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Asymmetric Adjustment in the City of 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. Rental adjustment is seen to be asymmetric, depending both on the direction of the supply and demand shocks and on the state of the space market at the time of the shock. Vacancy adjustment does not display asymmetries. There is also a supply adjustment equation. Two three-equation systems, one with symmetric rental adjustment and the other with asymmetric adjustment, are subjected to positive and negative shocks to employment. These illustrate differences in the properties of the two systems.

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

Asymmetric Adjustment in the London Office Market

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Introduction

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 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).[2]

We use the longer data set to test for different responses of rent and vacancies 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 how rent and vacancy respond. We find significant asymmetric responses of rent.

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 explain the change in supply and estimate consistent systems of equations using the Seemingly Unrelated Regressions (SUR) approach. We illustrate our results in Section 6 by contrasting the responses of rent, vacancies and supply to positive and negative employment shocks using both the symmetric rental adjustment equation and the asymmetric equation. Section 7 concludes. An appendix discusses the relationship between the City office market and the recently developed Docklands office cluster.

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[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.

[2] The credit crunch has led to a rent and vacancy correction in the City; at end 2008, vacancy rates had risen back to 7 percent and nominal rents had fallen 17 percent from their peak values with significant falls in capital values observed.

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

$$\ln D(R,E) = \lambda_0 + \lambda_R \ln R + \lambda_E \ln E \tag{1}$$

where *R* is the real effective rent on new contracts and *E* is the employment that occupies office space. The price elasticity, $(_R$, is negative and the 'income' elasticity, $(_E$, 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:

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

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:

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

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).[3] 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:

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

where ε_R = ln*R* - ln*R** and is calculated as the residual from equation (3) where v* is treated as constant. The adjustment coefficients are β_E for the response to

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[3] 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.

employment shocks, β_S for supply shocks, β_v for the vacancy rate gap, and β_R for the rent gap. In the estimation, the lagged vacancy rate is a regressor and the constant term, β_0, is an estimate of $-\beta_v v^*$ and thus $-\beta_0/\beta_v$ is an estimate of v*.[4]

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.[5] 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 ‘upward only’ reviews (to market or unchanged depending on which is higher) 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 is publicly available and rental agreements are signed *before* lease

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[4] 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.

[5] 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.

commencement, 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 η_E and η_S indicate the impact of concurrent shocks to employment and supply and η_R and η_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. The estimated constant term, $\psi_v v^*$, is a third estimate of the natural vacancy rate. 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 ε_{R-} would have a quantitatively stronger effect than negative. The same would apply for positive and negative values of $v^* - v$.

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), who use employment data from the whole south east region surrounding London, new construction data from the metropolitan area and vacancy rate data just for the central London area, making interpretation of results problematic. We have attempted to confine our analyses to data series that relate only to the City of London.[6] 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 its Development Schedules. These are 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, all in square metres. From 2007, the Corporation switched from a calendar year to a financial year basis of reporting (data as at March and September), missing a publication date. At the same time, there were definitional changes, meaning that the stock series are not consistent beyond 2006.

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[6] The appendix discusses the extent to which the City can be considered a separate sub-market and the possible influence of the development of the Docklands office cluster to the East of the City. We conclude that it is appropriate to consider the City of London separately during the period.

DTZ provided market-based data on prime (class A) rent level.[7] CB Richard Ellis (CBRE) provided vacancy rate figures that are for space available (newly constructed space and second hand space available for letting). There is no robust average rent series for the City, and indices of secondary (class B) rents do not seem robust. Generally the top or marginal rent will drive business decisions, including the decision to develop. The vacancy rate figure is based on agents' estimates of availability and, hence, focuses on investment quality space and excludes most of the low quality space at the bottom of the market.

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). 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 a ten year lease life and then convert that to an annual equivalent to adjust the face rent, based on the standard quarterly in advance UK lease contract:

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

where R_{Eff} is effective rent, R_{Head} is headline rent, P is the rent 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 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-office and back-office functions that may be remote.[8]

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[7] 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 very strongly correlated.

[8] 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

We examined a number of employment series and chose the Financial and Business Services (FBS) series produced at local authority level.[9] 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 financial employment in City total employment has increased from around 58 percent 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 strong upward trends, growing at 0.97 percent (supply) and 1.80 percent (employment) over the 1977-2006 period. But movements around the trend are strongly negatively correlated (-0.60). This largely results from two periods. In the late 1980s and early 1990s, stock growth (based on the surge in employment 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). After 2000, first the dot.com collapse reduced employment while supply was still responding to earlier employment increases, and then the employment rebound coincided with supply responding to the earlier collapse. 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

(Blake *et al.,* 2000). Small area employment statistics are subject to a publication lag and are frequently revised after publication, making extending the time series difficult.

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

Estimation Results for the Symmetric Rent and Vacancy Models

We approach the estimations as follows.[10] First, we estimate the rent model over both the earlier 1977-1996 period and the full 1977-2006 period and compare the estimates. We note large differences. Then we do the same for the vacancy rate model.

A. Comparing the Rent Models for 1977-96 and 1977-2006

Table 1 contains separate estimates of the rent models based on data ending in 1996 and in 2006. 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

The second set of estimates in Table 1 is based on 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 percent in the shorter period to 76 percent in the longer period – possibly not surprising as the same variables are being used to explain two cycles rather than one. The implied price (rent) elasticity is similar, but the income (employment) elasticity falls from 0.58 to 0.38 (1.90/4.95) owing to the decline in the employment coefficient (although, see above, there are issues with these data).[11]

The short-run adjustment equation also has reduced explanatory power relative to that estimated over the shorter period - the adjusted R^2 falls from 83 percent to 69 percent - and large changes in all coefficients occur. That on the change in supply nearly doubles in absolute value and becomes statistically different from zero; 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. The implied natural vacancy rate is 4.15 percent. However, once the equation is embedded in the system of equations, the implied natural vacancy rises to 6 percent (in running the system of equations, the estimates are constrained to be equal).

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

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

Figure 3 plots actual, equilibrium (the fitted values from the long-run equation in Panel A of Table 1) and predicted real rent over the 1977-2006 period. The predicted real rent series is a dynamic prediction of our two-equation (long run and short run) model insofar as the lagged rents used in the calculation each period are those predicted in the previous period rather than the actual previous values. The figure shows that predicted rent tracks equilibrium rent throughout the estimation span. Both of these series under predict actual real rent by 20 to 30 percent in the early 1980s and 15 and 30 percent in 1988 and 1989. Only in the last two years do predicted and equilibrium real rent diverge sharply, and here predicted rent tracks actual.

Figure 3: 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 percent 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 percent to 65 percent. The implied natural vacancy rate for the full period estimates is 8.20 percent, about double the 4.15 percent rate implied by the rental adjustment equation.

Table 2: The Basic Vacancy Rate Models

Figure 4 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 two percentage points too high throughout the 1980s. Further, only about two-thirds of the 13 percentage point jump between 2000 and 2003 is explained.

Figure 4: 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:

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

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

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

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 final rent estimate, the price elasticity of demand is -0.20 and v* is 0.0603.[13] Our two hidden vacancy rates and the actual vacancy rate are plotted in Figure 5. As in EGHS (2008), the two measures move together, given the common impact of R in the two measures.[14] Moreover, they move inversely with v, as equation (9) indicates.

Figure 5: Two Measures of Hidden and the Actual Vacancy Rates

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 by HMT (2002), who provide a survey of the early literature on space market adjustments.

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[12] An added complication arises due to the upward only nature of the UK rent review clause in leases. We have made appropriate adjustments.

[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.

[14] The broadly defined vacancy rate and the log of real effective rent are highly correlated.

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 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 high. 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 equation in the top of 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 equation. Note that the adjusted R^2 has risen from 69 percent to 74 percent. 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 Rent Equation

The bottom panel tests whether the impacts of positive shocks on rent vary when 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 to equilibrium) than if it were above equilibrium. Similarly, we expect that a positive supply shock would lower rent more if it were above equilibrium than if it were below.

This is precisely the pattern we find, with all four coefficients being correctly signed and being of the expected relative magnitudes, that is, the positive shocks have bigger impacts when they are moving rent toward equilibrium. However, neither the employment nor supply coefficients in the above and below equilibrium rent cases are statistically different from each other (t-values on the differences are less than unity).[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). Given this result, we do not allow for different responses varying with the level of rent in the asymmetric system estimations and simulations.

We next consider asymmetries in the vacancy rate equation. The first equation of Table 4 reproduces the symmetric results of Table 1, and the second 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 percent with the symmetric estimates to 63 percent with the asymmetric. That is, there is not significant evidence that an asymmetry exists. Thus we use the symmetric equation in the system estimations below and in all simulations.

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

Table 4: Asymmetries in the Vacancy Rate Equation

Completing the Estimation

Before running simulations we need to estimate the change in stock equation (and endogenize employment). We also need to estimate all the model equations simultaneously to ensure internal consistencies.

Explaining the Change in Supply

We tested up to the fifth lags of the rent residual and the vacancy rate. By progressive elimination of lags with incorrectly signed coefficients and with the most insignificant but correctly signed coefficients, we were left with only the third lag of both variables. The change-in-supply equations based on this lag are shown in Table 5.

The first equation contains 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. In contrast, the high and low vacancy rate coefficients are approximately equal, suggesting a symmetric effect. In the second equation, we retain only the positive rent error and combine the high and low vacancy rate variables. This equation is used in our simulations.

Table 5: Change in Stock

Figure 6 plots actual and predicted change in supply based on the two equations in Table 5. Although the fitted model broadly follows the pattern of changes, it is not generally good at picking up the spikes.

Figure 6: Predicted and Actual Stock Growth Rates

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

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

Finalizing the Systems

The best individual models are used in two system estimations, one with a symmetric rent adjustment equation and the other with asymmetric adjustment. These models are estimated using the Seemingly Unrelated Regressions (SUR) approach with the lagged vacancy rate coefficients of the rent, vacancy rate and supply 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 6.03, reasonably close to the 7.1 percent EGHS found for Stockholm.

Table 6: System Estimations with Symmetric and Asymmetric Rent Equations

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 percent) and create the other series first from the system with symmetric rental adjustment and then from that with asymmetric adjustment. In equilibrium, real rents have no trend and stock is increasing at 0.7 percent annually in both systems. The shocks are 10 percent increases and decreases in trend employment.

Figure 7 shows how the vacancy rate, the hidden rate, equilibrium rent, actual rent and supply change relative to their base (unshocked) trends in response to a 10 percent increase in employment. The vacancy rate plunges by 2.7 percentage points and real rent rises, initially by 22 percent, and, another three percent over the next three periods. (This causes rent to exceed the new equilibrium rent until period nine.) The hidden vacancy rate is largely the mirror image of the actual rate, initially rising be 2.7 percent.

Both the vacancy rate and rent series then reverse themselves as demand shrinks in response to the rent increase and the eventual addition to supply. However, the lagged supply increase, up by 5.4 percent after nine periods, causes the vacancy rate to overshoot by 1.6 percentage points in the eighth year and rent to undershoot by 8 percent in the tenth year. The adjustment continues as the system oscillates towards a new equilibrium in which rent is 2.5 percent higher and supply is 3.4 percent higher.

Figure 7: A Positive Employment Shock with Symmetric Rental Adjustment

The initial rent increase is virtually identical to that EGHS (2008, Figure 5) obtain when simulating their Stockholm model in a comparable manner, although the vacancy rate decline (and hidden rate increase) are about a percentage point less. After the initial impacts, though, the simulations are strikingly different. In the EGHS simulation, equilibrium rent stays about 20 percent higher; the increase in supply is a far smaller 1.25 percent and equilibrium rent is only about 40 percent as responsive to the supply increase. Moreover, there is negligible cycling in the rent and vacancy series.

In understanding the differences between the two outcomes, it should be noted that the estimated rent models are different in structure: the EGHS model has two lags of rents (with negative coefficients) and a coefficient of nearly -2 on the lagged vacancy rate. Further, the EGHS short run coefficients are lower than their long run coefficients – ours are the opposite. These have the effect of dampening the simulated system for EGHS but creating oscillations for us, albeit of decreasing amplitude (see below for a discussion of oscillations in the City of London office market).[16]

Next we simulate the system with asymmetric rental adjustment in the same way. The response to a positive employment shock is shown in Figure 8. Here rent jumps by 31 percent in the first year, rather than just 22 percent, owing to the 20 percent larger employment shock coefficient. Because rent is 8 percent above equilibrium (and stays above through period 4), the rent error correction term causes rent to fall immediately. The induced oscillation has a shorter period due to initial size of the overreaction and the faster supply response. The minimum rent occurs in period seven rather than ten. Like the rent cycle, the vacancy rate cycle is accelerated in the asymmetric system. Again the system oscillates towards a new equilibrium; this time with rent and supply being roughly three per cent higher.

Figure 8: A Positive Employment Shock with Asymmetric Rental Adjustment

We also simulate a 10 percent *decrease* in employment to both systems (see Figures 9 and 10). For the system with a symmetric rent adjustment, the movements are nearly the opposite of those pictured in Figure 7.[17] Rent immediately plunges by 20 percent and then oscillates. The system moves to a new equilibrium with rent and supply 4.4 and supply 2.9 percent lower, respectively.

However, the response of the system with asymmetric rent adjustment to a negative employment shock is much different than that with symmetric rent adjustment. Rather than rent plunging in the first year, it declines linearly over four years. Rent does not respond directly to the shock (the change-in-employment coefficient is zero) but only indirectly (gradually) to the decline in equilibrium rent. The initial

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[16] In addition, the City of London market is about 60% larger than the Stockholm market and the institutional contexts are very different – for example, lease terms are substantially longer in London with rents only periodically marked to market, and with a floor set by the existing rent . Further, the rent and vacancy rate series show different time patterns between the cities. Stockholm real rent has a strong 4.5 percent trend growth rate, while the City of London real rents are essentially trendless.

[17] There are two reasons why the results of a positive and negative shock to the system with symmetric rent adjustment are not perfect mirror images. First, the modeled impact is to the log of rent so, while the log of rent results are mirror images, when results are delogged for presentation, rents are not. Second, the supply responses are a little different as the change is supply equation has only a positive rent error.

larger difference between rent and equilibrium rent increases supply before the impact of the high vacancy rate generates supply reductions. Moreover, the eventual fall in supply has no immediate impact on rents as the coefficient is zero. The largest differences from the symmetric rent adjustment model are a severe dampening of the oscillations in rent and the vacancy rate, and a rather different equilibrium in which rents are 9.1 percent lower and supply is 1.9 percent lower.[18]

Figure 9: A Negative Employment Shock with Symmetric Rental Adjustment

Figure 10: A Negative Employment Shock with Asymmetric Rental Adjustment

All four simulations of our two models generate oscillations in rents, the vacancy rate and supply. These vary from nine to 16 periods depending on the system and the shock. These cycles are consistent with Barras (2005), who constructs a model of building activity in office markets where the equilibrium growth path determines a natural rate of building starts determined by the economic growth rate and building depreciation. At any point in time, the market clearing equilibrium is defined by the natural occupancy and vacancy rates, the real rent level and the capitalization rate. Dynamic behavior of the model in response to a shock depends on lags in three adjustment processes: demand response to changes in rents, the development response to changes in demand (which also depends on the rental adjustment process) and the lag between construction starts and completions. Barras applies this model to the City of London, using data covering different time periods to estimate adjustment coefficients. His results point to strong cyclical behavior in City office market and persistent cycles with a building cycle period of around 12-14 years.[19]

Summary and Conclusion

We examine space market adjustment processes in the City of London, using an extended time series running from 1977-2006, 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

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[18] In the symmetric system it takes supply 12 periods and rent 30 periods to oscillate within +/-0.5 percent of the new equilibrium. In contrast, adjustment in the asymmetric system takes only eight and 15 periods, respectively.

[19] These findings are consistent with Barras's earlier work on office development and building lags (for a review, see Ball *et al.,* 1998, chapter eight).

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.

Next we consider asymmetric responses to employment and supply shocks. The response may depend on whether the shock is positive or negative. Responses to decreases in employment and supply are limited because tenants are locked into long-term leases and supply decreases are often temporary, the discarded stock being replaced by new development. Indeed, we find that positive employment shocks have a positive, significant impact on rental growth, and positive supply shocks have a significant negative effect. In contrast, neither negative demand nor supply shocks had significant effects.

Asymmetric responses might also arise depending on whether 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 should 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 responses are not statistically significant, possibly due to the limited degrees of freedom with our data set.

Excess of rent over equilibrium rent, and thus of price over replacement cost, triggers development and thus increases in the stock with a three year lag. The change in stock is also negatively to the lagged three-year vacancy rate. These lagged relationships introduce a negative feedback in the model that causes oscillations in the responses of rent and the vacancy rate to employment changes.

To illustrate what asymmetric rental adjustment implies for the workings of the space market, we subject the two three-equation systems to a permanent 10 percent increase/decrease in employment. The systems differ only in the rental adjustment equation. In all simulations, rent and vacancy move sharply in opposite directions in response to a shock and then oscillate but with a dampening of the amplitude. With the symmetric rent adjustment model, the positive/negative shocks produce near mirror image impacts, with long period oscillations towards new equilibriums where rent and supply are roughly three percent higher/lower.

With asymmetric adjustment, a positive shock shortens the period of oscillation by about three years. But it is the response to negative shocks where asymmetry really matters. With the negative shock there is no initial response to the fall in employment, and rent declines linearly over four years, rather than just falling in the first year. The period of the oscillations, at around 11 periods is the shortest of all four simulations and, as with the positive shock to the asymmetric system, the oscillations are severely dampened. The *new* equilibrium has rents six percent lower and supply one percent higher than with the symmetric system..

Further research on asymmetric responses to shocks to the space market using other data sets is likely to yield worthwhile results. Of particular interest would be the nature of the adjustment process and whether oscillations were created by a shock. Other possible areas of research involve more equations in the model, perhaps covering the capitalization rate and modeling the relation between starts and completions and the change in supply.

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Appendix: The City and Docklands

While prior research (for example, Blake et al. 2000) has argued that the City of London operates as a distinct sub-market, defined by the strong concentration of global financial service employment, comments to the authors have suggested that the development of the office cluster in Docklands and, specifically, the growth of Canary Wharf (a major regeneration scheme with around 14 million square feet of office space around four miles from the City of London) will have had an impact on the occupational decisions of financial firms and, hence, on rental adjustment processes. We investigated this possibility.

The first firm (State Street) moved into Canary Wharf in 1991, but the financial difficulties of the early 1990s and issues of transport linkages constrained growth until the opening of the Jubilee Line subway link in late 1999. The working population reached 13,000 in the mid-1990s but rose rapidly across the 2000s, increasing from less than 10 percent of the City's financial and business service employment to over 33 percent by 2006. It should, though, be emphasized that this is total employment: it includes retail workers, ancillary staff and all those employed in non-financial work, including a substantial media cluster (figure A1). There are significant data issues in relation to Docklands and it is not possible to construct a robust and consistent time series for employment, supply, vacancy and effective rent as it is for the City of London.

We should note, first, that we have actual employment numbers for the City, after locational choices have been made: we do not have to model the choice of location. Nonetheless the impact of Docklands on rents in the City appears minimal. Rental levels are hard to assess (there were some unusual lease terms at Canary Wharf that make estimation of effective rents problematic). However, as figure A2 shows, rental levels in Docklands largely track those of the City. The growth of Canary Wharf as an office cluster saw the rent differential narrow, but only from 60 percent to 80 percent of City rents. Docklands real rental growth 1994-2006 has a correlation of 0.75 with City rental growth. More significantly, Docklands rental growth appears to lag behind City growth; the correlation of City rents to Docklands rents one year later shows a correlation is 0.65. This is not simply a momentum effect; the correlation with Docklands leading the City by one year is statistically insignificant and a one-lag Granger causality test shows the City Granger causing Docklands rents at the 0.05 significance level,[20] but with no evidence of causality from Docklands to the City. Further analysis is constrained by limited degrees of freedom.

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[20] The null hypothesis that the City does not cause Docklands is rejected with an F statistic of 6.926, probability 0.038. The null hypothesis that Docklands does not cause City rents cannot be rejected, F statistic 0.648, probability 0.447.

With no evidence of a direct link between Docklands rental growth and City rental growth, it seems unlikely that the development of Docklands and Canary Wharf had a significant impact on rental adjustment processes in the City. Secondary evidence of a Docklands impact would come from examination of the impact of employment change on rents. If there are significant effects, these should be evidence of significant time variation in the adjustment to employment change. Examination of the recursive coefficients for employment for both the long term and short term models shows no evidence of a structural break once the system stabilizes, using standard confidence intervals (see Figure A3). Given this and allied to the fact that we have a robust and consistent dataset for the City which includes actual employment data after firms have made their choice of location, we conclude that the focus on the City of London is reasonable.

Figure A1: Employment in Docklands and the City of London

Figure A2: Real Rents, Docklands and City of London

Figure A3 Recursive Coefficents for Employment: Short Run Model

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

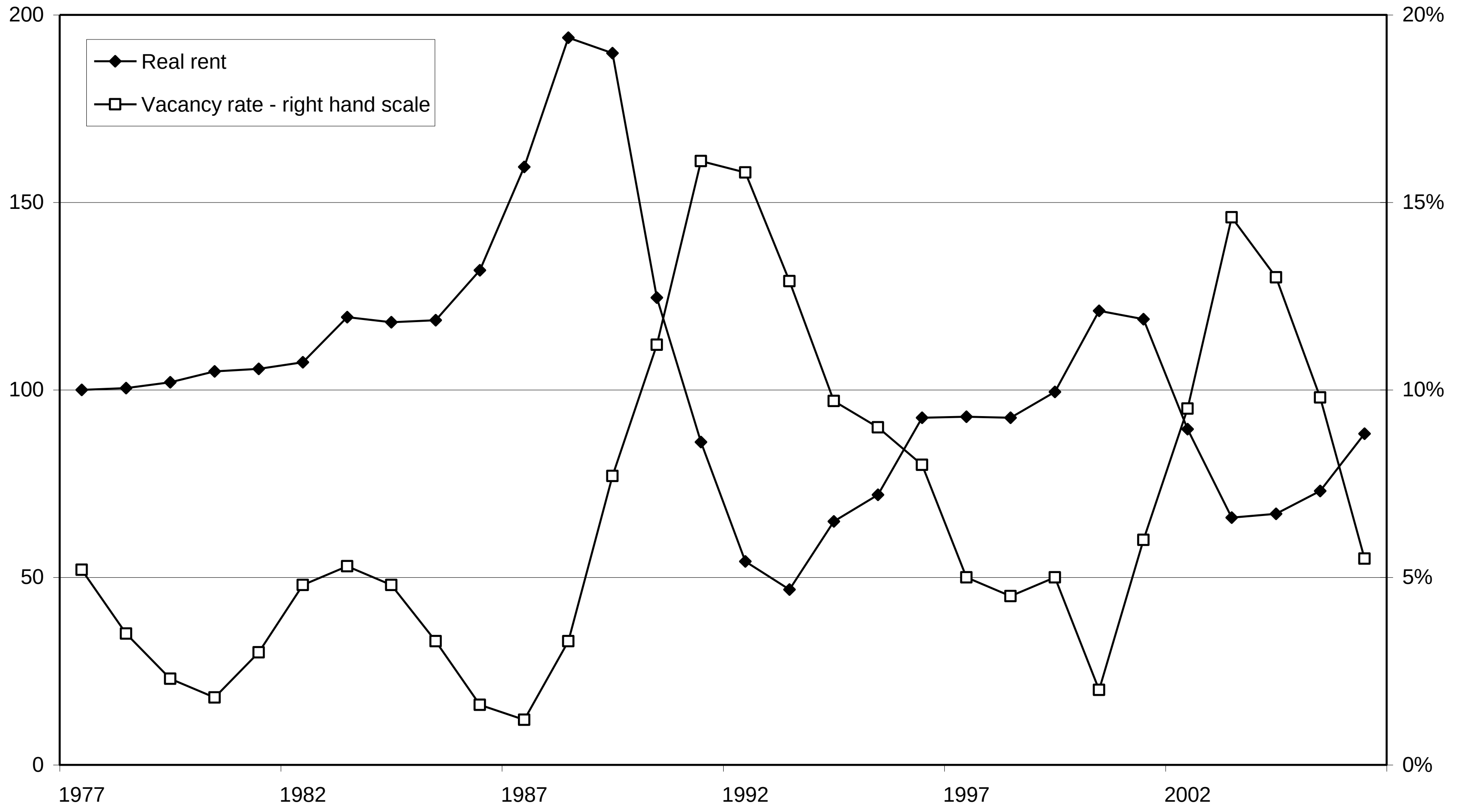

Figure 2: Office Stock and Financial and Business Service Employment, City of London

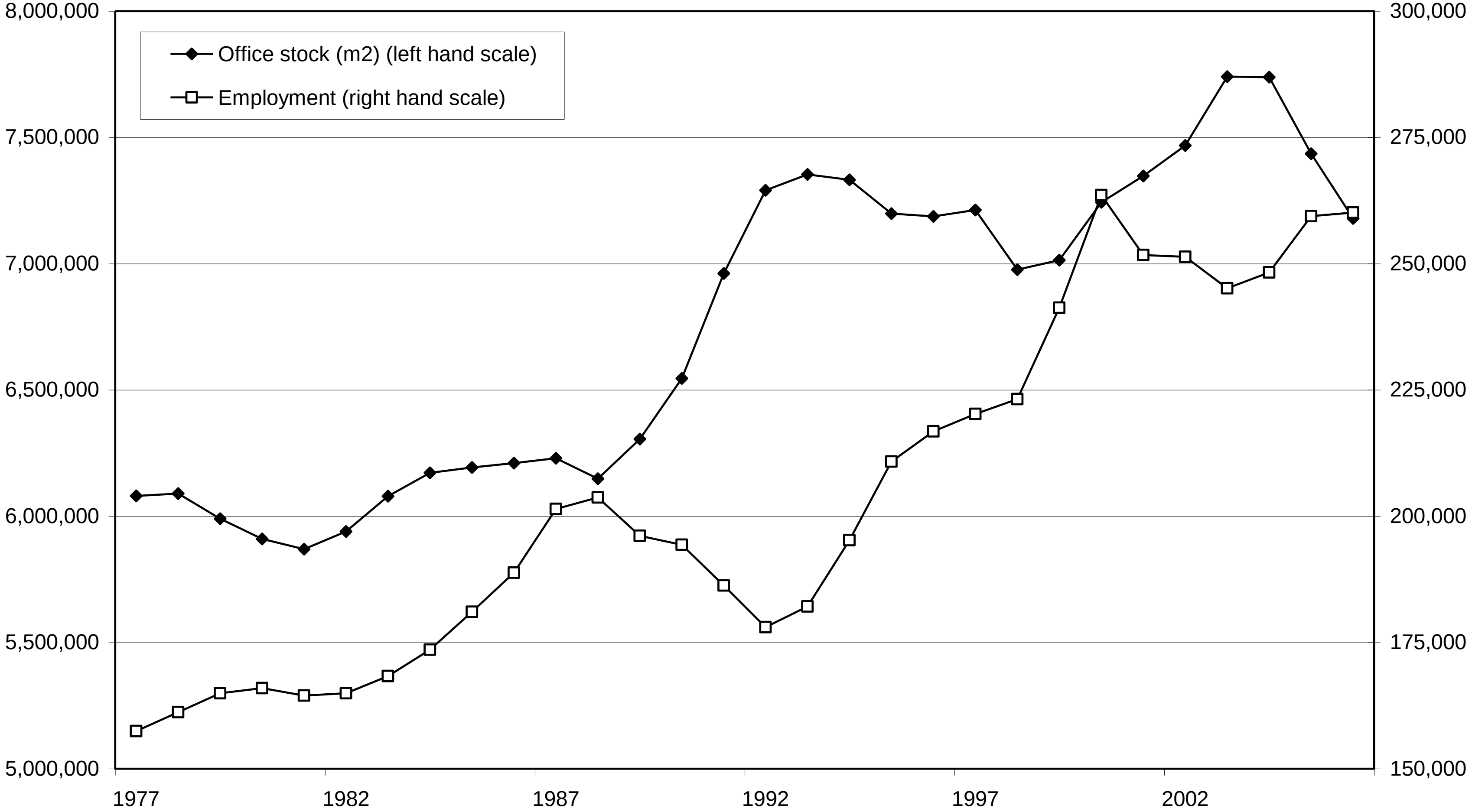

Figure 3: Predicted, Equilibrium and Actual Real Rent

Figure 4: Predicted and Actual Vacancy Rates

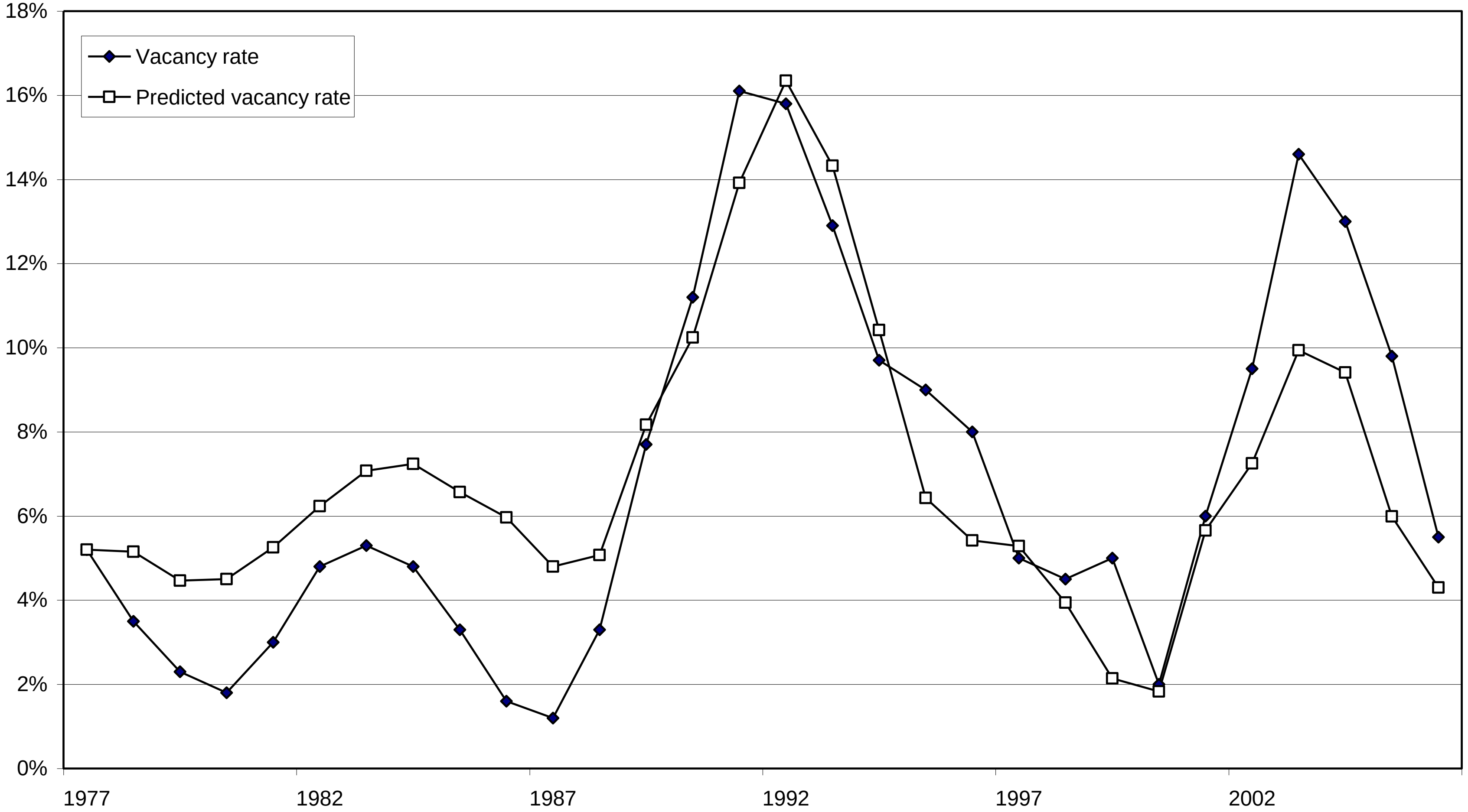

Figure 5: Two Measures of Hidden and the Actual Vacancy Rates

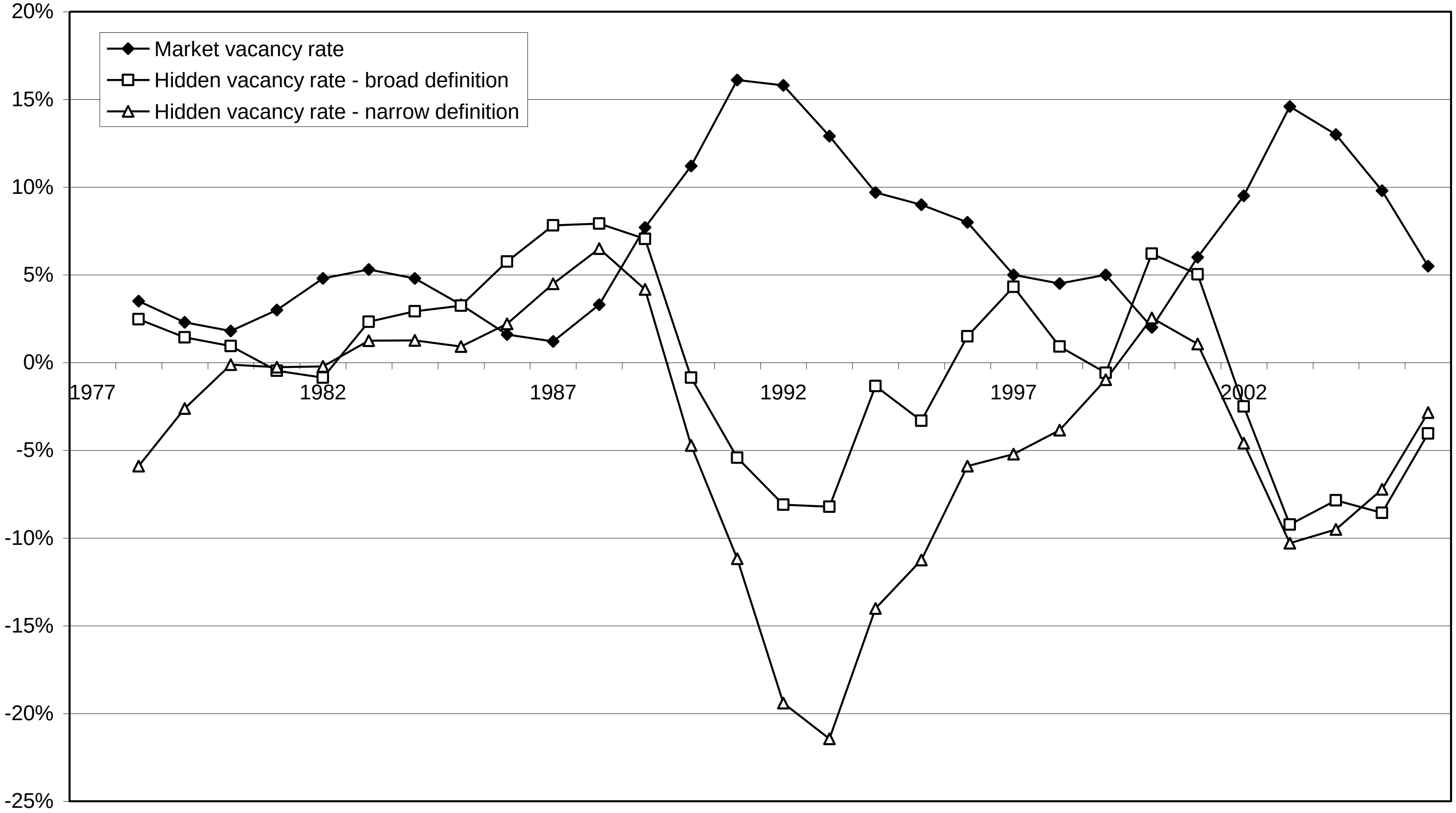

Figure 6: Predicted and Actual Stock Growth Rate

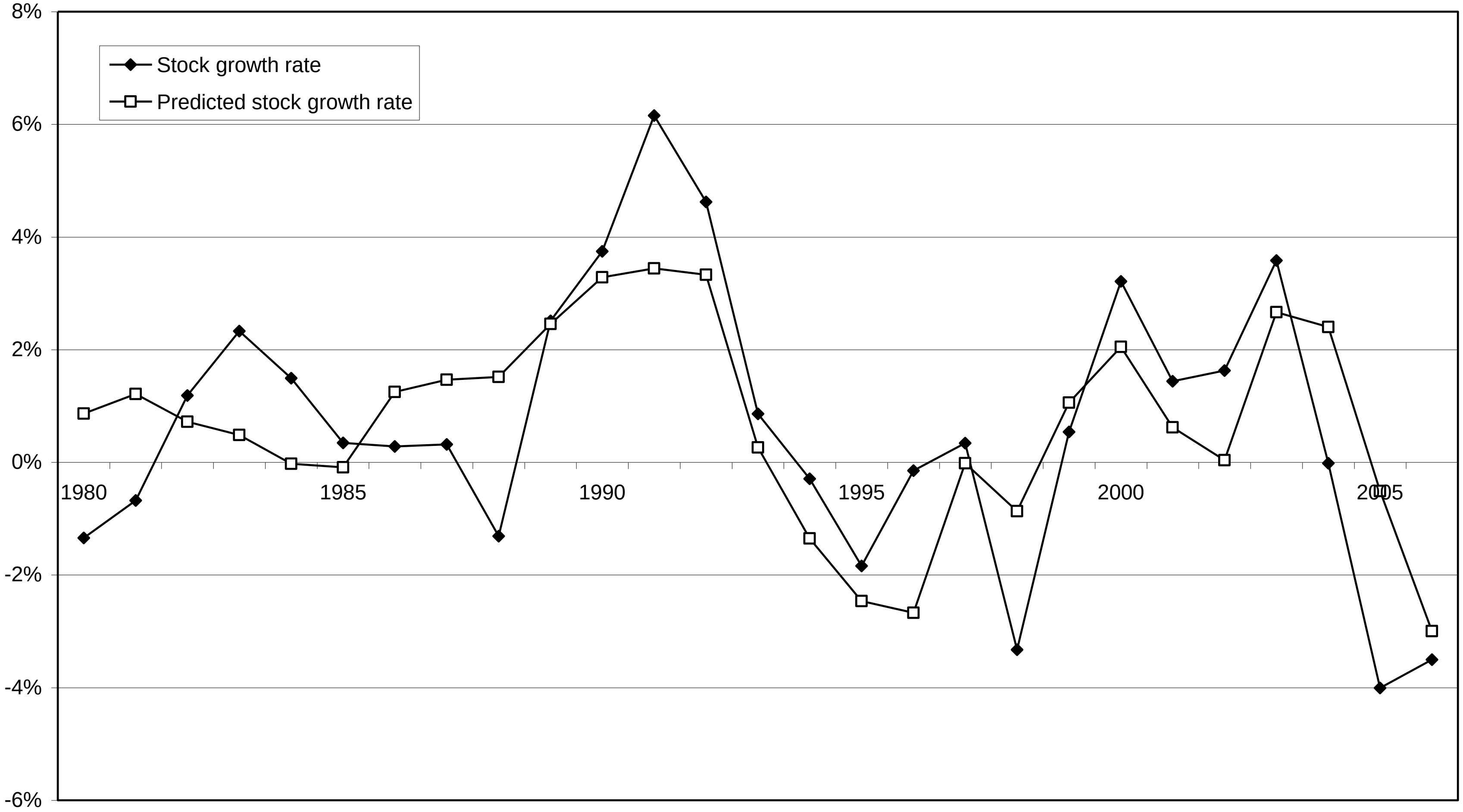

Figure 7: A Positive Employment Shock with Symmetric Rental Adjustment

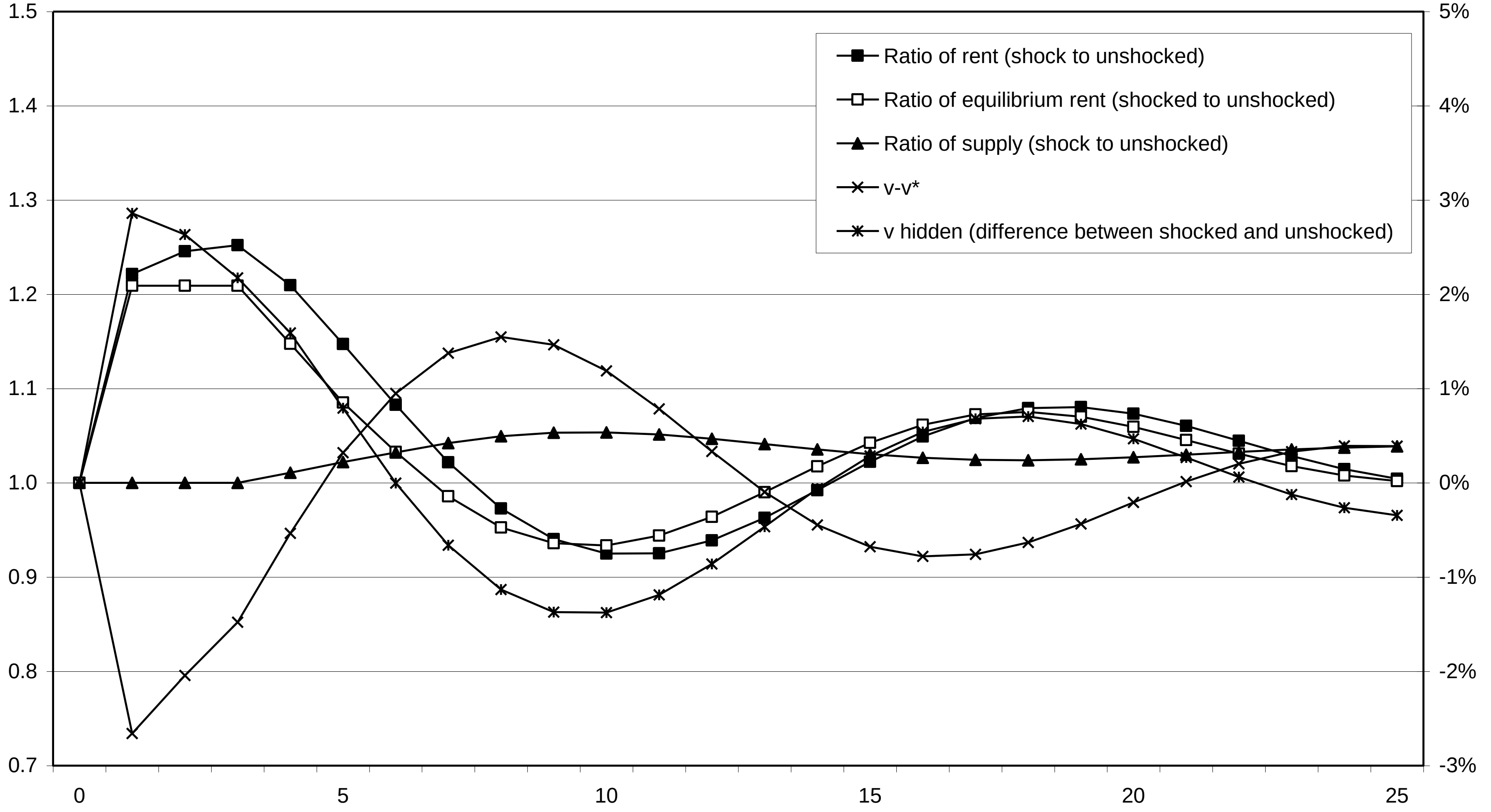

Figure 8: A Positive Employment Shock with Asymmetric Rental Adjustment

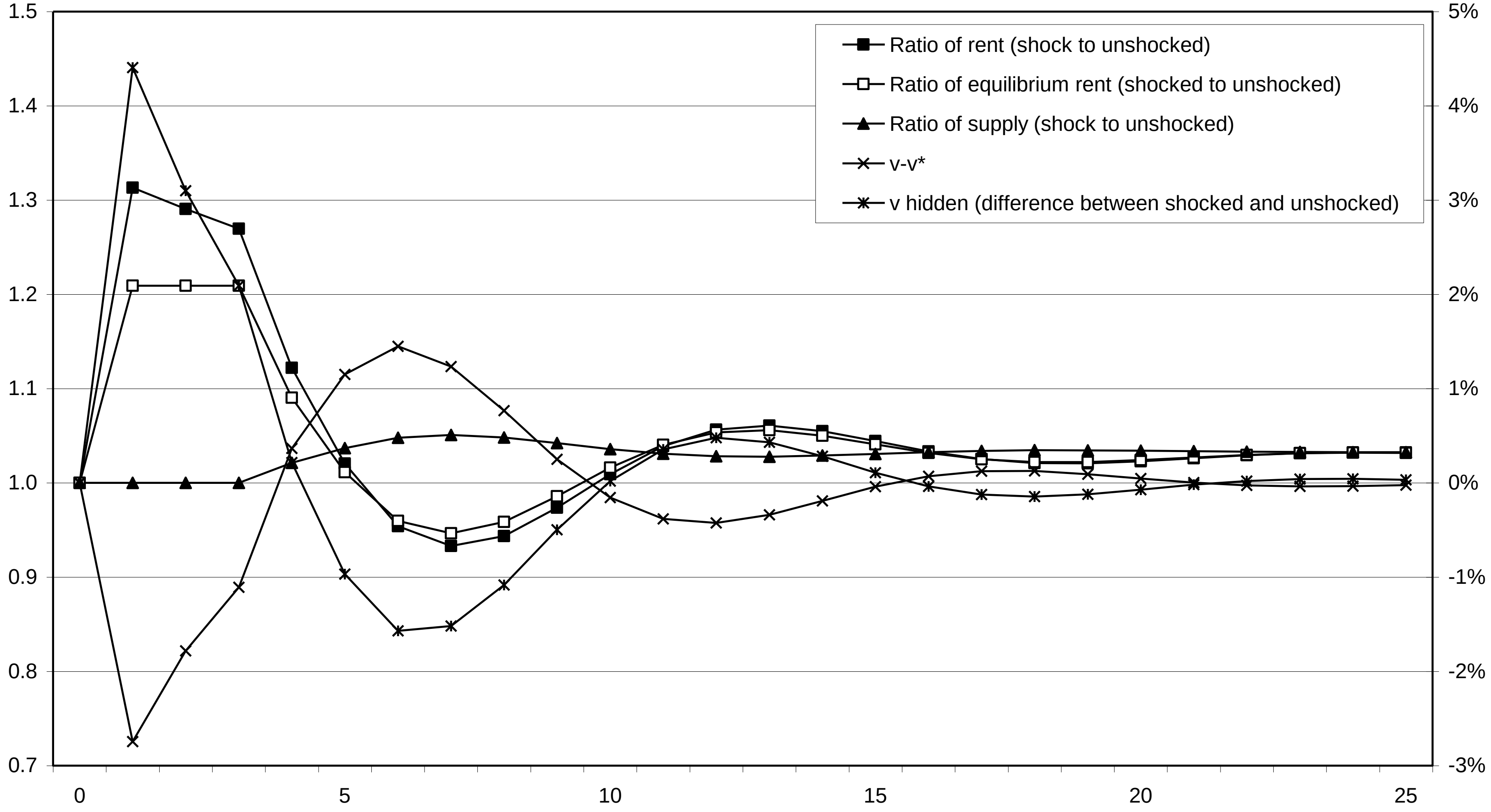

Figure 9: A Negative Employment Shock with Symmetric Rental Adjustment

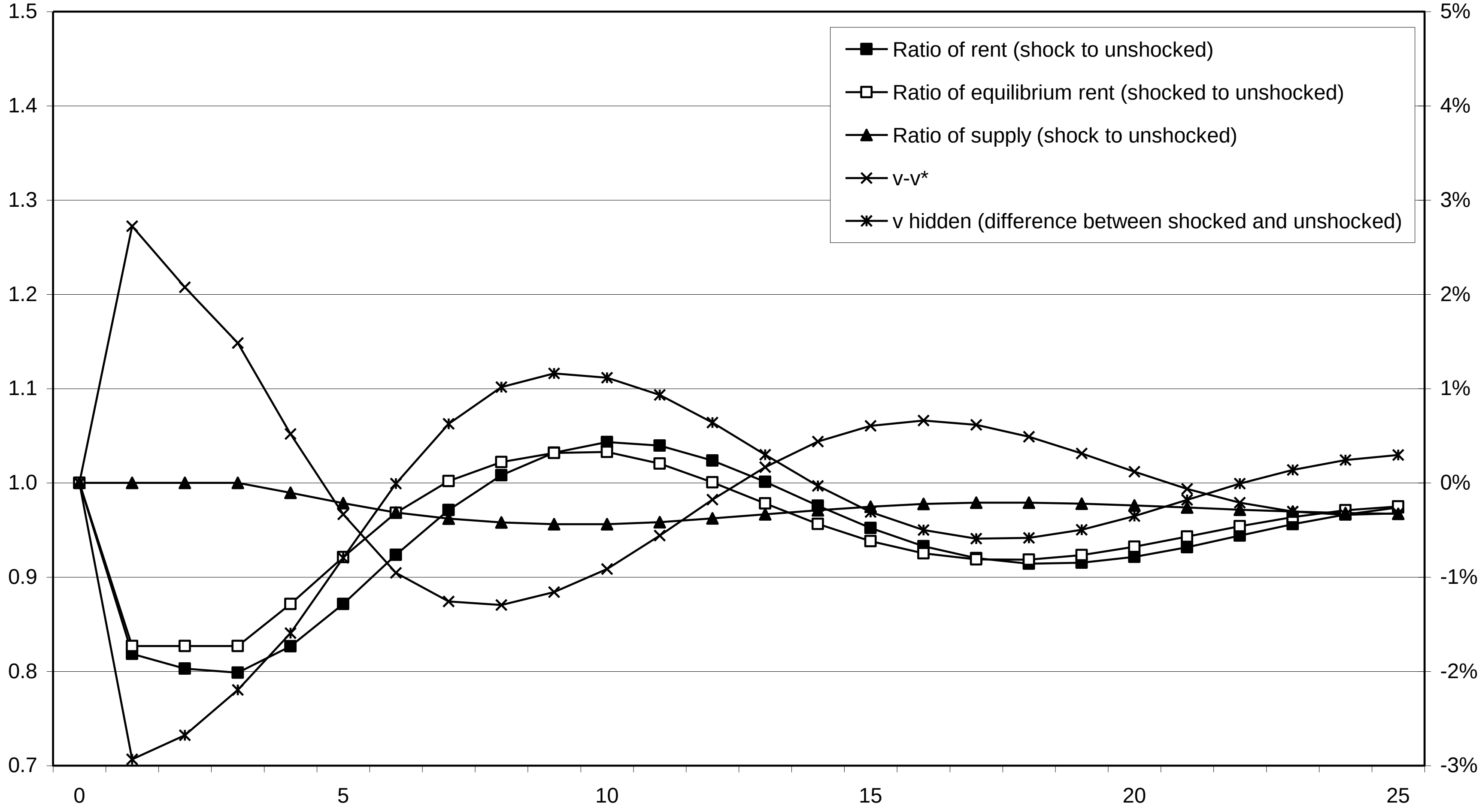

Figure 10: A Negative Employment Shock with Asymmetric Rental Adjustment

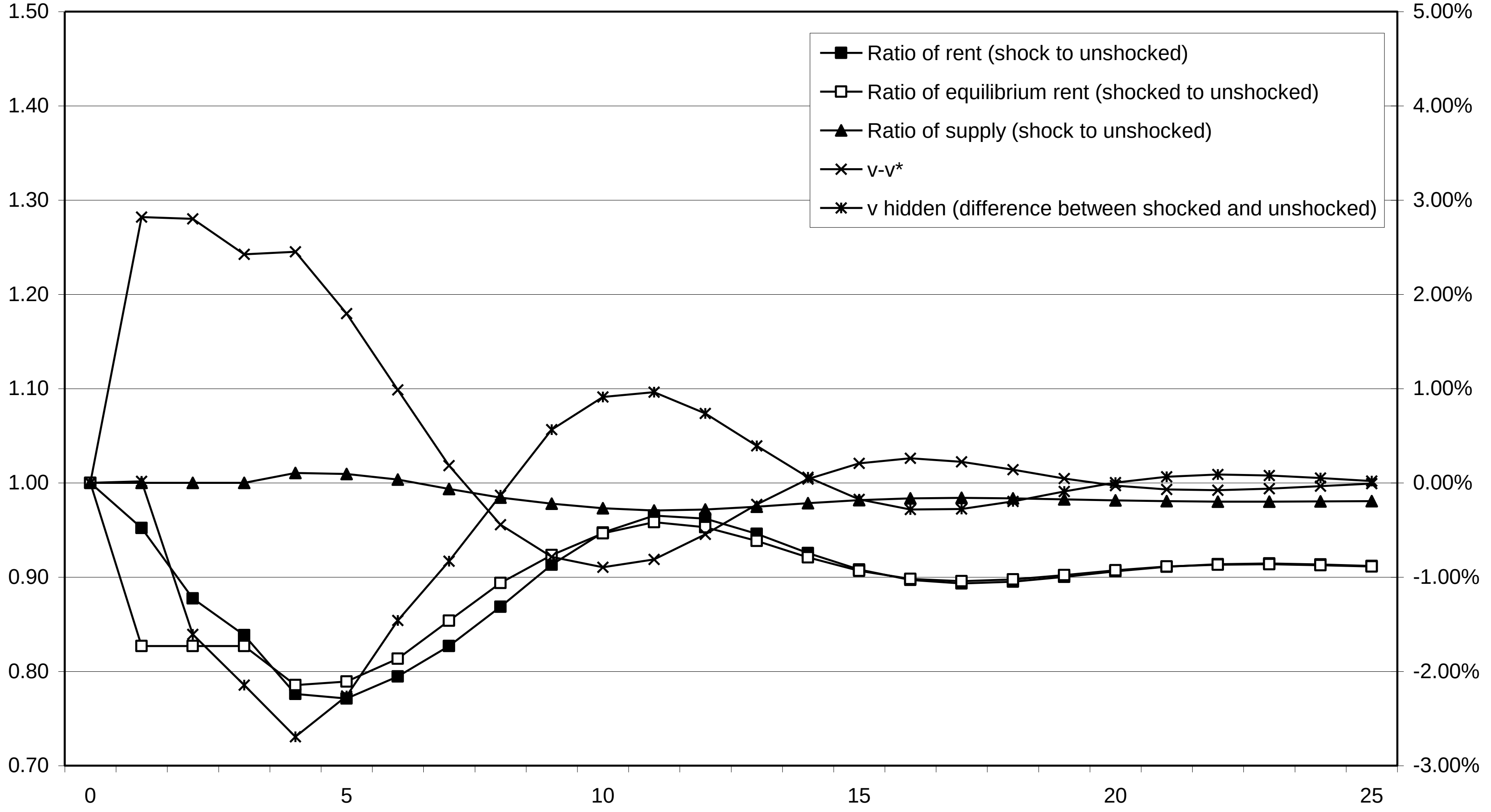

Table 1: The Basic Rent Models

Panel A: Long Run Models - Dependent Variable ln(real rent)						
	1977-1996			1977-2006		
Variable	**Coefficient**	Std. Error	Prob.	**Coefficient**	Std. Error	Prob.
C	**14.63**	1.74	0.00	**18.67**	1.60	0.00
l(employment)	**3.02**	0.37	0.00	**1.90**	0.29	0.00
l(stock)	**-5.22**	0.44	0.00	**-4.95**	0.52	0.00
Adjusted R-squared	**88%**			**76%**		

Panel B: Short Run Models – Dependent Variable Δln(real rent)						
	1978-1996			1978-2006		
Constant	**0.01**	0.04	0.83	**0.04**	0.04	0.35
dl(employment)	**2.82**	0.83	0.00	**2.24**	0.63	0.00
dl(stock)*	**-1.30**	1.56	0.42	**-2.39**	1.03	0.03
Rent error (-1)	**-0.86**	0.20	0.00	**-0.44**	0.16	0.01
Vacancy rate (-1)	**-0.71**	0.51	0.18	**-0.92**	0.47	0.06
Adjusted R-squared	**83%**			**69%**		
Durbin-Watson stat.	**1.77**			**1.80**		

Table 2: The Basic Vacancy Rate Models

Dependent variable: Δ(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
Δln(employment)	**-0.28**	0.14	0.06	**-0.32**	0.09	0.00
Δln(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: Asymmetries in the Rent Equation

Dependent variable: ∆ln(real rent)
Period: 1978-2006

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
∆ln(employment)	**2.24**	0.63	0.00						
∆ln(employment) (+ve)				**2.98**	0.82	0.00	**2.71**	0.74	0.00
∆ln(employment) (-ve)				**-1.52**	1.94	0.44			
∆ln(stock)	**-2.39**	1.03	0.03						
∆ln (stock) (+ve)				**-5.67**	1.87	0.01	**-5.02**	1.37	0.00
∆ln (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: ∆ln(real rent)

Variable	Coeff	Std. Error	Prob.
Constant	**0.04**	0.04	0.30
∆ln(employment) (+ve) and lagged residual (+ve)	**1.41**	1.50	0.36
∆ln (employment) (+ve) and lagged residual (-ve)	**2.43**	0.93	0.02
∆ln (stock) (+ve) and lagged residual (+ve)	**-6.45**	1.91	0.00
∆ln (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: Asymmetries in the Vacancy Rate Equation

Dependent variable: Δ(vacancy rate)
Period: 1978-2006

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

Dependent variable: Δln (stock) **Period: 1980-2006**						
Variable	**Coefficient**	Std. Error	Prob.	**Coefficient**	Std. Error	Prob.
C	**0.02**	0.01	0.09	**0.02**	0.01	0.00
Rent error (-3) (+ve)	**0.17**	0.03	0.00	**0.15**	0.03	0.00
Rent error (-3) (-ve)	**-0.07**	0.05	0.18			
Vacancy rate (-3)				**-0.35**	0.07	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	**64.0%**			**63.4%**		
Durbin-Watson stat	**1.45**			**1.30**		

Table 6: Systems Estimations with Symmetric and Asymmetric Rent Equations

With Symmetric Rent Equation Period: 1980-2006				**With Asymmetric Rent Equation Period: 1980-2006**			
Dependent: Δln(real rent)	Coeff	Std. Error	Prob.		Coeff	Std. Error	Prob.
Constant	0.06	0.03	0.04	Constant	0.05	0.03	0.08
Δln(employment)	2.00	0.49	0.00	Δln (employment) (+ve)	2.72	0.50	0.00
Δln (stock)	-3.04	0.88	0.00	Δln (stock) (+ve)	-5.24	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)	-0.95	0.42	0.03	Vacancy rate (-1)	-0.74	0.40	0.07
Adjusted R-squared	68%			Adjusted R-squared	74%		
Durbin-Watson stat	1.74			Durbin-Watson stat	1.73		
Dependent Δ(vacancy rate)							
Constant	0.01	0.005	0.00	Constant	0.01	0.004	0.00
Δln (employment)	-0.25	0.08	0.00	Δln (employment)	-0.26	0.08	0.00
Δln (stock)	0.43	0.14	0.00	Δln (stock)	0.46	0.13	0.00
Rent error (-1)	0.04	0.02	0.08	Rent error (-1)	0.04	0.02	0.06
Vacancy rate (-1)	-0.22	*	*	Vacancy rate (-1)	-0.23	*	*
Adjusted R-squared	60%				61%		
Durbin-Watson stat	1.59				1.63		
Dependent: Δln(stock)							
Constant	0.02	0.005	0.00	Constant	0.02	0.005	0.00
Rent error (-3)	0.14	0.03	0.00	Rent error (-3) (+ve)	0.14	0.03	0.00
Vacancy rate (-3)	-0.36	*	*	Vacancy rate (-3)	-0.36	*	*
Adjusted R-squared	61%				61%		
Durbin-Watson stat	1.25				1.23		

Note: * The coefficients on the vacancy rate are constrained so that the estimates of the implied natural vacancy rate (obtained by taking the negative of the constant divided by the vacancy rate coefficient) are the same for all three equation, so there is no standard error or probability output from the estimation. The implied natural vacancy rate is 6.03%, with the Symmetric Rent Equation, and 6.27% with the Asymmetric Rent Equation.

Figure A1: Employment in Docklands and the City of London

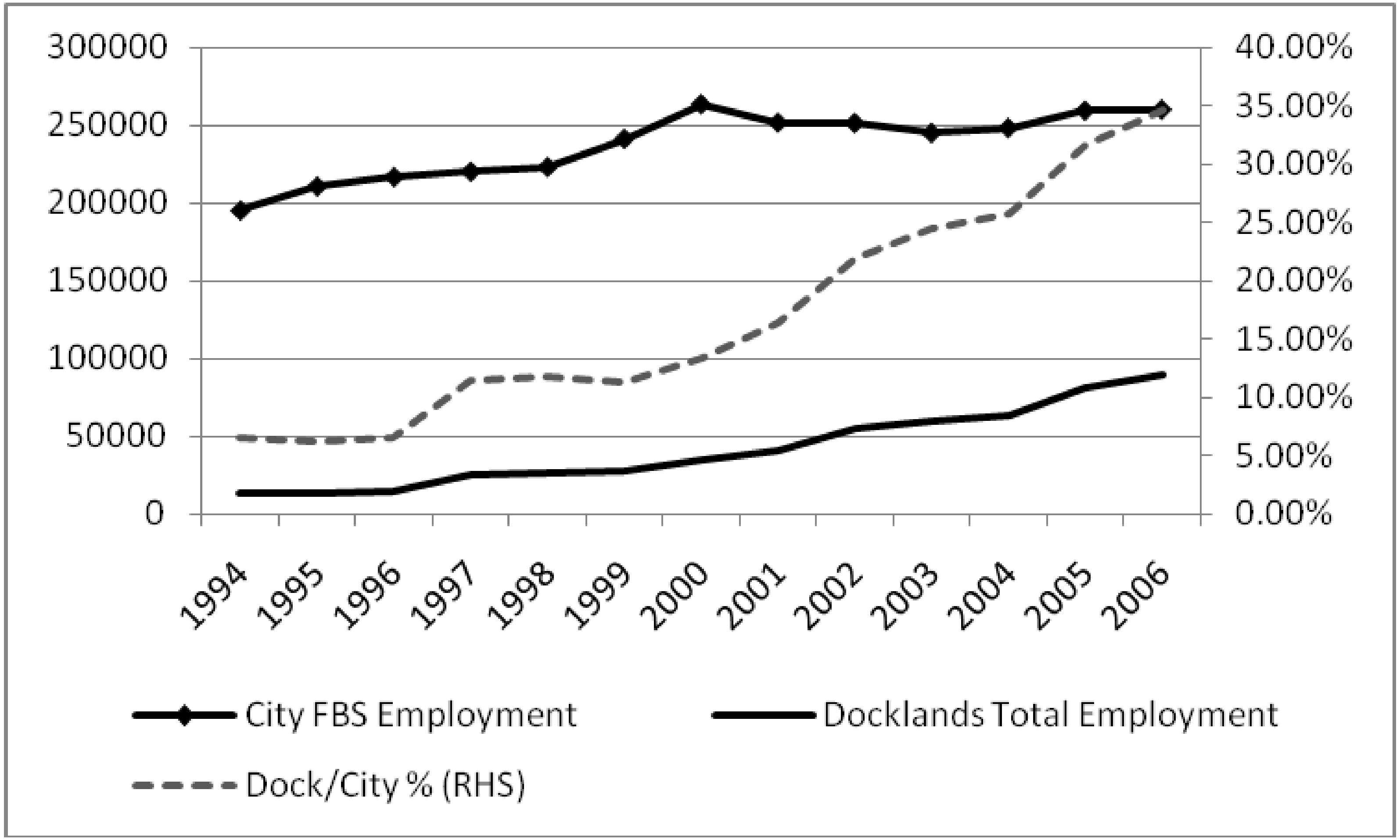

Figure A2: Real Rents, Docklands and City of London

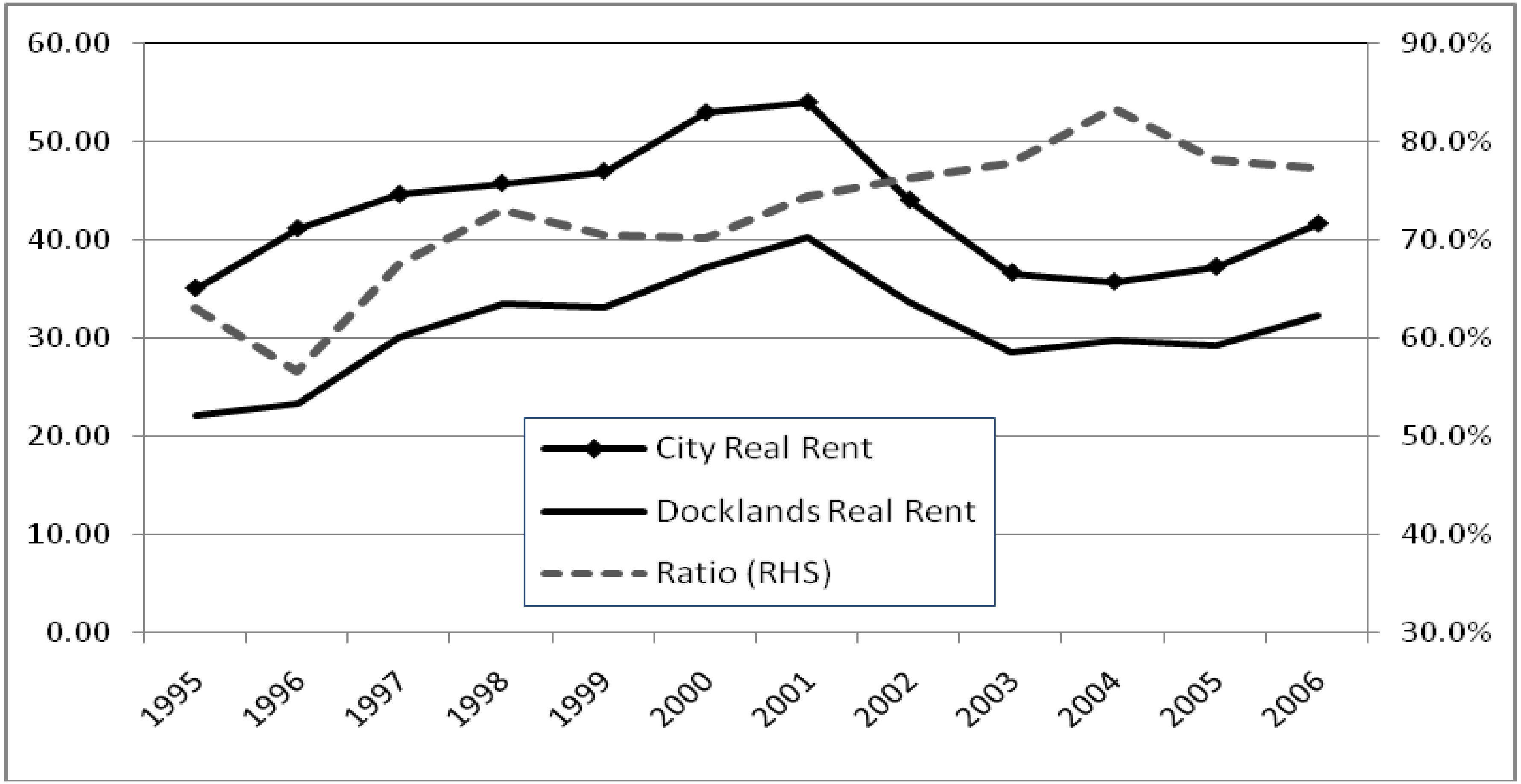

Figure A3 Recursive Coefficents for Employment: Short Run Model