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ABSTRACT

We analyze the joint dynamics of property space markets using an error-correction model, where rent and vacancies adjust to deviations from equilibrium rent and vacancies. The analysis is based on a new lease rent series for the Stockholm office rental market for the time-period 1977 –2002 constructed by standard hedonic methods applied to a data-set of some 2,400 individual leases. Simulations illustrate the separate roles of rent and vacancy rate movements in the adjustment process. We calculate the natural vacancy rate assuming a trending equilibrium. Property markets may be slow to adjust because tenants are constrained by long-term leases and may be slow to adjust to current rents for other reasons. This gives rise to "hidden vacancies" (the difference between space occupancy and demand at the current lease rate). Using our market rent series and the lease-length distribution, we estimate a time series on the average rent on existing leases. We find that most of the variation in hidden vacancies is explained by the difference between demand at current and average rent.

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1. Introduction

If all lease contracts were renegotiated every time period and there were no search and transaction costs and other market frictions, then there would be no vacancies. Rents would continuously adjust to equate demand and supply, and there would be no vacancies and no deviation of rents from equilibrium given the current supply. Commercial property space markets are more complex than this. Rents are the outcome of a search process, where landlords and prospective tenants look for a good match in terms of rent and characteristics of the premises. As a result the vacancies are a central feature of property markets. Because demand and supply for individual units are continuously subject to idiosyncratic shocks, some vacancies would exist even if there were no aggregate shocks to the market. Market shocks cause vacancies to deviate temporarily from their normal ("natural") level during a transition period until equilibrium is restored.

A simplified characterization of market equilibrium in a world of one period leases is that demand equals supply minus natural vacancies, where the natural vacancy rate depends on the frequency of shocks and the properties of the matching process between units and tenants. Outside equilibrium, rents adjust gradually, reflecting slow dissemination of information and strategic pricing decisions by landlords. Occupied space equals demand at the current rent and vacancies adjust so as to maintain equality between occupied space and supply minus vacancies. In such a world the deviation of the vacancy rate from its natural level would simply be a mirror image of the deviation of rent from its equilibrium level.

In practice, rents and vacancies are not simple mirror images of each other but play separate roles in the adjustment process. The main reason is multi-period lease contracts, which lock tenants into contracts signed in earlier periods. Furthermore, space consumption may be locked in due to moving costs even in a world with one-period contracts. We can draw a distinction between long run (or normal) demand, depending on the rent on newly-written leases only, and short run demand (defined to equal observed space occupancy), which depends on other factors, in particular historic lease terms. This is somewhat analogous to the rigidities in labor markets with long-term wage contracts restricting current employment as analyzed in the macro literature. To illustrate, if most space were leased under long-term contracts at earlier low rental rates, then current short-run demand would be higher than if all space were being leased at today's high current rents. We refer to this temporary (until leases roll over) higher space usage as "hidden vacancies".

In this paper we develop and use data from the Stockholm office market to better understand the roles of rents and vacancies in the adjustment process in commercial space markets. This market is particularly interesting because the typical lease length in Sweden has increased from only one year to three years during the 30 period covered by our data. The key model input we create is a series of real rents for new leases holding physical characteristics and lease length and other contract features constant. These rent indexes are computed from estimates of a hedonic rent equation based on 2485 individual office leases written during the 1972-2002 period. Based on these rent measures and data on vacancies, the supply of office space and office-sector employment, we estimate an error-correction model of rents, vacancies and supply.

In long-run equilibrium employment, supply and real rent grow at constant rates and vacancies equal the natural rate. Defining natural vacancies in a trending equilibrium (which is necessary given the clear upward trend in real rent) – rather than the standard definition based on a stationary equilibrium where rent remains constant – makes an important difference. We estimate the natural vacancy rate for Stockholm to be 7.1 percent, a third less than that estimated under the standard definition.

A key feature of our analysis is the separate treatment of the dynamics of rents and vacancies, each adjusting to the deviation of both variables from their equilibrium levels. Our estimates indicate that about a third of a gap between current and equilibrium rents and a fourth of a gap between vacancies and natural vacancies are closed within a year. Moreover, adjustment of each variable is significantly related to the disequilibrium gap in the other. We illustrate the workings of the model through simulations of shocks to employment, the exogenous variable in the model. The adjustment towards the new equilibrium is cyclical with rents overshooting the new equilibrium by 25 percent after five years. During much of the adjustment process rents are above equilibrium while vacancies remain below the natural rate, indicating the presence of hidden vacancies. We also demonstrate that historically hidden vacancies, as measured by our model, have been strongly correlated with the difference between demand based on current rents and demand based on average rents in the stock of all contracts.

Section 2 gives details about our estimate of a constant-quality rent index. Section 3 provides a background discussion of developments in the Stockholm office market since the 1970s, including a presentation of the data used. Next, we turn in Section 4 to a discussion of the simultaneous determination of the vacancy rate and real rent, providing both a brief literature review and a specification of the model to be estimated. Time series regressions explaining the rent, vacancy and supply adjustment processes are then reported in Section 5, where we also present measures of the natural vacancy rate and analyze the development of hidden vacancies. In Section 6 we report simulations based on the model estimates to illustrate key characteristics of the rent/vacancy adjustment process and the nature of property cycles. Finally Section 7 concludes.

2. Estimates of Constant-Quality Lease Rates

The key data input into the current study is an index series of real rent per square meter of constant-quality newly leased office space in Stockholm CBD. We create this from a sample of 2485 individual office leases written between 1972 and 2002 using the hedonic methodology employed, e.g., by Wheaton and Torto (1994) and Webb and Fisher (1996). The offices are owned by a set of institutional investors, including insurance companies, pension funds, and specialized property holding companies. For the most recent years, 1998 – 2002, we draw on a database maintained by SFI/IPD Swedish Property Index based on information from 13 major owners with holdings covering about 30 percent of total CBD office space. For the years prior to 1998 we have collected leases from the archives of two of the most important owners in this group with holdings close to 40 percent of all SFI/IPD offices in the Stockholm CBD.

The index is meant to apply to standard office leases with normal lease terms. We have deleted non-standard observations based on the following criteria: leases for a shorter term than nine months (which have notably different renewal rights); leases for unusually large or small premises (below 25 square meters and above 2500 square meters), and observations with apparent data coding errors in any variable used in the index estimation. The remaining lease observations are used for the estimation of the constant quality rent index.

Table 1 presents annual data on the numbers of leases and properties, the average lease length, and the fraction of the leases that were newly written. The number of leases in the data base varies considerably over time, ranging from less than 40 per year between 1973 and 1976 to close to 200 between 1999 and 2001. The main reason for the high numbers of observations in the last few years is the addition of many more property owners from 1998 when we have access to the SFI/IPD data: the number of new leases triples from 1998 to 1999. But there are large variations from year to year for other reasons. Part of the variation reflects the different phases of the property cycle. The increase in number of leases during the market boom in the late 1980s (especially 1989) coincides with increased new supply, whereas the low numbers in the early 1990s reflects a surge in vacancy rates. Some of the variation could also be due to missing observations. For the earlier period we have accessed all leases still remaining in the archives of the two property owners. But because we do not have access to records on the total stock of rental premises of these owners, we have no way of checking for missing observations. Our general impression, however, is that the files of leases that we have examined are complete and that all new contracts were added chronologically as the old ones expired.

The number of lease observations is also affected by the length of leases signed in previous years; the shorter are leases, the more frequently an office appears in the data base. The distribution of the length of newly signed leases is directly observed in the data. We use these data to calculate the fraction of all leases expiring. These calculations are based on the assumption that we observe a random sample of all contracts and that the total stock of offices remains constant. To start, we assume that all leases in the stock in 1972 had a remaining maturity of one year. The distribution of maturities in the stock for subsequent years is calculated recursively, deriving the fraction of expiring leases from the observed distribution of lease lengths in preceding years. For each year the observed length distribution for new leases is applied to the fraction of leases expiring, i.e., one-year leases written in the previous year, two-year leases written two years ago, etc. Based on this we compute the fraction of leases expiring in year t as the fraction of leases with one year to go in t-1. The increase in average lease length from just over one year in the early 1970s to over three years in the late 1980s reduces the fraction of newly signed leases in our data base. This fraction dropped from 3/4 in the 1970s to 1/3 in recent years.

Our data include key information about the lease: contract rent, starting and closing date, and size of the premises. Furthermore we know if the lease is the result of the renegotiation with an old tenant. Because the data come from the same set of landlords, individual offices undoubtedly appear several times in the data set. Unfortunately the data do not allow us to identify individual offices, but we can identify the building in which the office is located. In the hedonic regression we capture quality differences across offices by building age and by an indicator variable for each building in the data set. The data also indicate the presence of special clauses like inflation indexation, heating clauses, graduated rent clauses, and rent concessions. For the period 1972-1991 there is quantitative information about rent concessions and various forms of graduated rents allowing us to transform contract rents into effective rents along the lines of Hendershott (1996) and Webb and Fisher (1996). Such concessions were present in a small minority of all contracts.

For later years we only have indicators of the presence of special contract clauses and are constrained to capture the average impact on rent through dummy variables. The extent to which this may bias our index estimates depends on the variability of rent concessions over time. It is likely that free rent periods and the like were more common during the market crisis of the early 1990s than during other periods. If the average size of concessions was the same all years this should not lead to biased index estimates. It is more likely, however, that the concessions also were larger than usual during these years, in which case our index estimates for this period are upward biased. Exact variable definitions along with sample statistics are stated in Table 2.

Using these data we estimate a hedonic rent equation for newly-written leases with time represented by year dummies. We take special care with the lease-length term. In studies using basically the same data for a shorter time period, Gunnelin and Söderberg (2003) and Englund et al. (2004) found that the relation between rent and lease length often is non-linear. Short leases tend to be more expensive due to transaction costs, and the impact of term on rent varies over time reflecting expectations of future rent levels. To allow for a time-varying non-linear relation we interact lease-length and lease-length squared with year dummies. The constant quality rent index is calculated as the rent for a standard contract by evaluating the estimated equation for each year holding all explanatory variables constant at their sample average values.

The estimated equation is presented in Table 3. It has a high explanatory power (adjusted R^2 = 0.962) largely due to the inclusion of property dummies. Square meter rent is seen to increase with size for smaller offices, reaching a maximum at 1250 sq. meters**,** and to decrease for larger offices. The rent level is 5 per cent lower for a renegotiated contract than for a contract with a new tenant. According to the estimated coefficients inflation indexation and being charged separately for heating (HEAT_2) both tend to raise the rent, which may appear counterintuitive. We interpret these results as reflecting unmeasured quality characteristics; such heating and indexation clauses are more common for high-quality offices.

The resulting index series is plotted in Figure 1. It exhibits a strong cycle around an upward trend in real rent in the late 1980s and early 1990s and again in the late 1990s and early 2000s. Having estimated the real rent level for new leases and the distribution of leases over maturities, we can calculate the average rent in the stock in a given year by assigning the new lease rent in each year to the portion of the stock existing in the given year that was leased up in that year and summing across all lease up years. This time series for average real rent is also plotted in Figure 1. The differences between the new and average series were relatively small during the 1970s and 1980s, when leases were short and rents were relatively stable. However, when leases lengthened and real rents plunged and then rebounded in the 1990s, the percentage difference fell to a minimum of -25 percent in 1993 and then rose to a maximum of 26 percent in 2000.

3. The Stockholm Office Market during Three Decades

The development of the Stockholm office market since the early 1970s is illustrated in Figure 2, which plots the data series used in our empirical analysis. A general control of residential and commercial rents was introduced in Sweden during the Second World War and remained in force with little change until the early 1970s. Residential rents remain regulated even today, but with some reform of the rent setting system. As a result residential rents still fail to reflect site rents, particularly in central locations in Stockholm. For office rents a four-year deregulation process started in 1972. This involved the right for tenants to a gradual adjustment towards market rent between 1972 and 1976. The deregulation process was evaluated after the adjustment period. In effect there was a threat of reinstalling some form of control. It is reasonable to believe that this restrained landlords for several years and put some constraints on rent setting during the 1970s.

The top panel plots our rent index of newly leased office space together with a measure of vacancies. The vacancy rate series refers to office space in the inner city of Stockholm. It derives from estimates by property consultants. For the period before 1989 we have obtained vacancy estimates directly from a leading consulting company, the Catella Property Group. For later years they come from the property consultant NewSec AB (accessed from the data base of the Swedish Central Bank; www.riksbanken.se). The geographical area for which the vacancy data are estimated is not defined exactly by the suppliers, but is somewhat wider than the CBD for which we have rental data.

Real rents developed smoothly during the transition years of deregulation with modest changes between 1972 and 1977. Following years are characterized by two pronounced rent cycles: thirteen years of boom between 1977 and 1990 with real rents increasing by 10.5 percent per year, a sharp bust between 1990 and 1994 with rents falling by 13.8 percent per year bringing rent back to its 1981 level, a long recovery between 1994 and 2001 with rent increases averaging 8.9 percent per year, and finally the onset of a new recession after 2001. Vacancies mirror rents fairly closely. They remained below 5 percent throughout the 1970s and 80s and started to shoot up only in 1990, the year when real rent peaked. During the crisis vacancies reached unprecedented levels, peaking above 20 percent in 1993. It then took another five years for the vacancy rate to get down below five percent again. Finally it turned upwards again after 2000.

The lower panel of Figure 1 depicts the drivers of this development, the supply and demand for office space. Supply is measured by the number of square meters of office space in the inner city of Stockholm. The series is constructed starting from an inventory of the stock of office space, estimated in 1968 by Statistics Stockholm. For later years we have added data on net additions of new office space, measured in square meters, using publicly available data on building permits and demolitions from Statistics Stockholm. To proxy the demand for office space we use office sector employment in the city of Stockholm, a somewhat wider area than that of the other series.[1]

These series show strong and sustained trends. Supply increases every single year, at an average rate of 1.3 percent over the whole period. The growth in office employment was even stronger (on

[1] From 1985 these data are taken directly from the Labor Force Surveys (*Arbetskraftsundersökningen*, *AKU*). For earlier years they were estimated based on census data (for 1970, 1975, 1980 and 1985), interpolated using data on the total population.

average 3.4 percent per year from 1972 to 2002), but with larger short-term fluctuations related to the business cycle. Note especially the contrast between the sharp 3.9 percent annual decrease during the 1989-93 crisis and the sustained rise in earlier and later years. Office employment grew by 4.4 percent annually between 1977 and 1989 and by 5.9 between 1993 and 2002. The supply changes were much smaller and smoother with little variation over time: increases of 1.5 percent annually during the 1977-1989 period, 1.4 percent during the 1989-1993 crisis and 0.5 percent during the 1993-2002 recovery. The combined impact of these demand and supply data is consistent with the actual real rent development: sharp rises in the 1980s and again in the latter part of the 1990s, with a plunge in between.

4. Modeling the Office Space Market

There is a long literature dealing with the adjustment process in rental office markets, beginning with Smith (1974); see Hendershott, MacGregor and Tse (2002) for a recent survey. Much of the early literature focused on the role of vacancies as a driver of rent adjustment. In analogy with the Phillips curve, a common formulation expressed the rate of change of real rent as a function of the deviation of vacancies from a natural vacancy rate, implicitly defined as the vacancy rate consistent with constant real rents. While this formulation gave important insights, it had some shortcomings as a representation of the dynamics of space markets. In particular, it left the equilibrium rent level out of the picture; this rent was neither determined by the model nor did it play any role in the adjustment process.

The first paper to explicitly model rent dynamics as an adjustment process towards a varying equilibrium was Wheaton and Torto (1994). They assumed that rent adjusts gradually towards its equilibrium level and argued based on search theory – e.g., Arnott (1989) and Wheaton (1990) – that the equilibrium rent at any time should lie between the reservation rents of landlords and tenants. Reservation rents cannot be observed but were assumed by Wheaton and Torto to depend on the number of vacancies and the flow of new tenants searching for office space. This led them to estimate an equation where the rate of change in real rent depended on the vacancy rate and the absorption of office space.[2] An alternative indicator of the flow of vacancies and tenants looking for a contract is the number of existing contracts that expire in a particular period. The Wheaton-Torto model does not include the underlying determinants of demand and supply and is probably best seen as applying in the short and medium run.

A more general model of the adjustment process would allow rents on new leases, R, to adjust to

[2] In the empirical study Wheaton and Torto used net absorption, equal to the increase in the stock of leased space, rather than gross absorption which would be more in line with theory.

the gaps between both the equilibrium and actual rent levels and the current and natural vacancy rates. This equation may be specified in log-linear terms as:

$$\Delta \ln R_t = \ln R_t - \ln R_{t-1} = \beta_v (v^*_{t-1} - v_{t-1}) + \beta_R (\ln R^*_{t-1} - \ln R_{t-1}), \qquad (1)$$

where v is the vacancy rate and asterisks denote equilibrium values. The adjustment coefficients are β_v for the vacancy rate gap and β_R for the rent gap. If v^* is treated as a constant, as generally has been the case, it can be calculated as the estimated constant term in the regression divided by β_v. Based on the search theory argument sketched above we would expect that the rates of adjustment depend on the fraction of contracts expiring.

Some of the papers estimating equations like (1) have been based on one-equation models, where the equilibrium rent level, R^*, has been taken as specified outside the model. Hendershott (1996) and Hendershott, Matysiak and Lizieri (1999) calculated R^* as the user cost of capital – the product of replacement cost and the sum of the real discount factor, the depreciation rate and the operating expense rate (all divided by 1-v*). While straightforward in principle, this approach has two potentially serious problems. The first is the determination of the discount factor (i.e., the real return requirement): treating it as a constant certainly introduces error. Second, changes in the real discount rate may at least partly get capitalized into land price, which in central locations is a dominant part of replacement cost. Because equilibrium land price (and hence replacement cost) is not directly observable, the impact of changes in the real return requirement on equilibrium rent would then be unknown; with full capitalization there would be no impact.

4.1 Equilibrium rent

An alternative approach – adopted by Hendershott, MacGregor and Tse (2002) – that avoids these problems is to specify a long-run equilibrium model of the space market and use this model to estimate the equilibrium rent. In a minimal model demand for office space may be expressed as a log-linear function of real rent and a demand indicator, e.g., employment in a key sector like financial services (E)

$$\ln D(R, E) = \lambda_0 + \lambda_R \ln R + \lambda_E \ln E, \qquad (2)$$

where the price elasticity λ_R is negative and the 'income' elasticity λ_E is positive. In a search market context R should be thought of as the average rent on new contracts. Actual space occupancy may deviate from the demand function because of transaction costs and because tenants are locked into old contracts.

At the equilibrium rent and vacancy rate, demand will equal total supply minus equilibrium vacancies.

$$D(R^*, E) = (1 - v^*)S \,. \tag{3}$$

Taking the logarithm of (3), substituting from (2) and solving for $\ln R^*$ then gives

$$\ln R^* = \gamma_S[\ln(1 - v^*) - \ln \lambda_0] + \gamma_E \ln E + \gamma_S \ln S \tag{4}$$

where the parameters of the demand equation (the price and income elasticities) can be retrieved from estimates of (4) as $\lambda_R = 1/\gamma_S$ and $\lambda_E = -\gamma_E / \gamma_S$. In reality equilibrium values will never be observed because the market is constantly affected by shocks to the underlying determinants (in this case supply and employment). We only observe the outcome of an adjustment process where rents and vacancies tend to move toward equilibrium. In this equation natural vacancies are taken as exogenous, determined by structural characteristics of the local office market.

In modeling and estimating the adjustment process the dynamic properties of the variables are crucial. In many cases *R, E*, and *S* can be expected to be non-stationary. A quick glance at Figure 2 certainly indicates that to be the case for the Stockholm data. The equilibrium condition (4), on the other hand, links these variables to each other, suggesting the possibility that the deviations from equilibrium are stationary, i.e. that the series are cointegrated. The equilibrium relation also contains the natural vacancy rate. In principle one would expect this to be a stationary variable, since it is bounded by zero and one. In limited samples, however, it may appear to be non-stationary. If the variables in (4) are cointegrated, a standard OLS regression in levels will have stationary residuals and yield consistent parameter point estimates.

Equations like (4) have been widely estimated on European data for all property types.[3] Demand drivers used in the literature vary depending on the property type under consideration, and these variables typically carry high *t*-ratios (although the standard errors are of questionable accuracy). In contrast, the supply term has had little explanatory power, probably because decent quality supply data are rarely

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[3] Early studies include Gardiner and Henneberry (1988 and 1991) and Silver and Goode (1990); see Hendershott, MacGregor and White (2002), for a survey and panel estimation of UK regional real rents.

available. Such an equation is naturally treated as the first step in an error-correction model. The error term from this equation is an estimate of the deviation of rents from equilibrium, $\ln R - \ln R^*$. In a second step the estimated error is inserted into an adjustment equation like (1), which can be estimated by OLS following the standard two-step procedure. If we take v to be stationary, we cannot estimate a deviation of v from v^* to be inserted into the adjustment equation. We may nevertheless include v as a regressor in the adjustment equation in line with those studies that estimate (1) treating v^* as being constant over time.[4] The value of v^* may then be inferred by evaluating this equation in steady-state. The identification of natural vacancies is discussed in more detail in Section 4.4.

4.2 Hidden vacancies

The rent variable is naturally interpreted as the real rent on currently signed leases. This is the rent concept measured by our rent index. At any instant, there are several reasons why occupied space may deviate from demand at this current rent level. The primary reason is that many tenants are locked into old contracts and can only adjust their space consumption at considerable transaction costs. Thus their demand depends on past, as well as current, rental rates. In addition, in a search market tenants may have a distorted view of current rent offers and form demand based on a perception of R other than average contract rent. Moreover, space consumption can typically only be adjusted through moves and even with one period contracts moving entails costs for both tenants and landlords. We can represent this difference between demand as a function of current rent and actual space occupancy by introducing the concept of hidden vacancies (that may be either positive or negative). The hidden vacancy rate, vh, may be implicitly defined by the market clearing condition:

$$D(R_t, E_t) \equiv (1 - v_t - vh_t)S_t \tag{5}$$

Alternatively, and algebraically more convenient, we may define a variable X as the ratio of occupied space, $(1\text{-}v)S$, to space demanded at current rents, $(1\text{-}v\text{-}vh)S$. That is, $X = (1\text{-}v)/(1\text{-}v\text{-}vh))$ and $\ln X \approx vh$. Then the market clearing identity is[5]

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[4] If v were non-stationary, one could test for the number of cointegrating vectors among the variables R, S, E and v. Based on two cointegrating vectors one could estimate two residuals that could be interpreted as the deviations of v and R from their equilibrium values.

[5] Note the difference between the identity (6) and equation (3) that characterizes an equilibrium toward which the market evolves but does not necessarily ever reach.

$$X_t \cdot D(R_t, E_t) \equiv (1 - v_t) S_t \tag{6}$$

If there were never any hidden vacancies ($X = 1$), then rents and vacancies would be mirror images of each other. R above equilibrium would imply v above equilibrium and vice versa, and there would be no point in specifying separate rates of adjustment to the rent and vacancy gaps as in equation (1).

If multi-period contracts were the only reason for occupied space deviating from demand at the current rent level, then X would simply be the ratio of demand at average rent to demand at current rent. Expressing these demands in the form of equation (2),

$$\ln X_t = \lambda_R (\ln Ravg_t - \ln R_t) , \tag{7}$$

where $Ravg_t$ is the average lease rate across all contracts at t.

To obtain a broader estimate of the hidden vacancy rate, we rewrite (3) and the log of (6) substituting from the demand equation (2):

$$\lambda_0 + \lambda_R \ln R^* + \lambda_E \ln E = \ln(1 - v^*) + \ln S \approx -v^* + \ln S$$

$$\lambda_0 + \lambda_R \ln R + \lambda_E \ln E + \ln X = \ln(1 - v) + \ln S \approx -v + \ln S$$

Subtracting the left side of the second from the first, equating it to the difference of the right hand sides and solving yields

$$\ln X \approx \lambda_R (\ln R^* - \ln R) + (v^* - v) . \tag{8}$$

Here the hidden vacancy rate is related to the percentage gap in demand caused by the deviations of rent and the vacancy rate from their respective equilibrium values.

In the empirical analysis we will calculate ln$X$ according to both (7) and (8). The difference between these two measures is an estimate of the extent to which the hidden vacancy rate reflects factors other than the existence of long-term contracts.

4.3 Dynamics of rent, vacancies and supply

Substituting the lagged error from the long-run equation (4) into equation (1) and adding variables to reflect concurrent shocks to employment and supply, we have a standard error-correction equation with the addition of lagged vacancies (implicitly the gap between lagged vacancies and the constant natural vacancy rate) as an extra disequilibrium indicator:

$$\Delta \ln R_t = \beta_0 - \beta_v v_{t-1} - \beta_R \varepsilon_{R,t-1} + \beta_E \Delta \ln E_t - \beta_S \Delta \ln S_t \,. \tag{9}$$

Here ε_R (=R-R*) is the residual from the cointegrating long-run regression. The immediate responses to employment and supply shocks are given by the coefficients β_E *and* β_S. The coefficients β_R and β_v, respectively, indicate the response of rents to deviations of rents and vacancies from their equilibrium values.

The fraction by which rent adjusts to disequilibrium ought to depend on how locked into existing contracts landlords are. To illustrate, if there is a large *v*-*v** gap and only a small percentage of leased space is rolling over (only a little of the existing space is "in play"), then a larger decline in rent may be needed to generate the same reduction in unoccupied space than would be the case if a high percentage of space were rolling over. That is, the estimated responses likely depend on the fraction of all leases expiring.

For the dynamics of vacancies we posit an analogue to (9):[6]

$$\Delta v_t = \eta_0 - \eta_v v_{t-1} + \eta_R \varepsilon_{R,t-1} - \eta_E \Delta \ln E_t + \eta_S \Delta \ln S_t \tag{10}$$

where η_R and η_v are the responses of the vacancy rate to the initial rent and vacancy rate gaps, and η_E and η_S indicate the impact of concurrent shocks to demand and supply.

Turning to the determinants of supply, traditional investment theory suggests that new construction is triggered when property values are sufficiently high relative to construction costs, i.e., a Tobin's q argument. Real-option theory qualifies the trigger rule and points out the role of uncertainty in the timing of new supply. Hence, in order to model supply one would want time series of property prices, construction costs and a measure of uncertainty. Unfortunately, reliable time series for these variables are currently not available for the Stockholm market.

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[6] Hendershott, Matysiak and Lizieri (1999) determine *v* by estimating the space demand function and then solving equation (5) with $X = 1$. Space demand is estimated in two steps: first a long run demand (equation (2)) and then an error-correction absorption equation. Doing this properly requires the long run demand elasticities in equations (2) and (4) be consistent and proxies for ΔX be included in the absorption equation.

To simplify supply modeling we take a short-cut by positing that changes in supply, in analogy with rents and vacancies, 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. Furthermore if real production costs did not change over time they would be subsumed in the constant. 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 allow for contemporaneous change in E to affect current supply. Thus, we specify the following supply model:

$$\Delta \ln S_t = \psi_0 - \psi_v v_- + \psi_\varepsilon \varepsilon_{R-}. \tag{11}$$

Here the notation v_- and ε_{R-} indicates an unspecified time lag from investment decisions to the time when new office space is put on the market. We will let the data determine the time lag.

4.4 The natural vacancy rate

Equations (9)-(11) jointly describe the dynamics of rent, vacancies and supply. Provided that the system is stable these processes will converge towards an equilibrium, characterized by $R = R^*$ and $v = v^*$. Assuming that the natural vacancy rate is a constant, v^*, it can be inferred from the estimated equations. The customary approach in the literature has been to define v^* as that rate which holds in a static world where rent and its determinants are all constant. Using that definition the natural vacancy rate can be estimated directly from equation (9) as the ratio of β_0 to β_v. In our three-equation model it could also be inferred from (10) or (11) in analogous fashion. To impose consistency on the estimated model one can restrict the intercepts in the three equations to yield the same estimate of v^*.

But the Stockholm office market has been far from stationary. *E, S* and, most importantly, R all display strong positive trends. In a non-stationary world it is more appropriate to define natural vacancies in relation to a trending equilibrium. To do so we note that the cointegrating equation (4) must hold at all t in steady-state. Differentiating this equation yields

$$\Delta \ln R^* = \gamma_E \Delta \ln E + \gamma_S \Delta \ln S \tag{12}$$

Solving this simultaneously with (9)-(11), while setting $\Delta v_t = \varepsilon_{R,t-i} = 0$ and all $v_{t-i} = v^*$, yields an estimate of v^* along with estimates of the equilibrium trends (Δln) in *E, S,* and *R*.

5. Empirical Analysis

Our model consists of the long-run relation (4) linking the levels of real rent, employment and supply and the dynamic relations (9)-(11) characterizing the development over time of real rent, the vacancy rate and supply, taking employment to be exogenously determined. The model is estimated in two steps, starting with the cointegrating relation and proceeding with the dynamic equations using the residuals from the cointegrating equation.

5.1 The long-run relation

Stationarity tests reported in the appendix are generally unable to reject the hypothesis that lnR, lnE and lnS are I(1), whereas tests for a unit root in v are indecisive.[7] Based on this and the fact that v is logically bounded between zero and one, we treat v as I(0). Johansen trace tests suggest the presence of one or two cointegrating relations between lnR, lnE and lnS. Based on our model discussion above we choose to estimate a model with one cointegrating vector. The estimated coefficients of the cointegrating equation are quite sensitive to the choice of starting date before 1977 but change little for later starting dates. We take this as an indication that deregulation was effectively completed only in 1977 and base the econometric analysis on data starting in that year. Another reason for discarding the first few years of data is that the number of leases was quite small during some of these years but effectively doubled between 1976 and 1977, thereby increasing the accuracy of the rent index estimates.

Results based on 1977-2002 data are reported in Table 4. The price elasticity (unity divided by the ln*S* coefficient) is -0.55 and the income elasticity (the ln*E* coefficient divided by the ln*S* coefficient) is 1.04. For London data, the corresponding elasticities were – 0.24 and 0.92 (Hendershott, Matysiak and Lizieri, 1999). That is, the income elasticities are similar, but the Stockholm price elasticity is about double.

Figure 3 depicts the estimated equilibrium real rent (R^*), the observed real rent on new leases (*R*), and the predicted rent level (which is discussed in the next section). Actual rent tracked equilibrium reasonably closely through 1985, but was far above equilibrium between 1986 and 1990, having jumped

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[7] According to the Phillips-Perron test non-stationarity cannot be rejected for any of the variables. According to the augmented Dickey-Fuller test non-stationarity can be rejected at the 6 per cent level for ln*E* and for *v*. Taking stationarity as the null hypothesis, this can only be rejected for ln*S* at conventional levels.

about twice the increase in equilibrium during the late 1980s. After being back on track for about five years, actual was below equilibrium during the 1997-99 period, lagging the sharp increase in equilibrium rent during the second half of the 1990s. This difference between R and R^*, i.e., the residual from the cointegration equation, is employed in the short-run estimation.

5.2 The dynamics

In estimating the three-equation system (9)-(11) we account for the possibility that the error terms may be correlated, and use the method of seemingly unrelated regressions (SUR). We generally allow for lagged one- and two-period changes in the left-hand variable in order to eliminate residual autocorrelation. The rent adjustment equation includes two lags of the rate of change of rents, whereas the vacancy and supply equations do not include any lagged terms. In the rent and vacancy equations the disequilibrium variables – the errors from the cointegrating equation and vacancies – are both lagged one period in keeping with the standard error-correction formulation. In the supply equation the corresponding terms only get significant at lag t-3. We interpret this as indicating the time lag from decision to completion of new construction.

The estimates are presented in Table 5. In the interest of parsimony we restricted the coefficients on lagged one- and two-period rent change in the rent adjustment equation to take the same value.[8] The error-correction mechanism works as anticipated; the rent and vacancy rate gap variables have correctly signed and statistically significant effects. Consider as an example an initial position with rents being ten percent below equilibrium. Over the next year this will cause rents to go up by 3.8 percent according to the baseline model, closing over a third of the gap. But it will also have cross effects causing the vacancy rate to decline by 0.6 percentage points and new construction to increase by 2.4 percent three years later. The induced deviation of vacancies from their equilibrium level will in turn speed up the adjustment processes of rents and investment in following periods, and the increase in building will modify the rent increase needed to restore equilibrium. Rents may approach the new equilibrium smoothly or cyclically depending on details of the parameter estimates. The interplay between rent and vacancy adjustment will be further illustrated in Section 6 by means of simulations.

We have explored the hypothesis that the rate of adjustment towards equilibrium depends on the fraction of leases rolling over. Adding interaction terms between this variable and the rent gap and vacancy rate yielded generally insignificant estimates. This may be due to imprecision in measuring this

[8] Unrestricted estimation yields a small and insignificant lag one coefficient (-0.19) but a large and significant lag two coefficient (-0.44). The difference between the coefficients is not significant, however. The P-value for a Wald test is 0.21. Constraining the lagged rent coefficients to be equal has a negligible impact on the other coefficients.

variable, which was constructed from our observations on new leases. We also note that the variable is dominated by a strong trend as the average lease length increased from one to three years during the sample period with little year-to-year variation (see Table 1).

Contemporaneous changes to supply and employment are included in both the rent and vacancy rate equations in a symmetric fashion so as to allow for an immediate impact of supply and demand shocks. The coefficients for the employment disturbance are economically and statistically significant in both equations. The short-run elasticity of rent with respect to employment is 1.2, compared to an equilibrium elasticity of 1.9. Furthermore, a one percent increase in employment is met by an immediate decrease of a third of a percentage point in the vacancy rate. The supply coefficients on the other hand are not statistically significant in either equation. This may reflect the impact of building lags; with long term contracts it may be building starts rather than completions that affect rents. The supply coefficient in the rent adjustment equation is large, however, indicating a short-term elasticity of rent with respect to supply of above one, although not statistically significant. In the rent adjustment equation lagged rent changes come in with a negative sign. The estimated coefficient, constrained to be equal at both lags, is negative (-0.32). This indicates an element of cyclicality in the adjustment process.

The bottom panel of Table 5 presents the supply equation. As noted, the vacancy and rent dis-equilibrium variables are significant only when lagged three years. Other lags add nothing to the explanatory power, nor do current or lagged employment changes. We take this as an indication of time-to-build effects; only information available a few years back in time affects today's addition to supply. The estimated equation suggests that Stockholm supply is very inelastic; the coefficient on the rent equilibrium error is only 0.024. Current rents 20 percent above normal will only induce an half percent addition to the stock of office space. Vacancies have similarly small effects. This may reflect a lack of available new building space, as suggested by the strong upward trend in real rents. Another specification of the supply equation, including asset price and building costs, might of course yield a stronger supply response.

The estimated equations account for more than half of the variation in rent and vacancy change (adjusted R^2 of 0.6 in both equations), whereas the explanatory power of the supply equation is lower (R^2 = 0.3). To illustrate the overall fit of the equations, we have dynamically simulated the model. We start with the observed values of R, v and S in 1977 and compute the changes between 1977 and 1978 using current actual changes in E and lagged actual values of R, v and S for 1977 (and 1976 for R) as well as the lagged (1977) value of R^* obtained by solving the long-run relationship using 1977 values of S and E. For 1979 and later years we use the simulated 1978 values of R, v and S, not the actual values. And so on through 2002.

The actual and predicted values of *R* and *v*, respectively, are plotted in Figures 3 and 4**.** They indicate that the model tracks the broad patterns in rent and vacancies reasonably well. In particular the model captures the turning points of the cycle in the late 1980s and early 1990s. However, it under-predicts the volatility of the cycle. Looking at rents, nearly half of the sharp 50 percent rise from 1985 to 1990 is missed and the same for the sharp reversal in 1991-93. Predicted rent level is back on track in 1995 and following years until the model fails to capture the 2002 rent decline. Turning to the vacancy rate, the model overpredicts vacancies during the 1980s but gets the timing of the surge in vacancies peaking at 22 percent in 1994 and the subsequent reversal right. However, only 60 percent of the magnitude is explained. From the mid 1990s the model tracks actual vacancies quite closely, but the surge in vacancies in 2002 is underpredicted.

5.3 Natural vacancies

The natural vacancy rate is a key variable in characterizing a rental market. Indeed much of the earlier literature focused on this (see the Hendershott, MacGregor and Tse, 2002, survey). The prevailing approach is to define the natural vacancy rate based on a stationary equilibrium. Employing this definition, the natural rate can be computed as the negative of the ratio of the constant term to the vacancy rate coefficient from any of the three dynamic equations. The values for the baseline model are 0.094 (rent equation), 0.125 (vacancy) and 0.193 (supply). When the coefficients are constrained to yield equal values across the three equations, the estimate is 0.115. However, inspection of the vacancy plot in Figure 2 suggests that a two-digit natural vacancy rate is implausibly high. Observed vacancies exceeded ten percent in only four of the 30 years and remained under five percent for nearly all of the first two decades.

Instead we propose, as discussed in Section 4.4, defining the natural vacancy rate in terms of a trending equilibrium, where the trends are restricted by the cointegrating relation. This yields the far more plausible natural rate of 7.1 percent indicated at the bottom of the table. Not surprisingly, the trend values solved for are close to the mean growth rates of *R, E*, and *S* over the estimation period.

5.4 Hidden vacancies and staggered lease contracts

We conjectured that variation in the hidden vacancy rate defined by the ln*X* variable is primarily explained by tenants and landlords being locked into long-term leases. If historical rent levels are lower than current rent, then we would expect space occupancy to exceed demand at current rent, i.e., positive hidden vacancies would exist. Generally speaking there should be a positive correlation between hidden vacancies and the difference between current and average rents. Our long run rent equation gives estimates of λ_R ($1/\gamma_S$ = -0.555) and a time series on lnR^* - ln$R$ (= ε, the residual). The estimate of v^* is 0.0711. Thus our alternative estimates of the hidden vacancy rate from equations (7) and (8) are

$$\ln X = 0.555(\ln R - \ln Ravg) \tag{7'}$$

$$\ln X = 0.555(\ln R - \ln R^*) + 0.0711 - v\,. \tag{8'}$$

Figure 5 plots these two measures of the hidden vacancy rate. They are clearly positively correlated but with pronounced differences over extended periods. The broad measure is higher from 1981 to 1992 and lower for all years thereafter. For the earlier period this difference between the two measures reflects the combination of below natural-rate vacancies (until 1989) and above equilibrium average rents (from 1986). During the latter period, when the broad measure is lower than the narrow measure, vacancies were above the natural rate until 1997 and average rents below equilibrium from 1995 to 2001. Throughout the 1980s the narrow measure is constantly close to zero. With contracts remaining quite short (two years on average) the difference between rents on new leases and the average rent was rather small. Even when rents accelerated in 1986, narrow hidden vacancies only increased to just above 7 percent. The broader measure on the other hand increased much further reaching almost 17 percent in 1986 and 1987 and 18 percent in 1990, indicating that tenants were slow to adapt their space occupancy even as contracts were renewed.

In the depth of the crisis in 1991-92, hidden vacancies according to both measures turned strongly negative. According to our estimates the sharp drop in rents was the combination of a decrease in equilibrium rent and an alignment between market and equilibrium rents. Negative hidden vacancies were simply the other side of two-digit open vacancies. By 1993 this underconsumption of space was almost fully accounted for by the difference between current and average rent, i.e. the broad and narrow measures only differed by 1.5 percent. The market recovery during the latter part of the 1990s led to an increase in hidden vacancies. The narrow measure peaked at almost 13 percent in 2000. Interestingly the broad measure remained negative throughout the 1990s and only became marginally positive in 2000 and 2001. Apparently tenants were reluctant to increase space consumption despite below-equilibrium rent levels.

6. Simulating Employment Shocks

The best way to understand the working of the model is by simulating the impact over time on R and v of employment shocks. We start from an equilibrium situation with R, E, and S all growing at their trend rates and vacancies being at the natural rate. We consider the impact of a 10 percent permanent increase in the level of employment relative to its trend growth rate. Figure 6 illustrates the impact on real rent, supply and vacancies. The top panel shows the development over time of the equilibrium rent level after the employment shock relative to its level in the absence of the employment shock, based on the cointegrating relation in Table 4.

The result is an immediate increase in equilibrium rent by 21 percent followed by a slow adjustment downwards as supply is adjusted (with a three year lag). Because the increase in supply is very small, the long-run equilibrium rent path remains 18 percent above the original path. The graph also illustrates the development of the current rent level relative to its path in the absence of the disturbance. We see that it rises by a little over half of the equilibrium increase in the first year and most of the rest in the second. It continues to rise for the next three years, overshooting by about 5 percentage points (25 percent of the equilibrium increase). This unwinds over the next eight years.

About half of the expansion in space demand is initially met by a three-and-a-half percentage point decline in the vacancy rate. This is slowly reversed over the next decade. By the fourth year, rent is above equilibrium but vacancy is still below equilibrium. This may seem implausible: with rent above equilibrium we would think demand would be insufficient and thus vacancy would be above equilibrium. This paradox is resolved by hidden vacancies, the bottom line in the graph, which amount to around 3.5 percent of space. While the rent on new leases is above equilibrium, some old leases carry below equilibrium rents and thus space occupancy is higher than the new lease rate indicates and the recorded vacancy rate is about two percentage points below equilibrium (total, recorded plus hidden, vacancies are above equilibrium, as expected). Adding hidden and open vacancies, the "total" vacancy rate exceeds the natural level of 7 percent throughout the adjustment process.

The assumption of a single permanent shock may not fully capture actual rent cycles that often appear to be driven by a series of disturbances. To simulate the dynamics of rents and vacancies during such a cycle we have assumed a sequence of four annual positive five percent shocks to employment followed by four negative five percent shocks. The results are shown in Figure 7. The employment cycle drives up equilibrium rents by more than 40 percent at the peak in year 5, with market rents following quite closely. When the process reverses and equilibrium rent starts falling, market rents follow with a lag of about one year. During years 6-8 rents are roughly ten percent above equilibrium. Rent then declines to about five percent below equilibrium in years 12-15 and finally approaches equilibrium from below.

These developments give rise to quite a strong cycle in open vacancies, first decreasing to below 2 percent and then increasing up to 11 percent in response to the employment reversal and the supply increase. The hidden vacancy rate, in contrast, surges to six percent in year 5 with the increase in real rent above equilibrium, and then falls to minus four percent in year 12, when rents are furthest below equilibrium.

7. Conclusion

We draw a distinction between long run (or normal) demand for space, depending on real rent on newly-written leases and a demand driver only, and short run demand (defined to be equal to observed space occupancy), which depends on history, in particular the real rent on all existing leases. Space consumption may be locked in by long-term contracts in conjunction with transaction costs and restrictions on the breach of contracts. If most space had been leased under long-term contracts at earlier low rental rates, then current space consumption would be higher than if all space were being leased at today's high current rents. We refer to this excess space demand as hidden vacancies, vacancies that may turn into open vacancies in the future when leases roll over if market rent remains at its current level. We show that the narrow measure of hidden vacancies based on the difference in demand between current and average rent tracks our broader measure of hidden vacancies fairly well, but far from perfectly.

Our model indicates that a sudden increase in space demand is initially met by a sharp decrease in vacancies, as well as a modest increase in rents (and the creation of hidden vacancies). But the vacancy decline is only temporary. In the intermediate run, rents must rise farther to choke off demand. And because many space users have longer term leases and thus do not immediately face the higher rent, rents overshoot this rise in equilibrium rent to restrict that limited portion of demand facing the higher lease rate. Eventually, of course, new supply comes on line and existing leases roll over, both of which reverse the rent increase. Future research should examine how adjustment in other space markets compares with our estimates for the Stockholm office market.

In equilibrium the model converges to an equilibrium growth rate in real rents and a constant ("natural") vacancy rate. Thus, we compute the natural vacancy rate based on such a trending equilibrium. This yields a far more plausible estimate of 7.1 percent than the customary computation, which assumes a stationary equilibrium where real rent is constant and yields an implausibly high (double digit) estimate. Researchers need to consider the nature of the equilibrium carefully in this and other contexts.

Given the important role of long-term contracts in understanding hidden vacancies one would expect the whole dynamics of the process to depend on fraction of all contracts that is written each year. We have explored the hypothesis that the pace of adjustment, and hence the extent of hidden vacancies and the implied natural vacancy rate, depends on the fraction of all contracts that are renegotiated but were unable to identify such an effect econometrically. Future research should investigate this hypothesis more fully on alternative data sets.

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Table 1. **Number of leases, number of properties, average lease length, and fraction of new contracts.**

Year	Number of leases	Number of properties	Average lease length (months)	Fraction new contracts
1972	59	16	14.2	1.00
1973	18	12	17.6	1.00
1974	24	10	16.3	0.67
1975	31	13	12.8	0.78
1976	35	19	25.5	0.74
1977	74	16	17.6	0.75
1978	43	16	15.3	0.75
1979	60	14	20.2	0.75
1980	57	22	18.8	0.55
1981	77	23	22.1	0.52
1982	64	21	27.6	0.58
1983	71	20	29.5	0.55
1984	56	20	28.3	0.45
1985	45	18	37.6	0.42
1986	48	23	29.8	0.48
1987	73	35	40.9	0.44
1988	112	33	31.9	0.45
1989	149	36	39.4	0.42
1990	105	40	39.1	0.35
1991	61	36	35.7	0.34
1992	87	41	36.2	0.40
1993	96	37	39.4	0.37
1994	105	31	40.8	0.36
1995	69	29	39.8	0.37
1996	62	26	37.5	0.37
1997	58	39	38.1	0.37
1998	68	63	37.9	0.37
1999	183	79	40.3	0.30
2000	198	73	39.2	0.36
2001	181	64	37.8	0.33
2002	116	41	36.3	0.32
Total	2,485			

Note: *Number of leases* refers to the number of contracts in our data base first effective in a certain year. *Number of properties* refers to properties where the offices covered by those leases are located. *Average lease length* refers to the unweighted average across these contracts. *Fraction new contracts* is calculated as described in the text.

Table 2. **Definition of variables in the rent index regression and descriptives for 1972–2002.**

Variable	Definition	Mean	Std. dev.
Rent	Rent per square meter (per year), real (in 1992 SEK).	2,046.0	1,338.7
Size	Total rental space per lease unit (in thousand square meters).	0.2964	0.3797
Age	Effective age of the building, in the year when the lease contract was written, as estimated by the assessment authority taking renovations into account (in years).	41.9	20.1
Renego	Dummy = 1 if contract is the result of renegotiations with the previous tenant.	0.436	-
CPI	Percentage of rent that is indexed to the Consumer Price Index.	0.799	0.377
Term	Length of the rental period (in months).	33.53	16.40
Heat_1	Dummy for heating clause = 1 for leases where the tenant provides and pays for heating. (1998–2002 only).	0.0056	-
Heat_2	Dummy for heating clause = 1 for leases where base rent is net of heating expenses, which are charged separately (1998–2002 only).	0.0640	-
Heat_3	Dummy for heating clause = 1 for leases where type of heating clause is unknown (1998–2002 only).	0.0241	-
Concession	Dummy = 1 for concessions and graduated rent for leases 1992–2002 (only); otherwise = 0. (Rents for leases 1972–1991 are transformed to effective rents).	0.0716	-
Unknown_esc	Dummy =1 if lease escalation clause is unknown (1998–2002 only).	0.0314	-
Prop_tax	Dummy =1 if base rent is net of property tax (1992–1997 only).	0.1163	-

Table 3. **OLS estimates of the hedonic rent index model for 1972–2002. Dependent variable is ln*Rent*.**

	Coefficient	*t*-value
Intercept	5.0213	26.74
Heat_1	0.0401	0.66
Heat_2	0.0909	3.18
Heat_3	–0.0372	–0.95
Prop_tax	–0.0196	–0.86
Concession	–0.0192	–1.10
Renego	–0.0468	–5.01
Unknown_esc	0.0747	2.26
CPI	0.0529	3.22
Size	0.1970	6.04
$Size^2$	–0.0803	–4.70
Adjusted R^2	0.962	

Note: The model includes year dummies, *Term* and *Term* squared interacted with year dummies and 182 property dummies. *Age* was (close to being) a linear combination of other variables and thus excluded.

Table 4. **OLS estimates of cointegrating equation, 1977–2002. Dependent variable is ln*R*.**

	Coefficient	*t*-value
Intercept	13.499	1.40
Ln*S*	–1.803	–2.42
Ln*E*	1.880	9.08
Adjusted R^2	0.786	

Table 5. **Seemingly-unrelated-regression estimates of error-correction model**

Dependent Variable	Coeff	t-value
Rent		
Intercept	0.1881	(3.04)
dlnR(t-1)	-0.3217	(-2.43)
dlnR(t-2)	-0.3217	(-2.43)
DlnS	-1.3783	(-0.72)
DlnE	1.2159	(3.40)
v(t-1)	-1.9742	(-3.48)
ε(t-1)	-0.3780	(-3.62)
Adjusted R^2	0.581	
Vacancy rate		
Intercept	0.0292	(3.78)
DlnS	-0.0809	(-0.22)
DlnE	-0.3579	(-4.97)
v(t-1)	-0.2327	(-3.58)
ε(t-1)	0.0604	(2.85)
Adjusted R^2	0.579	
Supply		
Intercept	0.0146	(6.40)
v(t-3)	-0.0759	(-2.79)
ε(t-3)	0.0236	(2.71)
Adjusted R^2	0.322	
Natural vacancy	0.0711	
dlog*R* trend	0.0460	
dlog*S* trend	0.0092	
dlog*E* trend	0.0333	

Figure 1. **Real rent in Stockholm 1972–2002 (SEK per square meter, 1992 price level) on new leases and average rent across all leases.**

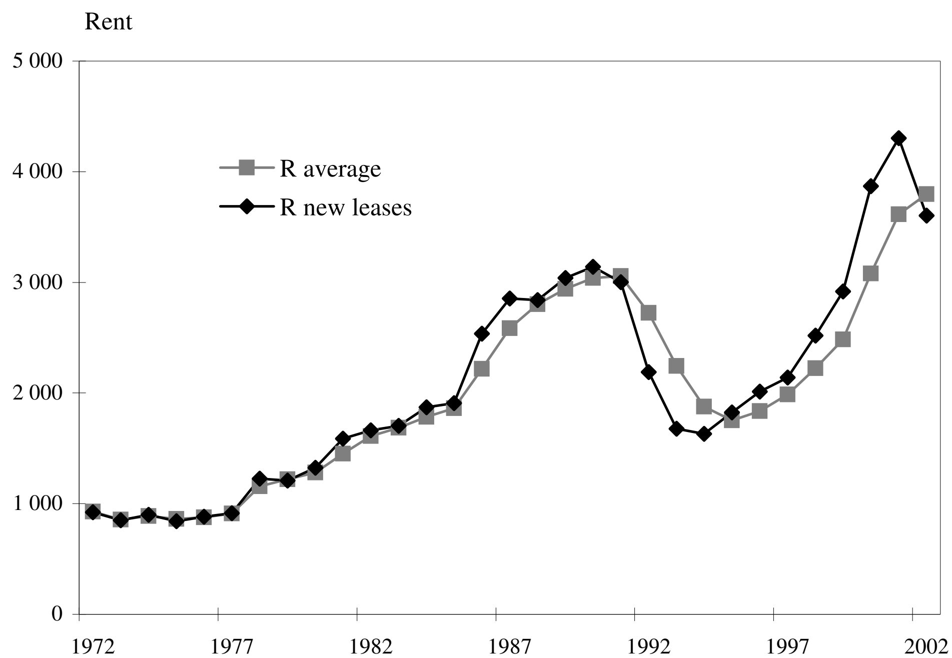


Figure 2. **Real rent (new leases), vacancy rate, supply of office space and employment in service industries, Stockholm 1972–2002.**

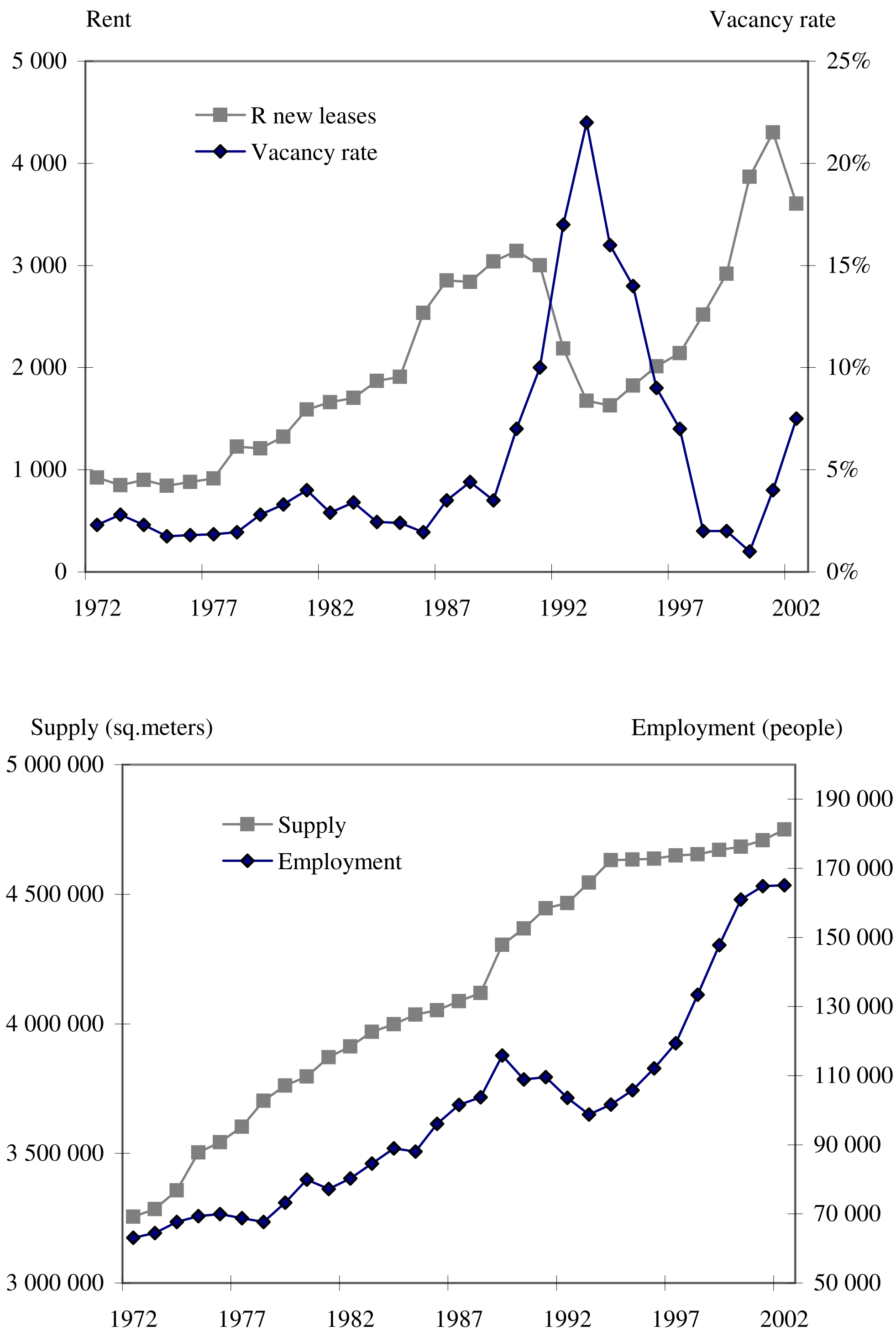


Figure 3. **Real rent for new leases, estimated equilibrium rent (*R**), and predicted real rent, 1977–2002.**

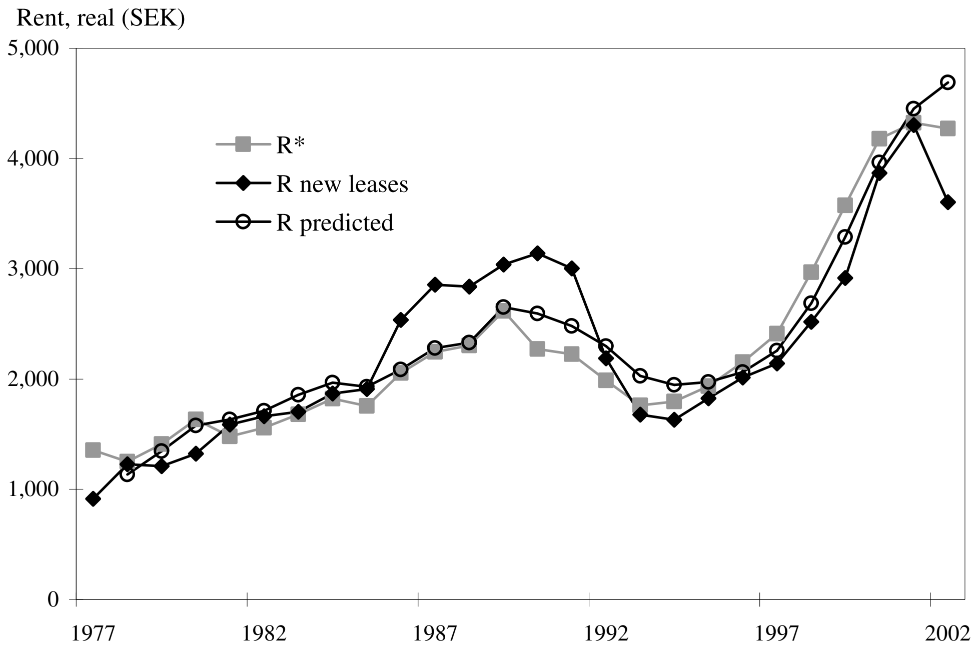


Figure 4. **Actual and predicted vacancy rate, 1978–2002.**

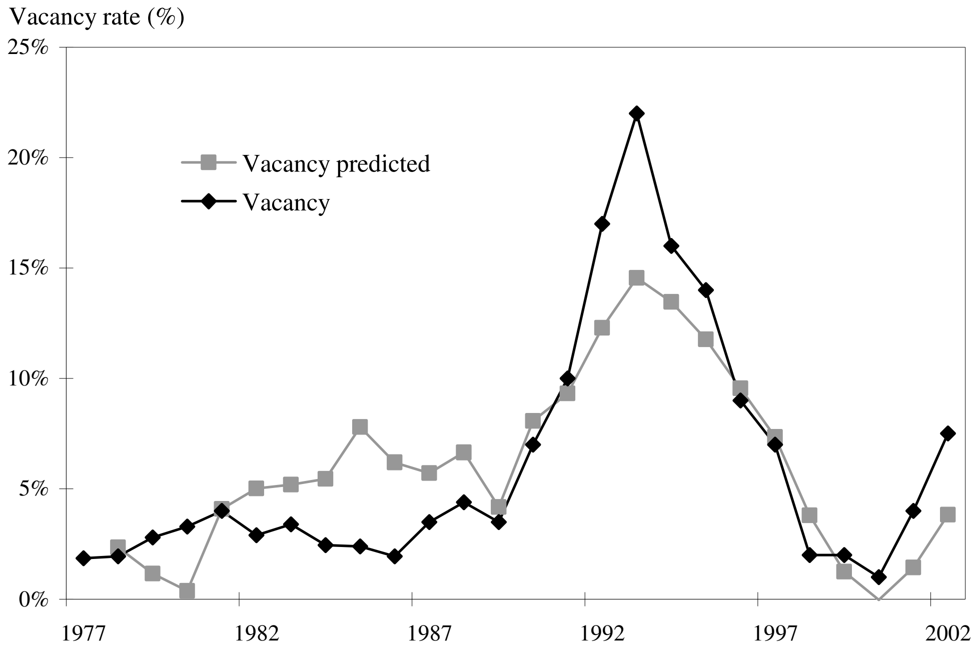


Figure 5. **Two measures of hidden vacancies, 1977–2002.**

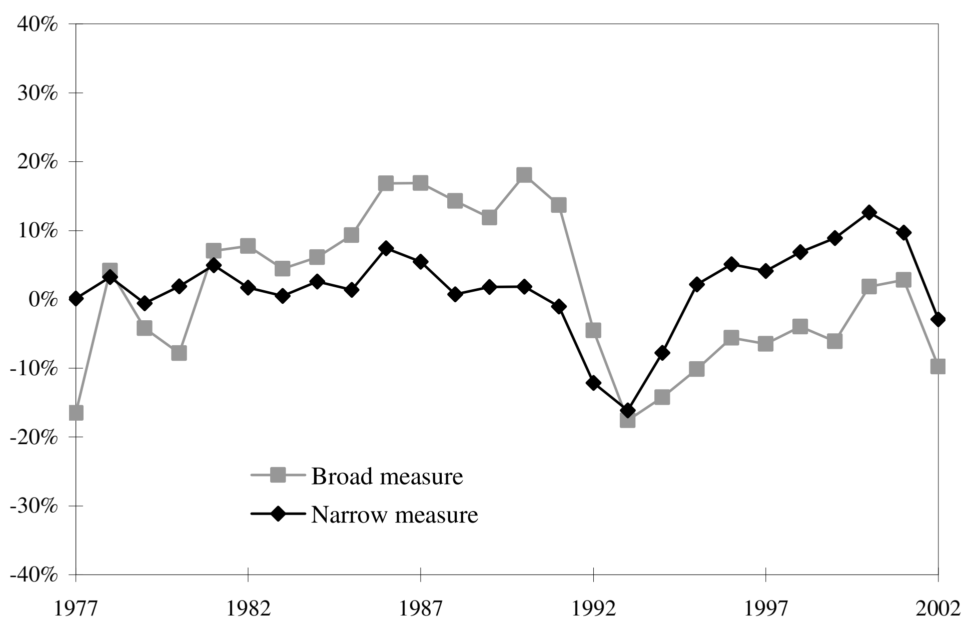
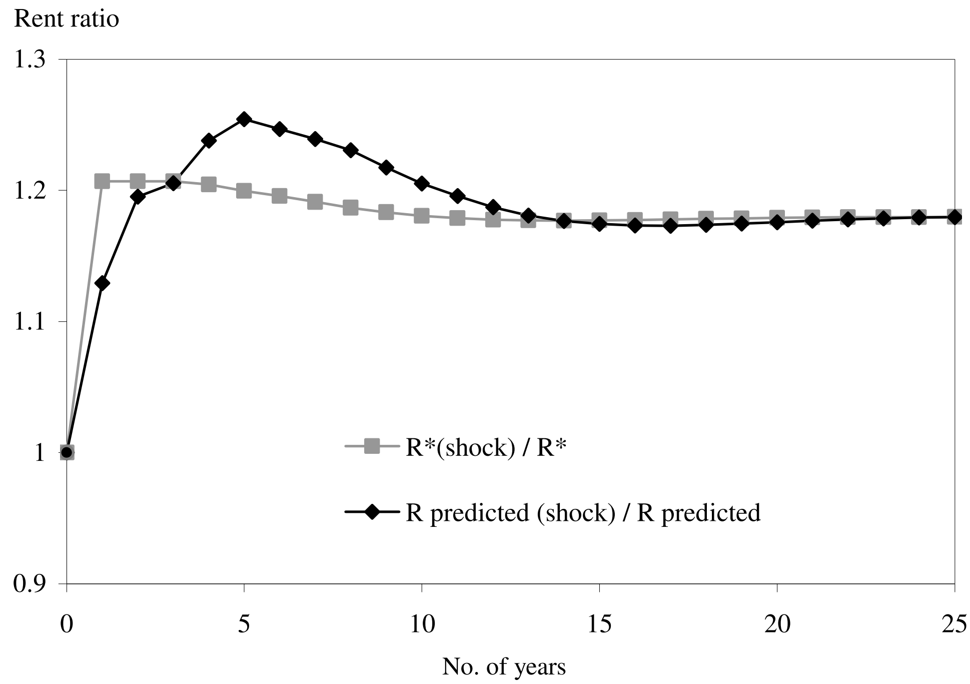


Figure 6. **Simulated impact of a permanent 10 percent employment increase in addition to trend.**



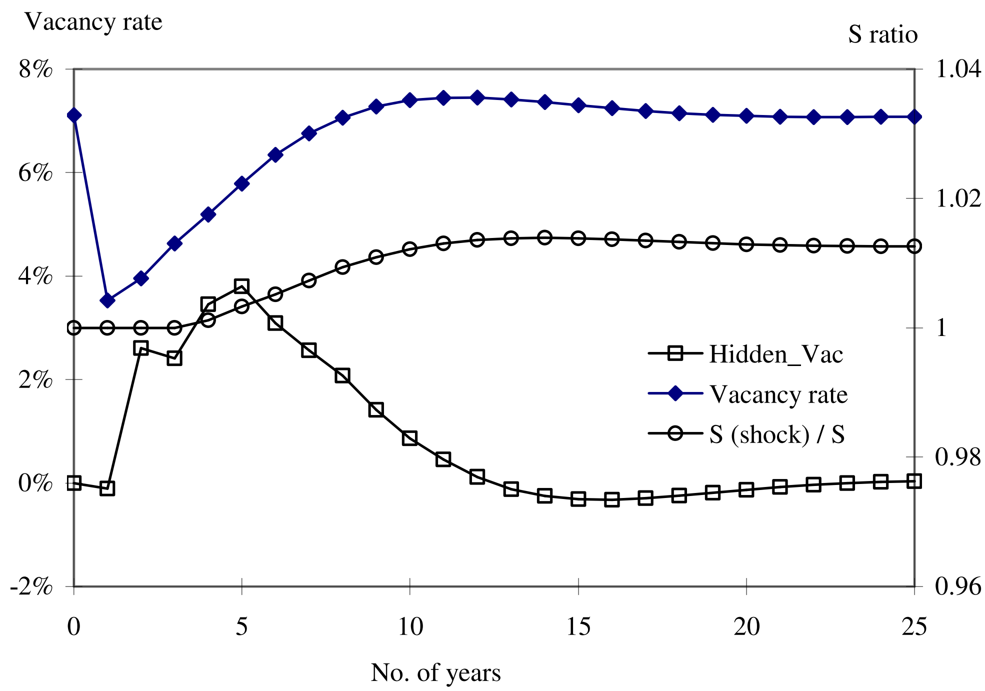
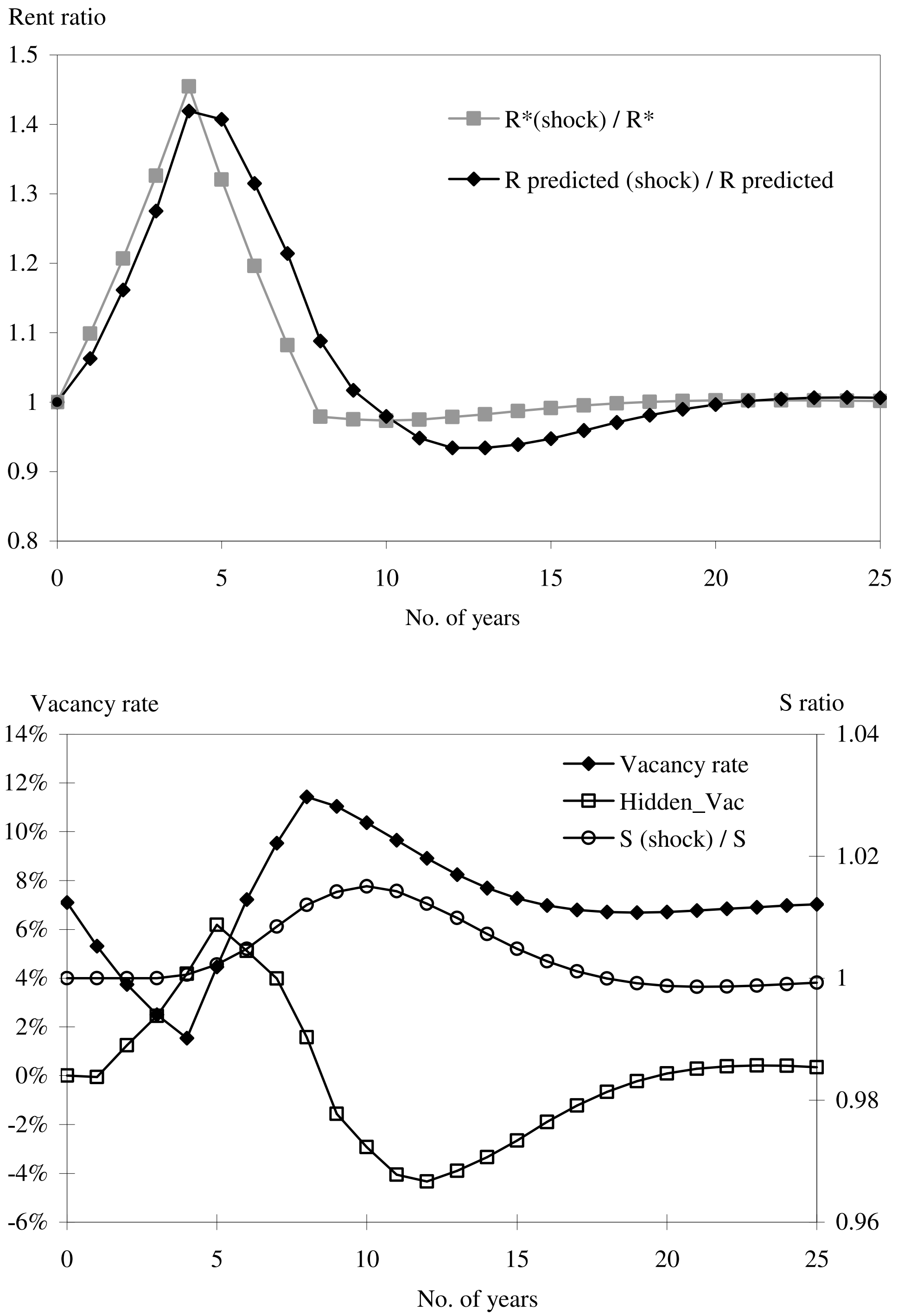


Figure 7. **Simulated impact of an employment cycle: four years of 5 percent increase over trend, followed by four years of 5 percent decrease below trend.**



APPENDIX: TESTS FOR UNIT ROOTS, STATIONARITY AND COINTEGRATION.

Unit root and stationarity tests, 1977-2002 data

	ADF		*PP*		*KPSS*	
Variable	*test statistic*	*prob. value*	*test statistic*	*prob. value*	*test statistic*	*prob. value*
ln*R*	-2.49	0.33	-1.92	0.61	0.102	>0.10
ln*E*	-3.54	0.06	-1.80	0.68	0.085	>0.10
ln*S*	-0.90	0.94	-1.08	0.91	0.147	<0.05
vac	-3.52	0.06	-1.83	0.66	0.104	>0.10

ADF: Augmented Dickey-Fuller unit root test. Null hypothesis: unit root. Intercept and trend in test equation. Automatic selection of no. of lags (maximum=3). MacKinnon (1996) one-sided p-values.
PP: Phillips-Perron unit root test. Null hypothesis: unit root. Intercept and trend in test equation. Automatic selection of bandwidth. MacKinnon (1996) one-sided p-values.
KPPS: Kwiatkowski-Phillips-Schmidt-Shin (1992) test. Null hypothesis: stationarity.Intercept and trend in test equation. Automatic selection of bandwidth. Critical values at the 5% and 10% levels are 0.146 and 0.119, respectively.

Cointegration test for ln*R*,ln*E* and ln*S*, 1977-2002 data

No. of cointegrating vectors	*Johansen test statistic*	*Prob. value*
None	46.06	0.0023
At most 1	14.66	0.1545
At most 2	3.77	0.0522

Johansen unrestricted rank test allowing for quadratic deterministic trend. Intercept and three lags of differenced variables in test equation. MacKinnon-Haug-Michelis (1999) p-values.