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# FORECASTING OFFICE BUILDING RENTAL GROWTH – USING A DYNAMIC APPROACH

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**Abstract**

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 over a five to ten year timeframe.

This research focuses on office rental growth forecasts and overviews many of the office rent models that have evolved over the past 20 years. A model by DiPasquale and Wheaton is selected for testing in the Brisbane, Australia office market. The adaptation of this study did not provide explanatory variables that could assist in developing a reliable, predictive model of office rental growth.

In light of this result, the paper suggests a system dynamics framework that includes modified econometric models based on historical data as well as user input guidance for the primary variables. The rent forecast outputs would be assessed having regard to market expectations and probability profiling undertaken for use in simulation exercises. The paper concludes with ideas for ongoing research.

**Key Words**

**Forecasting, Office Rents, System Dynamics, Econometric Modelling, Simulation**

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## 1.0 Introduction

Earlier approaches in estimating rental growth rates in discounted cash flow valuation exercises were often overly simplistic, generating projections that were far from realistic (Hendershott 1996; Born & Pyhrr 1994). Kummerow (1997) found, during the 1980s, Australian valuers commonly adopted a single, linear and compounding rent growth rate in their assessments. A recent survey of valuers in the city of Brisbane, Australia, found that most valuers use broad cyclical rent forecasts in cash flow studies, but that the conservative nature of recent forecasts in this city appear to lack fortitude in recognising the volatility of the property market. *Figure 1*, below, illustrates this inconsistency with a comparison of the historical volatility of prime office rents spliced onto the median of forecasts from five major valuation firms.

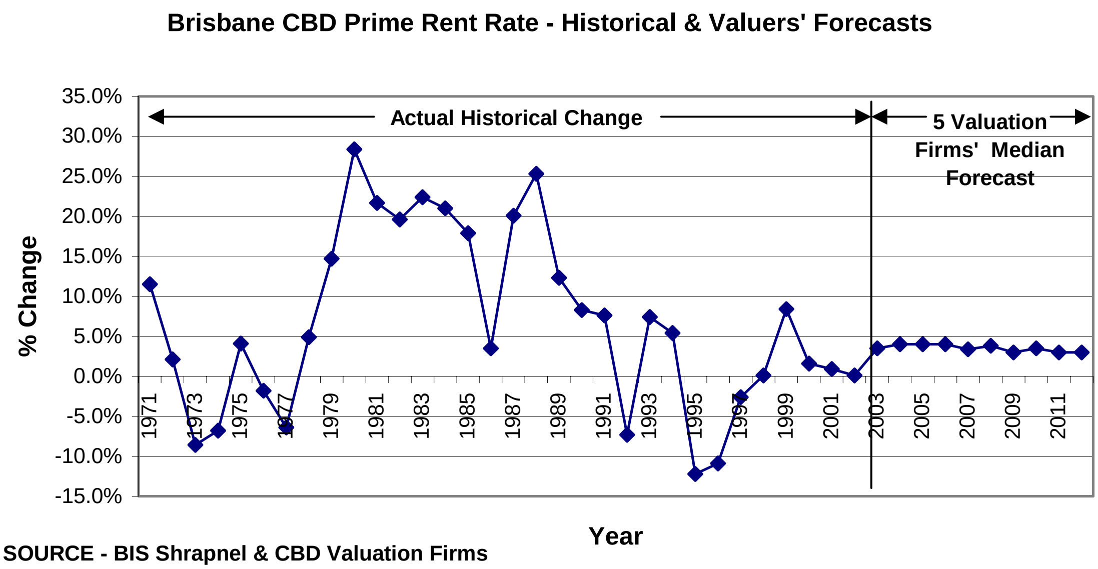



Figure 1 – Historical and Forecast Percentage Change – Brisbane Prime Office Rents

Asset managers are emphasizing the importance of realistic rental growth forecasts and requiring valuers to justify their forecasts. This study examines whether existing or adapted econometric models developed from historical data can be used to predict future rental growth rates.

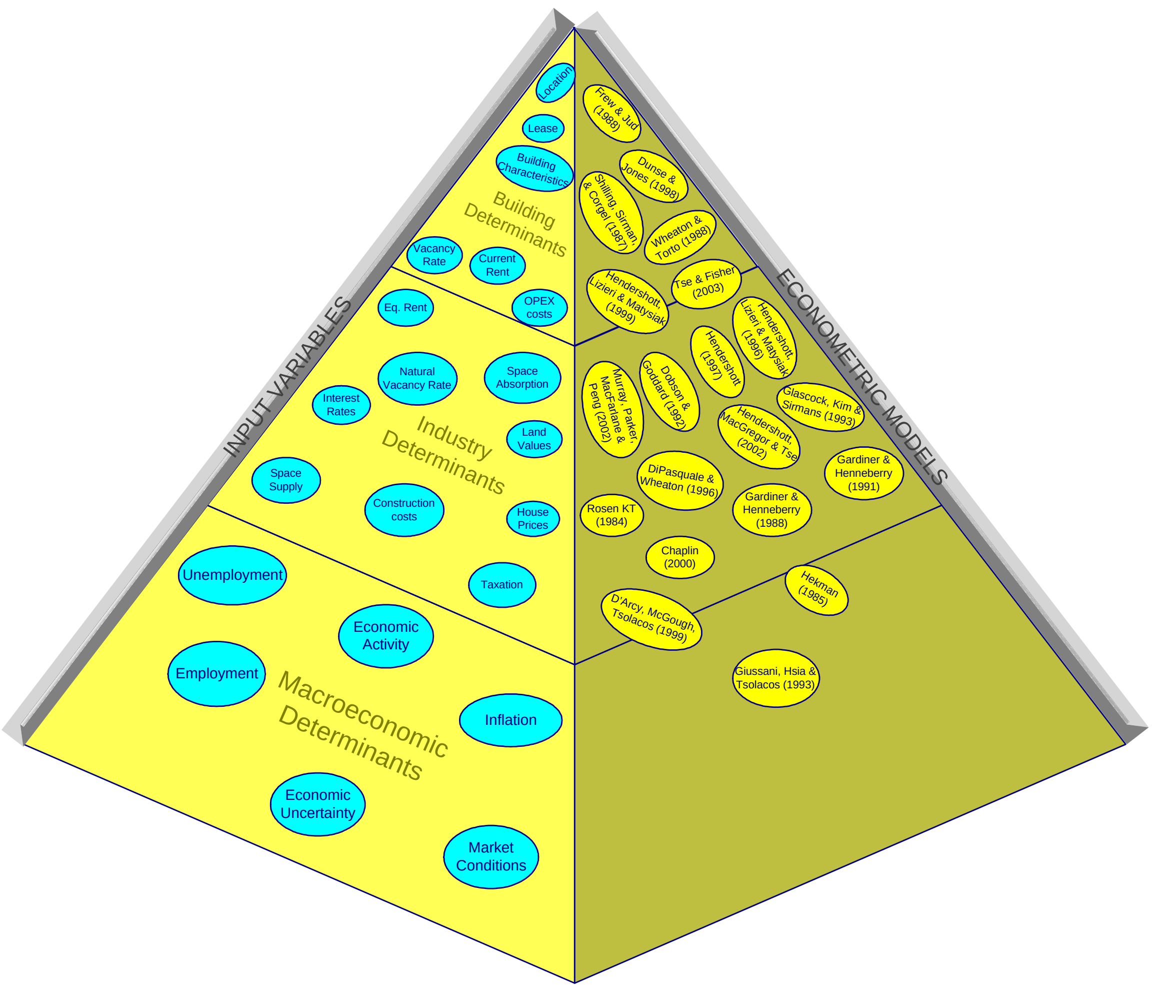
Initially a literature review of property cycle analysis is undertaken and thereafter an econometric model is tested using data from the Brisbane office market. As the results from this study are unhelpful in providing a model for predictive purposes, reference is made to the incorporation of the simulation process and the incorporation of System Dynamics in the forecasting process.

## 2.0 Literature Review on Property Cycles

Much research has been devoted to the nature and causes of property market cycles. Born and Pyhrr (1994) conducted practical tests to determine the impacts of accounting for market and economic cycles in property cash flow assessments. McGough and Tsolacos (1995) examined commercial building activity in the UK and its procyclicality with demand side factors, such as GDP and employment growth. Clayton (1996) found, in a Canadian study, real estate returns were a function of general capital market conditions. Kaiser (1997) investigated real estate cycles over a long term extending from the 1800s and argued for the existence of "long cycles" with durations of 50 to 60 years. These "long cycles" were said to be driven by prior periods of above-average inflation. Canter, Gordon and Mosburgh (1997) examined the impact of economic fundamentals on building vacancy rates as a generator of property cycles. The relationship between macroeconomic variables and the property market was said to provide the ability to distinguish between the different stages of real estate cycles when looking at property returns (Grissom and Delisle 1999). Mueller (1999) determined rental growth rates to be statistically different at six different points in the property market cycle. In a defining study, Pyhrr, Roulac and Born (1999) nominated cycles' "*pervasive and dynamic impacts on real estate returns, risks and investment values*". Again, this study raised the key linkages between macroeconomic factors and property supply and demand factors. With a wider view, Dehesh and Pugh (2000), considered the impact of globalisation, economic agglomeration and financial deregulation on real estate cycles.

Many of these and other researchers have recognised the cyclical influences and negative impacts of overbuilding on office vacancy rates and, consequently, on office rents. Barras (1994) considered several cyclical influences, of different periodicity, conspired to produce major, speculative building booms. Barras also considered these occurrences to be self-replicating over time. Gallagher and Wood (1999) noted the property market's tendency to over-react to economic trends, generating excess office construction and this was known to have a negative impact on market performance. The causes of these occurrences were quoted as being: the long-term investment nature of real estate; development lags; space demand uncertainty; high adjustment (acquisition / disposal) costs; and the "*unbridled enthusiasm*" of developers. In this context, Kummerow (1999) spoke of "*allocative and production inefficiencies*" in terms of resources. Sivitanidou and Sivitanides (2000) raised the concept of "*irreversible investment*" in relation to the "*highly cyclical and highly volatile*" office-commercial construction activity in the US.

Past research on property cycles and the supply and demand dynamics of property markets has been paralleled by studies aimed at developing rent, return and space supply forecasting models. Office rent models have been evolving over the past 20 years and the majority of the models explicitly quantify causal relationships between changes in rent levels and property market and macroeconomic determinants. *Figure 2*, below, provides a visual representation of the 20 identified models.



Of interest is a comparison of the relative dominance of the explanatory variables adopted in the 20 models. The following chart provides a representation of the relative level of adoption of the various property, market, economic and financial factors. *Appendix 1* (*Office Rent Models – Determinants*) and *Appendix 2* (*Office Rent Models – Equations / Results*) provide greater detail on the structures of the models.

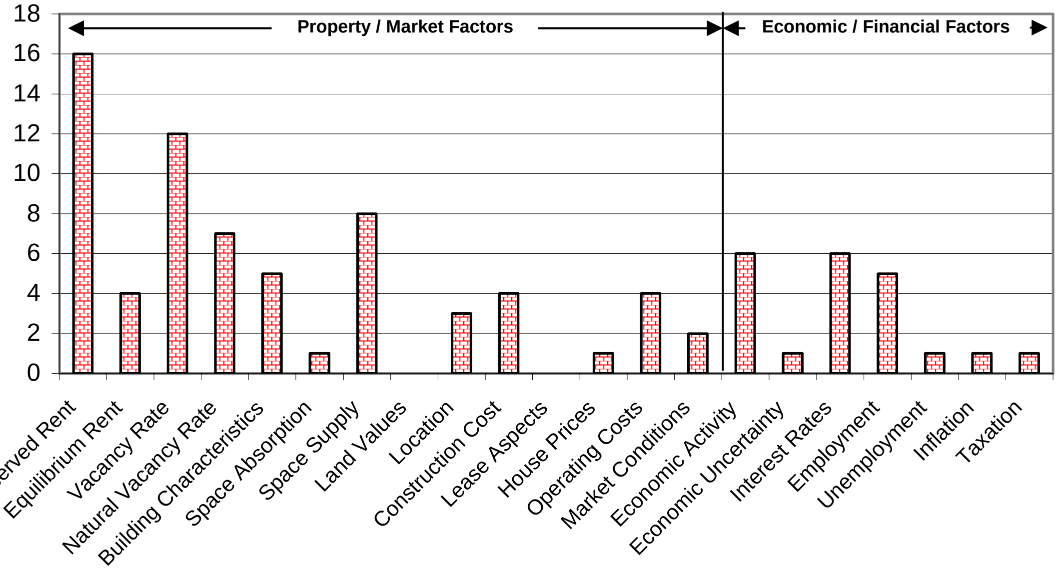



Figure 3 – Explanatory Variables – Frequency of Adoption by Researchers

Aside from historical or observed rents, the dominant property / market determinants adopted for office rents include observed and natural vacancy rates and space supply. The prevalent economic / financial determinants adopted include economic activity, interest rates and employment.

**3.0 Dominant Econometric Models**

McDonald (2002) surveyed office market econometric models and the study focused on the models developed by Wheaton, Torto and Evans (1997) and Hendershott, Lizieri and Matysiak (1999). Both these models were estimated for the London office market and served as forerunners to the "RICS model" developed in 2000 by the RICS Research Foundation. In commenting on Wheaton Torto and Evans model, McDonald stated that its "*theoretical framework is arguable the best among available models*". A varied version of this model was estimated for the San Francisco office market and was published in 1996 (DiPasquale and Wheaton). The following is a tabulation of the series of equations:

| | |
|---|---|
| **① TOTAL SPACE – Accounting Identity** | |
| $S_t = (1 - \delta)S_{t-1} + C_t$ | Where:<br>$S_t$ = Total Space in period t<br>$C_t$ = Completions in period t<br>$\delta$ = Demolitions / Removals / Space Conversions |
| **② VACANCY RATE – Accounting Identity** | |
| $V_t = \dfrac{(S_t - OC_t)}{S_t}$ | Where:<br>$V_t$ = Vacancy Rate in period t<br>$S_t$ = Total Space in period t<br>$OC_t$ = Occupied Space in period t |
| **③ OCCUPIED SPACE – Accounting Identity** | |
| $OC_t = OC_{t-1} + AB_t$ | Where:<br>$OC_t$ = Occupied Space in period t<br>$OC_{t-1}$ = Occupied Space in previous period<br>$AB_t$ = Net Space Absorption in period t<br><br>Notes:<br>US data indicates strong relationship between office employment growth and net space absorption. When these two factors diverge, the amount of space per worker must be changing. Space use varies across occupations and should vary with the level of office rents. When vacancies are high and rents are low, space per worker expands and vice versa. |
| **④ NET ABSORPTION MODEL EQUATION 1 – Regression** | |
| $OC^*_t = \alpha_0 + E_t\left[\alpha_1 + \alpha_2 \dfrac{(E_t - E_{t-1})}{E_t} - \alpha_3 R_t\right]$ | Where:<br>$OC^*_t$ is the amount of space all firms in the market would, in principle, demand if there were no lease, moving or adjustment costs to obtaining such space<br>$E_t$ is the number of Office Workers at time t<br>$R_t$ is the Current Rent for space<br>$\dfrac{E_t - E_{t-1}}{E_t}$ is current or expected growth rate of firms<br>$\alpha_1$ determines the baseline amount of space per worker<br>α2 + α3 determines how much space use increases with greater employment growth<br>[…] term within brackets represents amount of office space demanded per worker<br><br>Notes:<br>$OC_t$ does not equal $OC^*_t$ because firms cannot adjust their space consumption in response to changes in demand (ie. employment growth or rent movements) |

| | |
|---|---|
| **⑤ NET ABSORPTION MODEL EQUATION 2 – Adjustment** | |
| $OC_t - OC_{t-1} = AB_t = \tau_1[OC^*_t - OC_{t-1}]$ | Where:<br>$OC_t$ = Occupied Space in period t<br>$OC_{t-1}$ = Occupied Space in previous period<br>$AB_t$ = Net Space Absorption in period t<br>$\tau_1$ is the portion of office space occupiers that change the amount of space they occupy, from what prevailed in the market previously, to what is now desired |
| **⑥ NET ABSORPTION MODEL EQUATION 3 – Combination of ④ and ⑤** | |
| $AB_t = \tau_1[\alpha_0 + E_t[\alpha_1 + \alpha_2 \frac{(E_t - E_{t-1})}{E_t} - \alpha_3 R_t]] - \tau_1 OC_{t-1}$ | Symbols as for Equations ④ and ⑤ |
| **⑦ RENTAL ADJUSTMENT MODEL EQUATIONS – Regression** | |
| $R^* = \mu_0 - \mu_1 V_{t-1} + \mu_2 \frac{AB_{t-1}}{S_{t-1}}$<br><br>$R_t - R_{t-1} = \mu_3(R^* - R_{t-1})$<br><br>$= \mu_3(\mu_0 - \mu_1 V_{t-1} + \mu_2 \frac{AB_{t-1}}{S_{t-1}}) - \mu_3 R_{t-1}$ | Where:<br>R* is the equilibrium rent that eventually emerges in the market – determined as a linear function of absorption and vacancy rates<br>$V_{t-1}$ = Vacancy Rate (%) in previous period<br>$AB_{t-1}$ = Net Space Absorption (%) in previous period<br>$S_{t-1}$ = Total Space in previous period<br>$R_{t-1}$ = Rent for Space in previous period<br><br>Notes:<br>Given a stock of space and the level of office employment, these combined equations depict how rents eventually adjust to equate office demand to a given stock of office space. |
| **⑧ OFFICE SPACE SUPPLY EQUATION – Regression** | |
| $C^*_t = \beta_0 + \beta_1 S_{t-8} + \beta_2 S_{t-8} V_{t-8} + \beta_3 AB_{t-8}$<br><br>$C_t - C_{t-1} = \tau_2 (C^*_t - C_{t-1})$<br><br>$C_t = \tau_2 (\beta_0 + \beta_1 S_{t-8} + \beta_2 S_{t-8} V_{t-8} + \beta_3 AB_{t-8}) + (1 - \tau_2) C_{t-1}$ | Where:<br>$C^*_t$ = level of desired Completions<br>$S_{t-8}$ = Total Space 8x6 months previous<br>$V_{t-8}$ = Vacancy Rate 8x6 months previous<br>$C_{t-1}$ = Completions in previous period<br>$\tau_2$ = adjustment rate to account for the gradual response by construction - actual completions at time t are assumed to move proportionally (at rate $\tau_2$) to the difference between desired completions and those just undertaken<br><br>Notes:<br>Reasonable to assume the desired rate of new completions (% of stock) depends on the developers' estimate of the level of rents at the time of project delivery. Hence, the absolute level of new completions will depend on estimated future rents together with the current stock of space. |

Table 1 – DiPasquale and Wheaton Office Market Econometric Model – Derived from DiPasquale and Wheaton (1996 : 293-309)

A diagrammatic representation of the workings of this model has been produced below:

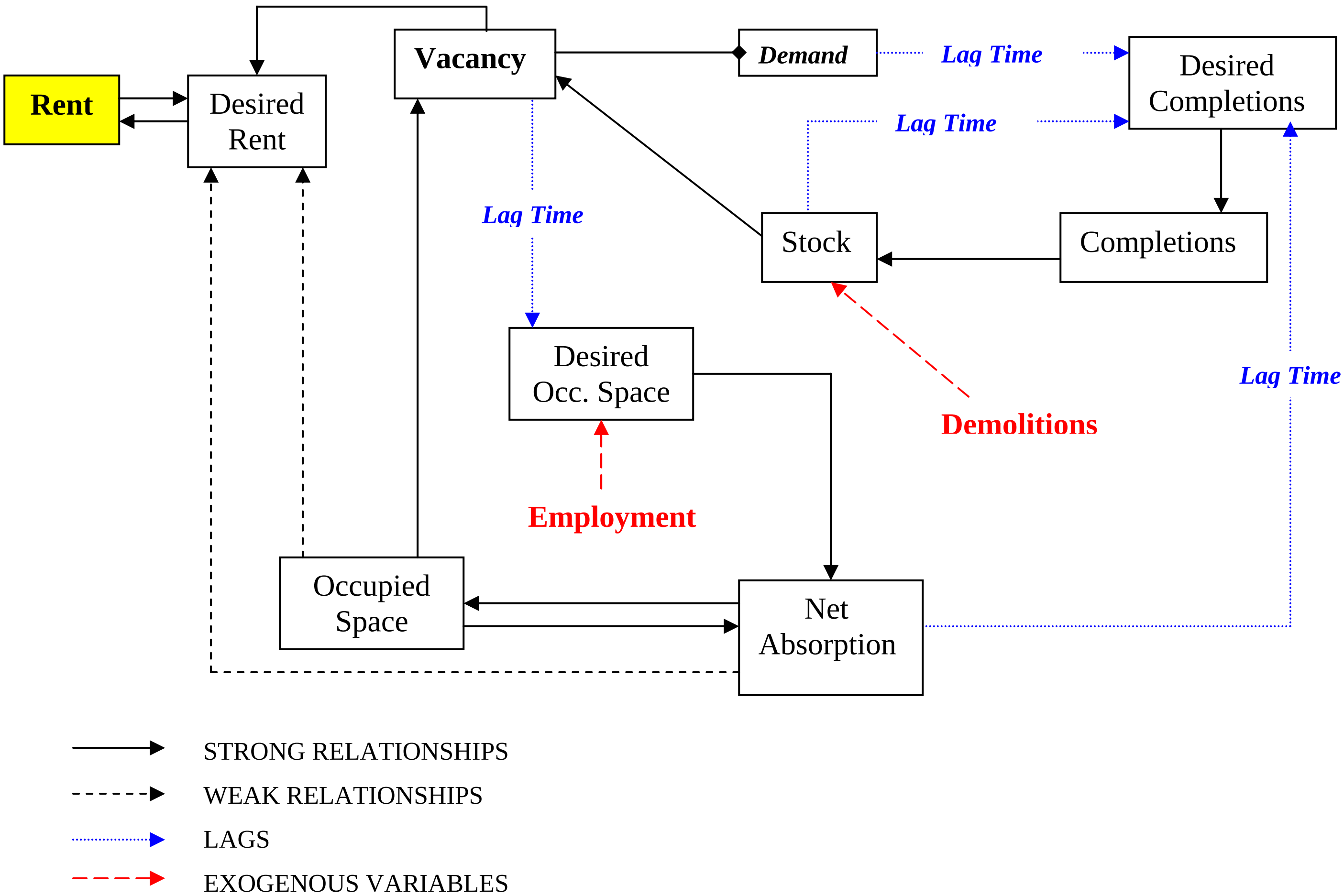



Figure 4 – Conceptual Map – DiPasquale and Wheaton Office Market Model (1996)

The publication of full econometric models is relatively rare. The DiPasquale / Wheaton – Wheaton / Torto / Evans models incorporate the majority of the explanatory variables found to be dominant in the many models that have evolved over time. This together with McDonald's (2002) support for the framework and the relative transparency of how the models were applied to the San Francisco and London markets assisted in selecting the framework for testing and forecasting with data for Brisbane, Australia.

## 4.0 Brisbane Central Business District Data

Brisbane is the capital of the Australian State of Queensland and is the third largest Australian central business district in terms of office floor area with a total net lettable area of approximately 1.65M square metres. Some of the city's fundamental office market variables and their change over the last 31 years are mapped in the charts below:

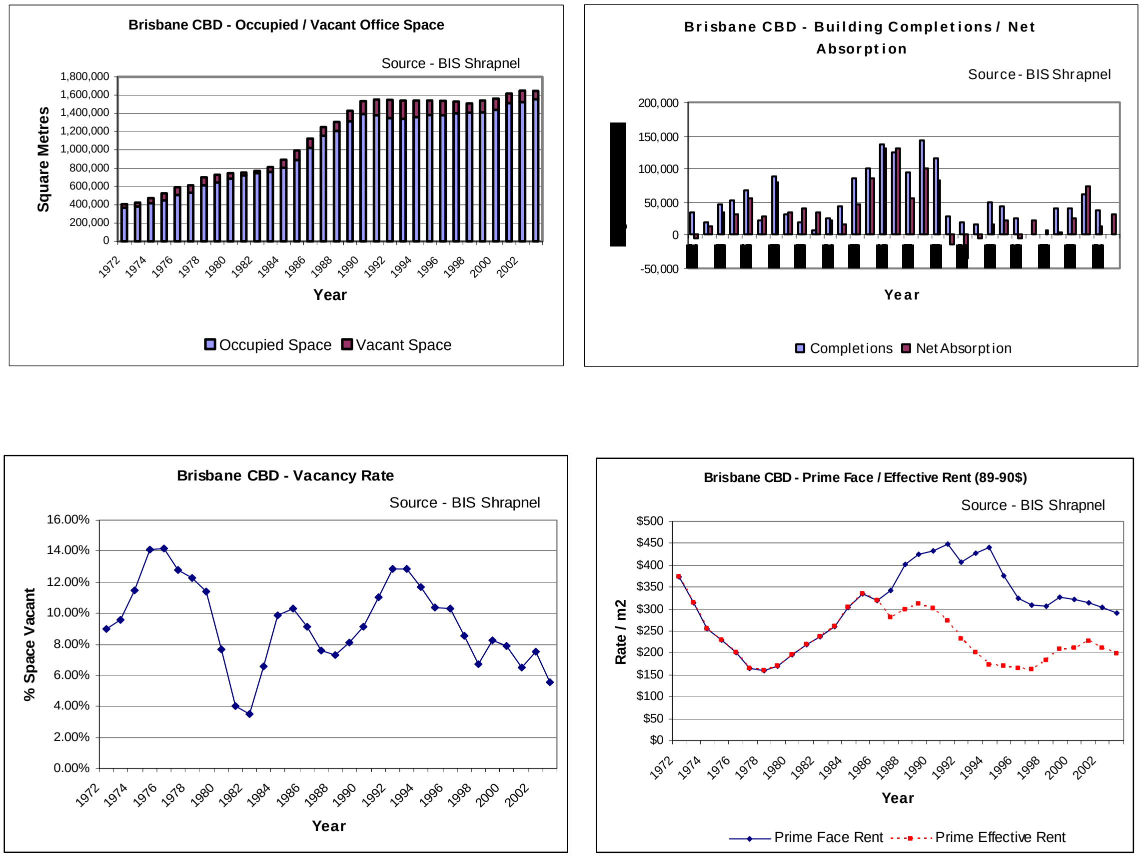



Figure 4 – Brisbane CBD Market Variables – Historical Change

A frequent lament of property researchers is the quality and extent of available property market data (for example: Jones 1995; Mitchell and McNamara 1997; Tsolacos and McGough 1999; Mueller 2002; MacFarlane, Murray, Parker and Peng 2002). In this instance, due to the lack of longer term CBD employment data, the scope of the study has been limited to annual data extending from 1980 to 2003. Some summary statistics for the data utilized for model testing are tabulated below:

| Variable | Period | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| Vacancy (%) | 1980-2003 | 8.5% | 2.4% | 3.5% | 12.9% |
| Occupied Space ($\Delta$m²) | 1980-2003 | 37,450m² | 43,636m² | -33,600m² | 132,100m² |
| Net Absorption ($\Delta$m²) | 1980-2003 | 37,433m² | 43,646m² | -33,600m² | 132,000m² |
| Employment ($\Delta$) | 1981-2003 | 1,450 | 1,689 | -1,300 | 4,100 |
| Withdrawals (m²) | 1980-2003 | 14,825m² | 13,698m² | 0m² | 48,300m² |
| Completions (m²) | 1980-2003 | 52,979m² | 43,992m² | 0m² | 142,300m² |
| Work Space Ratio ($\Delta$m²) | 1981-2003 | 0.2m² | 0.8m² | -1.0m² | 2.3m² |
| Gross Effective Rent ($/m²) | 1980-2003 | $195 | $39 | $152 | $264 |

Table 2 – Data Summary Statistics

## 5.0 Results of Brisbane Study

A summary of some of the results from applying the DiPasquale and Wheaton model to the Brisbane data is set out below. Some adjustments to the lag periods have been adopted to better reflect the workings of the Brisbane market.

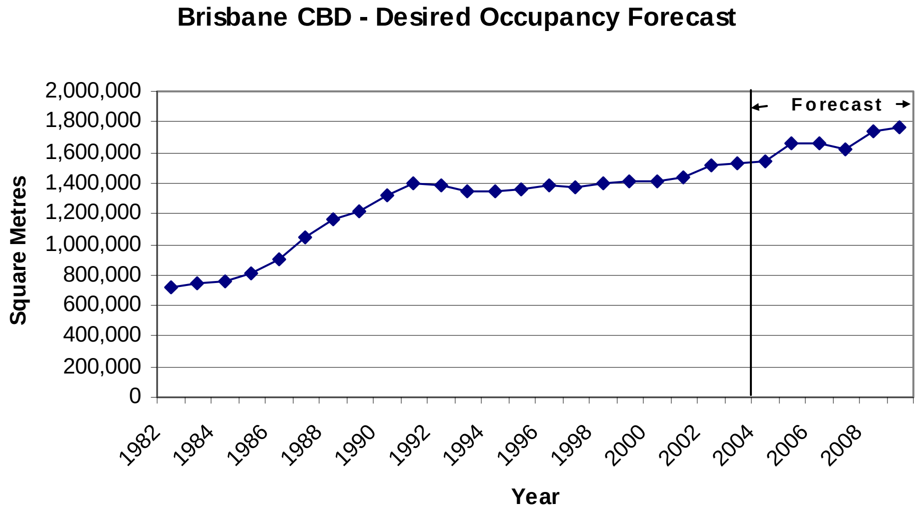
***Equation 4 – Net Absorption Model – Desired Occupancy***

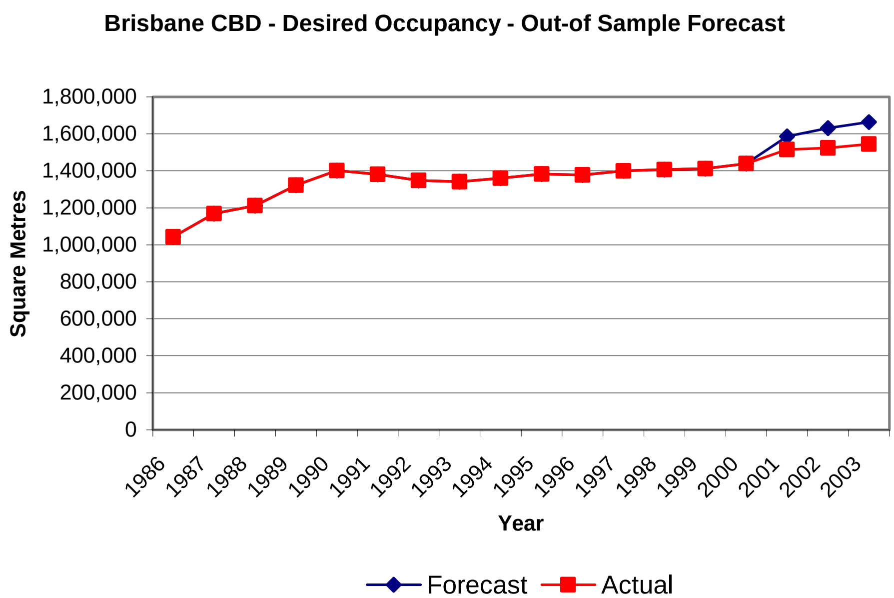
$OC^*_t = \alpha_0 + \alpha_1 E_{t-2} + \alpha_2(E_t - E_{t-2}) + \alpha_3 E_{t-2}{*}V_{t-2}$

| Descriptor | Coefficient | t-statistic |
|---|---|---|
| Intercept | 57,345.49 | (0.323) |
| $\alpha_1$ | 3.60 | (4.250) |
| $\alpha_2$ | 13.24 | (1.254) |
| $\alpha_3$ | 16.61 | (2.101) |
| Adjusted $R^2$ = 0.74 | Durbin-Watson = 0.29 | |

DiPasquale and Wheaton substituted lagged vacancy (four years) in their estimated equation for San Francisco as a proxy for rent. This was due to a data availability issue. However, the same substitution, with a lag of two years, had the effect of marginally improving the fit of the equation for Brisbane. Unfortunately the results indicated that the only significant variable in the equation was employment lagged by two years. In addition, the Durbin-Watson statistic indicates positive autocorrelation in the residuals signaling the explanatory power of the equation is weak and needs enhancement in the Brisbane context.

Using the equation to cast forward a five year forecast generates a plausible result, but the true test of an out-of-sample forecast (three years) confirms further refinement is required. The graphs, below, show the results:




The calculation of the Theil's U-statistic (6.95) for the out-of-sample forecast infers a naïve forecast would eclipse the forecast derived from the equation.

Applying the equation for equilibrium rent from DiPasquale and Wheaton, resulted in the following output:

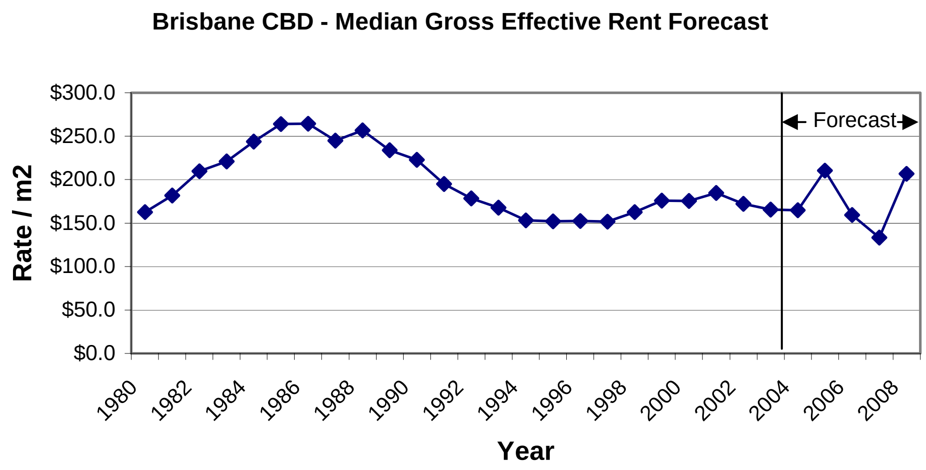
***Equation 7 – Equilibrium Rent***

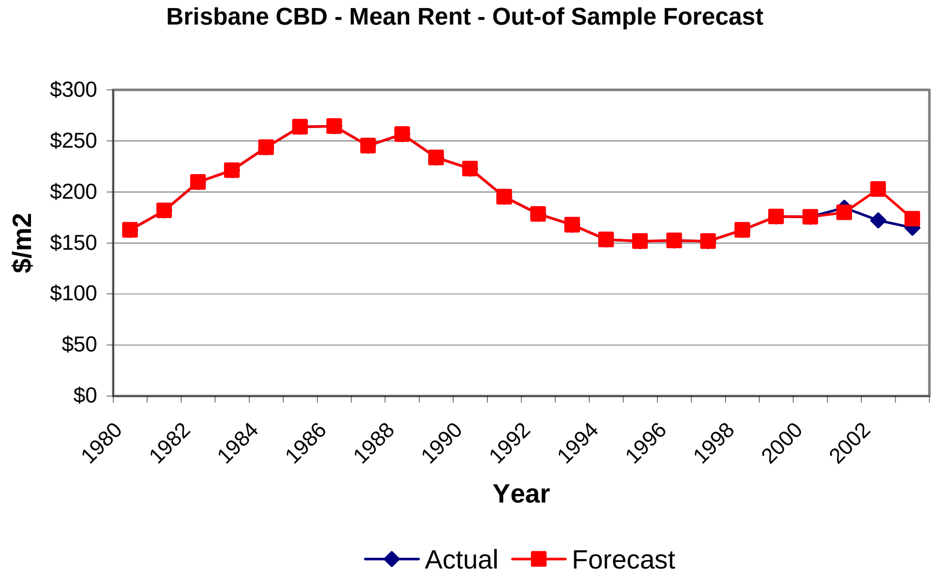
$$R^* = \mu_0 - \mu_1 V_{t-1} + \mu_2 \frac{AB_{t-1}}{S_{t-1}}$$

| Descriptor | Coefficient | t-statistic |
|---|---|---|
| Intercept | 160.27 | (7.116) |
| $\mu_1$ | 103.26 | (0.436) |
| $\mu_2$ | 825.28 | (5.220) |
| Adjusted $R^2$ = 0.53 | Durbin-Watson = 1.18 | |

Surprisingly, the vacancy rate variable did not register as significant in this case while the lagged absorption / stock ratio was found to influence the level of equilibrium rent.  A case for further refinement of the equation's structure is supported by a degree of positive autocorrelation remaining in the residuals.

Using the stock, new supply, absorption and vacancy forecasts derived from the model, a five year forecast of the equilibrium rent was generated.  Applying the results to the DiPasquale and Wheaton rent equation [$R_t = \mu_3(R^* - R_{t-1}) + R_{t-1}$ where $\mu_3$ is an adjustment parameter quantifying speed of movement towards equilibrium rent] a five year median gross effective rent forecast is generated.  The results were found to be quite erratic and the out-of-sample forecast Theil's U-statistic confirmed a naïve forecast would produce a far superior result.






The results of this analysis are disappointing although no reasonable fit was anticipated. While much further work is required to estimate a model that exhibits a sound fit to the Brisbane market, this research will extend beyond the application of econometric models into a potentially complementary area of system dynamics.

**6.0 System Dynamics**

System dynamics theories offer the opportunity to model the complex interrelationships of the real estate environment and to observe their dynamic behaviour over time, with particular respect to how these interrelationships impact the investment prospects facing the building company or even the private investor.  Strangely enough, simulation modelling in general seems to be a relatively new concept in the real estate industry.

Other industry sectors have proven that the use of well-calibrated structural models, such as system dynamics simulators, can do a reasonable job of forecasting in situations where regression and trend forecasts have proven their individual weaknesses (Sterman, 1988; Sterman, 2000; Lyneis, 2000), but the use of such theories in real estate markets has been very sporadic. Forrester (1969), founder of system dynamics, developed Urban Dynamics, a complex model counting 150 equations for the prediction of urban growth and decline, used to understand America's urban crisis. Vennix (1996) offers a case study to illustrate the dynamics of the housing market from the perspective of housing associations.  Kim and Lannon (1991) examined Minneapolis' real estate activity arguing that delays, self-ordering dynamics, speculation and short-term individual gain are the factors that need to be addressed. Kummorow (1997, 1999) developed a series of dynamic models, integrating econometric and simulation principles with forecasting methods, to study and forecast supply and demand cycles for the areas of Sydney and Perth. Aptek Associates LLC also developed a series of corporate real estate simulation tools that can be used to do more accurate planning and forecasting (Klammt, 2001). Bakken, & Sterman (1993) designed a real estate flight simulator, in which the user takes command of a firm in the volatile market of office buildings and pilots it from start-up to success.

The adaptation of a statistical model to a system dynamics framework has several advantages. First of all, spreadsheet analyses are static in nature, no matter how complex the macros are, and do not take into account the changing dynamics of the market environment. Conversely, a system dynamics model does not simply determine future rates under current market conditions, but it also considers changes that occur overtime from the interaction of different variables. Secondly, allowing parameters such as employment growth and demolition rate to be varied exogenously by the user adds credibility to the simulation model, because it gives the user a better understanding of the industry structure and makes the user participate to the decision making process. On the other hand, we must also be very careful with the type and amount of freedom granted to the user. Assumptions should not deviate from reasonable ranges set in consistency with historical patterns to prevent the model from coming up with illogical values. Additionally, only a limited number of parameters should be given the possibility of having arbitrary values: the main inputs such as supply and demand should always be kept endogenous to the system.

Bertsche, Crawford and Macadam (1996) assert the existence of a deep body of theoretical literature that praise the power of simulations to change behavior by giving managers the opportunity to experiment, test their assumptions, and learn from their mistakes in a risk-free environment. But the literature has little to say about how the theory can be applied in real corporate situations. In fact, their study also shows that over 60 percent of US corporations have used some sort of simulation and that only a few have succeeded. This statistic shows that simulations can play a useful role in successful transformations, but if they are poorly designed they have no more than an entertainment value.  For this reason the econometric structure of the model remains a primary concern and it needs to be designed on the basis of logic, expert opinion, and historical trends.

**7.0 Application of System Dynamics**

Due to the inadequacy of econometric models this study is considering whether a system dynamics approach can provide a basis for rental growth forecasts. A four step approach has been identified:

a) Collect all the available mental and written information
b) Develop the structure of the model
c) Simulate and compare outputs with historical data
d) Evaluate the discrepancies

a) The first step is to collect information from many different sources: professional experience and knowledge, written database, and numerical database. Mental and written information will then be used to structure the model, while numerical data will be used for comparison of time-series.

b) Without doubt the most important priority remains the creation of an econometric model that is logically structured and that is market tested. System dynamics, as well as structural equation modeling (SEM), is based on causal relationships, where the change in one variable is assumed to result in a change in another variable. However, Forrester (1992) illustrates the peculiarity of system dynamics arguing that *"symptom, action, and solution are not isolate in a linear cause-to-effect relationship, but exist in a nest of circular and interlocking structures. In such structures an action can induce not only correction but also fluctuation, counterpressures, and even accentuation of the very forces that produced the original symptoms of distress."* Regression analysis, which has been widely adopted by previous researchers, has the great limitation of allowing only a single relationship between dependent and independent variables at a time.  SEM can estimate many interrelated equations at once, but it assumes the linearity of all relationships (Hair 1998).  The structuring process involves the identification of decision making points; the expression in terms of equations of causal relationships among variables; and the estimation of some parameters from time-series data.

Some of the equations that are being considered while writing this paper are:

$$R_t = R_{t-1} + [R_{t-1} * (Eq\_V - V_t)] \quad (1)$$

where $R_{t-1}$ is the rent from the previous period, $V_t$ is the current vacancy rate, and *Eq_V* is the equilibrium vacancy rate, a fixed value specific to the analysed market used to trigger construction. 'Completions' ($C_t$) is a function of demand and most researchers seem to agree that vacancy rate is the engine that drives cycles. The adoption of a minimum vacancy value is required to make construction feasible (or to start the engine) and *Eq_V* represents this level.

$$C_t = S_{t-3} + S_{t-3} * (Eq\_V - V_{t-3}) \quad (2)$$

After careful consideration, a supply lag time of 3 years was chosen for the equation. Studies of the Sydney CBD have shown that 3 years is the best fit (Murray, Parker, MacFarlane & Peng, 2002), however not as many studies have been conducted in Brisbane. Cowley (2003) has compared the time taken to develop different buildings in the CBD and its results show that 3 years is probably a good estimate for Brisbane as well. The table shows that in average it takes 1 year for the acquisition process and 2 years to complete the building.

| **Project** | **Levels NLA** | **Date of Site Acquisition** | **Construction Commenced** | **Completion Date** |
|---|---|---|---|---|
| Waterfront Place | 40<br>59,179m² | Jul-84 | Mar-88 | Jun-90 |
| Riverside Centre | 40<br>51,687m² | Apr-84 | Apr-84 | Oct-86 |
| Central Plaza One | 36<br>40,290m² | Jan-85 | N/A | May-88 |
| Mincom Central | 13<br>24,619m² | Mar-94 | Dec-98 | Nov-00 |
| Hall Chadwick | 22<br>15,661m² | May-98 | Apr-00 | Oct-01 |
| CUA House | 17<br>18,000m² | Oct-00 | Feb-01 | May-02 |

The formula for vacancy in period $t$ is:

$$V_t = (S_t - OC_t) / S_t \quad (3)$$

where OC is the occupied space and is calculated by multiplying employment times space per worker in terms of square metres:

$$OC_t = E_t * SW_t \quad (4)$$

Total space at time $t$ is simply total space from the previous period plus constructions less space withdrawals:

$$S_t = S_{t-1} + C_t - \delta_t \quad (5)$$

$C_t$ is the symbol for completions, while $\delta_t$ includes demolitions, removals, and space conversions. Employment ($E_t$) and demolition rate ($\delta_t$) are the only two variables that are external to the feedback cycle and therefore the user must select a value for each period $t$. The range values for $E_t$ are set to 80000-105000. Employment has always been incremental, going from 46,500 units in 1980 to 85,000 in 2003. In fact, only three small drops were registered in the period of study ($n=24$): 1,000 in 1983; 700 in 1991; and 100 in 1998. The parameters chosen for $\delta_t$ are instead 0 (in the event that there are no demolitions registered in the period $t$) and 50,000. In the last thirty-four years ($n=34$), the highest number of demolitions registered in a single year has been 48,300 (1994), and there has been an average of 10,953 per year.

Space per worker depends upon differentials between current and previous rent:

$$SW_t = SW_{t-1} + [SW_{t-1} * (R_t - R_{t-1})] \quad (6)$$

where SWt-1 is space per worker in the previous period.

c) The third step involves simulations and sensitivity testing to produce a wide array of time-series output. The output is then compared with time-series from real life and behavioural characteristics from the model are identified and compared with the corresponding characteristics of real time-series.

d) The final step is the analysis of the discrepancies that the comparison between time-series has revealed. Each discrepancy has to be evaluated separately and a decision needs to be made on whether or not modify the structure of the model to align the behaviour of the variable with the real system. When the model is finalized, it can be used for forecasting or policy analysis.

**8.0 Conclusions**

Recent observations of rent forecasts adopted by Brisbane property professionals for cash flow studies resurrect concerns raised by researchers about the use of overly simplistic, near linear forecasts for a variable that has experienced significant historical volatility.

A review of literature on property cycles revealed an increasing amount of research being devoted to the subject through an evolutionary process covering the previous 20 years. The recent formulation and publication of a cycles research framework and classification model (Pyhrr, Born, Manning & Roulac 2003) represents a significant advance in the drive for a standardised approach in categorising research on the subject.

Many studies have recognised a natural progression from the property cycle discipline to the field of property market variable forecasting. The dominant method for evaluating the value / viability of major commercial buildings / developments requires the incorporation of rent forecasts in cash flow analyses. An examination of 20 rent growth models developed since 1984 has provided an indication of the dominant explanatory variables adopted by researchers. The prevalent property / market determinants have included historical rent levels, vacancy rate, natural/equilibrium/structural vacancy rate and space supply. The prevalent economic / financial determinants adopted have included economic activity, interest rates and employment.

The DiPasquale and Wheaton (1996) econometric model was selected for testing with Brisbane city data on the basis that it incorporated many of these dominant explanatory variables. The explanation of the model was generally more comprehensive than normally published. In addition, a recent study (McDonald 2002) comparing the relatively few published commercial property market econometric models indicated the theoretical soundness of this model.

The out-of-sample forecasts produced for Brisbane city using the model produced disappointing results, but this could be due to incompatibilities between the San Francisco and Brisbane markets rendering the model as a poor fit to the later. In addition, the time span of the available Brisbane data did not cover two complete market cycles and the quality of the CBD employment data needs to be further investigated. These aspects may have also contributed to the relatively weak explanatory power of the equations.

Testing and development of rent models for Brisbane will continue with the aim of developing a forecasting module for incorporation with the office building investment evaluation model developed by the Australian Cooperative Research Centre for Construction Innovation. However, it is anticipated the application of system dynamics will accentuate the forecasting module by truly reflecting the causal relationships and dynamic interaction of market variables to surpass the existing static rent models that purely rely upon multiple regression equations. In addition, the scope to incorporate simulation capabilities in a user friendly package offers significant advantages.

## APPENDIX 1 - OFFICE RENT MODELS – DETERMINANTS

| Researcher(s) | Year | DETERMINANTS: Property / Market Factors: Current Rent | Equilibrium Rent | Vacancy Rate | Natural Vacancy Rate | Building Characteristics | Space Absorption | Space Supply | Land Values | Location | Construction Cost | Lease Aspects | House Prices | Operating Costs | Market Conditions | Economic / Financial Factors: Economic Activity | Economic Uncertainty | Interest Rates | Employment | Unemployment | Inflation | Taxation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rosen KT | 1984 | | | | | | | | | | | | | | | | | | | | | |
| Hekman JS | 1985 | | | | | | | | | | | | | | | | | | | | | |
| Shilling J, Sirman C & Corgel J | 1987 | | | | | | | | | | | | | | | | | | | | | |
| Wheaton WC & Torto RG | 1988 | | | | | | | | | | | | | | | | | | | | | |
| Frew J & Jud GD | 1988 | | | | | | | | | | | | | | | | | | | | | |
| Gardiner C & Henneberry J | 1989 | | | | | | | | | | | | | | | | | | | | | |
| Gardiner C & Henneberry J | 1991 | | | | | | | | | | | | | | | | | | | | | |
| Dobson SM & Goddard JA | 1992 | | | | | | | | | | | | | | | | | | | | | |
| Glascock JL, Kim M & Sirmans CF | 1993 | | | | | | | | | | | | | | | | | | | | | |
| Giussani B & Tsolacos S | 1993 | | | | | | | | | | | | | | | | | | | | | |
| Hendershott PH, Lizieri CM & Matysiak GA | 1996 | | | | | | | | | | | | | | | | | | | | | |

| | | Property / Market Factors | | | | | | | | | | | | | | Economic / Financial Factors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Researcher(s) | Year | Current Rent | Equilibrium Rent | Vacancy Rate | Natural Vacancy Rate | Building Characteristics | Space Absorption | Space Supply | Land Values | Location | Construction Cost | Lease Aspects | House Prices | Operating Costs | Market Conditions | Economic Activity | Economic Uncertainty | Interest Rates | Employment | Unemployment | Inflation | Taxation |
| DiPasquale D & Wheaton WC | 1996 | ■ | ■ | ■ | | | ■ | ■ | | | | | | | | | | | ■ | | | |
| Hendershott PH | 1997 | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | |
| Dunse N & Jones C | 1998 | ■ | | | | ■ | | | | ■ | | | | | | | | ■ | | | | |
| D'Arcy E, McGough T & Tsolacos S | 1999 | ■ | | | | | | ■ | | | | | | | | ■ | | | ■ | | | |
| Hendershott PH, Lizieri CM & Matysiak GA | 1999 | ■ | ■ | ■ | ■ | ■ | | | | | ■ | | | ■ | | | | | | | | |
| Chaplin R | 2000 | ■ | | | | | | ■ | | | | | | | | ■ | | | | | | |
| Murray J, Parker D, MacFarlane J & Peng V | 2002 | ■ | | ■ | | | | ■ | | | | | | | | | | ■ | | | | |
| Hendershott PH, MacGregor BD & Tse RYC | 2002 | ■ | | ■ | | | | ■ | | | | | | | | | | | ■ | | | |
| Tse RYC & Fischer D | 2003 | ■ | | ■ | ■ | | | | | | | | | | | | | | | | | |

## APPENDIX 2 – OFFICE RENT MODELS – EQUATIONS / RESULTS

| Researcher(s) | Year | Equations (Researchers' Notation) | Key | | Data | Results (Rent) |
|---|---|---|---|---|---|---|
| Rosen KT | 1984 | $R_t = f(V^*_t - V_t, P^*_t)$ where $V^*_t = f(i_t, R^e_t)$ and $\Delta SQFT_t = f(V_t, R^e_t, CC_t, i, TAX)$ | $R_t$ = change in net rents<br>$V^*_t$ = optimal vacancy rate<br>$V_t$ = actual vacancy rate<br>$P^*$ = change in price level<br>$R^e_t$ = expected rent levels | $i_t$ = interest rate<br>$SQFT_t$ = occupied space<br>$CC_t$ = construction cost<br>TAX = tax laws affecting real estate | San Francisco Office Rents – 1961-1981 | Adjusted $R^2 = 0.55$. Said to confirm an inverse relationship between rent change and deviations between the actual and "optimal" vacancy rate and a direct relationship with the cost of living |
| Hekman JS | 1985 | $R_t = \alpha_0 + \alpha_1 Vt + \alpha_2 Y_t + \alpha_3 E_t + \alpha_4 U_t + \varepsilon_{1t}$<br>$Q_t = \beta_0 + \beta_1 R^*_t + \beta_2 G_t + \beta_3 C_t + \beta_4 I_t + \varepsilon_{2t}$ | $R_t$ = real rent per sq. ft<br>$V_t$ = vacancy rate (A Grade)<br>$Y_t$ = Gross National Product<br>$E_t$ = total employment (local)<br>$G_t$ = office employment ratio | $U_t$ = unemployment rate (local)<br>$C_t$ = construction cost per sq. ft<br>$I_t$ = interest rate ratio | 14 US cities – 1979-1983 | $R^2 = 0.40$ with lags. Overreactions of supply to market signals, such as high rents, perceived to create periods of sustained low or high vacancy rates and rents. |
| Shilling J, Sirman C & Corgel J | 1987 | $R = b_0 + b_1 E - b_2 V$ where $b_0 = b_2 V^n$ | R = change in rents<br>E = change in operating expenses<br>V = observed vacancy rate<br>$V^n$ = normal vacancy level | | 17 US cities – 1960-1975 | $R^2$ ranging from 0.66 to 0.98 for cities. Vacancies said to play an important role in responding to demand fluctuations and in setting short-run prices (significant at 90% for 11 of 17 cities). |
| Wheaton WC & Torto RG | 1988 | $R(t)/R(t-1) - 1 = a[b + ct - V(t)]$ | R(t) = real rent (average effective)<br>V(t) = vacancy rate<br>b + ct = "structural" vacancy rate | a = speed of adjustment parameter | National US rent and vacancy data (spliced) – 1968-1986 | $R^2 = 0.78$. Excess vacancy said to have strong relationship with rents. Indicated "structural" vacancy rate had risen over time. Provided seven forecast for office rent. |
| Frew J & Jud GD | 1988 | $R_t = f(V_t, D_t, A_t, F_t, C_t, H_t)$ | $R_t$ = marginal rental rate<br>$V_t$ = vacancy rate<br>$D_t$ = distance from CBD<br>$A_t$ = building age | $F_t$ = number of floors<br>$C_t$ = % common area<br>$H_t$ = location adjacent major thoroughfare / highway (dummy) | Survey of 66 buildings in Greensboro, USA | Adjusted $R^2$ ranging from 0.49 to 0.58 depending on data format. All variables, except "common area %" and "distance from CBD" found to be significant. |
| Gardiner C & Henneberry J | 1989 | $RR_t = a + b.GDPR_t + c.GDPR_{t-2} + d.FSR_t$ | $RR_t$ = rent level<br>GDP = Gross Domestic Product | FSR = ratio of regional floor space to total national floorspace | Eight UK regions – office rent index – 1977-1984 | $R^2$ ranging from 0.397 to 0.975 for the eight regions. Model had difficulty in forecasting rents for a declining region. |
| Gardiner C & Henneberry J | 1991 | $R_t = \alpha(1-\lambda_1)(1-\lambda_2) + (\lambda_1 + \lambda_2)R_{t-1} - \lambda_1\lambda_2 R_{t-2} + \beta(1-\lambda_1)(1-\lambda_2)D_t + (u_t - \lambda_2 u_{t-1})$ | $R_t$ = rent bid<br>$\lambda_1$ = "adaptive expectation" parameter (0-1)<br>$D_t$ = demand for floorspace | $\lambda_2$ = "partial adjustment" parameter (0-1) | Eight UK regions – office rent index – 1977-1984 | $R^2$ ranging from 0.51 to 0.98 for combined "habit persistence" model. Model said to improve forecasts for declining regions. |

| Researcher(s) | Year | Equations (Researchers' Notation) | Key | Data | Results (Rent) |
|---|---|---|---|---|---|
| Dobson SM & Goddard JA | 1992 | $logR_t = a + b.logR_{t-1} + c.logR_{t-2} + d.logI_t + e.logH_t + \varepsilon_t$ (+ regional dummies) | $R_t$ = rent index (inflation adjusted)<br>$I_t$ = real interest rate (spread)<br>$H_t$ = house price index (local) | Four UK regions – 1972-1987 | Adjusted $R^2 = 0.94$. Interest rates and house prices said to have positive effects on office rents. |
| Glascock JL, Kim M & Sirmans CF | 1993 | $y_t = X_t\beta + v_t y + W\delta + \xi t J_T + u_t$ | $y_t$ = average real rent<br>$X_t$ = constant and variable that vary over time periods and individual buildings<br>$v_t$ = location characteristics<br>$w_t$ = market condition variables | Baton Rouge, USA – six sub-markets – 1984-1989 | Used random effects and heteroscedastic autoregressive models. Suggested rent process different across time and building classes. Assumption of parameter constancy is not supported. |
| Giussani B & Tsolacos S | 1993 | $\Delta_1 RERV = \alpha_0 + \alpha_1 A_4(\Delta_1 GDP) + \alpha_2[(\Delta_1 BFI_{t-5} + \Delta_1 BFI_{t-6})/2] + \alpha_3\Delta_1 PROF_{t-2} + \alpha_4[(\Delta_1 NO_{t-26} + \Delta 1NO_{t-27})/2] - \alpha_5 UNCER$ | RERV = estimated rental value<br>GDP = real Gross Domestic Product<br>BFI = employment (banking, finance and insurance)<br>PROF = market conditions index (tender price – building cost)<br>NO = office buildings new orders<br>UNCER = uncertainty | UK quarterly rent index – 1971-1991 | Adjusted $R^2 = 0.67$. Indicated most significant variable to be uncertainty (4th quarter standard deviation of change in GDP), followed by GDP and employment. |
| Hendershott PH, Lizieri CM & Matysiak GA | 1996 | $\%dR = \alpha + \lambda v + \beta (R^* - R)$<br>where $R^* = (r + dep + oper)RC$ and $\alpha = -\lambda v^*$<br><br>$Completions = \alpha + \beta(Gap_{t-1} + Gap_{t-2})$ | %dR = % change in real effective rents<br>v = actual vacancy rate<br>R* = equilibrium rent<br>r = real interest rate<br>v* = equilibrium vacancy<br>dep = depreciation rate<br>oper = operating expense ratio<br>RC = replacement cost<br>Gap = R* - R | City of London prime office face rents – 1977-1995 | Adjusted $R^2 = 0.58$. Real effective rents considered to be mean reverting, responding to gaps between actual and equilibrium rents and actual and natural vacancy rates. |
| DiPasquale D & Wheaton WC | 1996 | $R_t - R_{t-1} = \mu_3(R^* - R_{t-1}) = \mu_3(\mu_0 - \mu_1 V_{t-1} + \mu_2 AB_{t-1}/S_{t-1}) - \mu_3 R_{t-1}$<br>Where:<br>$AB_t = \tau_1[\alpha_0 + E_t[\alpha_1 + \alpha_2 \frac{(E_t - E_{t-1})}{E_t} - \alpha_3 R_t]] - \tau_1 OC_{t-1}$ | $R_t$ = current rent<br>R* = equilibrium rent<br>$V_{t-1}$ = vacancy rate previous period<br>$S_{t-1}$ = total stock previous period<br>$AB_{t-1}$ = net space absorption previous period<br>$E_t$ = number of office workers at time t<br>$\tau_1$ = occupier space change adjuster | San Francisco office rent index – 1980-1992 | $R^2 = 0.73$. Equation developed as part of econometric model. Given a stock of space and a level of office employment, the equation was said to depict how rents adjust to equate office demand to a given stock of space. |
| Hendershott PH | 1997 | $(g_t - g_{t-1}) / g_{t-1} = \lambda_1 (v^* - v_{t-1}) + \lambda_2 (g^*_t - g_{t-1})$ | $g_t$ = actual real effective rent rate<br>$g^*_t$ = equilibrium real effective rent rate<br>$\lambda_1$ & $\lambda_2$ = positive adjustment coefficients<br>$v_t$ = actual vacancy rate<br>v* = natural vacancy rate (assumed to be constant over time) | Sydney annual rent data – 1970-1992 | $R^2 = 0.68$. Percentage change in effective rents was related to the gaps between actual and equilibrium rents and actual and natural vacancy rates. |
| Dunce N & Jones C | 1998 | $R(z_k) = \beta_0 + \sum_{i=1}^{n} \beta_i z_{ik} + \varepsilon_i$ | $R(z_k)$ = rent for space in kth building<br>$z_i$ = individual characteristics of space (25 variables including area, age, location, physical building aspects) | Glasgow – 477 asking rents – 1994-1995 | Adjusted $R^2 = 0.61$. Studied aimed at identifying and quantifying the contribution of different explanatory attributes to office rents. The results were said to emphasise the importance of age and location as the principal rent determinants. |

| Researcher(s) | Year | Equations (Researchers' Notation) | Key | | Data | Results (Rent) |
|---|---|---|---|---|---|---|
| D'Arcy E, McGough T & Tsolacos S | 1999 | $\Delta rent_t = \alpha_0 + \Sigma\alpha_{1i}\Delta gdp_{t-i} + \Sigma\alpha_{2i}\Delta sse_{t-i} + \Sigma\alpha_{3i}ofnc_{t-i} + e_t$ | Rent = real rent<br>gdp = Gross Domestic Product<br>sse = service sector employment | ofnc = volume of new office completions (first differences and natural logs) | Dublin prime rack (effective) rents – 1971-1997 | Adjusted $R^2 = 0.49$. Service sector employment found not to be significant. Key determinants of office rents said to be GDP (lagged one year) and new space (lagged three years). |
| Hendershott PH, Lizieri CM & Matysiak GA | 1999 | $\Delta R\% = \alpha + \lambda v + \beta (R^* - R)$ where $R^* = (r + dep + oper)$ and $\alpha = -\lambda v^*$<br><br>$Completions = \alpha + \beta(Gap_{t-1} + Gap_{t-2}) + \gamma DUM$ | $\Delta R\%$ = change in real effective rents<br>v = actual vacancy rate<br>$R^*$ = equilibrium rent<br>r = real interest rate<br>$v^*$ = equilibrium vacancy | dep = depreciation rate<br>oper = operating expense ratio<br>RC = replacement cost<br>$Gap = R^* - R$ | City of London – real new prime effective rents – 1975-1996 | Adjusted $R^2 = 0.69$. Real effective rents said to respond to gaps between actual and equilibrium rent levels and actual and natural vacancy rates. Construction and absorption said to feed back onto rents through their effects on the vacancy rate. |
| Chaplin R | 2000 | DLROHP = CONST + α.DLROHP(-1) + β.DLRBFQ1 + γ.DLRONOQ1(-1) + δ.DLRONOQ1(-2) + error | DLR = first difference and natural logs used<br>OHP = office rent index<br>BF = output of business and finance sector | ONO = office building new orders | Great Britain – office rent index | Adjusted $R^2 = 0.51$ (average). 15 model permutations tested. "Naïve competitors" often beat the best fitting models and these were unable to predict the correct timing of market changes. |
| MacFarlane J, Murray J, Parker D, & Peng V | 2002 | $\ln(R_{t-2}^{e,t}/R_{t-2}) = \beta_0 + \beta_1\Delta Y_{t-2} + \beta_2\Delta VAC_{t-2} + r_t$<br>$R_t = \beta_0 + \beta_1 VAC_{t-1} + \rho\, e_{t-1} + r_t$<br><br>$COMP_t = \beta_1 DEP_{t-1} + \beta_2 DEP_{t-2} + \beta_3 DEP_{t-3} + \beta_4 VAC_{t-3} + \beta_5\Delta VAC_{t-3} + \beta_6 RERENT_{t-3} + \beta_7\Delta RERENT_{t-3} + r_t$ | $R^{e,t}$ = expected real effective rent<br>R = real effective rent<br>Y = 10 year bond rate<br>VAC = vacancy<br>COMP = Completions<br>DEP = withdrawals / demolitions | RERENT = real effective rents | Sydney rent data – 1977-2000 | Adjusted $R^2 = 0.49$ (expected change in rents). Adjusted $R^2 = 0.90$ (rent estimation). Equations are variations of the RICS (2000) econometric model equations for London. Vacancy rates found to have strong influence on Sydney rents. Bond yields said to be insignificant. |
| Hendershott PH, MacGregor BD & Tse RYC | 2002 | $\Delta \ln R_t = \alpha_0 + \alpha_1\Delta \ln E_t + \alpha_2\Delta\ln(1 - v_t) + \alpha_3\Delta SU_t + \alpha_4\{ \ln R_{t-1} - \beta'_0 - \gamma'_1 \ln E_{t-1} - \gamma'_2\ln[(1 - v_{t-1})SU_{t-1}\}$ | R = real effective rent<br>E = employment<br>V = vacancy rate<br>SU = space supply | | Sydney and London market data – 1977-1996 | Adjusted $R^2 = 0.70$ to 0.80 for long-run error correction model. Vacancy and rent equilibrium variables were said to be highly significant in determining rent adjustments. Introduced time-varying equilibrium rent as explanatory variable. |
| Tse RYC & Fischer D | 2003 | $g_t = \alpha v_{nt} - \alpha v_t + \varepsilon v$ Where $v_{nt} = v^* + \epsilon_v$ | g = rent growth rate<br>$v_n$ = natural vacancy rate<br>v = vacancy rate<br>$v^*$ constant parameter<br>$\epsilon_v$ = time-varying constant | | Hong Kong (1975-1997), Sydney (1970-1996), Perth (1992-1994 monthly) & London (1975-1996) | Adjusted $R^2$ ranging from 0.36 to 0.611 for the four cities. Introduced time-varying vacancy rate. Static vacancy rates were said to exaggerate cyclical swings in rental growth rates. The "stationary component" of vacancy rates was said to vary across cities. |

## REFERENCES


**Bakken BE & Sterman JD**. (1993), "Commercial Real Estate Management Flight Simulator", MIT Sloan School of Management.

**Barras R** (1994), "Property and the Economic Cycle: Building Cycles Revisited", *Journal of Property Research* Vol 11 pp 183-197

**Bertsche D, Crawford C & Macadam S** (1996), "Is Simulation Better than Experience?", *The McKinsey Quarterly,* no. 1, pp. 50–57

**Born WL & Pyhrr SA** (1994), "Real Estate Valuation: The Effect of Market and Property Cycles", *Journal of Real Estate Research* Vol 9 No 4 pp 455-486

**Canter T, Gordon J & Mosbaugh P** (1996), "Integrating Regional Economic Indicators with the Real Estate Cycle", *Journal of Real Estate Research* Vol 12, No 3 pp 469-485

**Chaplin R** (2000), "Predicting Real Estate Rents: Walking Backwards into the Future", *Journal of Property Investment and Finance* Vol 18 No 3 pp 352-370

**Clayton J** (1996), "Market Fundamentals, Risk and the Canadian Property Cycle: Implications for Property Valuation and Investment Decisions", *Journal of Real Estate Research* Vol 12 No 3 pp 347-367

**Cowley M** (2003), "*Property Market Cycles*", Master Dissertation, Queensland University of Technology.

**D'Arcy E, McGough T & Tsolacos S** (1999), "An Econometric Analysis and Forecasts of the Office Rental Cycle in the Dublin Area", *Journal of Property Research* Vol 16 No 4 pp 309-321

**Dehesh A & Pugh C** (2000), "The Internationalisation of Post 1980 Property Cycles and the Japanese Bubble Economy, 1986-96", *International Journal of Urban and Regional Research* Vol 18 Issue 1 March pp 147-165

**DiPasquale D & Wheaton WC** (1996), Urban Economics and Real Estate Markets, Prentice Hall, New Jersey

**Dobson SM & Goddard JA** (1992), "The Determinants of Commercial Property Prices and Rents", *Bulletin of Economic Research* Vol 44 No 4 pp 301-321

**Dunse N & Jones C** (1998), "A Hedonic Price Model of Office Rents", *Journal of Property Valuation and Investment* Vol 16 No 3 pp 297-312

**Forrester J.** (1969), *Urban Dynamics*, Productivity Press, Portland, Oregon.

**Forrester J.** (1992), "Policies, decisions and information sources for modeling", *European Journal of Operational Research* Vol 59, Issue 1 pp 42-63

**Frew J & Jud GD** (1988), “The Vacancy Rate and Rent Levels in the Commercial Office Market”, *Journal of Real Estate Research* Vol 3 No 1 pp 1-8

**Gallagher M & Wood AP** (1999), “Fear of Overbuilding in the Office Sector: How Real is the Risk and Can We Predict It?”, *Journal of Real Estate Research* Vol 17 No 1/2 pp 3-32

**Gardiner C & Henneberry J** (1989), “The Development of a Simple Regional Office Rent Prediction Model”, *Journal of Property Valuation and Investment* Vol 7 No 1

**Gardiner C & Henneberry J (**1991), “Predicting Regional Office Rents Using Habit-Persistence Theories”, *Journal of Property Valuation and Investment* Vol 9 No 3

**Giussani B, Hsia M & Tsolocas S** (1993), “A Comparative Analysis of the Major Determinants of Office Rental Values in Europe”, *Journal of Property Valuation and Investment* Vol 11 No 2 pp 157-173

**Glascock JL, Kim M & Sirmans CF** (1993), “An Analysis of Office Market Rents: Parameter Constancy and Unobservable Variables”, *Journal of Real Estate Research* Vol 8 No 4 pp 625-637

**Grissom T & DeLisle JR** (1999), “A Multiple Index Analysis of Real Estate Cycles and Structural Change”, *The Journal of Real Estate Research* Jul/Aug Vol 18 Issue 1 pp 97-129

**Hair, JF** (1998), *Multivariate Data Analysis,* Prentice Hall, Upper Saddle River, N.J.

**Hekman JS** (1985), “Rental Price Adjustment and Investment in the Office Market”, *AREUEA Journal* Vol 13 No 1 Spring pp 32-47

**Hendershott P** (1996), “Rental Adjustment and Valuation in Overbuilt Markets: Evidence from the Sydney Office Market”, *Journal of Urban Economics* Vol 39 No 1 pp 51-67

**Hendershott P & Lizieri C & Matysiak GA** *(1996)*, “Modelling the London Office Market”, *The Cutting Edge 1996*, *RICS Research*, London

**Hendershott P, Lizieri C & Matysiak G** (1999), “The Workings of the London Office Market”, *Real Estate Economics* Vol 27 pp 365-387

**Hendershott PH, Macgregor BD & Tse RYC** (2002), “Estimation of the Rental Adjustment Process”, *Real Estate Economics* Vol 30 No 2 pp 165-183

**Jones C** (1995), “An Economic Basis for the Analysis and Prediction of Local Office Property Markets”, *Journal of Property Valuation and Investment* Vol 13 No 2 pp 16-30

**Kaiser RW** (1997), “The Long Cycle in Real Estate”, *Journal of Real Estate Research* Vol 14 No 3 pp 233-258

**Klammt F** (2001), “Modelling In Corporate Real Estate”, *18th International Conference of the System Dynamics Society*, Bergen, Norway.

**Kim DH & Lannon-Kim C** (1991), “Minneapolis’ Real Estate Game: When Will It End?”, *The Systems Thinker (r),* Vol.2 No.5, pp.7-9.

**Kummerow M** (1997), “Commercial Property Valuations with Cyclical Forecasts”, *The Valuer & Land Economist* Vol 34 No 5 February pp 424-428

**Kummerow M** (1999), “A Systems Dynamics Model of Cyclical Office Oversupply”, *Journal of Real Estate Research* Vol 18 Issue 1 pp 233-255

**Lyneis J** (2000), “System Dynamics for Market Forecasting and Structural Analysis”, *System Dynamics Review*, vol. 16 no. 1, pp. 3-24.

**MacFarlane J, Murray J, Parker D & Peng V (**2002), “Forecasting Property Market Cycles: An Application of the RICS Model to the Sydney CBD Office Market”, *8th PRRES Conference*, Christchurch.

**McDonald JF** (2002), “A Survey of Econometric Models for Office Markets”, *Journal of Real Estate Literature* Cleveland Vol 10 Issue 2 pp 223-242

**McGough T & Tsolacos S** (1995), “Forecasting Commercial Rental Values Using ARIMA Models”, *Journal of Property Valuation and Investment* Vol 13 No 5 pp 6-22

**Mitchell PM & McNamara PF** (1997) “Issues in the Development and Application of Property Market Forecasting: The Investor’s Perspective”, *Journal of Property Finance* Vol 8 No 4 pp 363-376.

**Mueller GR** (1999), “Real Estate Rental Growth Rates at Different Points in the Physical Market Cycle”, *Journal of Real Estate Research* Vol 18 No1 pp131-150

**Mueller GR** (2002), “What will the next real estate cycle look like?”, *Journal of Real Estate Portfolio Management* May-August Vol 8 Issue 2 pp 115

**Pyhrr SA, Born W, Manning MA & Roulac SE** (2003), “Project and Portfolio Management Decisions: A Framework and Body of Knowledge Model for Cycle Research”, *Journal of Real Estate Portfolio Management* Vol 9 No 1 pp 1-16

**Pyhrr SA, Roulac SE & Born WL** (1999), “Real Estate Cycles and their Strategic Implications for Investors and Portfolio Managers in the Global Economy”, *Journal of Real Estate Research* Vol 18 No 1 pp7-69

**Rosen K** (1984), “Toward a Model of the Office Building Sector”, *AREUEA Journal* Vol 12 No 3 Fall pp 261-269

**Shilling J, Sirmans C & Corgel J** (1987), “Price Adjustment Process for Rental Office Space”, *Journal of Urban Economics* Vol 22 pp 90-100

**Sivitanidou R & Sivitanides P** (2000), “Does the Theory of Irreversible Investments Help Explain Movements in Office-Commercial Construction”, *Real Estate Economics* Vol 28 pp 623-661

**Sterman JD** (1988), “Modelling the Formation of Expectations: The History of Energy Demand Forecasts**,** *International Journal of Forecasting*, 4: 243-259.
**Sterman LD** (2000), *Business Dynamics: Systems Thinking and Modelling for a Complex World*, Irwin/McGraw-Hill, Chicago, IL.
**Tse RYC & Fischer D** (2003), “Estimating Natural Vacancy Rates in Office Markets Using a Time-Varying Model”, *Journal of Real Estate Literature* Vol 11 Issue 1 pp 37-45
**Tsolacos S & McGough T** (1999), “Rational Expectations, Uncertainty and Cyclical Activity in the British Office Market”, *Urban Studies* Vol 36 No 7 pp 1137-1149
**Vennix J** (1996), *Group Model Building*, Wiley & Sons, England.
**Wheaton WC & Torto RG** (1988), “Vacancy Rates and the Future of Office Rents”, *AREUEA Journal* Vol 16 No 4 pp 430-436
**Wheaton WC, Torto RG & Evans P** (1997), “The Cyclic Behaviour of the London Office Market”, *Journal of Real Estate Finance and Economics* Vol 15 No 1 pp 77-92.