Estimation of the Rental Adjustment Process

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Abstract

Rental adjustment equations have been estimated for a quarter century. In the U.S., models have used the deviation of the actual vacancy rate from the natural rate as the main explanatory variable, while in the UK, drivers of the demand for space have dominated the estimation. The recent papers of Hendershott (1996) and Hendershott, Lizieri and Matysiak (HLM, 1999) fall into the former category. We re-estimate these equations using alternative formulations and present evidence that changes in real interest rates were not capitalized into Sydney and London real land prices.

We then derive a model incorporating supply and demand factors within an Error Correction framework, and show how the U.S. and UK traditions are special cases of this more general formulation. We next estimate this equation using data from the City of London office market. Our initial specification of this more generalized model is greatly superior to the vacancy rate model. Finally, we estimate a two-equation variant with a separate vacancy rate equation; this model also performs much better than that of HLM. Importantly, our model passes standard modern econometric requirements for unit roots and co-integration.

Keywords: rent change; vacancy; office markets; London; Sydney

1. Introduction

Rent, the price of space, is arguably the most important variable in property economics. The value of space is the present value of current and future rents, and rent is a large component of many household and business budgets. As a result, rent determination has been extensively studied over the last quarter century.

The primary focus in U.S. research has been adjustments to deviations of the vacancy rate from the natural or equilibrium rate. Not surprising given this focus, significant emphasis has been directed towards how the natural rate varies spatially and temporally. Given the greater tendency of office markets toward overbuilding and thus to wider swings in office than in retail, industrial or residential vacancy rates, it is also not surprising that most research has been concerned with this property type.

Recently, U.S. researchers have realized that the simple vacancy rate model is inadequate and that more structure is needed. The current state of the art was illustrated recently in the Hendershott, Lizieri and Matysiak (1999) -- hereafter HLM -- study of the London office market. U.K. researchers, on the other hand, have estimated reduced form demand-supply equations, finding drivers of the demand for space, in particular, to be important determinants of real rents. While this gives added structure, it seems inappropriate to give up the obvious explanatory power of the vacancy rate.

In section 2, we review the key literature on rental adjustment models based on the deviation of the vacancy rate from its natural level, and in section 3, we consider the addition of the deviation of actual rent from equilibrium rent in earlier studies of the London and Sydney markets. We test alternative specifications of the HLM model in section 4, and obtain evidence that changes in real interest rates were not capitalized into real Sydney and London land prices. We derive an Error Correction Model (ECM) for rental adjustment in section 5. This model requires estimating both a long run rent equation derived from the underlying supply and demand for space and a difference equation including the error from the long run equation as a regressor. In section 6, we estimate this model using the HLM London data. While the vacancy rate (and the supply of occupied space) is a key component of the equation, financial and business services employment is even more important. This equation reduces the unexplained variance of the HLM equation by 30 percent.

2. Estimation of Vacancy Rate Models

Rental adjustment equations, linking the change in real rents to deviations in the vacancy rate from the equilibrium or natural vacancy rate, are a well-established part of the modeling of property markets.[1] This approach has its origins in labor economics, where real wage inflation has been related to deviations of the employment rate from the natural or full employment rate. In macroeconomics, these same deviations (with the full employment rate renamed the nonaccelerating inflation rate of unemployment, NAIRU) have been used to explain the inflation rate. Possible application to the rental housing market was first noted by Blank and Winnick (1953).

The basic relationship may be written as:

$$\%?R_t = ?(v^* - v_{t-1}) \qquad (1)$$

where: $\%?R$ is the percentage change in real rents; v^* is the natural vacancy rate; v_{t-1} is the lagged vacancy rate; and $?$ is the adjustment factor. In the estimation v^* is calculated from the constant in the regression. Smith (1974) was the first to provide empirical support for the vacancy rate model. Using data from five Canadian cities, he regressed the rate of change in rents on the vacancy rate, lagged

[1] For full reviews of the early literature, see Eubank and Sirmans (1979), Rosen and Smith (1983) and Shilling, Sirmans and Corgel (1987).

vacancy rate, and the current and lagged rate of change in property taxes. The vacancy rate and its lagged value were usually significant, but the impact of tax changes was less clear. Eubank and Sirmans (1979) used the more general rate of change in operating expenses, rather than property taxes, to capture cross-section variation in these and considered four U.S. cities and four apartment building types in each city. Overall, the vacancy rate variables worked poorly, but operating expenses worked well.

Much of the subsequent research concentrated on possible spatial and temporal variation in the natural vacancy rate. Rosen and Smith (1983) estimated a pooled model for housing rents in 17 U.S. cities with fixed city effects and found the vacancy rate and operating expenses to be significant. Their estimates of natural vacancy rates by city varied from six to over 23 percent. This range is implausibly large, owing to cities with unbelievably high natural rates. Shilling, Sirmans and Corgel (1987) employed the pooled approach for office market data from 17 U.S. cities. The expenses variable was significant in only four cities and the vacancy rate in 11 (at the 10 percent significance level). Here, too, the variation in natural vacancy rates is implausible, ranging from one to 21 percent.

Gabriel and Nothaft (1988), using real housing rents, investigated 16 cities over the shorter 1981-85 time frame and obtained more reasonable natural vacancy rate values of four to ten percent. In a second estimation they treated the natural vacancy rate as endogenous, relating it to such factors as the growth in rental units and population and the level and dispersion of rents in the city. Here the range in city natural vacancy rates was seven to 12 percent.[2]

The natural vacancy rate can vary across time as well as space. Wheaton and Torto (1988) estimated the basic model (with the current vacancy rate but without operating expenses) for the US office market over the period 1968-86. They introduced a linear trend to accommodate a hypothesized rise in the natural rate and estimated a six percentage point rise, which they attributed to the spatial expansion of office centers, the broader base of tenants, increases in tenant turnover and a shortening of the average length of lease. Although this formulation results in a better fit, the six point rise is implausibly large and is clearly period specific; their data cover a cycle and a half, with the vacancy rate starting at four percent and ending at 18 percent. The linear trend increase arguably reflects the overbuilding associated with the generous tax

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[2] In unpublished recent work, Gabriel and Nothaft (2000) decompose vacancy into two components, incidence of becoming vacant and duration of vacancy, and find a low and very narrow range of natural vacancy rates across cities.

depreciation allowances of the 1981 Tax Act (Hendershott and Kane, 1992), rather than the factors Wheaton and Torto suggested.

If one's interest is in the spatial and temporal variation in natural vacancy rates, it seems reasonable to investigate these rates directly, rather than attempting to infer this variation from a rental adjustment equation. Grenadier (1995), building on Voith and Crone (1988), undertook such an analysis, using semiannual data for 20 cities over the period 1960-91. Variances in individual city vacancy rates were decomposed into a common time-varying component and city-specific fixed effects. City-specific persistence terms were also included to allow for lagged adjustment toward equilibrium. The common time varying component was statistically significant, but the magnitude of the temporal rise in the natural vacancy rate was minor, less than a full percentage point from the early 1970s to the early 1990s. This is the magnitude of increase that the factors Wheaton and Torto identified would reasonably explain. The magnitude of the range in city natural vacancy rates, excluding Houston and Dallas, whose high rates are almost certainly attributable to the saving and loan problem (Hendershott and Kane, 1992), varied from two to twelve percent. This ten point variation, while still surprisingly large, is certainly more plausible than the earlier estimates of a twenty point variation.

3. Equilibrium Rents

The basic vacancy rate model is fundamentally deficient because equilibrium real rents are unspecified and can, if fact, end up anywhere depending only on the pattern of past shocks. Consider a market starting in full equilibrium being hit with a supply shock that raises the vacancy rate above the natural rate. Over time, demand for space grows, returning the vacancy rate to the natural rate. During the period the vacancy rate is above the natural rate, the vacancy rate model implies a monotonic decline in real rents. Thus, when the vacancy rate returns to the natural rate, real rents will be far below their initial, presumably unchanged, equilibrium value. A series of supply shocks (or negative demand shocks) would drive "equilibrium" real rents lower and lower. In contrast a series of positive demand shocks would drive rents higher and higher.[3]

In full equilibrium, the vacancy rate will equal the natural rate, real rent will be at its equilibrium level, capital values will equal replacement costs and little development will take place. If vacancies fall below

[3] A second lesser flaw relates to the vacancy rate. If the lagged value is employed, current demand and supply shocks cannot affect rents. And the current vacancy rate should not be used as a regressor, as many have done, because it is endogenous; both rent and vacancy act to clear the space market.

the natural rate, real rents will rise above their equilibrium level and induce development that will continue until vacancies *and* real rents return to equilibrium. Similarly, if the vacancy rate rises above the natural rate, rents will fall below their equilibrium level and development will stop until demand growth returns rents and the vacancy rate to their initial levels.

Hendershott (1996) proposed and estimated a model for Sydney that both allows a more general rental adjustment path and constrains rents to return to their equilibrium level:

$$\%?R_t = ?(v^* - v_{t-1}) + ?(R_t^* - R_{t-1}) \tag{2}$$

where R_t^* is the time varying equilibrium (natural) real rent. HLM (1999) estimate the same equation for London.[4] The equilibrium rent in equation (2), R^*, is the user cost of capital – the product of replacement cost and the sum of the real interest rate (from the capital market), the depreciation rate (*?*) and the operating expense rate (*?*). Thus, the identity is:

$$R_t^* = (r_t + RP + ? + ?)RC \tag{3}$$

where r_t is real risk-free interest rate, *RP* is the risk premium and *RC* is replacement cost, including real land costs.[5] In the empirics, equilibrium rent varies only with the long-term real default-free rate; *RP*, *?*, *?* and *RC* are all taken to be constant.[6] For Sydney, Hendershott uses 3% for *RP*, 2.5% for *?*, and 5% for *?*. For London, HLM set these parameters at 2%, 2%, and 1.5%, respectively. The large difference in the operating expense ratio is due to the fact that tenants pay many of these expenses directly in the UK (the full insuring and repairing lease) but not in Australia.

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[4] Both Hendershott (1996) and HML adjust headline rents to take account of letting incentives and use the GDP deflator to convert to real rents. The HLM model has equations for completions, net absorption and rental adjustment). Here we concentrate solely on the rental adjustment equation.

[5] Actually, the right hand side should be divided by 1-v* because rent is earned on occupied space only. Empirically, this would simply result in an offsetting upward revision in measured RC.

[6] The depreciation rate may vary with the building cycle, older buildings being discarded at a more rapid rate when vacancies are high, and the risk premium may also be time-varying, with the premium growing when property markets weaken. However, these variations are not likely to be large.

Given the long-term nature of office leases, in both studies the nominal default-free rate was taken to be a long-term Treasury rate and the (long term) expected inflation rate was calculated as a simple average of the rate of change in the GDP deflator in the current and two previous years. Unfortunately, this led to substantially negative estimates of the real default-free Treasury rate during the middle 1970s. In the later London study, negative real default-free interest rates were truncated – this real rate being set at the maximum of the calculated rate and one per cent – whereas in the Sydney study they were not.

The source of the negative rates was the OPEC oil shock. In the UK, inflation leapt from 8 percent in 1973 to 19 percent in 1974 and 26 percent in 1975, before receding to 9 percent in 1976. To build this surge in inflation into long-term expected inflation estimates requires one to presume that investors believed that oil prices were going to continue *rising* at the 1974-75 rate over the next decade. Because this is implausible, the London truncation seems quite reasonable.

Setting *RC* is more difficult. In both studies, the authors determine *RC* by selecting a year in which actual and equilibrium rents were likely to have been equal (1986 and 1983, respectively, in Sydney and London), substituting actual rent for equilibrium rent in equation (3), and solving. The real value of *RC* is then assumed to be constant over time. Given that replacement cost must include real land costs, this assumption is rather strong.

In fact, some might argue that changes in real interest rates are fully capitalized into real land prices. If this were so, changes in r would be offset by changes in *RC* and $R*$ would be approximately constant. In this case, equation (2) reduces to

$$\%?R_t = (?v^* + ?R_t^*) - ?v_{t-1} - ?R_{t-1} \qquad (2')$$

where the term in brackets is a constant.[7]

4. A Closer Look at the Estimates

The original results for Sydney and London are reproduced in columns 1 and 2 of Table 1. All coefficients have the expected signs and are significant. The implied natural vacancy rates for the two

[7] Wheaton and Torto (1994) specify R* as a function of the tenant arrival and vacancy rates, which also introduces lagged R into the equation.

markets are 6.4 and 7.1 per cent, respectively, i.e., there is trivial difference. To make the estimates more comparable, the Sydney equation is re-estimated with the real interest rate set at the maximum of the calculated rate and one percent, as was done in the London study. This adjustment (column 3) improves the fit, raising the adjusted R^2 above that of the London model and producing a natural vacancy rate of 5.1 percent. Note that the vacancy and rent gap coefficients in this equation and in the London equation are virtually identical.

The HLM formulation resembles an Error Correction Model (ECM) in that rents are specified as adjusting to the difference between long run and actual rents. But rather than estimating an equation to determine long-run rents, it is defined by equation (3). As an alternative, we have regressed actual real London rents on current and lagged values of the primary driver of equilibrium rents, their estimate of the real default-free Treasury rate, and a constant to reflect the risk, depreciation and expense parameters. Unfortunately, this equation has little explanatory power.

Table 1: London and Sydney rental adjustment equations

	Original Models			Separate Components	
	Sydney	London	Re-estimated Sydney	Sydney	London
Constant	0.112	0.201	0.139	0.282	0.094
	(0.033)	(0.046)	(0.029)	(0.120)	(0.160)
v_{t-1}	-1.76	-2.83	-2.71	-2.89	-2.87
	(0.46)	(0.54)	(0.42)	(0.44)	(0.55)
$R_t^*-R_{t-1}$	2.57	3.72	3.85		
	(0.61)	(0.57)	(0.71)		
R_t^*				2.86	4.68
				(1.07)	(1.47)
R_{t-1}				-3.76	-3.45
				(0.70)	(0.69)
Adj-R^2	61%	69%	71%	71%	68%
DW	1.87	1.61	1.92	2.09	1.69
v*	6.4%	7.1%	5.1%	9.8%	3.3%

Notes: standard errors are in brackets; DW is the Durbin-Watson statistic; original models were re-estimated and validated from original data sets and rescaled for comparison; the Sydney re-estimated model is based on a lower bound of 1% for the default free real rate.

This raises the possibility that the explanatory power of the rent gap variable comes entirely from the lagged rental rate, as Wheaton and Torto (1994) might hypothesize. As noted above, this would be the case if changes in the real risk-free rate are largely capitalized into land prices so that R^* is constant. To test this hypothesis, we break the R_t^*-R_{t-1} variable into its two components and estimate separate coefficients. The last two columns of Table 1 contain the results for Sydney and London. In both cases, both components are statistically significant with their expected signs and are not significantly different from each other in absolute value. Real rents do seem to be reverting toward a level driven by the real default-free interest rate – changes in real interest rates are not capitalized into land prices. Thus the assumption of constant real replacement cost, which underlies the analysis of property asset bubbles in Hendershott (2000), may not be a bad approximation.

There is a possible statistical concern with this specification. Not surprisingly, the dependent variable is integrated of order zero (I(0)) while both explanatory variables are I(1) (see Table A1). However, the evidence for a co-integrating relationship between the I(1) variables is weak and the single vector that can be determined has incorrectly signed coefficients (using the Johansen cointegration test within *Eviews* a cointegrating relationship cannot be detected with a one period lag on the first difference in the VAR but appears with two lags).

5. An Alternative Formulation

As an alternative to the rental adjustment models discussed above, we derive a reduced-form estimation equation from a model of the occupied space market. Let the demand for space be a function of real effective rent (R) and employment (E):

$$D \; ? \; ?_0 R^{?_1} E^{?_2} \qquad (4)$$

where the $?_i$ are constants (the 'price' elasticity being negative and the 'income' elasticity being positive). The market clearing rent for a given level of vacancy is that which solves

$$D(R, E) \; ? \; (1 ? v) SU \qquad (5)$$

where SU is supply and v is the vacancy rate. Substituting equation (4) into (5) and solving for R

$$R\ ?\ ?_0 E^{?_1}[(1 ? v)SU]^{?_2} . \qquad (6)$$

Taking logs of both sides of equation (6) gives:

$$\ln R\ ?\ \ln ?_0\ ?\ ?_1 \ln E\ ?\ ?_2 \ln(1 ? v)\ ?\ ?_2 \ln SU \qquad (7)$$

The coefficients on the vacancy rate and supply variables should not differ. The underlying elasticities can be obtained from these estimates as $?_1\ ?\ 1/?_2$ and $?_2\ ?\ ??_1/?_2$.

This type of equation, without the vacancy rate, has been widely estimated on European data for all property types, mainly by UK researchers.[8] Demand drivers used in the literature include retail sales, consumer expenditure, financial and business services output and employment, manufacturing output and employment and GDP, depending on the property type under consideration. These variables are typically highly significant. In contrast, decent quality supply and vacancy data are rarely available. Some studies use construction orders (a flow variable) rather than a stock, some use proxy variables and some omit supply altogether. Most studies that test supply proxies find them to be insignificant. Vacancy rate data are even more difficult to obtain in Europe, and we know of no estimation of a variant of equation (7) that uses vacancy rates.

The residual in the estimation of equation (7) is

$$u_t\ ?\ \ln R_t\ ?\ \overset{?}{?}_0\ ?\ \overset{?}{?}_1 \ln E_t\ ?\ \overset{?}{?}_2 \ln[(1 ? v_t)SU_t], \qquad (8)$$

the difference between the actual and estimated (long run) values. If the levels variables are integrated of order one (I(1)) and are co-integrated, this error is stationary and its lagged value can be used in a short run dynamic model as an adjustment process.[9]

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[8] For a survey of this research, see Hendershott, MacGregor and White (2001).

[9] Formally, a series with no deterministic trend and which has a stationary and invertible autoregressive moving average (ARMA) representation after differencing d times, but which is not stationary after differencing *d*-1 times, is said to be integrated of order *d*.

The components of a vector $\mathbf{x}_t$ are said to be co-integrated of order *d, b,* if $\mathbf{x}_t$ is *I(d)* and there exists a non zero vector ? such that $?^T\mathbf{x}_t$ is *I(d-b), d*>=*b*>0. The vector ? is called the co-integrating vector.

The short run model is a difference equation with an Error Correction term, namely the lagged error described by equation (8):

$$? \ln R_t \; ? \; ?_0 \; ? \; ?_1 ? \ln E_t \; ? \; ?_2 ? \ln(1 ? v_t) \; ? \; ?_3 ? SU_t \; ? \; ?_4 u_{t ? 1} \qquad (9)$$

Thus, rent adjusts to short run changes in the causal variables and also to the lagged market imbalance, measured by the deviation of rent from its long run value. In the estimations, it is expected that $?_0$ will be approximately zero, $?_1$ will be positive, and $?_2$, $?_3$ and $?_4$ will be negative. $?_4$ = -1 means complete or full adjustment to the previous error.

A problem with this structure is that the current vacancy rate is an endogenous variable; both vacancy and rent operate to 'clear' the space market [equation (5)].[10] In effect, we have a two-equation model. To explain the vacancy rate, we first tested an analogue to equation (3), using the gaps between the natural and lagged vacancy rate and equilibrium and lagged rents. While tracking the general directional movement in the vacancy rate, this was very poor at estimating the magnitudes of changes in the vacancy rate. Regressions of the London vacancy rate on lagged values were then estimated in the spirit of Grenadier (1995), with much greater success. The best fitting relationship is

$$\underset{}{v_t} = \underset{(0.68)}{0.95} + \underset{(0.22)}{1.84 v_{t-1}} - \underset{(0.36)}{1.38 v_{t-2}} + \underset{(0.21)}{0.42 v_{t-3}} \qquad (10)$$

The adjusted R^2 is 0.90 for the 1976-96 period, and the equation standard error is 1.62. This AR(3) process allows for both persistence and time variation in the natural vacancy rate. We use the predicted rate from this equation in explanations of real rental changes.

In our models, we are looking for co-integrating relationships among variables that are individually integrated of order one, so the deviation from the equilibrium relationship is integrated of order zero, that is, it is stationary. (Banerjee *et al*., 1993)

[10] It can also be argued that the vacancy rate is partly determined by exogenous variables. Several studies have developed cross sectional models linking the natural vacancy rate to exogenous variables [see, for example, Rosen and Smith (1983) and Shilling, Sirmans and Corgel (1987)]. Arnott and Igarashi (2000) consider the demand for vacant space in the context of search models.

6. Estimation of the Reduced-Form ECM Model

We estimate the model using the HLM London data set. The series used are all I(1), and for all the equations estimated there exists a co-integrating vector with correctly signed coefficients (see the Appendix). Four basic models are reported in Table 2: two using the actual vacancy rate and two using our predicted rate. In each case there are versions with supply and vacancy rate as separate variables and with them combined as a single variable. The upper part of the table presents the results of the long run models and the lower part presents the short run models.

For the long run models, all coefficients are correctly signed and significantly difference from zero. When the vacancy rate and supply variables are entered separately, their coefficients are not statistically different from each other. The explanatory power is high, and no power is lost by replacing the actual change in the vacancy rate with the predicted change. The implied "price" elasticities of the demand for space (for models 2 and 4, respectively) are –0.19 and –0.24, and the "income" elasticities are 0.67 and 0.92.

In the short-run models, the employment, vacancy rate and error correction coefficients are all correctly signed and statistically significant. The stock variable, which HLM acknowledge is of questionable quality, is not significant and is incorrectly signed when the predicted vacancy rate is employed. This variable is dropped in Model 5.

The employment coefficient in the short model is close to that in the long run model, but the supply and vacancy coefficients are significantly lower. In all cases, the constant term is not significantly different from zero, and the ECM coefficient is not significantly different from negative unity, implying full adjustment in one year to the gap between long run and actual rents. The explanatory power is high, but, not surprisingly, is lower for the models using the predicted vacancy rate than those using the actual rate.

For proper comparison of our model with HLM, the models need to be estimated over a common time period. This requires re-estimation of the HLM (1999) model. These results are shown in the last column in Table 2. Our model 5 reduces the unexplained variance of the HLM model by 30 per cent. Incorporating the employment variable and using the error correction format is far superior to using the rent gap variable.

Table 2: The Error Correction Models

Variable	Model 1 1975-96	Model 2 1975-96	Model 3 1977-96	Model 4 1977-96	Model 5 1977-96	HLM 1977-96
Long run						
Constant	18.55	17.75	16.07	15.90	15.90	
	(2.11)	(1.74)	(2.22)	(1.73)	(1.73)	
Employment	3.74	3.58	3.84	3.80	3.80	
	(0.52)	(0.45)	(0.58)	(0.47)	(0.47)	
Stock	-5.69		-4.21			
	(0.90)		(0.91)			
(1–v)	-6.18					
	(1.40)					
Stock*(1–v)		-5.37				
		(0.76)				
(1–pred v)			-4.31			
			(1.50)			
Stock*(1–pred v)				-4.14	-4.14	
				(0.75)	(0.75)	
Adjusted R^2	80%	80%	79%	80%	80%	
DW	1.46	1.34	1.09	1.06	1.06	
Short run	1976-96	1976-96	1978-96	1978-96	1978-96	1978-96
Constant	-0.046	-0.023	-0.047	-0.005	-0.028	0.201
	(0.029)	(0.023)	(0.034)	(0.026)	(0.024)	(0.046)
? lnEmployment	3.75	2.59	3.37	2.09	2.80	
	(0.80)	(0.54)	(0.96)	(0.68)	(0.71)	
? lnStock	-2.07		1.70			
	(2.29)		(2.25)			
? ln(1 – v)	-4.26					
	(1.44)					
? ln[Stock*(1 – v)]		-3.91				
		(1.37)				
? ln(1 – pred v)			-2.00		-2.16	
			(0.98)		(0.90)	
? ln[Stock*(1–pred v)]				-1.72		
				(1.01)		
ECM	-0.95	-0.95	-0.87	-0.72	-0.83	
	(0.17)	(0.17)	(0.23)	(0.23)	(0.22)	
v_{t-1}						-2.77
						(0.55)
R_t* - R_{t-1}						3.58
						(0.84)
Adjusted R^2	79%	79%	72%	69%	73%	61%
DW	1.90	1.51	1.79	1.39	1.62	1.37
						v*=7.3%

Notes: standard errors are in brackets; DW is the Durbin-Watson statistic.

7. Conclusions

In this paper, we discussed the development of the vacancy rate model in the U.S. and the latest extension and estimation of it by Hendershott (1996) and HLM (1999). This estimation introduces the deviation from a time varying equilibrium rent as a variable and in doing so creates a link between the capital and space markets. Estimates of the model using London and Sydney office market data show the vacancy and equilibrium rent variables to be significant and to have remarkably similar coefficients. When the two rent gap components, lagged rent and equilibrium rent, were entered separately, their coefficients were statistically different from zero and not statistically different from each other in absolute value. This suggests that changes in real interest rates were not capitalized into Sydney and London land values.

We then derived a reduced-form equation based on the supply and demand for occupied space. Using the same London data, we estimated both a long-run equation and a short-run Error Correction Model. In the short-run model, the rate of change in real rents was related to rates of change in the supply and demand variables and the vacancy rate and to the lagged error from the fitted long-run equation. The ECM model has a number of clear advantages over the vacancy gap model. It is based on a structural model of the space market, and the coefficients have useful economic interpretations (the "price" and "income" elasticities of the demand for space are estimated to be about one-quarter and unity, respectively). On the other hand, the model requires both stock and vacancy rate data, and these are not available in many markets.

In contrast, the basic vacancy rate model is conceptually much simpler and does not require stock data. However, its theoretical underpinnings are weak. The introduction of the deviation of actual real rent from equilibrium rent is conceptually elegant but creates measurement difficulties in the absence of a market-based real, default-free interest rates and data on risk premia and real land values. Further, from our evidence, this model produces poorer estimates and may have problems of co-integration. Thus, where data permit, the ECM space market approach appears to be far superior.

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Appendix

Table A1: Unit Root Tests

	Augmented Dickey-Fuller test	Phillips-Perron test
Effective rents	Accept 5%	Accept 10%
D(Effective rents)	Reject 1%	Reject 5%
Employment	Reject 5% Accept 1%	Accept 10%
D(Employment)	Reject 1%	Reject 5%
Stock	Reject 5% Accept 1%	Accept 10%
D(Stock)	Reject 5%	Reject 5%
1 – v	Reject 5% Accept 1%	Accept 10%
D(1 – v)	Reject 1%	Reject 5%
Stock*(1 – v)	Accept 10%	Accept 10%
D(Stock*(1 – v))	Reject 1%	Reject 1%
1 – pred v	Accept 5%	Accept 10%
D(1 – pred v)	Reject 1%	Reject 1%
Stock*(1 – pred v)	Reject 5% Accept 1%	Accept 10%
D(Stock*(1 – pred v))	Reject 1%	Reject 1%
v_{t-1}	Reject 5% Accept 1%	Accept 10%
D(v_{t-1})	Reject 1%	Reject 5% Accept 1%
(R_t*-R_{t-1})	Accept 10%	Accept 10%
D(R_t*-R_{t-1})	Reject 1%	Reject 1%

Notes: All series can be assumed I(0); all variables in logs; D is the first difference; results with null hypothesis of a unit root (non stationary); all levels tests with a trend and constant; differences tests with neither.

Table A2: Co-integration tests

Variables	Null hypothesis and result
Rents, Employment, Stock, (1 – v)	None: reject at 1% At most 1: reject at 5% At most 2: accept One vector correctly signed
Rents, Employment, Stock*(1 – v)	None: reject at 5% At most 1: accept One vector correctly signed
Rents, Employment, Stock, (1 – pred v)	None: reject at 1% At most 1: reject at 5% At most 2: accept One vector correctly signed
Rents, Employment, Stock*(1 – pred v)	None: reject at 5% At most 1: accept One vector correctly signed
Percentage rental growth, lagged v, (current equilibrium rent – lagged rent) (*)	None: reject at 1% At most 1: accept One vector incorrectly signed

Notes: in all cases Johansen test used with constant and assumption of linear deterministic trend in the data; one lag of first difference, except (*) where two lags had to be used to obtain a cointegrating relationship.