Predictable or Not? Forecasting Office Markets with a Simultaneous Equation Approach

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Abstract

The main objective of this paper is to elucidate the capability of time-series regression models to capture and forecast movements in occupancy patterns, rental rates and construction activity.

The model presented is a three-stage simultaneous equation model. The first stage incorporates the office space market in terms of occupied space and absorption of new space. The second stage captures the adjustment of office rents to changing market conditions and the third stage specifies the supply response to market signals in terms of construction of new office space. The standard simultaneous model is subsequently modified to account for the specific characteristics using the New York market as a case study. The results demonstrate that the market reacts efficiently and predictably to changes in market conditions. The significance of the estimated parameters underscores the general validity and robustness of the simultaneous equation approach in modeling real estate markets. The modifications of the standard model, notably the inclusion of sublet space in the rent equation, contributed considerably to improving the explanatory power of the model. Finally, we test whether a non-linear function performs better than the original linear approach and find mixed evidence based on the limited empirical dataset of this study.

1 Introduction

This paper is part of a joint effort to explore the predictability of the U.S. and German office rental markets by comparing the results of two different forecasting models for New York City and a number of German market areas. Within this framework, the present paper documents the findings for testing the model with New York City office market data. In a second forthcoming paper, Dobner and Werling (2006) explore the possibility of forecasting German office markets with a reduced-form approach to model expected supply growth.

While the use of econometric forecasting models is well established in U.S. office market research, it is a fairly recent phenomenon in Germany for a number of reasons. Firstly, reliable time series data on German office market has been scarce in the past, thus precluding the application of all but the most basic forecasting tools. Secondly and more importantly, causal forecasting models are based on the assumption that market participants behave by and large rationally. German real estate markets are arguably less transparent and consequently less efficient than US markets. If that were the case, these causal forecasting models would be bound to fail in markets that are not sufficiently transparent and do not appear to follow the economic principles underlying these models such as the price elasticity of demand. Such effects may be brought about by intervening institutional factors that have a distorting effect on market prices.

It is not within the scope of this paper, however, to determine whether German or U.S. office markets generally conform to the efficient market hypothesis. Nevertheless, we aim to find important clues for assessing the workings of these markets by testing two types of models. The first model is a three-stage simultaneous equation system which is empirically tested using New York office market data. The second model uses a non-linear function to explain the development of office supply.

The simultaneous equation model is more comprehensive than the reduced-form approach in that it aims to explain not only new supply but also occupancy and rent levels which are exogenous to the second model. The second model may be plugged into the larger framework of the simultaneous equation model, however, to test whether this yields better empirical results than the linear approach. The first stage of the simultaneous equation model estimates occupied space and absorption of new space using a lagged partial adjustment approach. The second stage captures the adjustment of office rents to changing market conditions and the third stage specifies the supply response to market signals in terms of construction of new office space. The standard simultaneous equation model as laid out by Wheaton et al. (1997) is modified and developed further to account for the specific characteristics of the New York office market, particularly the importance of sublease space and the spread of Class A and Class B rental rates.

The remainder of this paper is organized as follows. After reviewing the relevant literature and explaining the methodology and differing assumptions, we proceed to empirically test the model in the context of the New York City office market.

2 Previous studies

The overall model structure and underlying theoretical principles have been utilized and refined in a number of earlier studies. One of the first researchers to use a similar three-component framework was Rosen (1984) who estimated demand (proxied by the amount of occupied space), supply (new construction), and rents for the San Francisco office market. At the core of this model is the assumption that the deviation of the actual vacancy rate from equilibrium or 'natural' vacancy rate determines the level of office rents. Hekman (1985) specified rent and supply equations for a panel of 14 cities. While his estimation results exhibited some problems with statistical significance levels, Hekman was among the first to introduce a measure of capital availability (ten year treasury bond rate minus three month T-bill rate) which has been used in subsequent econometric studies of the supply of office space (Viezer 1999) and is also used in this study. Wheaton (1987) developed a structural model of demand for and supply of office space. Demand (proxied by net absorption of space was specified as a function of real rents, the level of office employment and the rate of employment growth. In the absence of data on rents, vacancy rates were used and proved to be a significant determinant of absorption rates with a lag of three years. Wheaton's office construction equation incorporated the variables rents, vacancy, employment growth rates, inventory size, construction cost and nominal interest rates. The latter two variables, however, turned out to be insignificant in the empirical estimation. Pollakowski, Wachter and Lynford (1992) applied a similar modeling framework with an emphasis on the relevance of market size using pooled data from 21 cities across the US. The empirical estimation examined a number of different specifications with dummy variables capturing unobserved city-specific factors. This strand of models has been subject to criticism because of their failure to link rent to the capital markets. Hendershott, Lizieri and Matysiak (1999) specify a model for London which provides this link by incorporating the real gross redemption yield on 20 year government stocks as well as operating expense ratios and the replacement cost as independent variables in the rent equation. The performance of the model is enhanced by the use of time dummy variables for years with values not well explained by the OLS model. While the model adopted for this study is more similar to the specifications of the first strand of models as used by Wheaton (1987) and Wheaton, Torto and Evans (1997) in an application to the London market, the significance of the capital markets in determining rent as contained in the Hendershott model, have been tested but have not been found to enhance the explanatory power of the model for the New York case. The adaptation of the Wheaton model to the specific conditions of the New York market is also documented in Fuerst (2005a). Despite the failed attempt to link capital markets to rent levels in the empirical estimation of the New York model, dummy variables turned out to be helpful in capturing some of the effects in the immediate aftermath of the 9/11 attack. The theoretical framework of the three components is described in more detail below followed by the results of the empirical estimations of the models in the US and German markets.

3 Methodology and data

3.1 The model

The simultaneous equation model presented in this section consists of three interrelated modules. The first module yields occupancy levels and absorption rates. This information is in turn used in the second module which estimates rent levels. Again, the output of this module is used in the third module which yields new construction of office space. Thus, this model explains the most important variables of supply of and demand for office space intrinsically with a minimum of exogenous information.

Demand for Office Space: Estimating absorption and occupied office space

The main determinants of the total demand for office space in a given city are assumed to be the level of office employment and a measure of the intensity of space usage expressed as the average amount of square feet per office worker. Thus, the hypothetical level of occupied space is:

$$OS_t^* = \alpha_0 + E_t(\alpha_1 + \phi_1 \frac{(E_t - E_{t-1})}{E_t} - \phi_2 R_{t-1}) + Z_1 \qquad (1.1)$$

where E_t is the current total number of office workers in a city and R_{t-1} is the rent level of the previous period. The coefficient ϕ_1 denotes the degree to which dynamic growth in office employment translates into additional space consumption in excess of the space required to accommodate the employees of a firm. The inclusion of this dynamic aspect of office employment besides the variable representing the overall employment level is based on the empirical observation that firms tend to rent more space than needed based on their current operational needs. This phenomenon is analogous to purchasing an option in the financial markets whereby a buyer acquires the right to trade at a fixed price regardless of the actual future price of the asset in question. In the real estate market, office firms acquire an 'option' by leasing additional space in anticipation of further expansion in terms of employment and office space as well as further increases in rental rates in the overall marketplace. This phenomenon is key to understanding the reaction of the office market after the 9/11 attack on New York City. The coefficient ϕ_2 is a measure of the price elasticity of demand, i.e. the proportionate change in office space per worker that occurs in response to changes in rents. The underlying assumption is that firms will choose to consume less space per worker in times of high rents and more space in times of low rents. Z_1 is a 9/11 dummy variable that takes on the value of 1 in the period immediately following the 9/11 attack and 0 otherwise to account for the sharp decline in occupied space after 9/11 that would not be fully accounted for in an estimation of the standard model (for parameter values see the following section).

The hypothetical consumption of office space in Equation 1, however, does not equal the observed consumption. The discrepancy is due to the sluggish adjustment of demand levels towards hypothetical consumption brought about by the long-term nature of office leases (typically 10 years), information asymmetries and the cost of searching for adequate office space. Adjustment towards hypothetical aggregate space consumption is only gradual because only a fraction of leases expires every year. Moreover, finding adequate office space incurs considerable search cost and the lease negotiation process is complex and typically requires a long time. OS* reflects the amount of occupied office space in a market under conditions of perfect rationality, no lease restrictions, no information asymmetries and no adjustment costs. The following equation takes these friction costs into account:

$$OS_t - OS_{t-1} = A_t = \delta(OS_t^* - OS_{t-1}) \qquad \text{where} \quad 0 < \delta \leq 1 \tag{1.2}$$

At is absorption of office space in period t and δ is a coefficient indicating the rate of adjustment from the occupied space of the previous period towards the hypothetical aggregate space demand in the current period. For the purpose of the present study, two additional correction terms are included to account for the massive negative absorption that occurred on September 11, 2001 (Z_1) and for the exceptionally high positive absorption that occurred as a consequence of the re-opening of damaged buildings in the subsequent two quarters (Z_2, Z_3). The final equation for absorption is thus:

$$A_t = \delta_0(\alpha_0 + E_t(\alpha_1 + \phi_2 \frac{(E_t - E_{t-1})}{E_t} - \phi_3 R_t + Z_1) - \delta_0 OS_{t-1} + \delta_1 Z_2 + \delta_2 Z_3 \tag{1.3}$$

Thus, if office employment and rents remain stable over an extended period of time, actual occupied space will eventually equal hypothetical occupied space, absorption will be zero and the market is considered to be in equilibrium.

Rental rate adjustment and vacancy rates

The technical definition of the vacancy rate is that it is the residual of supplied space and demanded space in the following form:

$$V_t = \frac{S_t - OC_t}{S_t} \tag{2}$$

In order to arrive at a model of what drives vacancy rates and, more specifically, to capture the inverse relationship between rents and vacancies, most simultaneous equation models assume either an equilibrium rental rate or an equilibrium vacancy rate as a starting point with the latter option typically being specified in the following form:

$$\Delta R_t \div R_{t-1} = \lambda(V^* - V_{t-1}) \tag{3}$$

where ΔR_t denotes the change in rent from the previous observed period t-1 and R_{t-1} is the actual rent in period t-1. The coefficient λ indicates the extent to which the actual vacancy rate of the previous period V_{t-1} adjusts towards the hypothetical equilibrium or 'natural' vacancy rate V^*.

While this approach is theoretically sound, researchers attempting to estimate the natural vacancy rate of a given metropolitan market have faced numerous difficulties and the calculated rate is subject to great fluctuation both cross-sectionally and longitudinally. Shilling et al (1987) estimated individual natural vacancy rates for the most important office markets in the US based on the above equation and arrived at values ranging from 1% to 21% with most cities clustering in a corridor between 5% and 15%. This variance of natural vacancy rates is due to a series of diverging factors in the individual cities, such as market size, geographic shape, building inventory, institutional arrangements all of which make it difficult to arrive at a an accurate and reliable estimate of the natural vacancy rate.
Instead of calculating the hypothetical natural vacancy rate which marks the threshold above which rents are bound to react to further increases in vacancy, the approach chosen in this chapter expresses the state of a market in relation to a equilibrium rent which in turn is a function of the vacancy rate and absorption rate. Similar to the gradual adjustment in occupied space, observed rental rates will move towards equilibrium in the following linear form:

$$R_t - R_{t-1} = \mu_3 (R^* - R_{t-1}) \qquad (4.1)$$

where μ_3 is the degree of adjustment of observed rents towards equilibrium between two periods and equilibrium rent is determined by

$$R^* = \alpha_0 - \alpha_2 V_{t-1} + \alpha_3 (A_{t-1} \div I_{t-1}) \qquad (4.2)$$

It is assumed that the observed rental rates converge towards a steady state from one period to the next with an adjustment rate of α_1. The equilibrium rent R* is again largely determined by the vacancy rate and the absorption rate which is a proxy for the dynamics of a market. The absorption rate is simply the quotient of the quarterly absorption in square feet (A_{t-1}) and the total inventory of the market (I_{t-1}) and α_0, α_2 and α_3 are coefficients to be determined endogenously. Again, all dependent variables which determine R* are lagged at least one quarter due to the sluggish adjustment of rents to changing market conditions. As a consequence of the lag relationships, some markets may never reach equilibrium since they are in a constant state of adjusting to past shocks and disturbances but the underlying assumption is that the rental rate tends to adjust towards this equilibrium point at a certain rate.

Since supply is fixed in the short run, any change in occupied space is also a change in vacant space which in turn exerts upward or downward pressure on rents. The final equation developed for empirically modeling US and German office markets reads as follows:

$$R^{*} = \mu_0 - \mu_1 V_{t-n} + \mu_2 \frac{A_{t-n}}{S_{t-n}} + \mu_3 B_{t-n} + \mu_4 U_{t-n} \tag{4.3}$$

In this specification, two additional explanatory variables are included: the differential between Class A and Class B rents (B_{t-n}) and the amount of sublet space (U_{t-n}). Based on theoretical and empirical considerations, the differential is assumed to narrow in times of high rents and occupancy levels and widens as market conditions deteriorate. The rationale behind this assumption is that availability of Class A space is typically very low during the boom phase of the market, so that tenants with smaller rent budgets are pushed off to the Class B and C markets where they fill up space more quickly than would be the case if Class A rents were low. As soon as market conditions deteriorate again and vacancy rates rise, more firms perform a 'flight to quality', i.e. to Class A space, thus disproportionately driving down Class B rents. The oscillation of the spread between Class A and Class B rents serves thus as an indicator of changes in rent and position in the market cycle. The graphs presented in Figure 1 also suggest the existence of a relationship between rent levels and the A/B spread. The coefficient estimate of this variable in the specified model will be presented in Section 4 of this paper.

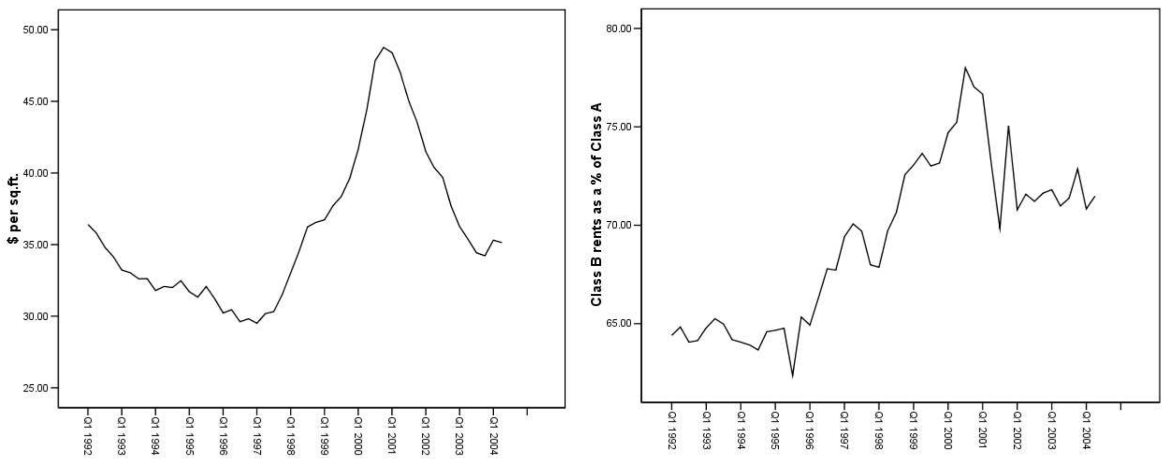


Figure 1: Convergence of rental rates during the peak phase of the market cycle: average rental rates (above) and rental rates in Class B buildings as a percentage of Class A rental rates. Data: CoStar Group, Grubb & Ellis

Moreover, sublease space is included in the model equation because it provides an additional measure for short-term corrections of the space needs of office firms that are not reflected in the overall vacancy rate due to the long-term nature of office leases. Overall, fluctuations in sublet space demonstrate that office firms do not have perfect foresight of the development of the market or their own future space needs. Therefore, sublet space can be thought of as the margin of error in a tenant's expectation of future space needs at the time of signing the lease. This phenomenon is caused by the long-term nature of the leases which forces tenants to estimate their space needs for about ten years in advance and creates a lock-in situation which can only partially be resolved by subletting some of the leased office space. In the aggregate, the amount of sublet space (or alternatively, the share of sublet space in total vacant space) is therefore a leading indicator of future demand for office space. Figure 2 gives a visual demonstration of this phenomenon which will be explored more formally in the framework when we estimate the coefficients of the modeling equations in Section 4 of this paper.

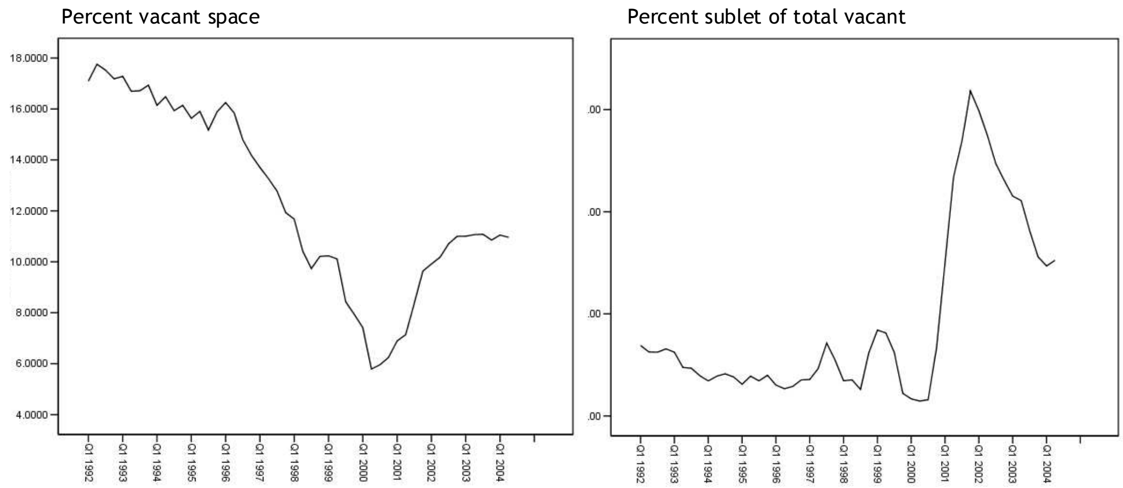


Figure 2: Sublet space as a percentage of total vacant space (above) and overall vacancy in percent (below). Data: CoStar Group, Grubb & Ellis, Source: Fuerst (2005b).

Linear and non-linear modeling of construction and supply growth

The third stage of the model links the existing framework to supply and new construction of office space. The stock of office space is updated between two periods in the following way:

$$S_t = S_{t-1} - T_t + C_t \tag{5}$$

where S_t is the total stock of office space, T_t is the amount of space that is demolished or permanently withdrawn from the market and C_t is the level of new construction.[1]

According to investment theory, construction of new office space at a particular site becomes feasible when the expected asset price of the building exceeds its replacement cost (Viezer 1999). The asset price of the building is a function of the net operating income (NOI) of a building, or more accurately, the present discounted value of the expected future income stream (net of tax and expenses). The three main components to estimate the asset price of a building are thus rent, vacancy and the capitalization rate. Since the simultaneous use of both rent and vacancy as independent variables is bound to

[1] Because of a lack of reliable data on the actual rate of buildings demolished or permanently taken off the market, it is assumed that the change in supply is net of a depreciation rate which is estimated to be less than one percent of the total stock per year in the empirical case.

introduce multicollinearity because of the mentioned strong statistical relationship between both only rent is included in lieu of a full NOI estimation. At the aggregate market level, the relationship can be specified in the following form:

$$C_t^* = \beta_0 + \beta_1 R_{t-n} + \beta_2 A_{t-n} + \beta_3 CC_t + \beta_4 (CA_{t-n}) \tag{6.1}$$

where C_t* is hypothetical construction determined by appropriately lagged rent levels, CC_t is a construction cost index and CA_{t-n} is a measure of capital availability. There are several possible proxies for capital availability to be found in the modeling literature. Hekman (1985) specifies it as the difference between the ten-year treasury bond rate and the three-month-treasury bill rates whereas Viezer (1999) includes additional variables for inflation and the differential between the corporate Baa bond rate and the ten-year treasury bill rate in line with the pre-specified Arbitrage Pricing Theory by Chen et al (1983). Replacement cost is not included in the above specification since there are no reliable data available to estimate the empirical model.

Parallel to the equations for occupied space and rent, the actual construction is a fraction of hypothetical construction in the following form:

$$C_t - C_{t-n} \psi_3 (C^* - C_{t-n}) \tag{6.2}$$

The appropriate lag structure between changes suggested in the equilibrium equation and delivery of space is to be estimated with measures of cross-correlation of equilibrium and observed delivery.

Based on earlier work done by Dobner and Werling (2006), we also test an alternative method for estimating construction activity. Instead of using the linear equation 8.1 we assume a non-linear relationship and replace the above module with a reduced-form model of the following form:

$$\Delta^+{}_t S = \beta\,[\arctan \delta (a_1 V_{t-3} + a_2 V_{t-2} - \tilde{V})] + \tilde{S} + u_t \tag{7}$$

where $\Delta^+{}_t S$ represents supply growth in the present period, β, δ, a_1, a_2 are regression coefficients with $a_1 + a_2 = 1$, $\tilde{S}$ is a natural growth rate of supply, analogous to $\tilde{V}$, the natural vacancy rate. The observed vacancy rate V_{t-n} enters the equation as a lagged variable and u_t represents the error term. In essence, the arctan function yields an S-shaped curve that tracks the typical cyclical construction activity found in most office markets. Cycle lengths may vary from six to ten years depending on the individual estimates for a given market.

The three stage model is now complete and the datasets and results of the empirical estimation will be presented in the following section.

3.2 Empirical database of New York office market data

The empirical estimation of the model draws on two distinct databases: A longer time series on rents, vacancy and absorption ranging from 1979 until 2004 based on market research by Insignia/ESG and reviewed by the Real Estate Board of New York (REBNY) as well as a shorter but more comprehensive database covering the period from 1992 until 2004. The shorter series was produced by Grubb & Ellis combining the firm's own market research with aggregated individual property data compiled by the CoStar Group. The parameters reported in the following section were obtained using the short series because it does not contain any data gaps. The longer time series was mainly used as an auxiliary dataset for testing purposes with the aim of ensuring the relative applicability and stability of parameter estimates of the shorter series. The shorter series might also be considered favorable from a theoretical viewpoint, since one of the underlying assumptions of the linear regression model is that no fundamental changes in the underlying economic conditions of a city take place throughout the modeled period which is more likely in the case of a series spanning 11 years (one full office market cycle) than with a series spanning 24 years. Considering the manifold changes in the economic and regulatory framework that have taken place since the late 1970s in New York City, makes it seem more appropriate to use the 11-year series. A further reason for the selection of the shorter data series is the fact that it is based on and consistent with submarket and individual building data used in subsequent steps of this research. The time increment used in this model is one quarter, which is different from most other modeling studies which use either annual or semi-annual data. Quarterly data are typically subject to greater fluctuations than annual or semi-annual averages, which eliminates a large part of the variation of more fine-grained data. Some datasets, such as employment exhibit seasonal bias when a quarterly model is used. Despite the fact that some of the datasets have to be deseasonalized and smoothed prior to being used in the model estimation, a quarterly time increment is being applied here to provide a more accurate picture of the workings of the market, especially in the wake of the 9/11 attack. The model was estimated with quarterly data as well but this did not yield a significantly better fit.

Inventory, occupancy and vacancy data

Figures on total inventory size differ widely among the providers of office market data. The appendix contains a comparison table of total inventory figures for different sources. A comparison of the ratio of office employment to office space shows that the applied dataset matches roughly the space per worker figures determined in research surveys.
The Grubb & Ellis data aggregate from a set of 680 office buildings comprising about 350 million square feet of office space. A possible bias of modeling results due to the construction of new buildings and change of sample composition should not be a serious concern in this case because new buildings from 1992-2004 constitute less than 1 percent of the pre-existing Manhattan inventory. A potentially more serious issue is the fact that Grubb & Ellis have changed the underlying sample size in 2002 by including more buildings (circa 10% of the original sample size). To correct for a possible bias in the

aggregate totals resulting from this, the original sample size has been retained for the purpose of this study and quarter-to-quarter percentage changes have been applied to the original sample. A heuristic check both longitudinally and cross-sectionally and an additional comparison with market data from other major researchers yielded that no distortions were detectable in the various market indicators.

As far as space accounting of the 9/11 attack is concerned, all destroyed and damaged buildings (31.2 million square feet) have been removed from the inventory data in the third quarter and re-inserted as buildings were gradually repaired and returned to their tenants. The construction variable which is usually the net change of inventory between two periods has been adjusted for this effect so that the re-opened buildings are not counted as new construction.

Rental data

The data on rent used in this study are asking rents per square foot aggregated from a large sample of buildings in the CoStar property information system. A known limitation of using asking rents is, of course that they are not as accurate as actual rents derived from lease transactions. Asking rent information is still sufficiently accurate provided that the inherent error is systematic. In practice, the difference between asking rents and actual rents varies according to the position in the market cycle. This difference will be highest at the outset of a recession. This occurs because landlords are initially reluctant to lower asking rents after a prolonged period of growth but will instead concede free rent periods and other incentives to prospective tenants. Only when market conditions have deteriorated considerably and vacant space becomes a serious problem, landlords will adaptively discount asking rents in order to attract tenants. While rents based on actual leases would be preferable, they are generally not available to researchers and pose additional problems, such as the adequate incorporation of non-monetary or non-rent-related incentives in the lease. In the absence of actual rents, asking rents are being used in this study despite their known inaccuracies and shortcomings. The asking rents and all other monetary variables are adjusted for inflation with the implicit price deflator as applied in the National Income and Product Accounts (NIPA).

Employment data

An office employment series is constructed using datasets compiled by Economy.com and the New Bureau of Labor Statistics of the New York State Department of Labor. The definition used to identify office-using industries is adopted from the New York City Office of Management and Budget (2003, 2004) and is used widely by researchers. It comprises the sectors financial activities, information, professional and business services, management of companies and administrative and support services. The classification of these industries is based on NAICS codes. While the bulk of office workers is included in this definition, the total number does probably not contain all employees working in an office-type establishment. There are a number of employees in other branches such as manufacturing not considered in this definition who are partially or fully classify as office users in practice. There exist no reliable figures on the proportion of office-using occupations within generally non-office using industries, so the aggregate figure of office workers in New York City is an approximation in the absence of data on the actual figure. Office space per worker as calculated from the independent data sources used in this study yields on average 300 square feet which is on the upper end of counts on space use by industry (CoStar 2004) which usually report averages of around 250 square feet for New York City. It can thus be concluded that a number of office workers are excluded from the above definition, however, in the absence of a precise definition of office workers in the current County Business Pattern employment statistics, it can be assumed that the margin of error and bias introduced by this circumstance is tolerable and does not invalidate the model estimation and projections as a whole.

4 Results of the empirical estimation

The model outlined earlier was estimated empirically using an OLS regression framework. Additional dummy variables have been included where the model was unable to capture the full magnitude of the effects of 9/11. Modifications and refinements of the basic structure are explained in more detail below. Table 1 reports some descriptive statistics of the most important variables of the model for the time period 1992-2004[2]. The descriptives underline the fact that Manhattan is a large and mature office market, as reflected in large absolute numbers of existing stock, employment and occupied space and relatively small first order differences compared to the total stock.

Table 1: Descriptive statistics of basic variables for the period 1992-2004

Variables	Mean	Standard Deviation
E (office employment in thousands)	929.566	64.890
E_t - E_{t-1} (change in office employment in percent)	0.169	1.431
S (inventory in million sq.ft.)	317.087	6.118
OS (occupied space in million sq.ft.)	283.688	13.165
S/W (space per worker in sq.ft.)	302.887	10.965
U sublet as % of total vacant	18.711	9.100
R (asking rent per sq.ft. in constant 1996 dollars)	35.625	6.516
B (Class B rents as a percentage of Class A rents)	68.892	4.213
A (absorption rate as a percentage of total stock)	0.134	1.533
C (annual delivery of new space in million sq.ft.)	0.835	1.045

Estimation of occupied space and absorption

As a first step, the demand for office space was estimated. Table 2 shows the results of the OLS estimation of hypothetically occupied total space. First order differences of employment as an indicator of the dynamics of office demand was tested but excluded in the final specification because the variable did not reach the required significance level. The estimated square footage per worker was multiplied by centered moving average values of office employment to eliminate seasonal bias in the estimation of the equilibrium level of occupied space OS*. Raw values of office employees have also been tested and significance levels have been found to be slightly higher. In order to minimize bias induced by the usage of quarterly data in the model estimation, however,

2 A longer time series (1983-2004) has also been used to estimate the model. Significance levels have been higher for the shorter time series which also meets the longitudinal homogeneity assumption of time series models better than the longer series.

deseasonalized data is preferable. A visual examination of the values of the dependent variable shows that the data is non-stationary. To control for the secular increase in occupied space, a time trend variable is included. Moreover, early estimations of the model were not able to fully capture the combined supply and demand shock of the 9/11 attack. The estimation was particularly complicated by the fact that total inventory was abruptly reduced by 34.5 million square feet in the third quarter of 2001. Inventory rose in the following two quarters when more than 20 million square feet of damaged office space in the vicinity of the World Trade Center were restored and tenants moved back into the restored buildings. To control for these exogenous events, three dummy variables were included. In the final form of the specification, all variables are significant and show the expected sign (Table 2).

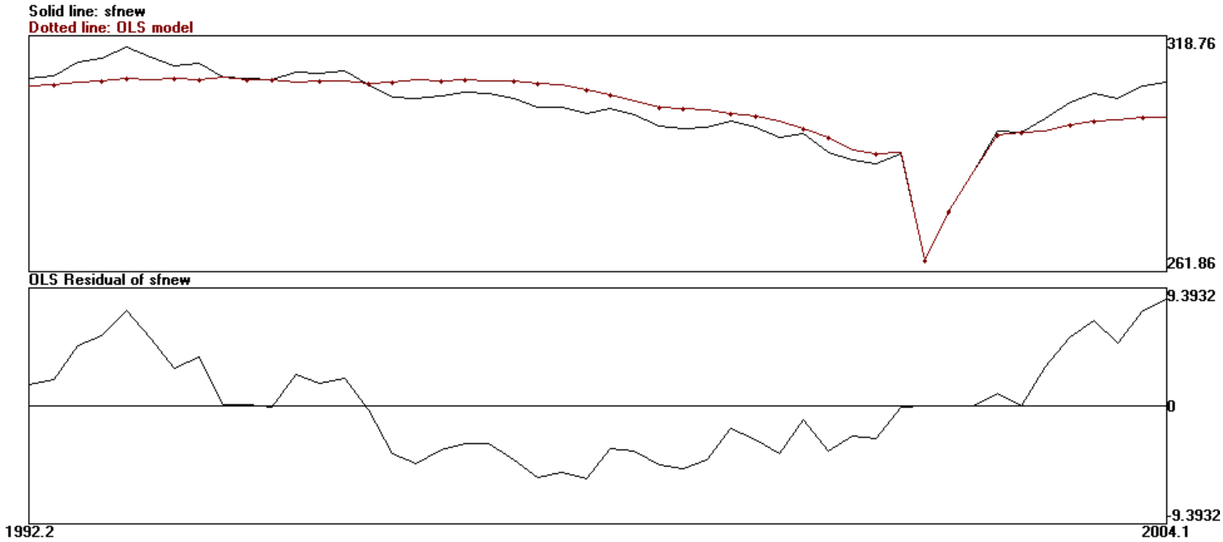
Table 2: Estimation of occupied space

Dependent variable OS*				
Variable	Coefficient	t-value	H.C. t-value[3]	Probability
α_0 (intercept of OS^*-OS_{t-1})	-2,200,000	-11.212	-14.435	.000
α_1 (basic sq.ft./worker)	339.54245	64.042	71.242	.000
R_{t-1}	-0.83845	-5.141	-5.039	.000
Z_1	-29.62176	-5.915	-24.840	.000
Z_2	-18.02937	-3.663	-16.911	.000
Z_3	-8.18453	-1.769	-7.651	.000
T (time trend)	-0.22253	-3.721	-2.713(	.000

Adjusted R^2 = 0.815
F test: F(5,42) = 42.62
Standard error = 4.564
Jarque-Bera/Salmon-Kiefer test[4] = 3.038184 (accept at 5%)
Breusch-Pagan test = 7.381228, p-value = 0.19380 (accept at 5%)
Information criteria:
Akaike: 3.20288E+00
Hannan-Quinn: 3.29127E+00
Schwarz: 3.43678E+00
Collinearity: highest VIF = 1.1, lowest eigenvalue = .907
n=49

3 H.C. = Heteroskedasticity consistent t-value. These t-values and standard errors are based on White's heteroskedasticity consistent variance matrix.

4 The Jarque-Bera/Salmon-Kiefer test of the null hypothesis that the model errors u_j are N(0,σ^2) distributed. This test actually tests the joint null hypothesis that the skewness $E[u_j^3]$ is equal to zero and the kurtosis $E[u_j^4]$ is equal to $3\sigma^4$, which hold if the u_j's are N(0,σ^2) distributed. Under the null hypothesis the test statistic involved has (for large n) a χ^2 distribution with 2 degrees of freedom. Of course, this is a right-sided test: The null hypothesis is rejected if the value of the test statistic is larger than the critical value.



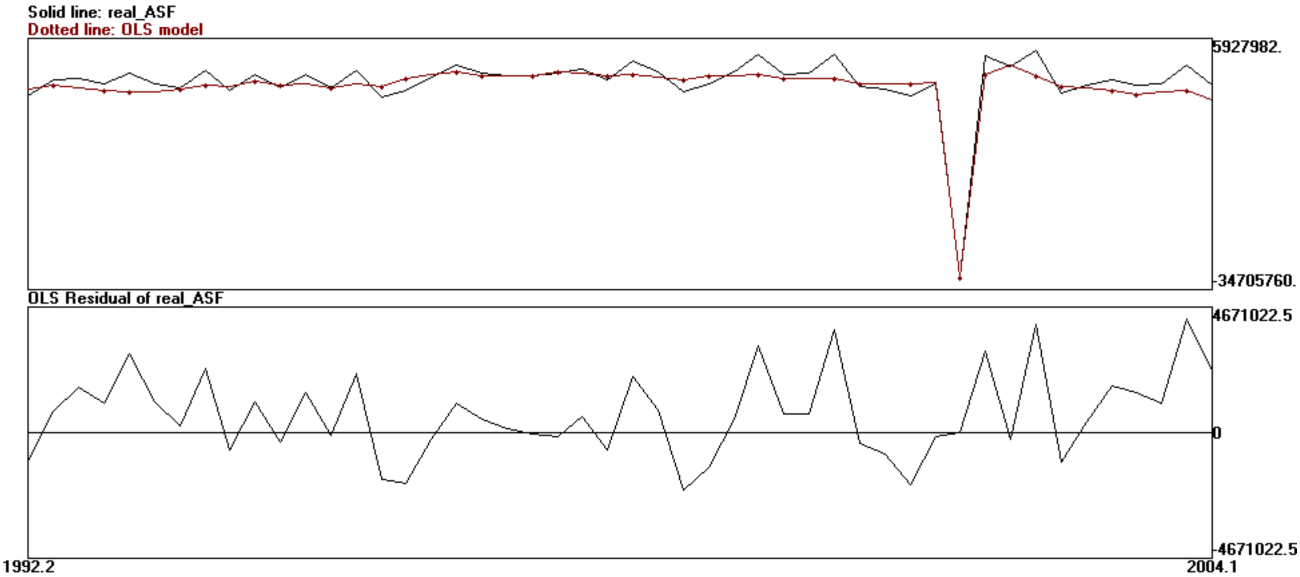
The parameter α_1 is a baseline amount of square feet per office employee that is inversely related to the rent level. At a long-term average rent of 36 dollars per sq.ft., this elasticity measure yields about 340 square feet per office worker. During periods of low rents (such as the early 1990's) space use rises to 360 square feet and is found to fall to approximately 285 square feet per worker during periods of high rents (1999-2001).

In the next step, quarter-to-quarter absorption is estimated as a function of the difference between desired and observed occupied space (Table 3). The coefficient of $OS^*\text{-}OS_{t-1}$ shows the adjustment speed of occupied space to the hypothetically demand for space. The adjustment rate is 0.2803 which means that 28% of the change in hypothetical demand for space is actually implemented from one period to the next. For the purpose of this estimation, two dummy variables have been included to account for the effects of 9/11. While Z_2 is intended to capture the negative absorption of 34 million square feet of office space that occurred in the third quarter of 2001 resulting from the attack, Z_3 accounts for the contrary effect of high positive absorption in the first two quarters of 2002 resulting from the re-opening of damaged buildings after restoration.

Table 3: Estimation of space absorption

Dependent variable A				
Variable	Coefficient	t-value (S.E.)	H.C. (S.E.)	probability
OS^*-OS_{t-1}	0.28023	4.727	4.567	.000
Z1 (3/11 dummy)	-25478610.68028 (1,753,875)	-9.298 (2,740,121)	-12.611 (2,020,390)	.000

Adjusted R^2 = 0.918
F test = 164.299
Standard error = 1.640.000
Jarque-Bera/Salmon-Kiefer test = 14.874 (reject at 5%)
Information criteria:
Akaike: 2.89796E+01
Hannan-Quinn: 2.90091E+01
Schwarz: 2.90576E+01
Collinearity: highest VIF = 2.001, lowest eigenvalue = .286
n=49



Estimation of rent levels

As outlined in the description of the model, the movement of vacancy and rental rates is among the most robust statistical relationships in real estate economics. It is noteworthy with regard to the discussion of the efficient market hypothesis within real estate markets that there is a significant lag for rents to adapt to changes in vacancy rates - despite the universal availability of timely market data. With the help of cross-correlation the optimal lag structure of vacancy was determined to be three quarters. This means that it takes landlords on the average three quarters before they effectively lower the rents to a level that is in line with prevailing vacancy rates. One reason for this is that landlords are reluctant to lower the rent at the onset of a recession. Only when vacancy rates become so manifest that landlords are faced with the decision to either lower the rents or accept large vacancies, they eventually start lowering the rent. It is surprising though that a lag can also be detected at the beginning of a market recovery when landlords would be expected to be more inclined to reacting to news about changing market conditions. This shows that market sentiment as established in the previous quarters prevails in the bargaining process and imperfect information is likely to contribute to persisting prices. Table 4 shows the specification of the rent equation.

Table 4 Estimation of the equilibrium rent

Dependent variable R*			
Variable	Coefficient	t-value (VIF)	probability
Constant	50.201	2.659	.012
B_{t-2}	0.092	0.399 (8.159)	.692
V_{t-3}	-1.551	-5.476 (10.136)	.000
A_{t-2}	0.328	1.278 (1.625)	.210
U_{t-2}	-0.969	-1.454 (1.822)	.155
Adjusted R^2 = .908 F = 94.55 Durbin-Watson 0.795 Collinearity, largest VIF = 10.136, lowest eigenvalue = .000 Standard error = 2.063 n=47			

All variables show the expected sign but the Class A/B rent spread variable (B) as well as the absorption rate does not reach the desired significance levels. Moreover, the diagnostic tests indicate serious multicollinearity and autocorrelation problems for this variable. Despite the fact that each of the included variables is theoretically and empirically sound as a single predictor, the above specification is not viable, probably because of the high degree of variance explained by one variable, the lagged vacancy rate. The rent spread variable B_{t-1} for instance is highly correlated with vacancy rates (R^2 =.91). Table 5 shows a re-estimation of the rent equation with only the vacancy rate and an additional dummy variable to capture the effects of 9/11 and the first differences modeled rather than absolute rent levels.

In this reduced specification collinearity remains within tolerable boundaries. Despite the fact that three variables have been discarded the model performs better overall and shows a slightly higher adjusted R^2 than the original specification. This version of the equation is therefore used for the estimation of the model. The test for ARCH confirms that this specification is also preferable because it does not exhibit significant autocorrelation of the residuals.

Table 5: Alternative estimation of the equilibrium rent

Dependent variable ΔR^*				
Variable	Coefficient	t-value (S.E.)	H.C. (S.E.)	probability
V_{t-3}	0.05352	3.768 (0.01420)	4.125 (0.01298)	.000
U_{t-2}	-0.14813	-8.583 (0.01726)	-7.631 (0.01941)	.000
T(time trend)	0.08091	7.169 (0.01129)	6.061 (0.01335)	.000
Adjusted R^2 = 0.6155				
F test = 22.39				
Standard error = 0.750195				
Jarque-Bera/Salmon-Kiefer test = 0.257 (critical 5.99, accept at 5%)				
Information criteria:				
Akaike: -5.11851E-01				
Hannan-Quinn: -4.67176E-01				
Schwarz: -3.92592E-01				
Collinearity: highest VIF = 1.567, lowest eigenvalue = .730				
n=47				
Test for ARCH u(t) is Gaussian white noise (accepted)[5]				

According to the specified model, the rent calculated from this equation is the equilibrium rent and the residuals of this regression can be interpreted as the deviation of the observed rent from the hypothetical equilibrium. In the next step, the lagged partial adjustment of actual rents to the equilibrium rent is estimated (Table 6):

Table 6: Estimation of change in rental rates

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[5] Test for ARCH(p) of u(t) = True value of
OLS Residual of r_diff1
Null hypothesis: u(t) is Gausssian white noise
Alternative hypothesis: V(t) = a(0) + a(1)u(t-1)^2 +.. +a(p)u(t-p)^2,
where V(t) is the conditional variance of u(t).
The ARCH test is the LM test of the joint hypothesis
a(1) =..= a(p) = 0
p = 1
Test statistic = 0.05
Null distribution: Chi-square with 1 degrees of freedom
p-value = 0.83022
Significance levels: 10% 5%
Critical values: 2.71 3.84
Conclusions: accept accept

Specification 2: Dependent variable ΔR*				
Variable	Coefficient	t-value		probability
R* R_{t-1}	0.68487	7.893 (0.08676)	7.692 (0.08903)	.000

Adjusted R^2 = 0.5753

F test = 22.39

Standard error = 0.7824220.750195

Jarque-Bera/Salmon-Kiefer test = 0.267 (critical 5.99, accept at 5%)

Information criteria:

Akaike: -4.69676E-01

Hannan-Quinn: -4.54863E-01

Schwarz: -4.30311E-01

Collinearity: highest VIF = 1.56, lowest eigenvalue = .730

n=47

Test for ARCH u(t) is Gaussian white noise (accepted)[6]

The R^2 of this specification is slightly lower than comparable values obtained in model runs done for other cities. An alternative specification which estimated absolute rent levels rather than changes in rent obtained a much higher R^2 (0.91) but the estimators were biased because of heteroskedasticity and autocorrelation of errors. Therefore, the partial adjustment change rate specification is used for the market forecast. Figure 3 illustrates that the predicted rents do not fully capture the peak of the rental rates but perform reasonably well during other phases of the market cycle.

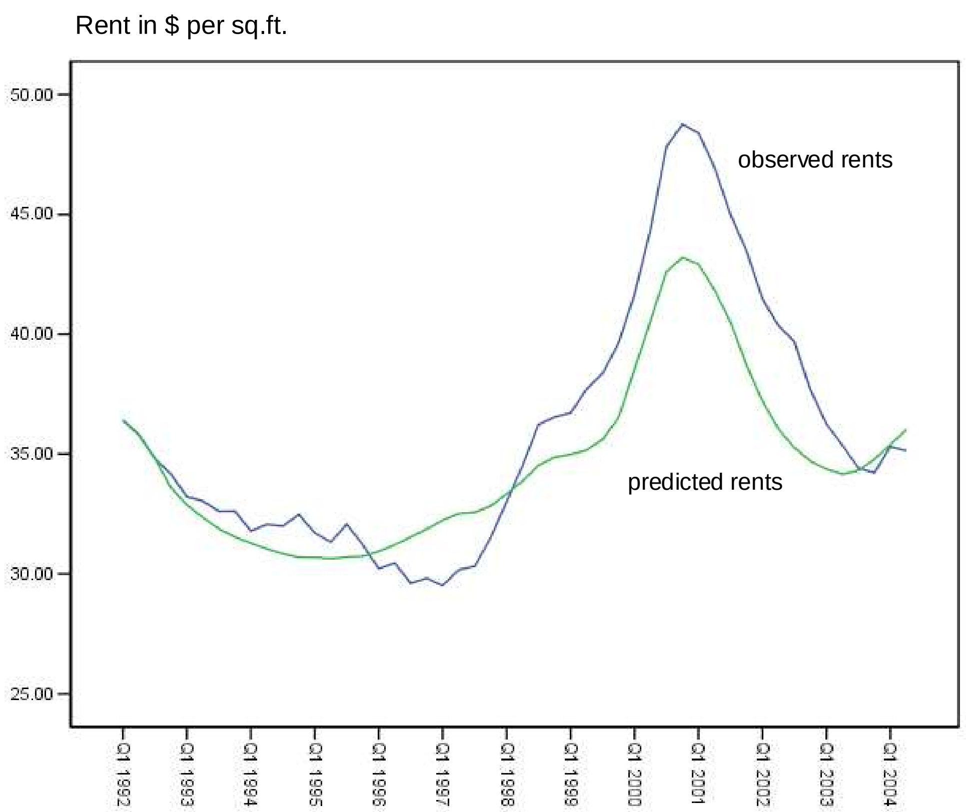

Figure 3: Fitted versus observed rents (rent in U.S. dollars per square foot)

Supply of office space: Estimating construction and total market inventory

Finding a model specification which yields a good fit for new construction of office space is more challenging than the estimations of the other two components. This is due to the fact that the delivery of new office space follows a somewhat erratic pattern in New York City with some periods exhibiting very high activity of new space delivery and virtually no activity in the next period. To account for these oscillations, a moving average value of space deliveries and new construction as a percentage of the total inventory rather than absolute values in square feet were used to estimate the equation. The model fit is further limited by the fact that almost no construction occurred in New York City during the 1990s even though the model would suggest some level of construction activity. The lack of construction is usually attributed to heightened risk-aversion by lenders after the real estate crash of the late 1980's. Table 7 shows a summary of the coefficient estimates using the variables lagged vacancy rate, rental rate, absorption and capital availability (proxied by the difference between the 10-year treasury bond rate and the 3-month treasury bill rate).

Table 7: Estimation of new space construction (linear regression)

Dependent variable C

Variable	Coefficient	t-value	H.C. (S.E.)	probability
V_{t-7}	-0.87920	-3.471 (0.25328)	-2.998 (0.29324)	.001
R_{t-4}	0.00604	8.550 (0.00071)	5.678 (0.00106)	.000
A_{t-4}	-0.01465	-2.581 (0.00568)	-2.297 (0.00638)	.001
CA_{t-6}	-0.01702	-1.777 (0.01118)	-1.494 (0.01139)	.120

Adjusted R^2 = 0.600844
F test: F(5,42) = 24.589
Standard error = 0.069824
Jarque-Bera/Salmon-Kiefer test = 0.257 (critical 5.99, accept at 5%)
Information criteria:
Akaike: -5.23513E+00
Hannan-Quinn: -5.17472E+00
Schwarz: -5.07130E+00
Standard error = 0.069824
n=43
Test for ARCH u(t) is Gaussian white noise (accepted p-value = 0.58447[7]

In the next step, we substitute the estimates of the linear regression approach with the arctan function as described in the previous section. Table 8 gives an overview of the coefficient estimates. Figure 4 visualizes the results of both the linear and the non-linear estimates. Both approaches are able to pick up the general trend of increasing construction activity over time in the selected empirical example albeit with various remarkable outliers. None of the models is capable of explaining the drop in office space deliveries in the New York market in the year 2000. The linear approach appears to capture the take-off phase in deliveries in 1999 better than the non-linear approach. Neither the visual examination nor the statistical fit of the models yield an unequivocal result as to which of the two models is preferable.

Table 8: Alternative estimation of new space construction(arc tangent function)

[7] The ARCH test is the LM test of the joint hypothesis
a(1) =..= a(p) = 0
p = 1
Test statistic = 0.30
Null distribution: Chi-square with 1 degrees of freedom
Significance levels: 10% 5%
Critical values: 2.71 3.84
Conclusions: accept accept

Dependent variable C	
Variable	Coefficient
a_1	1
a_2	0
$\tilde{V}$	13.61
$\tilde{S}$	1,510,172
β	-1,379,494
δ	5

Adjusted R^2 = 0.4711

Sum of squares=520.3075

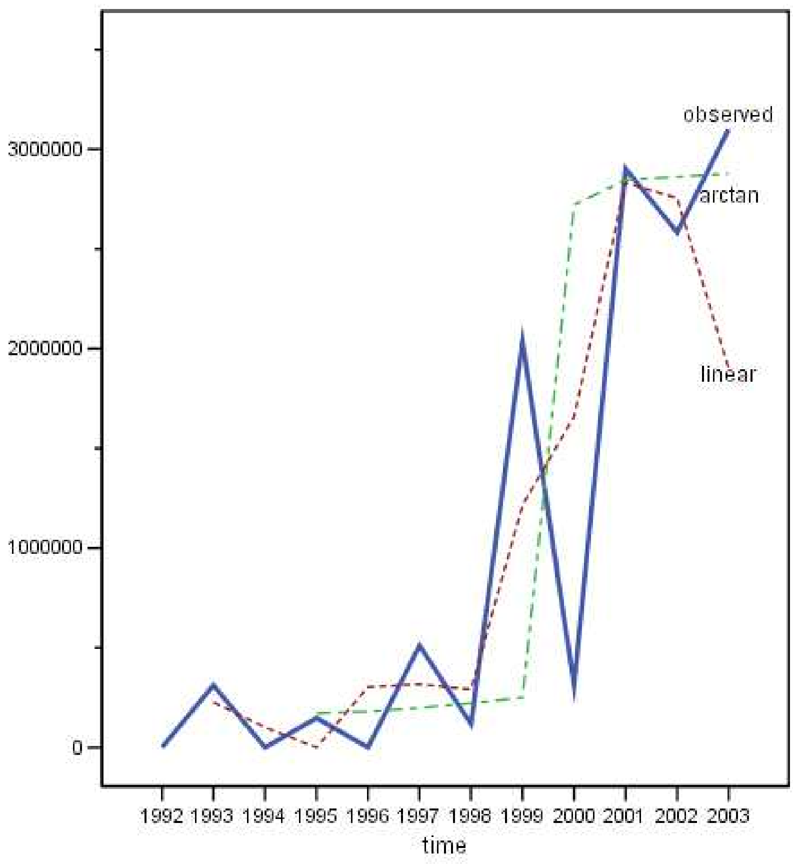

Figure 4: Fitted versus observed construction activity (annual construction of square feet of office space)

5 Conclusions and further work

To explore the predictability of office markets, a simultaneous equation approach was presented and empirically tested in this paper. The empirical results confirm that the model is based on sound economic assumptions. The model is even capable of incorporating the results of the extreme exogenous market shock of the September 11 attacks in the New York market. The significance of the estimated parameters underscores the general validity and robustness of the simultaneous equation approach. The modifications of the standard model, notably the inclusion of sublet space in the rent equation, contributed considerably to improving the explanatory power of the model. A non-linear arc tangent approach to predicting office space deliveries did not perform significantly better in the empirical case study than the linear function.

A number of further refinements are possible, however. First, a more comprehensive integration of capital markets would be desirable to capture the impact of these markets on investment in and construction of office real estate. In this context, the integration of urban land markets could enhance the model considerably. Moreover, it would be preferable if office employment were endogenized by modeling structural changes in the composition and trends in the spatial organization of office employment. This would require a module capable of forecasting the dynamics of individual office-using industries over a number of years.

Despite the mixed results of the non-linear approach in this initial test, a modified version of this function may eventually yield better results than the linear approach. Since the arc tangent function tested in this paper did not contain any exploratory variables apart from the vacancy rate, a logical subsequent step would be to enrich this non-linear algorithm with all the variables of its linear counterpart and compare the results.

Regardless of the functional form of its individual components, there is clear potential for the simultaneous equation model to evolve further because of its relatively open structure which allows for a flexible integration of theoretical advances and local market specifications.

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NOTE

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