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# Asymmetric Adjustment in the London Office Market

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## Abstract

*Earlier estimates of the behavior of the City of London office market are extended by considering a longer time series of data, covering two full cycles, and by explicitly modeling asymmetric space market responses to employment and supply shocks. A long run structural model linking real rental levels, office-based employment and the supply of office space is estimated and then rental adjustment processes are modeled using an error correction model framework. Adjustment processes are seen to be asymmetric, depending both on the direction of the supply and demand shock and on the state of the space market at the time of the shock. Both symmetric and asymmetric systems of equations are estimated, and unit shocks to employment are simulated to illustrate differences in the properties of the two systems.*

**Key Words** *Office Market Models, Rental Adjustment; Asymmetric Response; Vacancy Rate.*

# Asymmetric Adjustment in the London Office Market

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The London office market is possibly the most researched real estate market in the world as a result of its size, importance and the availability of data. Earlier modeling work was been based on only two decades of data (ending in 1996) that were dominated by less than a full real estate cycle (Hendershott, Lizieri and Matysiak, 1999; Hendershott, MacGregor and Tse, 2002; Wheaton, Torto and Evans, 1997).[1] The vacancy rate leaped from under 4 percent in 1986 to 16 percent in 1991 before falling to 8 percent in 1996. Adding just another decade of data both completes the earlier cycle (the vacancy rate fell to 2 percent in 2000) and adds another full cycle (the rate reached 15 percent in 2003 and returned to under 6 percent in 2006).

We use the longer data set to extend the analysis in two ways. First, we test for whether the earlier estimates of market adjustment are consistent with the most recent decade of London data. That is, we estimate models with the (revised) 1977-96 data and then use them to forecast the 1997-2006 period. Second, we test for different responses to employment and supply shocks depending on the nature of the shock and the stage of the real estate cycle. To illustrate, whether shocks to employment and supply are positive or negative or whether the vacancy rate is high or low when the shock occurs might affect the adjustment process.

Sections 1 and 2 describe the models we estimate and the data we employ. Estimates of the basic symmetric models are reported in Section 3. Determinants of asymmetric responses to shocks are discussed and estimates are presented in Section 4. In Section 5 we illustrate our results by contrasting the responses of rent, vacancies and supply to positive and negative employment shocks using both a symmetric set of equations and one in which we have allowed for asymmetries. Section 6 provides a discussion and conclusions.

## 1. The Model

Hendershott, MacGregor and Tse (2002, hereafter HMT) and Englund, Gunnelin, Hendershott and Soderberg (2008, hereafter EGHS) utilize a long-run equilibrium model of the space market to estimate equilibrium rents in the London and Stockholm

[1] Farrelly and Sanderson (2005) also use only two decades of London data, although theirs (quarterly) cover 1982-2002; Barras (2005) uses data that span 1974-2004 to generate elasticities for use in a simulation model of office supply.

markets. We adopt this approach, specifying the long-run demand for office space as a log-linear function of real rent and employment:

$$\ln D(R,E) = \lambda_0 + \lambda_R \ln R + \lambda_E \ln E \quad (1)$$

where $R$ is the real rent on new contracts and $E$ is the employment that occupies office space. The price elasticity, $\lambda_R$, is negative and the 'income' elasticity, $\lambda_E$, is positive. Actual space occupancy may deviate from the demand function because of transaction costs and because tenants are locked into old contracts. In the long-run equilibrium, the vacancy rate equals the natural rate, all leases carry the current rent, and all adjustments have been made. Thus, demand equals total supply minus equilibrium vacancies:

$$D(R^*, E) = (1 - v^*)S\ , \quad (2)$$

where the asterisks denote equilibrium values. Taking the logarithm of (2), substituting from (1) with $R$ replaced by $R^*$, and solving for $\ln R^*$ then gives

$$\ln R^* = \gamma_S[\ln(1 - v^*) - \lambda_0] + \gamma_E \ln E + \gamma_S \ln S\ , \quad (3)$$

where the parameters of the demand equation can be retrieved as $\lambda_R = 1/\gamma_S$ and $\lambda_E = -\gamma_E / \gamma_S$.

For the short-run adjustment process, we follow EGHS (2008), who extended the model of HMT (2002).[2] Rents on new leases, $R$, adjust to the current changes in the determinants of equilibrium rent (E and S) and to the gaps between both the actual and natural vacancy rates and the actual and equilibrium rent levels. Specifying the adjustment equation in log-linear terms:

$$\Delta \ln R_t = \beta_E \Delta \ln E_t + \beta_S \Delta \ln S_t + \beta_v (v_{t-1} - v^*) + \beta_R \varepsilon_{R,t-1}\ , \quad (4)$$

where $\varepsilon_R = \ln R - \ln R^*$ and is calculated as the residual from equation (3) where v* is treated as constant. The adjustment coefficients are $\beta_E$ for the response to employment shocks, $\beta_S$ for supply shocks, $\beta_v$ for the vacancy rate gap, and $\beta_R$ for the rent gap. In the

[2] The model used by HMT (2002) has a time-varying vacancy rate in the long run equation. To overcome endogeneity issues, an expected value was estimated from an AR(3) model. The consequent short run model, thus, contains a vacancy change term rather than the vacancy level as in this specification. We prefer the EGHS (2008) approach from a theoretical perspective and because it can also be seen as an improved vacancy adjustment model – see HMT (2002) for a review of this literature.

estimation, the lagged vacancy rate is a regressor and the constant term, $\beta_0$, is an estimate of $\beta_v$ v* and thus $\beta_0/\beta_v$ is an estimate of v*.[3]

Lagged adjustments may arise owing to data issues – in particular, from the frequency of observations, or they may relate to institutional arrangements and behavioral factors. We discuss these in turn.

First, the nature of our data makes the accurate estimation of responses to shocks difficult. All series are measured as at end of year and a shock is measured as a change from beginning to end of year. As it takes time for the market to respond to a shock, it matters whether the shock, in fact, occurs earlier or later in the year. When significant changes in the explanatory variables occur toward the end of the period, even a relatively fast behavioral response would be recorded largely in the following period. In contrast, a shock early in the period would more likely be recorded within the period.[4] To illustrate, suppose that employment rises by X during the first half of the year and falls by 2X during the second half, giving a total change of –X. Because the rise affects demand for three quarters of the year (on average) and the fall for only one-quarter, we could observe rent rising and vacancy falling in the current period, even though the underlying response is the opposite (even larger opposite movements would be recorded in the subsequent period).

Second, leases in the London office market are long (typically 25 years up to the early 1990s, falling to an average of 10-15 years by the end of the analysis period) with five-year rent reviews to market and penalties that hamper lease surrender or sub-letting. Thus occupied space is unlikely to adjust quickly to changes in either employment or market rent. In the short run, occupiers may respond to changes in demand for their services by altering the intensity of use of their existing space, until it becomes clearer whether the change in demand is temporary or is likely to be sustained. Thus, a decrease in employment in the firm may initially lead the firm to under-occupy or mothball space, creating so-called 'grey space'. Similarly, an increase in employment may initially lead firms to decrease floor space per worker. Only over time will the demand for space adjust and changes in rent and vacancy occur.

Third, published rental series are typically based on appraisers' estimates of rent, informed by what market letting evidence is available. Because not all letting evidence

[3] EGHS (2008) argue that this simple calculation is incorrect for Stockholm where real rents had a strong upward trend. This is not the case for London.

[4] If a shock occurs early in the period and is reversed late in the period, no net shock would be recorded, but there would be (offsetting) effects in both the current and subsequent periods.

is publicly available and agreements are signed *before* the date of the rental, rent series may be subject to smoothing and temporal aggregation effects (see Geltner *et al*., 2003, for a review of this literature). Finally, even in such a well researched market as that for London offices, there is scope for imperfect knowledge on demand, supply and rents, and on the impact of these on market outcomes.

All of the factors above apply to adjustments to both rents and the vacancy rate, which work together to bring the market back to equilibrium. This suggests the need to consider lagged adjustments to shocks to the causal variables.

A related factor is addressed by EGHS (2008), who emphasize that the vacancy rate cannot simply be solved from an equation like (2), as was done in earlier models of the London market, because (2) holds only in equilibrium. They introduce the concept of hidden vacancies, which clear the space market when it is out of equilibrium (*vh* is the hidden vacancy rate):

$$D(R,E) = (1 - v^* - vh)S \; . \tag{5}$$

No longer are rent and vacancies mirror images of each other, *v* always being below *v** when *R* exceeds *R** and vice versa. Thus EGHS (2008) estimate an independent vacancy rate equation that is analogous to the rental adjustment equation:

$$\Delta v_t = \eta_0 + \eta_E \Delta \ln E_t + \eta_S \Delta \ln S_t + \eta_v v_{t-1} + \eta_R \varepsilon_{R,t-1} \tag{6}$$

where $\eta_E$ and $\eta_S$ indicate the impact of concurrent shocks to employment and supply and $\eta_R$ and $\eta_v$ are the responses of the vacancy rate to the initial rent and vacancy rate gaps. In (6), $\eta_0 = \eta_v v^*$, and the natural vacancy rate can be computed as $\eta_0 / \eta_V$. We estimate a similar equation and in our system estimations we constrain the implied natural vacancy rates in equations (4) and (6) to be equal.

Tobin's q framework suggests that supply is forthcoming in response to an excess of property value over construction costs. To employ this framework directly, one would need, at a minimum, time series of property prices and construction costs. Unfortunately, reliable time series for these variables are not available for the London market. Following Hendershott, Lizieri and Matysiak (1999) and EGHS (2008), we take a short-cut by positing that changes in supply depend on lagged values of *R*-*R** (positively) and *v*-*v** (negatively). One way of justifying this is to note that if the real discount factor were constant over time and expectations of future time paths of *R* and *v* were systematically related to differences between current and equilibrium values, then there would be a close connection between current rents and vacancies on the one hand and property prices on the other.

Given that it takes time to build, the time lag from the disequilibrium indicators to the increase in supply may be longer than the corresponding one-year lag in the rent and vacancy adjustment equations. By the same argument it does not seem reasonable to expect that contemporaneous changes in *E* affect current supply. Thus, we specify the following supply model:

$$\Delta \ln S_t = \psi_v (v^* - v)_- + \psi_\varepsilon \varepsilon_{R-} . \qquad (7)$$

where the minus subscript denotes lagged values. Given that relatively high property values could give rise to a development boom, while low values can do no more that limit replacement investment (Hendershott, Lizieri and Matysiak, 1999), one would expect that positive $\varepsilon_{R-}$ would have a quantitatively stronger effect than negative. And similarly for positive and negative values of $v^*$ - $v$.

## 2. The Data

Although the City of London office market is heavily researched, it is not easy to assemble a consistent and reliable dataset. There are particular difficulties associated with geographical boundaries as was evident, for example, in Wheaton, Torto and Evans (1997), where the data utilized ranged from central London through –the Greater London metropolitan area to the wider region surrounding London. We have attempted to confine our analyses to data series that relate only to the City of London. Time series tend to be short and low frequency, which further complicates analysis and application of sophisticated statistical models.

For supply data, we rely on the stock estimates of the Corporation of London, as part of their Development Schedules. These are now produced twice yearly (with a considerable publication lag) but are only annual before 1987. The series include a stock estimate, new construction starts and completions for office space. DTZ provided market-based data on prime (class A) rent level.[5] CB Richard Ellis (CBRE) provided vacancy rate figures that are for space available (newly constructed space and second hand space available for letting). CBRE also provide typical lease lengths and rent free periods (the period at lease inception where the tenant pays no rent as an incentive to sign the lease).

[5] CBRE also has an asking rent series. We use the DTZ series to provide comparability with the HLM (1999) and HMT (2002) models that used these data. The two rent series are strongly correlated.

The rent free period varies according to the letting cycle and it is thus necessary to convert headline (face) rents to effective rents. Following, Hendershott (1996) and Webb and Fisher (1996), we compute the present value of the tenants' rent over the full life of the lease and then convert that to an annual equivalent to adjust the face rent, based on the standard quarterly in advance UK lease contract:

$$R_{Eff} = R_{Head} - R_{Head}\left\{\frac{1-(1+i)^{-P}}{4[1-(1+i)^{-\frac{1}{4}}]}\right\}\bigg/\left[\frac{1-(1+i)^{-N}}{4[1-(1+i)^{-\frac{1}{4}}]}\right] = R_{Head}\left\{1-\frac{[1-(1+i)^{P}]}{[1-(1+i)^{N}]}\right\} \quad (8)$$

where $R_{Eff}$ is effective rent, $R_{Head}$ is headline rent, $P$ is therent free period in years, $N$ is the lease length in years, and $i$ is the appropriate discount rate (taken to be the UK long bond redemption yield plus 0.02). Real values of effective rent and supply are computed using the GDP deflator.

Employment data in office markets are often problematic. We want an estimate of office based employment, but aggregate employment figures will include workers who do not occupy office space. Moreover, official statistics tend to rely either on employment areas that do not coincide with the office market under investigation, as noted above, or on company reporting that can create assignment difficulties where there are multi-location offices. This is a particular problem for the City of London office market, where a very significant proportion of space is occupied by non-UK firms and where the City offices are supported by a web of middle- and back-office functions that may be remote.[6]

We examined a number of employment series and chose the Financial and Business Services (FBS) series produced at local authority level.[7] This covers the office employment sectors that dominate the City market and the spatial definition coincides with that of the Corporation of London stock figure. The original employment data used by HMT (2002) are not available for the later period, and the new FBS series is not available before 1982, so we indexed both to 100 in 1982 and spliced them at that point.

Financial and business service employment grew from around 154,000 in 1977 to 273,000 in 2006. The share of FBS employment in City total employment has increased

[6] The official estimates of City financial and business service employment may have understated growth in the late 1980s when international firms were moving into the City following the financial deregulation that culminated with the liberalization of the London Stock Exchange in October 1986 (Blake *et al.,* 2000).

[7] Farrelly and Sanderson (2005) also include communications employees.

from around 58% in 1982 to 73% in 2006 as the City has become increasingly functionally specialized.

Figure 1 plots the vacancy rate and real effective rent, showing the customary inverse relationship between the two highly cyclical series. Both are end of year data. Figure 2 graphs the supply and employment series. These series have similar, strong upward trends, growing at 0.97 percent (supply) and 1.80 percent (employment) a year over the 1977-2006 period. On the other hand, the movements around the trend have a strong negative correlation of -0.60. This negative correlation is driven, in large measure, by the late 1980s and early 1990s, when stock completions (from the surge of starts in the second half of the 1980s) coincided with the financial services downsizing that followed the worldwide October 1987 collapse in stock prices (most exchanges saw a 20 to 50 percent decline in a single day). This illustrates the importance of construction lags in the workings of the office market system.

**Figure 1: Real Effective Rent and Vacancy Rate, City of London**

**Figure 2: Office Stock and Financial and Business Service Employment, City of London**

## 3. Estimation Results for the Symmetric Rent and Vacancy Models

We approach the estimations as follows.[8] First, we estimate the rent model over the period 1977-1996 and compare it with earlier estimates of HMT (2002). We note large differences. Then we forecast rent in the 1997-2006 period, which is under predicted by large amounts. Last, we re-estimate for the full 1977-2006 period.

### A. Comparing the Rent Models for 1977-1996 and 1977-2006

Table 1 contains separate estimates of the rent models based on data ending in 1996 and in 2006, as well as the earlier HMT (2002) estimates. When we estimate over the 1977-96 period, employment and supply enter the long run equation (Panel A) with the expected signs and with t-ratios of 9 and 12. The implied price (rent) elasticity of space demand is -0.19 (1/-5.22), and the income (employment) elasticity is 0.58 (3.02/5.22). For the short run model (Panel B), all variables are correctly signed, but only the change in employment and the rent ECM are statistically significant.

**Table 1: The Basic Rent Models**

[8] There exist co-integrating vectors and the variables are I(0) or I(1), as appropriate. We do not report the diagnostics.

These results can be compared to those of HMT (2002), which were estimated over an identical time period. The differences in coefficient estimates for stock in the long run model (nearly three times as large) and employment in the short run model (over twice as large and now highly significant) are large, suggesting that the impact of the data revisions, which were large in the case of the employment data.[9] However, it should be noted that the vacancy rate has been added as a regressor in the new equation and it is on the margin of significance at 18 per cent.

Figure 3 illustrates how well our two-equation (long run and short run) model predicts real rent over the 1977-96 period and forecasts it through 2006. This is a dynamic prediction/forecast insofar as the lagged rents used in the calculation each period are those predicted/forecast in the previous period rather than the actual previous values. Predicted/forecast and actual rents, as well as equilibrium rent (predicted for 1977-96 and then forecast), are plotted. The rent prediction tracks actual and equilibrium rent rather closely over the 1977-96 period. The largest errors are for 1988-89, where predicted rent is 10 and 15 percent less than actual.

**Figure 3: Comparison of Predicted (1977-96) and Forecast (1997-2006) Rent, Equilibrium rent and Actual Rent**

The forecast beyond 1996, however, is poor. By 1999, forecasted rent exceeds actual by nearly 50 percent and this gap basically remains through 2006. The over-forecast stems largely from forecasted equilibrium rent rising by 70 percent between 1997 and 2000, due to a large response to a surge in employment, and remaining well above actual rent for the rest of the period. In essence, estimates based on data from the 1986-93 cycle do not forecast the 1994-2003 cycle, largely due to a large increase in equilibrium rent relative to actual.[10] A similar problem was noted by Blake *et al*. (2000).

Turning to estimates from the full 1977-2006 period, the supply coefficients in the two estimations of the long run model are similar, but the employment coefficient falls by more than a third. The adjusted $R^2$ declines from 88% in the shorter period to 76% in the longer period – possibly not surprising as we are using the same variables to explain two cycles rather than one. The implied price (rent) elasticity is similar, but the income

[9] The HMT employment series had a much steeper decline in the early 1990s than our series does. By 1992 the former was below any employment level in the 1970s. Our series falls to only the 1985 level.

[10] Farrelly and Sanderson (2005) find a structural shift around the middle of the 1990s.

(employment) elasticity falls from 0.58 to 0.38 owing to the one-third decline in the employment coefficient.[11]

The adjustment equation also has reduced explanatory power relative to that estimated over the shorter period - the adjusted $R^2$ falls from 83% to 69% - and large changes in coefficients occur. That on the change in supply nearly doubles in absolute value and becomes statistically different from zero, and that on the lagged vacancy rate rises by almost a third and nearly becomes significant. On the other hand, the rent error correction coefficient is halved. An estimate of the natural vacancy rate, the ratio of the constant term to the coefficient on the lagged vacancy rate, is 4.15**%.**

With the lower employment coefficient in the long run model, the large rise in employment in the late 1990s does not pull the equilibrium rent up nearly as much it did with the equation estimated over the shorter data span, and thus the equilibrium rent does not pull up predicted rent relative to actual. Figure 4 illustrates that the long period equation tracks actual and equilibrium rent closely after 1990, although the under predictions of real rent in 1988 and 1989 are now 15 and 30 percent.

**Figure 4: Predicted, Equilibrium and Actual Real Rent**

### B. Vacancy Rate Models and Hidden Vacancies

Estimates of vacancy rate adjustment for the 1978-96 and 1978-2006 periods are in Table 2. As can be seen, the estimated coefficients are quite similar, and all are correctly signed and statistically significant (except for the rent error, which is effectively zero). All coefficients in the equation estimated over the longer period have t-ratios of 2.5 to 3.5, except for the rent error which is statistically significant at the 11% level. The adjustment of vacancies to the gap between the equilibrium and actual vacancy rates is 0.23 for both estimations. The response to the shock variables is in the 0.3 to 0.5 range. The adjusted $R^2$ actually improves over the longer period, from 60% to 65%. The implied natural vacancy rate for the full period estimates is 8.20%, about double the 4.15% rate implied by the rental adjustment equation.

**Table 2: The Basic Vacancy Rate Models**

Figure 5 indicates how the predicted vacancy rate tracks the actual. The timing of both vacancy rate cycles is captured, as is the huge magnitude of the movement in the 1990s. However, the decline in the late 1970s is missed and thus the predicted rate is about

[11] These estimates are only 40 percent of those EGHS (2008) obtain for Stockholm.

two percentage points too high throughout the 1980s. And only about two-thirds of the 13 percentage point jump between 2000 and 2003 is explained.

**Figure 5: Predicted and Actual Vacancy Rates**

EGHS (2008) draw a distinction between demand in equilibrium and occupied space. Occupied space is the effective demand based on the rent paid and expectations of space needs when lease contracts were signed. Equilibrium demand is that which would exist if all tenants were paying the current lease rate and had current expectations of space needs. The difference between these demands is hidden vacancies, which will be positive if today's lease rate is above that paid when existing leases were signed and negative if the reverse is true. Hidden vacancies can be inferred from estimates of the space demand equation and equilibrium rent and vacancy rate. They show that the hidden vacancy rate, $v_h$, can be computed as

$$v_h = \text{price elasticity of demand x } (\ln R^* - \ln R) - v + v^* \qquad (9)$$

They also specify a narrow measure that depends solely on the existence of multiple period lease contracts:

$$v_n = \text{price elasticity of demand x } (\ln R\text{avg} - \ln R) \qquad (10)$$

Their average lease rate could be calculated directly from their individual lease data base. We impute an average lease rate from our new lease rate series. In London, 25-year leases with five year upward only adjustments have been customary. On this basis, a fifth of tenants will be paying the current market rent, a fifth will be paying the previous year's market rent and so on. Hence, the *lnRavg* in equation (10) is approximated by this five year moving average.[12]

Based upon our demand estimate, the price elasticity of demand is -0.2016 and v* is 0.06845.[13] Our two hidden vacancy rates and the actual vacancy rate are plotted in Figure 6. As in EGHS (2008), the two measures move together, given the common impact of R in the two measures. Moreover, they move inversely with v, as equation (9) indicates.

**Figure 6: Two Hidden Vacancy Rates and the Actual Vacancy Rate**

[12] An added complication arises due to the upward only nature of the UK rent review clause in leases. We have not attempted to adjust for this but are considering it.

[13] Here we use the value of the natural vacancy rate from the system estimation reported later in the paper where the values derived from the rent and vacancy rate equations are constrained to be equal.

## 4. Estimation of Asymmetric Adjustment to Shocks

Research on rental adjustment between the early 1970s and early 1990s linked the percentage change to the gap between the actual and natural vacancy rate. It was not until the middle 1990s that the gap between actual and equilibrium rent was introduced into the model (Wheaton and Torto, 1994). And, to the best of our knowledge, it was not until early this century that changes in the equilibrium rental rate, the employment and supply shock variables, were first employed as determinants of the adjustment process (HMT, 2002).[14]

As suggested above, a combination of data frequency, institutional factors and behavioral issues point to the need to consider lagged adjustments in the short run models. And the adjustments could vary depending on both the nature of the shocks and where the economy is in the real estate cycle when shocks occur. Regarding the nature of the shocks, there are likely differences in adjustment to positive and negative changes in the shock variables. Employment matters because it affects the demand for space. While one would think that demand would respond quickly to an increase in employment, would the response be as quick to a decrease? Most tenants are already locked into space by longer term leases. Quickly abandoning the space, thereby putting pressure on landlords to lower rent, is not really an option. One would hypothesize, then, that positive employment shocks would have a more immediate impact on both rent and vacancies than would negative shocks.

Positive supply shocks should also have a direct impact on markets; with supply up, vacancies directly rise or landlords need immediately to lower rents. Negative shocks are more complex. In heavily developed office markets such as the City of London, there are few vacant sites available for new development. Thus stock must be *withdrawn* to create new space in response to rising demand or profitability. A short term fall in stock, if it were the result of development and an anticipated future increase in stock, need not result in an increase in rent. In such circumstances, occupiers might use existing space more intensively in the short run in anticipation of better quality space becoming available rather than sign new leases on available space and thus reduce the vacancy rate.

A second possible source of asymmetry stems from the constraint that the vacancy rate cannot be negative (EGHS, 2008, p 107). For example, shocks that increase the demand

[14] See HMT (2002) for a survey of the early literature on space market adjustments.

for space relative to that available (positive employment and negative supply shocks) will necessarily have a smaller impact on the vacancy rate when the vacancy rate is initially low than when it is higher. Looking at our vacancy rate graph (Figure 1), it seems likely that vacancy rates below four percent would preclude significant declines.

Similarly, shocks could have different impacts depending on whether rent is above or below equilibrium. For example, if rent is already above equilibrium, positive shocks are less likely to raise it. In such circumstances, we might expect a greater impact on the vacancy rate. In contrast, if rents are below equilibrium, a positive employment shock might have a stronger effect on rents than on the vacancy rate, particularly if the vacancy rate were already low.

Here we report results for allowing for differential adjustment to positive and negative employment and supply shocks and to whether rent and vacancy are above or below equilibrium.

The first panel in Table 3 reproduces the basic results from Table 1. The second includes both positive and negative changes in employment and supply. Both positive changes are correctly signed and highly significant, while the negative changes have t-ratios less than one and the employment coefficient is wrongly signed. The negative shock variables are removed in the third panel. Note that the adjusted $R^2$ has risen from 69% to 74%. Both of the shock coefficients rise in absolute value when only the positive responses are considered: 21 per cent for employment and 110 per cent for supply. While the negative coefficients have become zero, negative responses will eventually occur, working more slowly via the error correction variables.

**Table 3: Asymmetries in the Rental Equation**

The next panel tests for whether the impacts of positive shocks on rent vary with whether rent is above or below equilibrium. We expect that a positive employment shock would raise rent more if rent were below equilibrium (speed the return) than if it were above equilibrium. Similarly, we expect that a positive supply shock would lower rent more if it were below equilibrium (speed the return) than if it were above equilibrium.

This is precisely the pattern we find, with all four coefficients being correctly signed and being of the expected relative magnitudes, i.e., the positive shocks have bigger impacts when they are moving rent toward equlibrium. However, neither the employment nor supply coefficients in the above and below equilibrium rent cases are statistically different from each other.[15] Given our limited observations, this is probably not surprising. While we have 29 total observations (22 degrees of freedom), there are only 21 and 18, respectively, with positive employment and supply changes, and the splits between above and below equilibrium rent are 10 and 11 (employment) and 13 and 5 (supply). In any event, we use the model in panel three in the asymmetric system estimations and simulations.

We next consider asymmetries in the vacancy rate equation. The first panel of Table 4 reproduces the symmetric results of Table 1, and the second panel allows differential responses to positive and negative employment and supply shocks. All coefficients are correctly signed, but the positive and negative coefficients are not significantly different from each other and the adjusted $R^2$ falls from 65% with the symmetric estimates to 63% with the asymmetric. That is, there is not significant evidence that an asymmetry exists. Thus we use the symmetric equation (first panel) in the system estimations below and in all simulations.

**Table 4: Asymmetries in the Vacancy Rate Equation**

## 5. Simulations of the Models

Before running simulations we need to estimate the change in stock equation and to estimate all the model equations simultaneously to ensure internal consistencies. We then simulate positive and negative employment shocks with the symmetric and asymmetric systems.

### A. Finalizing the Systems

Change-in-supply equations are shown in Table 5. The first equation contains three period lags of the rent and vacancy errors. Both coefficients are highly significant. We test for asymmetries in the second equation by including, as separate regressors, positive and negative rent errors and the vacancy rate above and below its mean. As expected, above equilibrium rents trigger development, while below equilibrium rents enter insignificantly with the incorrect sign. The high and low vacancy rate coefficients are approximately equal, suggesting a symmetric effect. In the third equation, we retain only the positive rent error and recombine the high and low vacancy rate variables. Relative to the first equation, the adjusted $R^2$ jumped from 49% to 63%. This equation is used in our final asymmetric system.

[15] Tests for different responses depending on whether the vacancy rate was above or below its mean also yielded inconclusive results.

**Table 5: Change in Stock**

Employment is exogenous to the system and we model it as an AR process:

$$\Delta \ln E_t = \underset{(0.01)}{0.01} + \underset{(0.17)}{0.38} \Delta \ln E_{t-1} \tag{11}$$

The best individual models are used in two system estimations, a symmetric system and an asymmetric system. These are estimated using the Seemingly Unrelated Regressions (SUR) approach with the coefficients of the rent and vacancy rate equations constrained to produce the same estimates of the natural vacancy rate. Thus, the final equations differ marginally from the unconstrained individual estimations reported above. The results are shown in Table 6. The implied natural vacancy rate is 6.85%, quite close to the 7.1% EGHS found for Stockholm.

**Table 6: Symmetric and Asymmetric Systems**

B. **The Simulated impacts of Employment Shocks**

We now compute the impact of positive and negative shocks to employment on rent, the vacancy rate and supply. We start with employment growing on its long term trend (1.8%) and create the other series first from the system of symmetric equations. Next, we raise trend employment by 10%. Figure 7 shows how the vacancy rate, rent and supply change relative to their base trends. The vacancy rate plunges by over 40% and real rent rises by 4 percent, although the peak rent doesn't occur until the third year. Both series then reverse themselves as demand shrinks in response to the rent increase and eventual addition to supply. However, the lagged supply increase causes the vacancy rate to overshoot by 20% (rent does not overshoot). The adjustment is basically complete after a decade. Supply and equilibrium (and actual) rent are up by just over a half percent, and the vacancy rate has returned to the natural rate. While both rent and the vacancy rate oscillate thereafter, these values are certainly not significantly different from the long run equilibrium.[16]

**Figure 7: Impact of Positive Employment Shock (Symmetric System)**

We also simulate a 10% decrease in employment. Because we are dealing with a symmetric equation system, the movements are the opposite of those pictured in Figure 8 and thus they have not been plotted.

[16] Barras (1994, 2005) discusses the reasons for oscillations in market responses to shocks.

Next we simulate the asymmetric equation system in the same way. The response to a positive employment shock is shown in Figure 8. Here rent moves noticeably differently than it does with the symmetric system. Rent peaks in the first year, not the fourth, owing to the much larger employment shock coefficient. Given both the quicker rent reversal and the much stronger supply response, rent overshoots its new equilibrium by 1.5 percent in the seventh year. Equilibrium is again restored after about a decade, although rent and vacancy exhibit another modest cycle.

**Figure 8: Impact of Positive Employment Shock (Asymmetric System)**

As is shown in Figure 9, the timing of the responses to a negative employment shock with the asymmetric system is much different than with the symmetric system. Rather than the rent trough occurring in the first year, it occurs in the fourth year, not responding directly to the shock but only indirectly (gradually) because of the decline in equilibrium rent. Supply also responds more slowing, again not responding directly to the decline in rent. The slow supply response drags out the rent return to equilibrium.

**Figure 9: Impact of Negative Employment Shock (Asymmetric System)**

## 7. Summary and Conclusion

We examine space market adjustment processes in the City of London, using an extended time series running from 1977 – 2006 and covering two complete property cycles. We estimate a long run rent relationship and the adjustment processes that return the system to equilibrium in response to employment or supply shocks. Real rent, the vacancy rate and supply are all explained. The modeling strategy extends the error correction model of HMT (2002) and incorporates some of the innovations in the Stockholm model of EGHS (2008). Extending the estimation period to include the 1997-2006 period provides different results. While the price elasticity (with respect to rent) is similar, the income elasticity (with respect to employment) falls sharply. The short run adjustment coefficients reflect that change, with supply shocks and response to vacancy more pronounced and the error correction coefficient smaller in size.

Next we consider asymmetric responses to employment and supply shocks. These may depend on either the nature of the shock (whether positive or negative) or the state of the market when the shock occurs (whether rent and the vacancy rate are above or below equilibrium). For example, responses to decreases in employment and supply are limited because tenants are locked into long-term leases and supply decreases are often temporary to be replaced by new development. Indeed, positive employment shocks have a positive, significant impact on rental growth, while positive supply shocks have a significant negative effect. Neither negative demand nor supply shocks had measureable, much less significant, effects.

Asymmetries might also arise depending on whether the current rent is above or below equilibrium rent. Positive employment shocks would be expected to have a quicker effect when rents are below equilibrium at the time of the shock, and positive supply shocks would have a quicker impact when rents are above equilibrium. That is, shocks operate more quickly if they are pulling rent toward equilibrium rather than pushing it away. The empirical estimates are consistent with this hypothesis, although differences in the timing of responses are not statistically significant. We attribute this to the limited degrees of freedom with our data set.

The change in stock is related positively to the lagged difference between rent and equilibrium rent and negatively to the lagged vacancy rate. In the asymmetric model the change responds to positive actual-equilibrium rent gaps, but not to negative gaps.

We subject both the symmetrically and asymmetrically estimated systems to a unit increase/decrease in employment. Rent and vacancy move in opposite directions and then return to equilibrium, where rent and supply rise/fall slightly in response to positive/negative employment changes. In all cases vacancy overshoots by about half the initial change, owing to the lagged change in supply, before returning to the natural rate. With the asymmetric model (stronger response to positive employment change), the adjustment is quicker and rent too overshoots by nearly fifty percent. Further research on asymmetric responds to shocks to the space market using other data sets is likely to yield worthwhile results.

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### *Table 1: The Basic Rent Models*

| Panel A: Long Run Models Dependent Variable ln(real rent) | | | | | |
|---|---|---|---|---|---|
| | 1977-1996 (Model 3 HMT, 2002) | | 1977-1996 | | 1977-2006 | |
| Variable | **Coefficient** | **Standard error** | **Coefficient** | Standard Error | **Coefficient** | Standard Error |
| C | **10.43** | 1.24 | **14.63** | 1.74 | **18.67** | 1.60 |
| ln(employment) | **2.89** | 0.57 | **3.02** | 0.37 | **1.90** | 0.29 |
| ln(stock) | **-1.87** | 0.50 | **-5.22** | 0.44 | **-4.95** | 0.52 |
| Adj $R^2$ | **70%** | | **88%** | | **76%** | |

| Panel B: Short Run Models – Dependent Variable ∆ln(real rent) | | | | | | |
|---|---|---|---|---|---|---|
| | 1978-1996 (Model 3 HMT, 2002) | | 1978-1996 | | 1978-2006 | |
| Variable | **Coefficient** | Standard Error | **Coefficient** | Standard Error | **Coefficient** | Standard Error |
| Constant | **-0.024** | 0.028 | **0.01** | 0.04 | **0.04** | 0.04 |
| ∆ln(employment) | **1.13** | 0.89 | **2.82** | 0.83 | **2.24** | 0.63 |
| ∆ln(stock) | | | **-1.30** | 1.56 | **-2.39** | 1.03 |
| Rent error (-1) | **-0.95** | 0.18 | **-0.86** | 0.20 | **-0.44** | 0.16 |
| Vacancy rate (-1) | | | **-0.71** | 0.51 | **-0.92** | 0.47 |
| Adj $R^2$ | **81%** | | **83%** | | **69%** | |
| Durbin-Watson d | **1.51** | | **1.77** | | **1.80** | |

### *Table 2: The Basic Vacancy Rate Models*

| Dependent variable: ∆(vacancy rate) | | | | | | |
|---|---|---|---|---|---|---|
| | 1978-1996 | | | 1978-2006 | | |
| Variable | **Coefficient** | Std. Error | Prob. | **Coefficient** | Std. Error | Prob. |
| Constant | **0.02** | 0.01 | 0.02 | **0.02** | 0.01 | 0.00 |
| ∆ln(employment) | **-0.28** | 0.14 | 0.06 | **-0.32** | 0.09 | 0.00 |
| ∆ln(stock) | **0.51** | 0.26 | 0.07 | **0.39** | 0.15 | 0.02 |
| Rent error (-1) | **0.00** | 0.03 | 0.92 | **0.04** | 0.02 | 0.11 |
| Vacancy rate (-1) | **-0.23** | 0.08 | 0.02 | **-0.23** | 0.07 | 0.00 |
| Adjusted R-squared | **60%** | | | **65%** | | |
| Durbin-Watson stat. | **1.25** | | | **1.67** | | |

***Table 3: Asymmetric Rent Responses to Positive and Negative Shocks 1978-2006***

| **Dependent variable: Δln(real rent)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | **Coeff** | Std. Error | Prob. | **Coeff** | Std. Error | Prob. | **Coeff** | Std. Error | Prob. |
| C | **0.04** | 0.04 | 0.35 | **0.03** | 0.05 | 0.49 | **0.04** | 0.04 | 0.29 |
| Δln(employment) | **2.24** | 0.63 | 0.00 | | | | | | |
| Δln(employment) (+ve) | | | | **2.98** | 0.82 | 0.00 | **2.71** | 0.74 | 0.00 |
| Δln(employment) (-ve) | | | | **-1.52** | 1.94 | 0.44 | | | |
| Δln(stock) | **-2.39** | 1.03 | 0.03 | | | | | | |
| Δln (stock) (+ve) | | | | **-5.67** | 1.87 | 0.01 | **-5.02** | 1.37 | 0.00 |
| Δln (stock) (-ve) | | | | **-0.58** | 1.90 | 0.76 | | | |
| Rent error (-1) | **-0.44** | 0.16 | 0.01 | **-0.44** | 0.15 | 0.01 | **-0.43** | 0.15 | 0.01 |
| Vacancy rate (-1) | **-0.92** | 0.47 | 0.06 | **-0.77** | 0.47 | 0.11 | **-0.74** | 0.44 | 0.10 |
| Adjusted R-squared | **69%** | | | **72%** | | | **74%** | | |
| Durbin-Watson stat. | **1.80** | | | **1.76** | | | **1.74** | | |

| **Dependent variable: Δln(real rent)** | | | |
|---|---|---|---|
| Variable | **Coeff** | Std. Error | Prob. |
| Constant | **0.04** | 0.04 | 0.30 |
| Δln(employment) (+ve) and lagged residual (+ve) | **1.41** | 1.50 | 0.36 |
| Δln (employment) (+ve) and lagged residual (-ve) | **2.43** | 0.93 | 0.02 |
| Δln (stock) (+ve) and lagged residual (+ve) | **-6.45** | 1.91 | 0.00 |
| Δln (stock) (+ve) and lagged residual (-ve) | **-3.20** | 3.04 | 0.30 |
| Rent error (-1) | **-0.31** | 0.18 | 0.10 |
| Vacancy rate (-1) | **-0.49** | 0.51 | 0.35 |
| Adjusted R-squared | **73%** | | |
| Durbin-Watson stat. | **1.68** | | |

***Table 4: Asymmetric Vacancy Rate Responses to Positive and Negative Shocks***

| **Dependent variable: Δ(vacancy rate)** | | | | | | |
|---|---|---|---|---|---|---|
| Variable | **Coefficient** | Std. Error | Prob. | **Coefficient** | Std. Error | Prob. |
| Constant | **0.02** | 0.01 | 0.00 | **0.02** | 0.01 | 0.04 |
| Δln(employment) | **-0.32** | 0.09 | 0.00 | | | |
| Δln (employment) (+ve) | | | | **-0.25** | 0.13 | 0.06 |
| Δln (employment) (-ve) | | | | **-0.44** | 0.30 | 0.16 |
| Δln (stock) | **0.39** | 0.15 | 0.02 | | | |
| Δln (stock) (+ve) | | | | **0.47** | 0.29 | 0.12 |
| Δln (stock) (-ve) | | | | **0.19** | 0.30 | 0.52 |
| Rent error (-1) | **0.04** | 0.02 | 0.11 | **0.04** | 0.02 | 0.14 |
| Vacancy rate (-1) | **-0.23** | 0.07 | 0.00 | **-0.25** | 0.07 | 0.00 |
| Adjusted R-squared | **65%** | | | **63%** | | |
| Durbin-Watson stat | **1.67** | | | **1.59** | | |

***Table 5: Change in Stock 1980-2006***

| **Dependent variable: ∆ln ( stock)** | | | | | | |
|---|---|---|---|---|---|---|
| Variable | **Coefficient** | Std. Error | Prob. | **Coefficient** | Std. Error | Prob. |
| C | **0.03** | 0.01 | 0.00 | **0.02** | 0.01 | 0.09 |
| Rent error (-3) | **0.08** | 0.02 | 0.00 | | | |
| Rent error (-3) (+ve) | | | | **0.17** | 0.03 | 0.00 |
| Rent error (-3) (-ve) | | | | **-0.07** | 0.05 | 0.18 |
| Vacancy rate (-3) | **-0.36** | 0.08 | 0.00 | | | |
| Vacancy rate (-3) (above average) | | | | **-0.36** | 0.08 | 0.00 |
| Vacancy rate (-3) below average) | | | | **-0.45** | 0.22 | 0.05 |
| Adjusted R-squared | **49.0%** | | | **64.0%** | | |
| Durbin-Watson stat | **1.04** | | | **1.45** | | |

***Table 6: Symmetric and Asymmetric Systems***

| **Symmetric System** | | | | **Asymmetric System** | | | |
|---|---|---|---|---|---|---|---|
| **Dependent: Δln(real rent)** | Coeff | Std. Error | Prob. | | Coeff | Std. Error | Prob. |
| Constant | 0.07 | 0.03 | 0.04 | Constant | 0.05 | 0.03 | 0.09 |
| Δln(employment) | 1.90 | 0.51 | 0.00 | Δln (employment) (+ve) | 2.51 | 0.52 | 0.00 |
| Δln (stock) | -3.14 | 0.89 | 0.00 | Δln (stock) (+ve) | -5.64 | 1.01 | 0.00 |
| Rent error (-1) | -0.44 | 0.14 | 0.00 | Rent error (-1) | -0.44 | 0.13 | 0.00 |
| Vacancy rate (-1) | -0.96 | 0.43 | 0.03 | Vacancy rate (-1) | -0.67 | 0.38 | 0.08 |
| Adjusted R-squared | 67% | | | Adjusted R-squared | 74% | | |
| Durbin-Watson stat | 1.70 | | | Durbin-Watson stat | 1.73 | | |
| **Dependent Δ(vacancy rate)** | | | | | | | |
| Constant | 0.02 | 0.01 | 0.00 | Constant | 0.02 | 0.01 | 0.00 |
| Δln (employment) | -0.30 | 0.09 | 0.00 | Δln (employment) | -0.34 | 0.09 | 0.00 |
| Δln (stock) | 0.55 | 0.16 | 0.00 | Δln (stock) | 0.44 | 0.15 | 0.00 |
| Rent error (-1) | 0.04 | 0.02 | 0.10 | Rent error (-1) | 0.04 | 0.02 | 0.08 |
| Vacancy rate (-1) | -0.25 | | | Vacancy rate (-1) | -0.26 | | |
| Adjusted R-squared | 63% | | | | 64% | | |
| Durbin-Watson stat | 1.72 | | | | 1.70 | | |
| **Dependent: Δln(stock)** | | | | | | | |
| Constant | 0.03 | 0.01 | 0.00 | Constant | 0.02 | 0.00 | 0.00 |
| Rent error (-3) | 0.08 | 0.02 | 0.00 | Rent error (-3) (+ve) | 0.16 | 0.03 | 0.00 |
| Vacancy rate (-3) | -0.37 | 0.07 | 0.00 | Vacancy rate (-3) | -0.36 | 0.06 | 0.00 |
| Adjusted R-squared | 48% | | | | 63% | | |
| Durbin-Watson stat | 1.03 | | | | 1.31 | | |

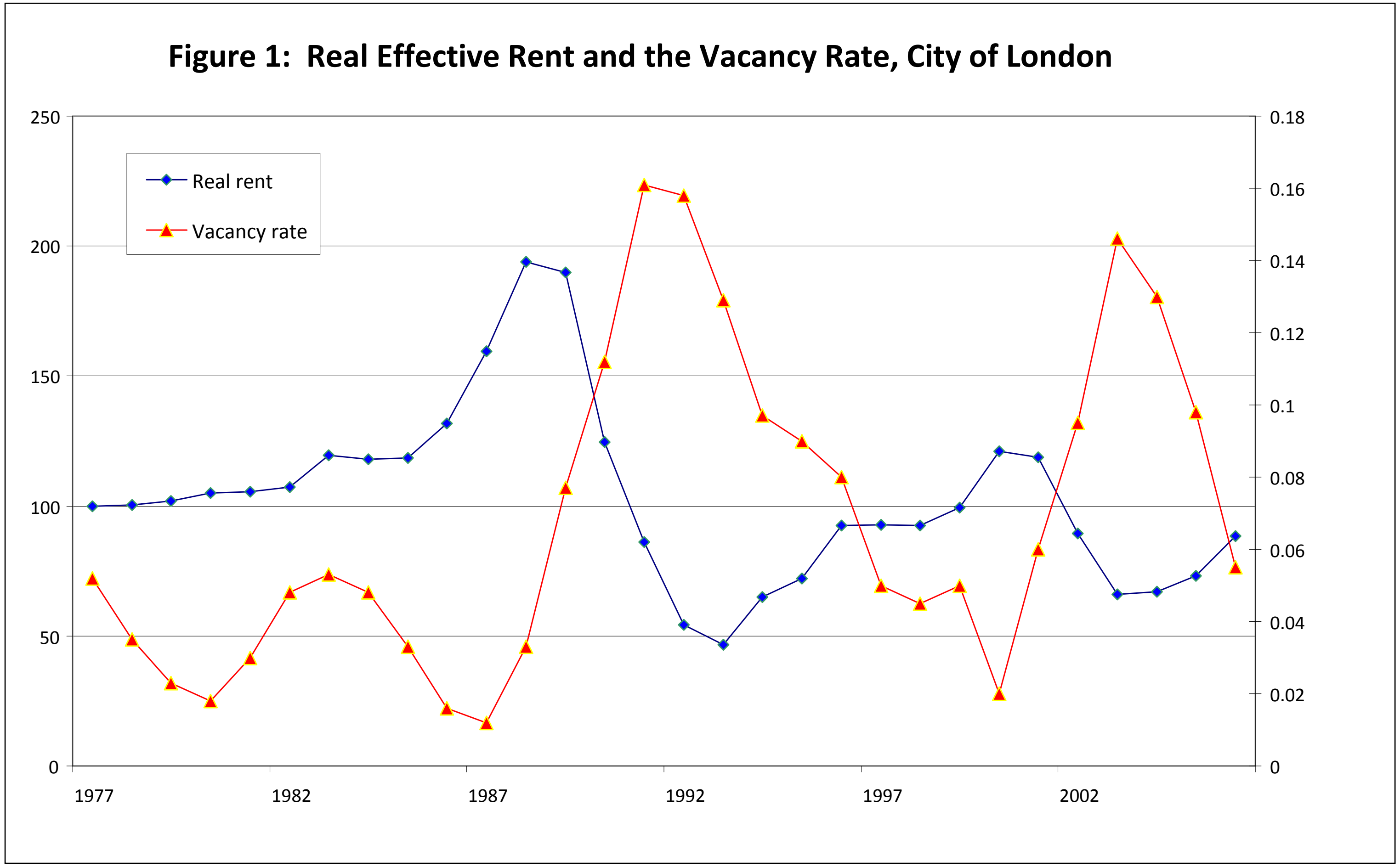
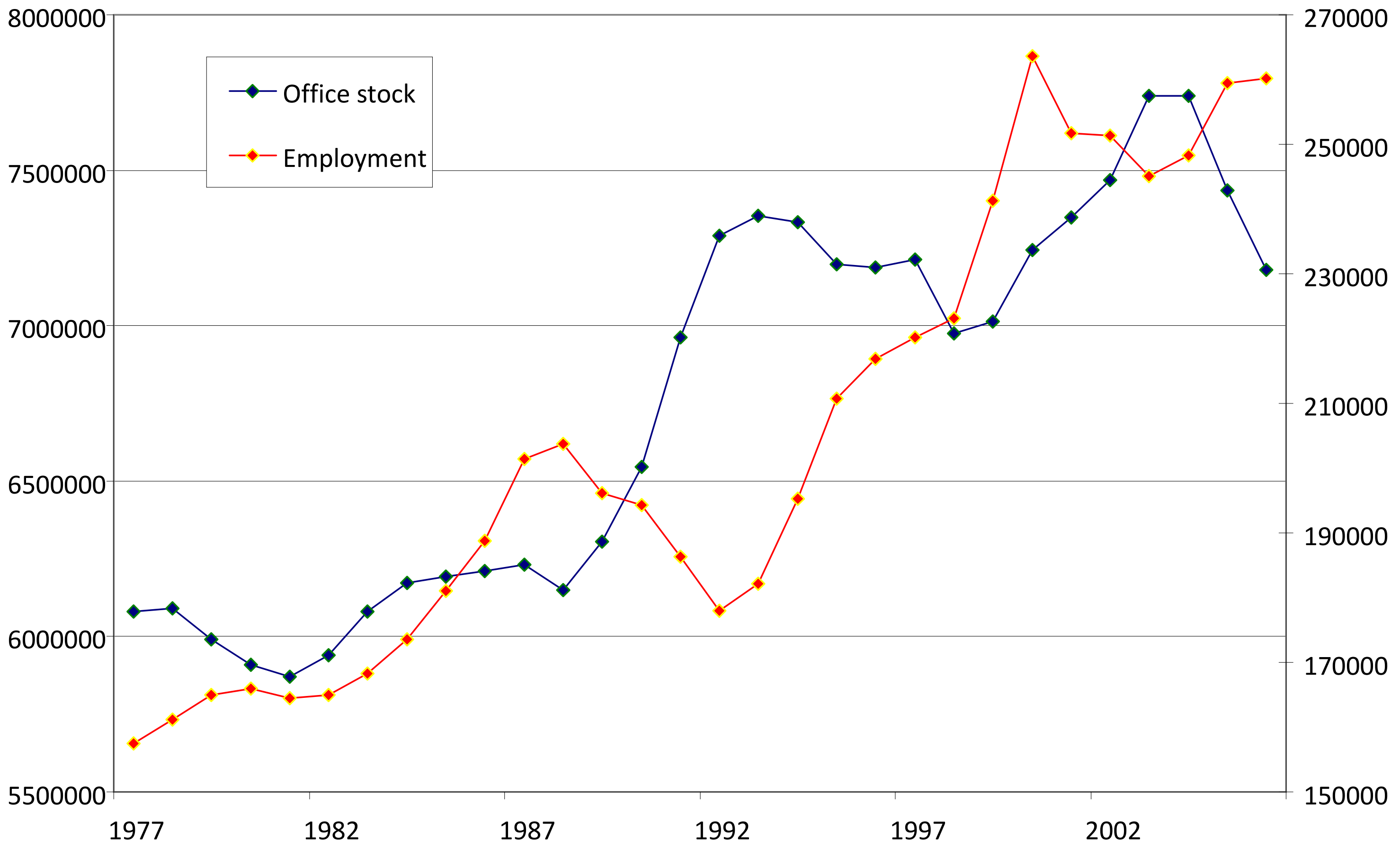
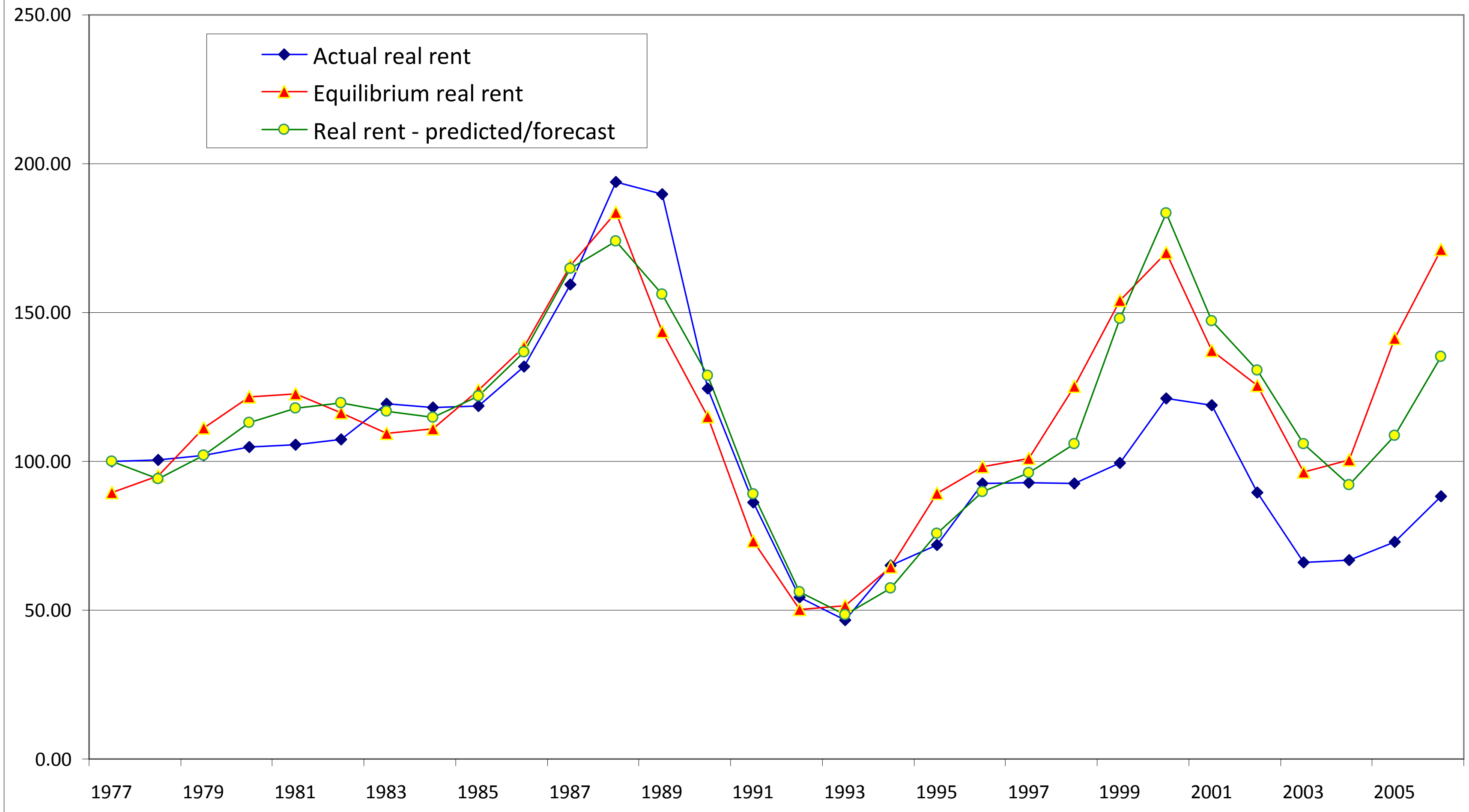


Figure 1: Real Effective Rent and the Vacancy Rate, City of London
250
200
150
100
50
0
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1977
1982
1987
1992
1997
2002
Real rent
Vacancy rate

**Figure 2: Office Stock and Financial and Business Service Employment, City of London**



## Figure 3: Comparison of Predicted (1977-96) and Forecast (1997-2006) Rent, Equilibrium Rent and Actual Rent



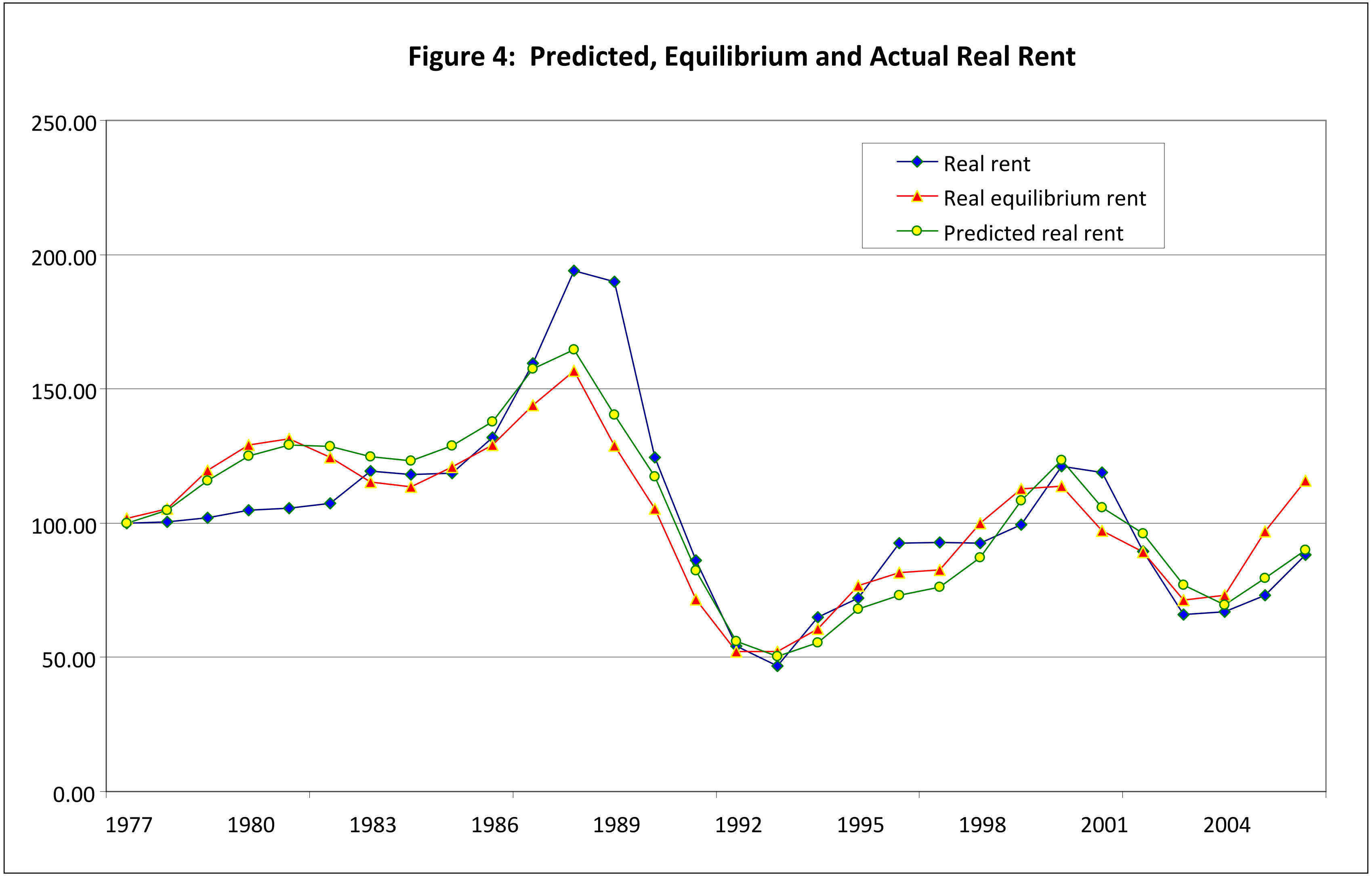
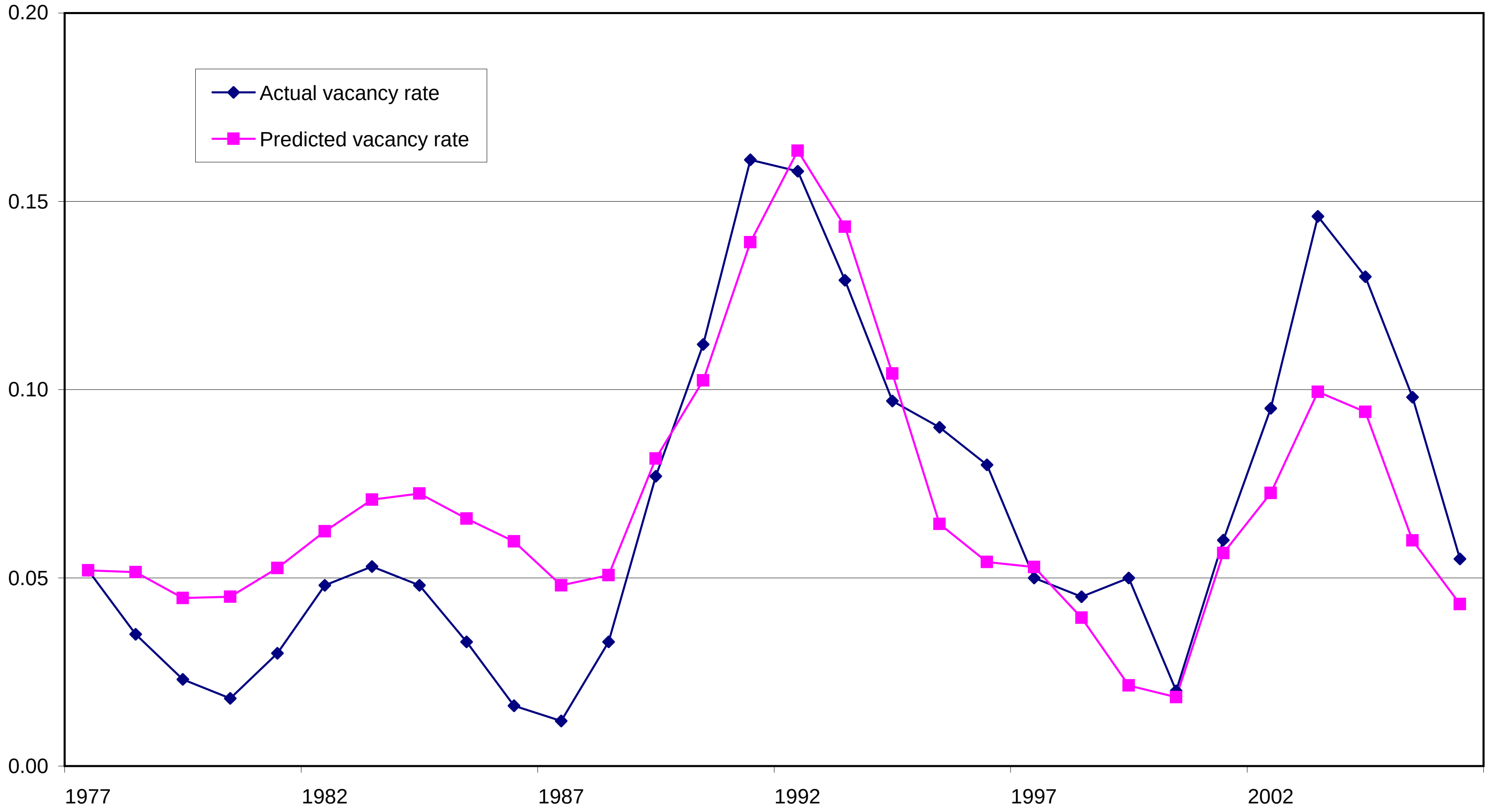


Figure 4: Predicted, Equilibrium and Actual Real Rent
250.00
200.00
150.00
100.00
50.00
0.00
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
Real rent
Real equilibrium rent
Predicted real rent

# Figure 5: Predicted and Actual Vacancy Rates



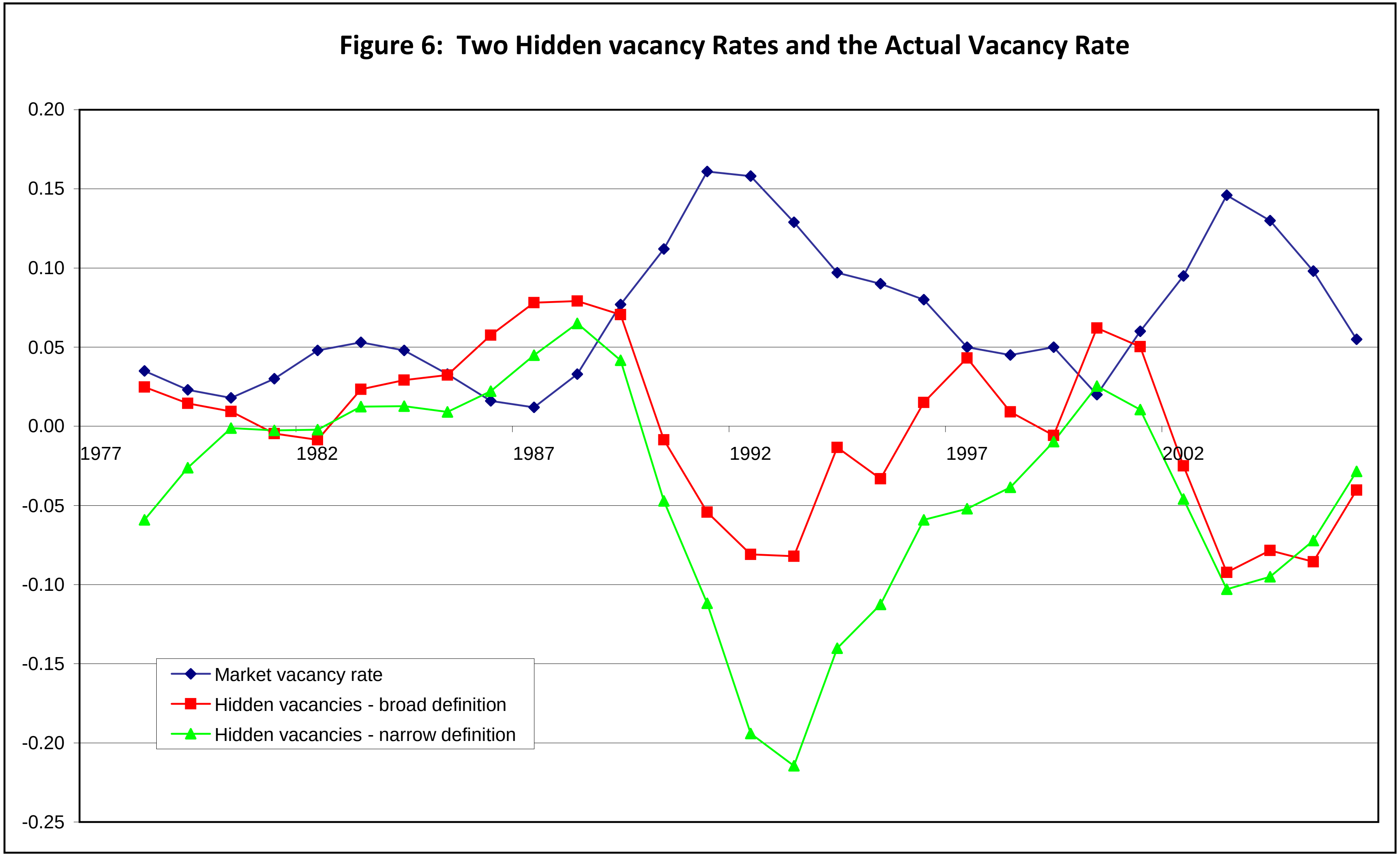


Figure 6: Two Hidden vacancy Rates and the Actual Vacancy Rate
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
1977
1982
1987
1992
1997
2002
Market vacancy rate
Hidden vacancies - broad definition
Hidden vacancies - narrow definition

**Figure 7: Impact of Positive Employment Shock (Symmetric System)**

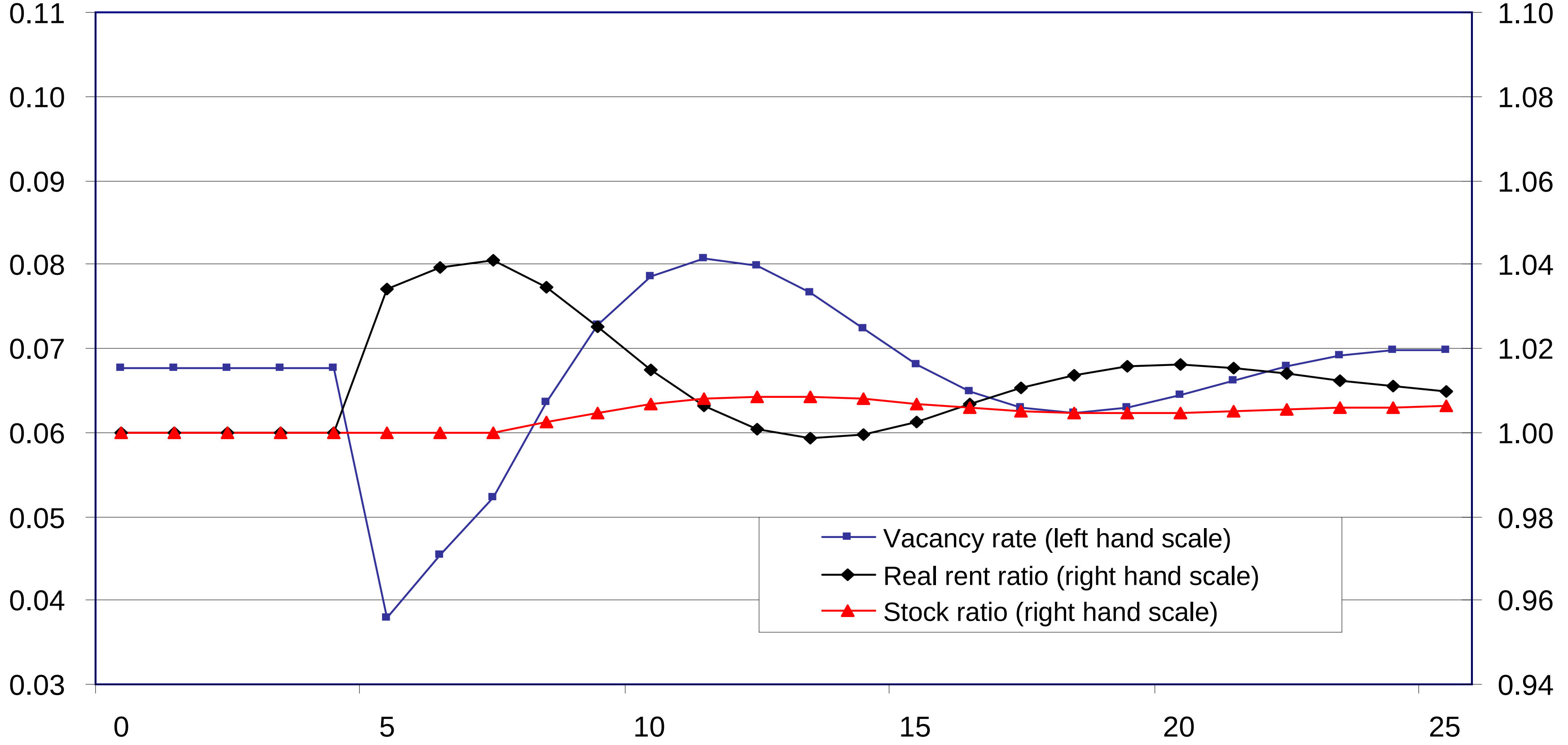


**Figure 8: Impact of Positive Employment Shock (Asymmetric System)**

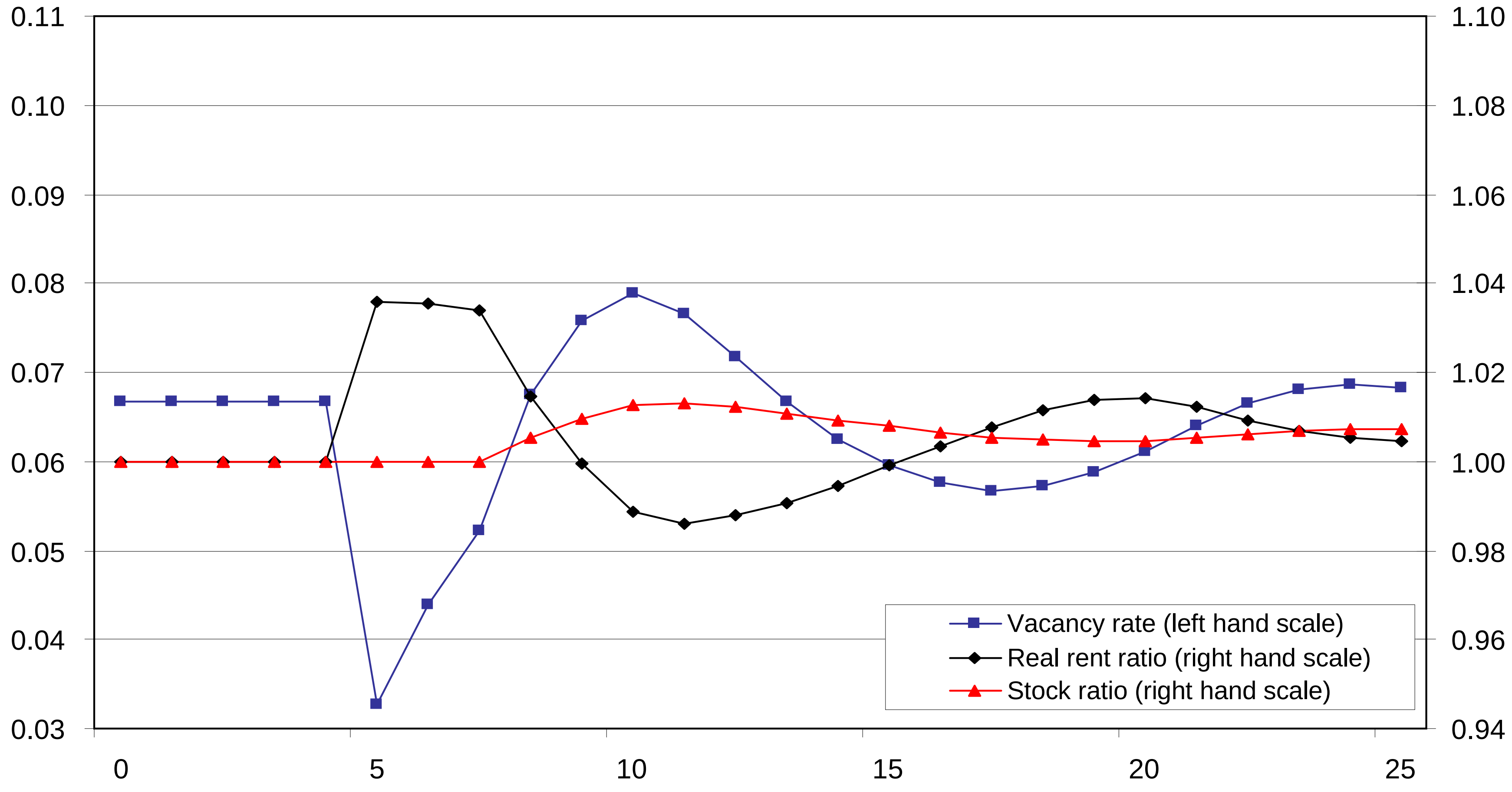


**Figure 9: Impact of Negative Employment Shock (Asymmetric System)**