squared	MAE	MAPE	Correlation	AICc
1,0,0	0.174	3.873	108.985	0.417	125.84
1,0,1	0.412	3.137	87.215	0.644	115.64
1,0,2	0.517	2.601	**66.035**	0.731	**109.85**
1,0,3	0.527	2.605	68.624	0.729	112.91
1,0,4	0.529	2.582	69.369	0.732	115.62
2,0,0	0.333	3.280	94.895	0.577	120.43
2,0,1	0.425	3.068	83.969	0.652	117.65
2,0,2	0.533	2.615	71.205	0.731	112.66
2,0,3	0.560	2.563	82.892	0.759	112.30
2,0,4	0.576	2.549	79.082	0.762	115.16
3,0,0	0.333	3.279	94.891	0.577	123.12
3,0,1	0.455	2.965	88.829	0.677	118.33
3,0,2	0.549	2.529	73.182	0.743	114.28
3,0,3	0.564	2.510	75.860	0.753	116.33
3,0,4	0.559	2.567	72.258	0.760	119.00
4,0,0	0.529	2.794	100.710	0.728	113.08
4,0,1	0.529	2.796	99.968	0.728	116.13
4,0,2	0.574	2.542	81.733	0.761	115.28
4,0,3	0.578	**2.470**	79.555	0.763	118.51
4,0,4	**0.589**	2.521	80.768	**0.769**	121.49

Table 4. Model fit statistics for ARIMA specifications

Empirical Results of the Regression Models

The statistical analysis suggests that Construction Orders is the best explanatory variable for Simple Regression framework (Table 6). Although a GDP based model has the smallest MAE value and greatest correlation coefficient, the Construction Orders based model has the smallest AICc value amongst competing specifications. 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 2.01 which is less than χ^2 (5.99). Therefore, the hypothesis of heteroskedasticity is rejected. It implies that test did not find a problem.

In case of the Multiple Regression, the modelling results indicate the satisfactory ability of the equation to track property rents (Table 6). Given the fact that changes of the rent series is modelled, R-squared of 0.553 suggests that the model succeeds in capturing dynamics of the rental series. The DW statistical value for Multiple Regression is 1.71. It suggests that autocorrelated disturbances are not present within the model, i.e. that values are independent. The White's test value WT is 5.04 which much is less than χ^2 (18.31). Therefore, the hypothesis of heteroskedasticity is rejected.

Vector Autoregressive (VAR) model tracks historic rent series with a greater accuracy than any other specification, with its R-square being 0.793 (Table 6). The DW statistics for the model is 1.545, what suggests that the model is well parameterised. White's test indicates that there are no problems with the specification. The WT value is 32.01, which is less than χ^2 (53.384).

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. Estimates from a VAR (3) (P-values in parentheses)

Out-of-sample Forecasting Accuracy Measurement

The statistical results indicate VAR (4) specification to be the best fitting model. Its R-squared and the correlation coefficient are the greatest of all sample models. The *AICc* also indicate it to be the best parameterised specification (Table 6). However, these results do not come as a surprise. The VAR model comprises three explanatory variables (Construction Starts, Construction Output and GDP), their lagged values, as well as past values of dependent variable itself. It all therefore explains its goodness to fit to the historic data.

However, when it comes to out-of-sample forecasting performance, VAR's accuracy is not so impressive. It's Theil's U value is poorer than that of some less sophisticated ARIMAX and Simple Regression models (Table 6; Figure 3; Figure 4). All that adds further to the suggestions that goodness of fit does not imply good forecasting performance, and that increased model sophistication does not necessarily yield greater forecasting accuracy (Chaplin, 1998; 1999; McGough et.al., 2000; Wilson et.al., 2000; Ball and Tsolacos, 2002; Newell et.al., 2002; Crawford and Fratantoni, 2003; Stevenson and McGarth, 2003).

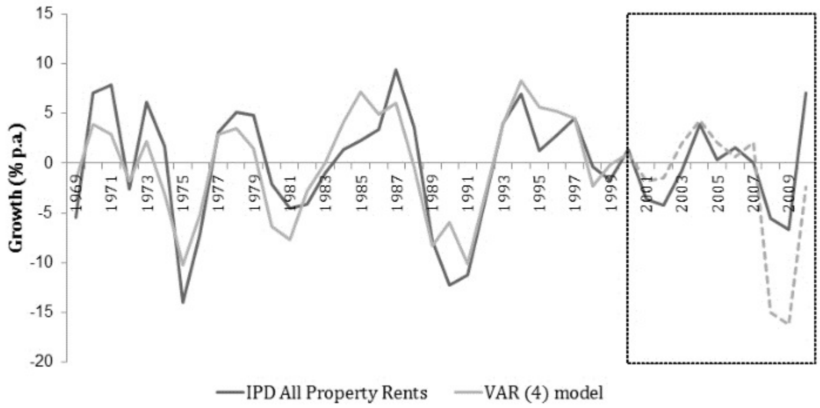

Figure 3. VAR (4) (model fit and forecasting accuracy) (1st.dif.)

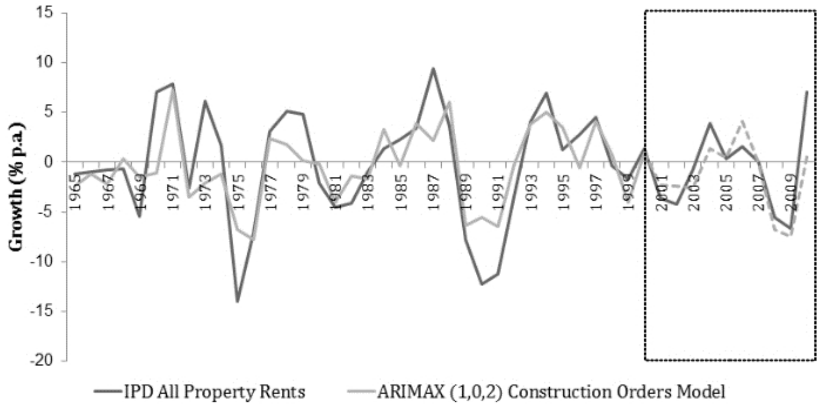

Figure 4. ARIMAX (1,0,2) Construction Orders (model fit and forecasting accuracy) (1st.dif.)

The most accurate of all sample models is ARIMAX Construction Orders (1,0,2) (ARIMAXCOr) specification, following Simple Regression Construction Orders (SRCOr) and ARIMAX GDP (4,0,0) (ARIMAXGDP) models. All the specifications have the smallest Theil's U statistical values. Although these 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. It also suggests that past values of rents itself, as well as change in Construction Orders are the most important explanatory variables to model IPD All Property Rent Index. Interestingly, property consultancies, including GVA (2009), also relate New Construction Orders and GDP growth to the dynamics of the commercial property rental cycle.

Combination Method

Combination forecasts are produced using two principle techniques, i.e. Simple forecasting Averaging (SA) and Regression (OLS) combination. 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.

The results of the study suggest that a combination forecast improves forecasting accuracy (Table 7; Figure 5). Comparing the best performing individual model forecast with the best performing combination forecasts, it is seen that the combination forecast has better statistical properties. Theil's U statistics for ARIMAXCOr+SRCCs OLS combination forecast is 0.32, while it is 0.33 for single ARIMAXCOr model.

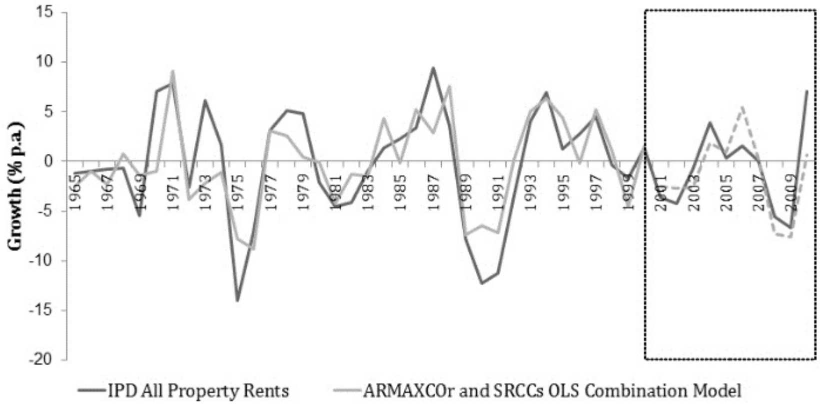

*Figure 5.*ARIMAXCOr and SRCCs OLS Combination (model fit and forecasting accuracy) (1st.dif.)

This therefore suggests that a combination approach can produce relatively accurate rental growth forecasts. The advantage of this technique comes from the fact that in the current research, combination forecasts contain an extra explanatory variable and is also parameterised on regression estimates which contain ex-post knowledge of the rental series. Although, on the other hand, the best performing combination forecast is produced using simple forecasting techniques which are combined using a simple combination principle.

Model Specification	**Model Fit statistics**					
	R-squared	**MAE**	**MAPE**	**Correlation**	**Theil's U**	**AICc**
Exponential Smoothing						
Simple Exponential Smoothing	-0.027	4.399	109.261	-0.2314	0.94	130.87
Holt's Linear Trend	-0.027	4.390	110.323	-0.2151	0.93	131.15
Brown's Linear Trend	-0.001	4.358	100.240	-0.2106	1.00	131.23
Simple Regression						
Bank Rate	0.001	4.333	98.261	0.029	0.95	130.47
Construction Costs	0.000	4.362	98.859	-0.020	0.97	130.49
Construction Orders	0.339	3.737	142.379	0.582	0.41	115.26
Construction Output	0.015	4.526	108.083	0.124	0.88	129.94
Construction Starts	0.001	4.346	97.929	0.034	0.93	130.46
Employment	0.031	4.092	87.638	0.176	0.82	129.36
GDP	0.322	3.631	120.185	0.568	0.47	118.50
Multiple Regression	0.553	3.061	141.647	0.743	0.46	109.35
Vector Autoregression	0.793	2.474	91.845	0.861	0.48	85.18
ARIMA (1,0,2)	0.517	2.601	66.035	0.731	0.85	109.85
ARIMAX						
Bank Rate (1,0,2)	0.521	2.582	66.398	0.734	0.82	112.32
Construction Costs (1,0,2)	0.520	2.612	66.688	0.733	0.74	112.46
Construction Orders (1,0,2)	0.604	2.608	80.827	0.789	0.33	103.24
Construction Output (1,0,2)	0.517	2.597	65.486	0.731	0.84	112.66
Construction Starts (1,0,2)	0.523	2.602	67.448	0.735	0.83	112.27
Employment(1,0,2)	0.515	2.597	66.645	0.729	0.84	112.90
GDP (4,0,0)	0.690	2.261	69.831	0.839	0.43	99.09

Table 6. Summary model fit statistics

	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	0.41	0.41	0.41	0.41	0.40	0.40	0.38	0.41	0.40	0.41	0.41	0.41	0.42	0.42	0.46	0.41	0.44	0.44	0.46	-
	0.51	0.51	0.53	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.44	0.48	0.49	0.50	0.48	0.48	0.48	0.48	0.49	

Table 7. Theil's U statistics for simple 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

CONCLUSIONS AND IMPLICATIONS FOR FURTER RESEARCH

The aim of the current paper was to assess whether combination forecasts from different forecasting techniques are more accurate than single model outputs. The paper investigated which of them - combination or single forecast - fits the UK commercial property market better, and which of these options forecasts more accurately.

The paper compared the forecasting ability of six alternative modelling techniques, including Exponential Smoothing, ARIMA/ARIMAX, Simple Regression, Multiple Regression, Vector Autoregression and Combination Forecasting to forecast the UK commercial property market rents. Their forecasting adequacy was then assessed in a ten-year out-of-sample period.

The best fitting individual model proved to be the VAR specification. 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 forecasts were 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, combination forecasting improves forecasting accuracy, e.g. the ARIMAXCOr+SRCCr OLS combination forecast had better statistical properties than the best single model.

It all therefore suggests that a combination approach improves property forecasting. It is also important to note that the best fitting combination forecast was produced using simple forecasting techniques which were combined using simple combination principle. In general, it therefore indicates that simple time series models, which are easier and cheaper to use, in combination are more accurate than large and sophisticated structures.

The implications for further research would be to assess alternative combination techniques and also examine whether combination of more than two forecasting models further improves the accuracy of the UK commercial property forecasting.

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