

Forecasting the Manhattan office market with a simultaneous equation model

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DRAFT: COMMENTS ARE WELCOME

The Manhattan office market is unique not only because of its size – it is more than twice the size of Chicago, the second largest agglomeration of office space in the United States - but also because of its maturity of its inventory and market structure. The singular market shock brought about by the destruction of 14.5 million square feet of office space on September 11, 2001 is another distinctive feature. These characteristics give rise to the question whether standard econometric market models can be applied successfully to the Manhattan market. For example, it can be argued that the use of change rates to capture market dynamics over time is problematic in a market of the size and maturity of Manhattan because these rates will naturally be low despite potentially large absolute numbers underlying these rates.

To explore the predictability of the Manhattan office market, a three-stage system of simultaneous equations is utilized in this paper. 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 equation model as laid out by Wheaton (1997) is modified to account for the specific characteristics of the Manhattan office market.

1 The model

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 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 *et al* (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 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. While the attempt to link capital markets to rent levels failed 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 attacks. The theoretical framework of the three components is described in more detail below followed by the results of the empirical estimation of the model for the Manhattan market.

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:

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

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 attacks 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 attacks 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:

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

A_t 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 three quarters (Z_2). The final equation for absorption is thus:

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

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:

$$V_t = \frac{S_t - OC_t}{S_t} \quad (2)$$

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:

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

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 an accurate and reliable estimate of the natural vacancy rate.

The concept of an equilibrium state inherent in the real estate market is, however, not necessarily an integral part of an office market model. For example, Key et al. (1994) specified the following rent equation:

$$R_t = \beta_0 + \beta_1 R_{t-n} + \beta_2 D_{t-n} + \beta_3 I_{t-n} + \beta_4 C_{t-n} + \beta_5 Q_t \quad (4)$$

The explanatory variables in this equation include average rent (R_{t-n}), a proxy for demand (D_{t-n}) which is typically either the number of office workers or an aggregate economic output measure, total inventory development (I_{t-n}), the rate of new construction (C_{t-n}) as well as interest rate levels (Q_t). Similar to the equilibrium model, it is assumed that rents do not react instantaneously to changes in the dependent variables because of long-term contracts and other status-quo conserving factors but will adjust with a time lag which is to be determined individually for each variable in the estimation process.

A micro-economic approach, however, is required to explain the relationship between demand for office space (proxied either by positive demand, office workers or negatively by vacant space). Since office space is a heterogeneous good and tenants typically have rather specific requirements as to the ideal location and attributes of an office building, the real estate market is generally characterized by high search costs. Arnott und Igarashi (2000) formulated the matching process of tenants to suitable space in the following way:

$$\Omega_S = (V / S)^{1/2} \quad (5.1)$$

and

$$\Omega_V = (S / V)^{1/2} \quad (5.2)$$

where Ω_S and Ω_V denote each the individual opportunities to match for a prospective tenant searching for space (S) and a landlord with rentable vacant units of space (V). Both the tenant match rate and the vacant unit match rate are a function of the quantitative relationship between offered space to the aggregate demand for space. Hence, the respective uncertainty of the tenant and the landlord are necessarily inversely related. In principle, landlords and tenants are both faced with a trade-off process between the cost of continued uncertainty on one hand and potentially suboptimal occupancy on the other. This also implies that a lower risk of vacancy for landlords necessitates higher search and uncertainty costs for tenants. For instance, in an office market characterized by a high vacancy rate, there is a relatively high probability for prospective tenants to find office space that matches their specific preferences while landlords in the same market condition face a low probability of finding a matching tenant willing to pay the desired rental 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 paper expresses the state of a market in relation to an 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:

$$R_t - R_{t-1} = \mu_3(R^* - R_{t-1}) \quad (6.1)$$

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

$$R^* = \alpha_0 - \alpha_2 V_{t-1} + \alpha_3 (A_{t-1} \div I_{t-1}) \quad (6.2)$$

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 the New York office market reads as follows:

$$R^* = \mu_0 - \mu_1 V_{t-n} + \mu_2 \frac{A_{t-n}}{S_{t-n}} + \mu_3 B_{t-n} + \mu_4 U_{t-n} \quad (6.3)$$

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.

Sublet space variable is included 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 (see Figure A-1 in the appendix).

Modeling supply of office space and new construction

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:

$$S_t = S_{t-1} - T_t + C_t \tag{7}$$

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.ⁱ

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 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:

$$C_t^* = \beta_0 + \beta_1 R_{t-n} + \beta_2 CC_t + \beta_3 (CA_{t-1}) \quad (8.1)$$

where C_t^* is hypothetical construction determined by appropriately lagged rent levels, CC_t is a construction cost index and CA_{t-1} 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 (1986). 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:

$$C_t - C_{t-n} \psi_3 (C_t^* - C_{t-n}) \quad (8.2)$$

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.

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

2 Empirical estimation of the model for the Manhattan office market

Data issues

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 and 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 attacks. 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 empirically known space per worker figures.

The Grubb and 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 and 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 attacks is concerned, all destroyed and damaged building (34.5 million square feet) have been removed from the inventory data in the third quarter and re-inserted as buildings were gradually restored. 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. Asking rents, as opposed to actual rents which are based on lease transactions, are known to be inaccurate. Assuming that the error is systematic but not fixed, the differences between asking and actual rents vary with the position in the market cycle. For instance, it can be assumed that the difference between asking rents and actual rents will be highest immediately at the outset of a recession. This is due to the fact that landlords are 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 the statistics from 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 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, 2001) 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.

Study area

The geographical reference area for all data applied in this study is the borough of Manhattan which contains most of the office space of New York City. In fact, the Manhattan office market can be considered as almost synonymous with New York City since only a small percentage of competitive office space is located in the boroughs outside of Manhattan. Spatial competition of the Manhattan market with office space in the wider metropolitan area, particularly along the New Jersey waterfront, on Long Island and in Connecticut are not explicitly modeled here but are the subject of follow-up research work. The eventual goal of this research is to arrive at a comprehensive cross-section time-series model that is able to capture the effects of suburbanization of office space and intra-regional competition. Table 1 contains an overview of all variables and data sources applied in the empirical estimation process.

Table 1 Overview of datasets used in the empirical estimation of the office market model

Data	Source
Inventory of office space (in sq. ft.)	Grubb and Ellis (1992-2004) Insignia ESG, Real Estate Board of NY (1979-2004)
Asking rents (in \$ per sq. ft.), Class A/B/C	
Net absorption	
Vacancy (in sq.ft.), sublet and direct	
Employment data by zip-code area and NAICS code (ES 202)	Bureau of Labor Statistics
Current Employment Statistics (CES) survey	Economy.com, Bureau of Labor Statistics
Employment projections for New York City (2004-2007)	New York City Office of Management and Budget
Economic output by NAICS code	New York City or submarkets
Floor area per employee (by branch)	CoStar
Sales transactions in Manhattan (2000-2004)	REAlert, Real Capital Analytics
Construction cost index	Turner building cost index, OECD building cost index
"Pipeline projects", proposed developments	Grubb and Ellis, Real Estate Board of NY
Baa bond ratings	Moody's Investor's Services
Three month treasury constant maturity rate	Federal Reserve Bank of Saint Louis
Ten-year treasury constant maturity rate	
New York business conditions index	National Association of Purchasing Management

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 2 reports some descriptive statistics of the most important variables of the model for the time period 1992-2004ⁱⁱ. 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 2 *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 3 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

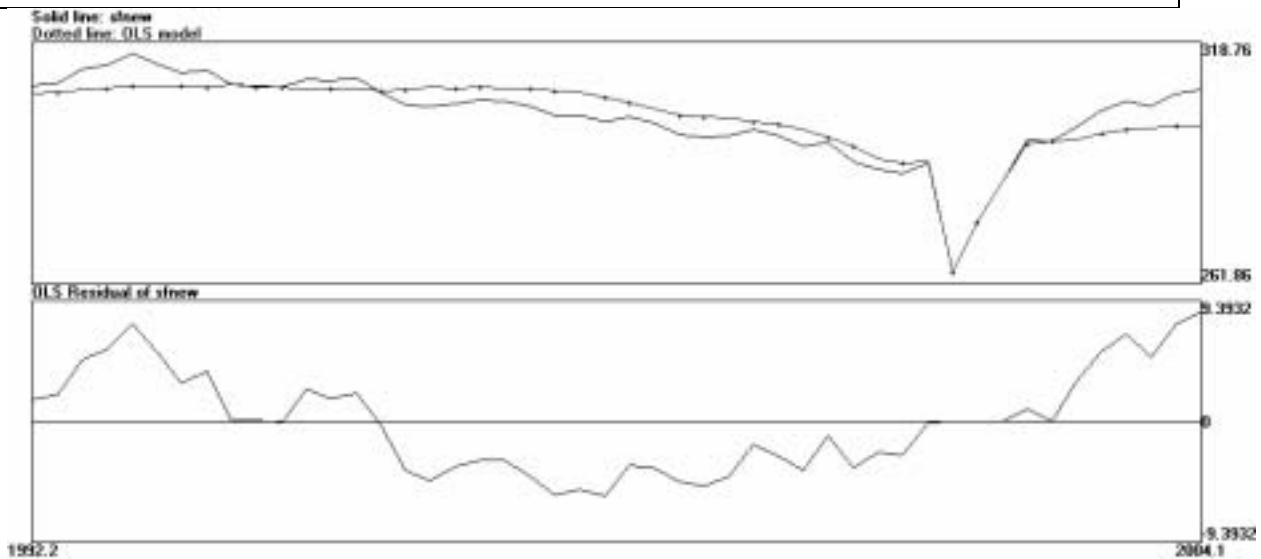
values of office employees have also been tested and significance levels have been found to be slightly higher. In order to minimize bias induced by the usage of quarterly data in the model estimation, however, deseasonalized data is preferable. A visual examination of the values of the dependent variable 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 attacks. 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 3).

Table 3: Estimation of occupied space

Dependent variable OS*				
Variable	Coefficient	t-value	H.C. t-value ⁱⁱⁱ	Probability
α_0 (intercept of OS*-OSt-1)	-2,200,000	-11.212	-14.435	.000
α_1 (basic sq.ft./worker)	339.54245	64.042 (5.30185)	71.242 (4.76607)	.000
R_{t-1}	-0.83845	-5.141 (0.16639)	-5.039 (0.16310)	.000
Z_1	-29.62176	-5.915 (5.00759)	-24.840 (1.19248)	.000
Z_2	-18.02937	-3.663 (4.92166)	-16.911 (1.06612)	.000
Z_3	-8.18453	-1.769 (4.87454)	-7.651 (1.06977)	.000
T (time trend)	-0.22253	-3.721 (0.05981)	-2.713(0.08202)	.000

$R^2 = 0.835$; Adjusted $R^2 = .0.815$
 F test: $F(5,42) = 42.62$
 Standard error = 4.564
 Jarque-Bera/Salmon-Kiefer test^{iv} = 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



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 (early 1990's) the suggested space use rises to rises to 360 sq. ft. and decreases to 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 4). The coefficient of $OS^* - OS_{t-1}$ 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

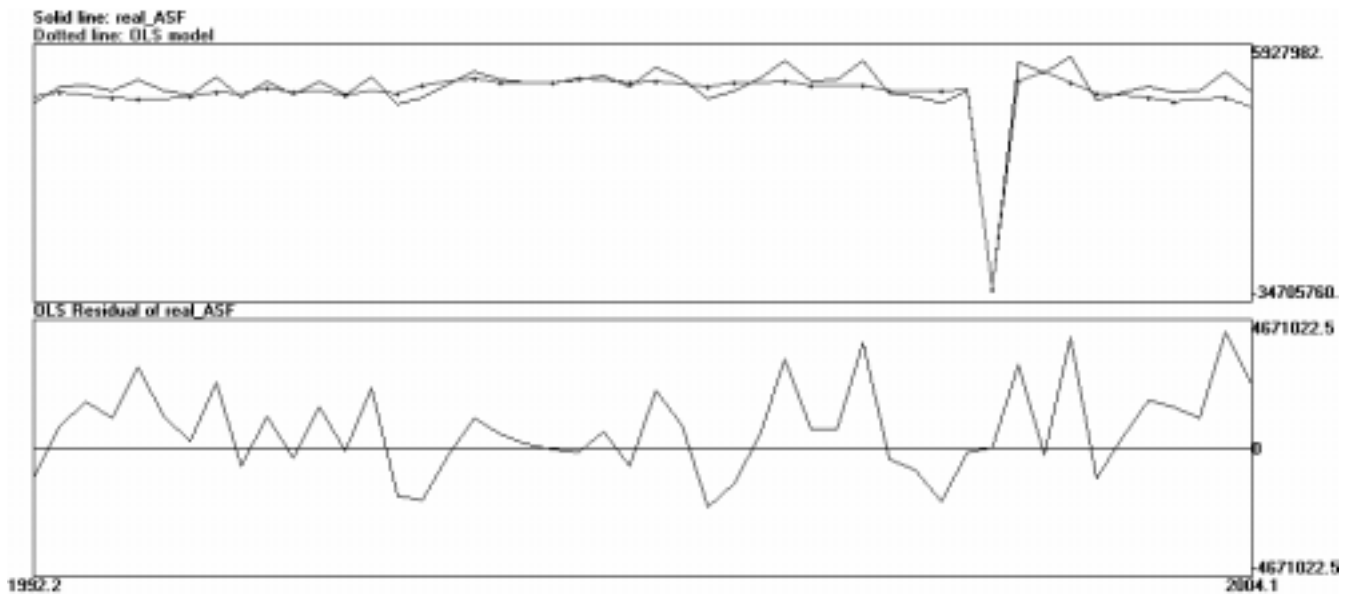
variables have been included to account for the effects of 9/11. While Z_2 is intended to capture the negative absorption of 34 million square feet of office space that occurred in the third quarter of 2001 resulting from the attacks, Z_3 accounts for the contrary effect of high positive absorption in the first two quarters of 2002 resulting from the re-opening of damaged buildings after restoration.

Table 4 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
$Z_{1(9/11 \text{ dummy})}$	-25478610.68028 (1,753,875)	-9.298 (2740121)	-12.611 (2020390)	.000

$R^2 = 0.835$; Adjusted $R^2 = .0815$
 F test = 42.62
 Standard error = 4.564
 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 = 1.1, lowest eigenvalue = .907
 N=49



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 5 shows the specification of the rent equation.

Table 5 Estimation of the equilibrium rent

Dependent variable R*			
Variable	Coefficient	t-value (VIF)	probability
Constant	50.201 (18.877)	2.659	.012
B_{t-2}	0.092 (0.231)	0.399 (8.159)	.692
V_{t-3}	-1.551 (0.283)	-5.476 (10.136)	.000
A_{t-2}	0.328 (0.257)	1.278 (1.625)	.210
U_{t-2}	-0.969 (0.667)	-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=45			

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 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 6 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 6 Alternative estimation of the equilibrium rent

Dependent variable $R^* - R_{t-1}$				
Variable	Coefficient	t-value (S.E.)	H.C. (S.E.)	probability
V_{t-3}	0.05352 (.078)	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 = 42.62 Standard error = 4.564 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 = 1.1, lowest eigenvalue = .907 N=47 Test for ARCH $u(t)$ is Gaussian white noise (accepted) _v				

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 7):

Table 7 Estimation of change in rental rates

Specification 2: Dependent variable $R_t - R_{t-1}$				
Variable	Coefficient	t-value		probability
$R_t - R_{t-1}$	0.68487	7.893 (0.08676)	7.692 (0.08903)	.000
Adjusted $R^2 = 0.5753$				
F test = 40.523				
Standard error = 0.782422				
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 = 1.1, lowest eigenvalue = .907				
N=47				
Test for ARCH u(t) is Gaussian white noise (accepted)				

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 1 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.

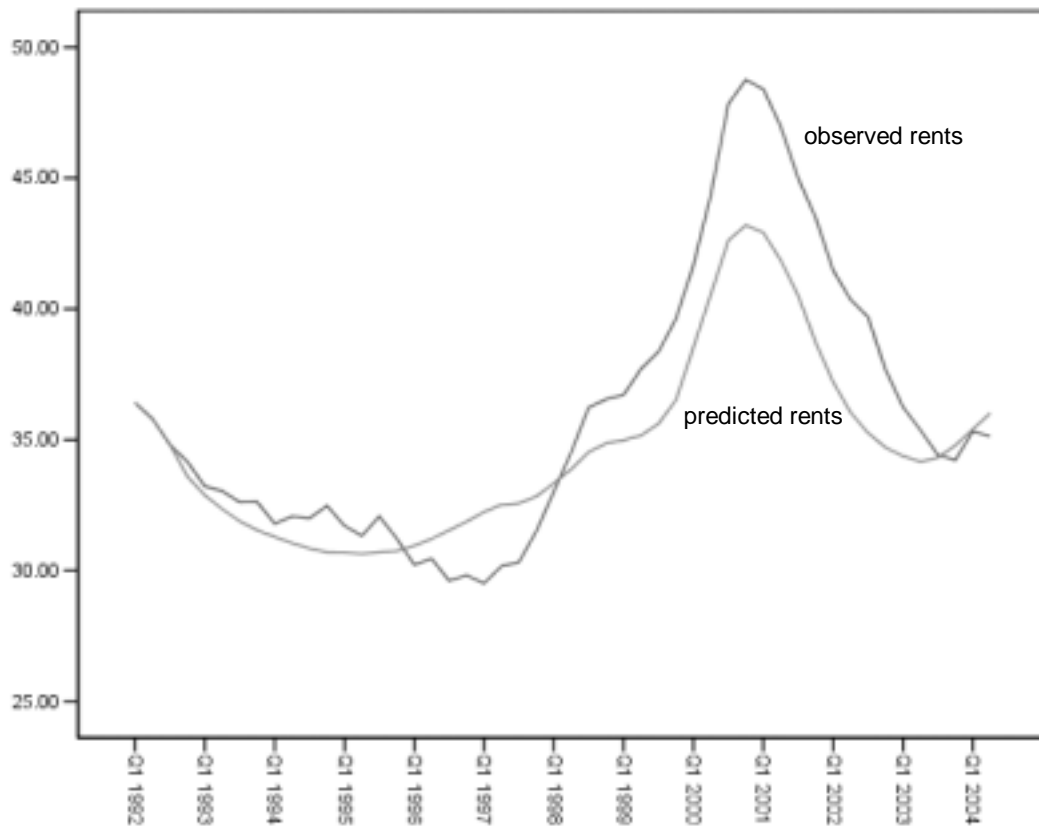


Figure 1 *Fitted versus observed rents*

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 8 shows a summary of the coefficient estimates.

Table 8 Estimation of new space construction

Dependent variable C				
Variable	Coefficient	t-value	H.C.S.e.	probability
Constant	.002	3.725	.001	.001
V ₆	-0.87920	-3.471 (0.25328)	-2.998 (0.29324)	.001
R ₆	0.00604	8.550 (0.00071)	5.678 (0.00106)	.000
CA ₆	-0.01702	-1.777 (0.01118)	-1.494 (0.01139)	.120

Adjusted R² = 0.600844
F test: F(5,42) = 42.62
Standard error = 4.564
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^{vii})

Results of scenario model runs

The simultaneous equation model is now set up to generate forecasts for the Manhattan office market. A general difficulty with using simultaneous equation models for forecasting purposes is that some of the explanatory variables are not modeled endogenously in the system and have to be obtained from extraneous sources whose quality can sometimes not be fully verified. The model presented in this study contains three such variables: the number of office workers (E) in the occupied space equation, the amount of sublet space (U) in the rent equation as well as capital availability (CA). Since sublet space and capital availability were mainly incorporated into the model for analytical purposes and cannot be forecasted reliably, the long run mean of these variables is assumed for the forecast period. Thus, only the office employment variable

needs to be specified exogenously. This is done by constructing three scenarios based on various professional forecasts. The base scenario is derived from the New York City Office of Management and Budget. In addition to this, an optimistic and a pessimistic variant was constructed and its plausibility checked with other employment projections (Partnership for New York City, 2003). Figure 2 illustrates the employment scenarios of the various scenarios. The spread between the optimistic and pessimistic scenario represents the bounds of possible developments for the Manhattan office market. The three scenarios are characterized as follows:

(A) Base Scenario

The base scenario assumes that office employment will recover only gradually with a growth rate of 0.6% in 2004 and approximately 1% from 2005 until 2007. These assumptions are based on the projections of the NYC Office of Management and Budget, 2003). Beyond the time horizon of the OMB projections, continued modest growth rate of 1% p.a. is assumed from 2007-2010. When these conservative growth rates are applied, pre-9/11 levels will not be reached until the end of the decade and will still be around 10% lower than they were at the height of the boom in 2000. This cautious scenario can thus be considered a "middle-of-the-road" baseline scenario for the purpose of the modeling exercise.

(B) Pessimistic Scenario

The pessimistic scenario assumes that New York will not regain its pre-9/11 employment levels in the office-using industries and will continue to lose office jobs due to a centrifugal movement of office firms away from Manhattan into the broader catalyzed by the ongoing technological advances. Office employment in Manhattan is thus assumed to decline by 1% p.a. through 2006 and to remain flat from 2007-2010. This scenario constitutes the lower bound within the set of conceivable office employment trajectories.

(C) Optimistic Scenario

The optimistic scenario envisions a recovery process of office employment with above average growth rates of the office-using service industry sectors of about 3.5% p.a. until 2007. According to this growth scenario, pre-9/11 office employment levels will be reached by the end of 2007. After the year 2007, office employment is assumed to continue growing at a slower rate of 1

percent p.a. until 2010. The assumed growth rate is derived from historical rates during similar phases (from 1998-2001 the average annual growth rate was 4% p.a.) and the employment assumptions of pre-9/11 forecasts corrected for the effects of 9/11. This scenario presupposes that New York City will remain the prime location for advanced financial services in the region and nationwide and that no significant movement from Manhattan to suburban areas or other regions will take place. The high growth rates are brought about by a preponderance of growth industries in the city's industrial composition and a continued secular shift in employment towards higher overall shares of service and office-using industries. This scenario constitutes the upper bound within the set of conceivable office employment trajectories.

Interpretation of results:

Figures 2 to 5 present the results of the forecasting model. The projected values of all three of the tested scenarios underline the robustness and plausibility of the model. As expected, the optimistic employment growth scenario yields the lowest vacancy rates and highest levels of occupied space whereas the pessimistic scenario generates higher vacancy. Interestingly, absorption turns positive for a period of time after 2007 even though there is no positive growth in office employment throughout the forecast period in this scenario. The model correctly reflects the effect that even under zero employment growth, absorption would temporarily turn positive as firms are choosing to consume more space per employee in their lagged adaptation to low office rents. Eventually, absorption becomes zero as employment is assumed to stagnate from 2007 onwards which is in line with the implications of the equilibrium model. Because of the more steady assumptions in employment growth, all projected absorption values exhibit lower oscillations than observed past values. Regarding rents and vacancy rates (Figures 3 and 4), the scenarios differ as expected from the optimistic scenario yielding the highest rents and the lowest vacancy rates but even this scenario does not reach the high-rent and low-vacancy pattern of the peak around the turn of the century. This is mainly due to the fact that the last office boom occurred after a period of virtually no new additions to the existing inventory in almost a decade whereas a considerable amount of office space was delivered from 2000 onwards. The optimistic scenario triggers construction of new office space in the amount of nearly 36 million square feet in the period of 2004-2010 (whereof 3.2 million square feet are 'known' deliveries of buildings currently under construction in 2004 and the rest is predicted by the model). Interestingly, the base scenario and even the pessimistic scenario generate new

construction of office space. The base scenario yields new construction of about 12.4 million square feet which is roughly the amount of space destroyed in the 9/11 attacks and the pessimistic scenario suggests new construction of 6.9 million square feet over the next six years. These findings are in line with the assumptions made in a recent rebuilding study carried out by Appleseed Consulting for the Lower Manhattan Development Corporation (Appleseed 2003). It is evident, however, that new office construction in the pessimistic variant would have to be constrained to the World Trade Center site almost exclusively to balance supply and demand in New York City. To compare the obtained values with actually planned pipeline projects in New York City, lists of planned and proposed construction projects throughout Manhattan, as maintained by Grubb and Ellis and the Real Estate Board of New York are reviewed. The pipeline projects amount to a total of 33.4 million square feet of new office space in Manhattan until 2010 (not including space already under construction). It is unlikely, however, that all the proposed projects will be implemented and only in the optimistic scenario would the construction of this amount of office space be justified by market conditions. Based on the model results, it seems reasonable to assume that there will be moderate growth of demand for office space until the end of the decade and unless a large amount of competing new office space will be built in Midtown Manhattan, the rebuilding of most of the space that has been destroyed during 9/11 in Lower Manhattan is feasible under the assumed scenarios.

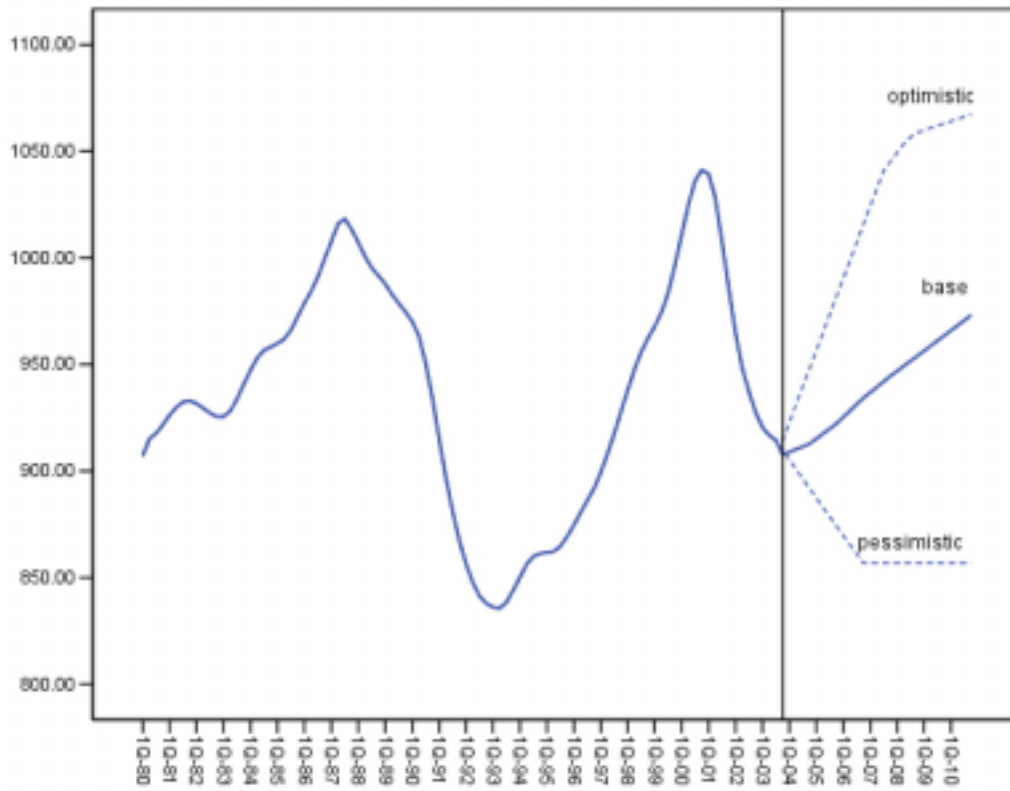


Figure 2 Office employment scenarios (in thousands of employees)

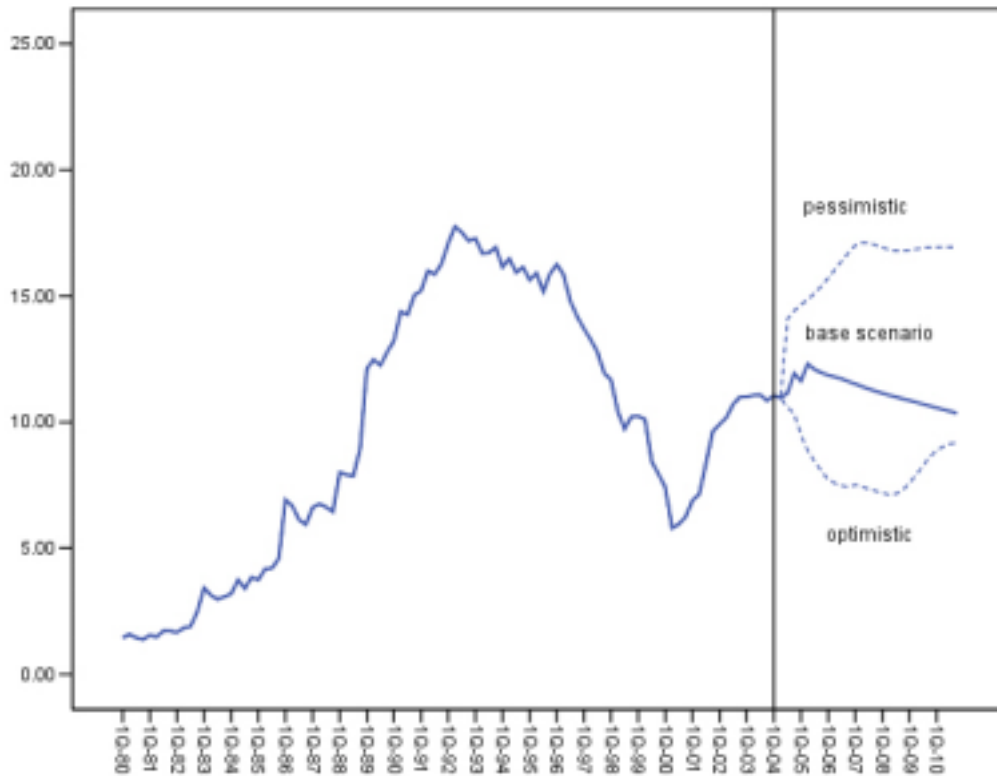


Figure 3 Vacancy rates (in percent)

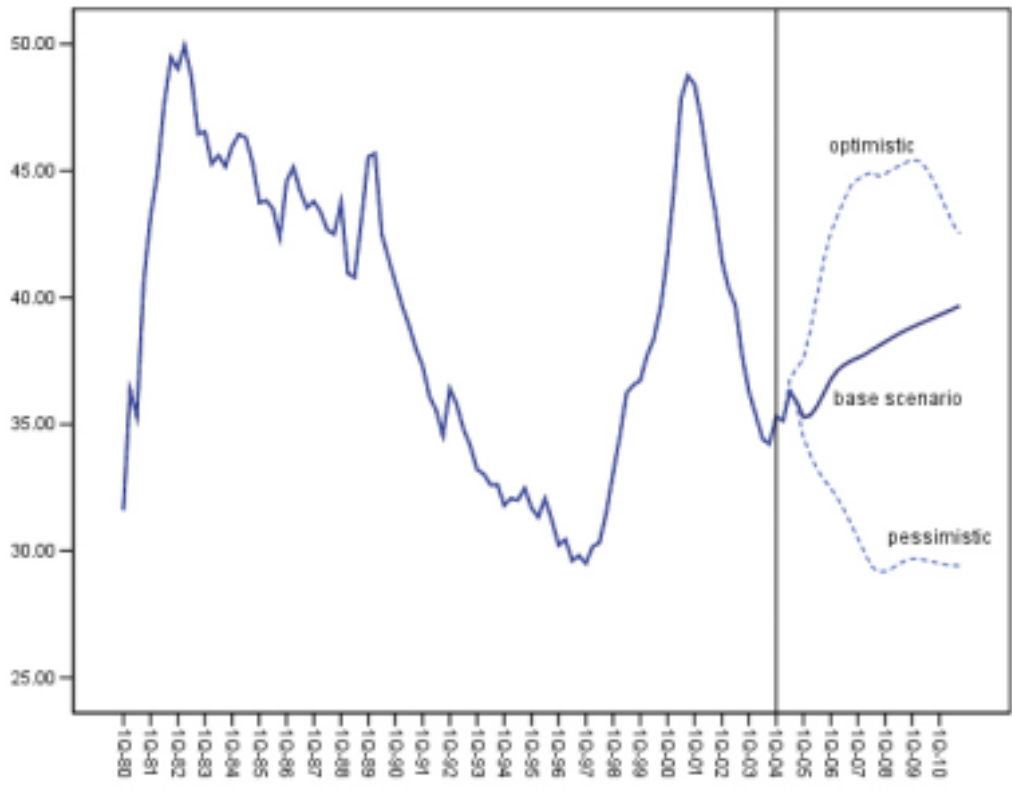


Figure 4 Rent per sq.ft. (in constant dollars)

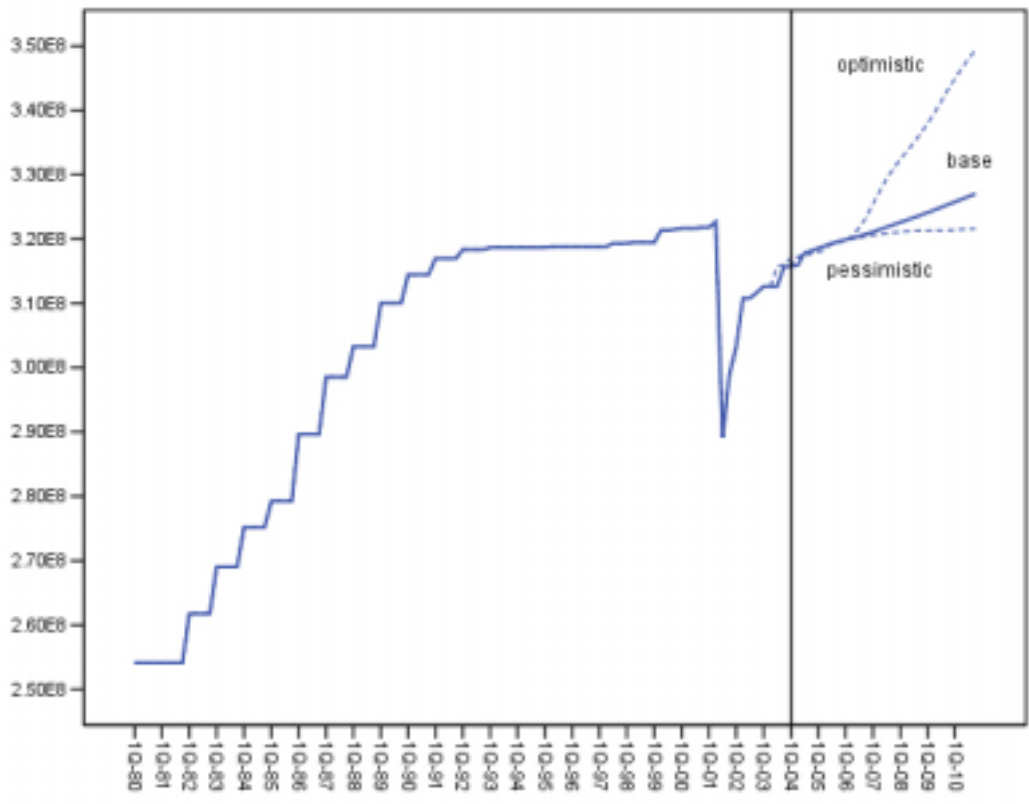


Figure 5 Inventory of office space (in sq.ft.)

5 Conclusions and further work

To explore the predictability of the Manhattan office market, a three-stage system of simultaneous equations was applied in this paper, where 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 model demonstrates that the Manhattan markets reacts efficiently and predictably to changes in market conditions, especially to the economic shock generated by the 9/11 attacks. 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 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. Lastly, it remains to be explored if a model specification can be found that fully captures the oscillations of the market cycle. All in all, there is clear potential for the simultaneous equation model to evolve further because this model is a relatively open system in contrast to the atheoretical prediction methods used to extrapolate past trends.

Appendix

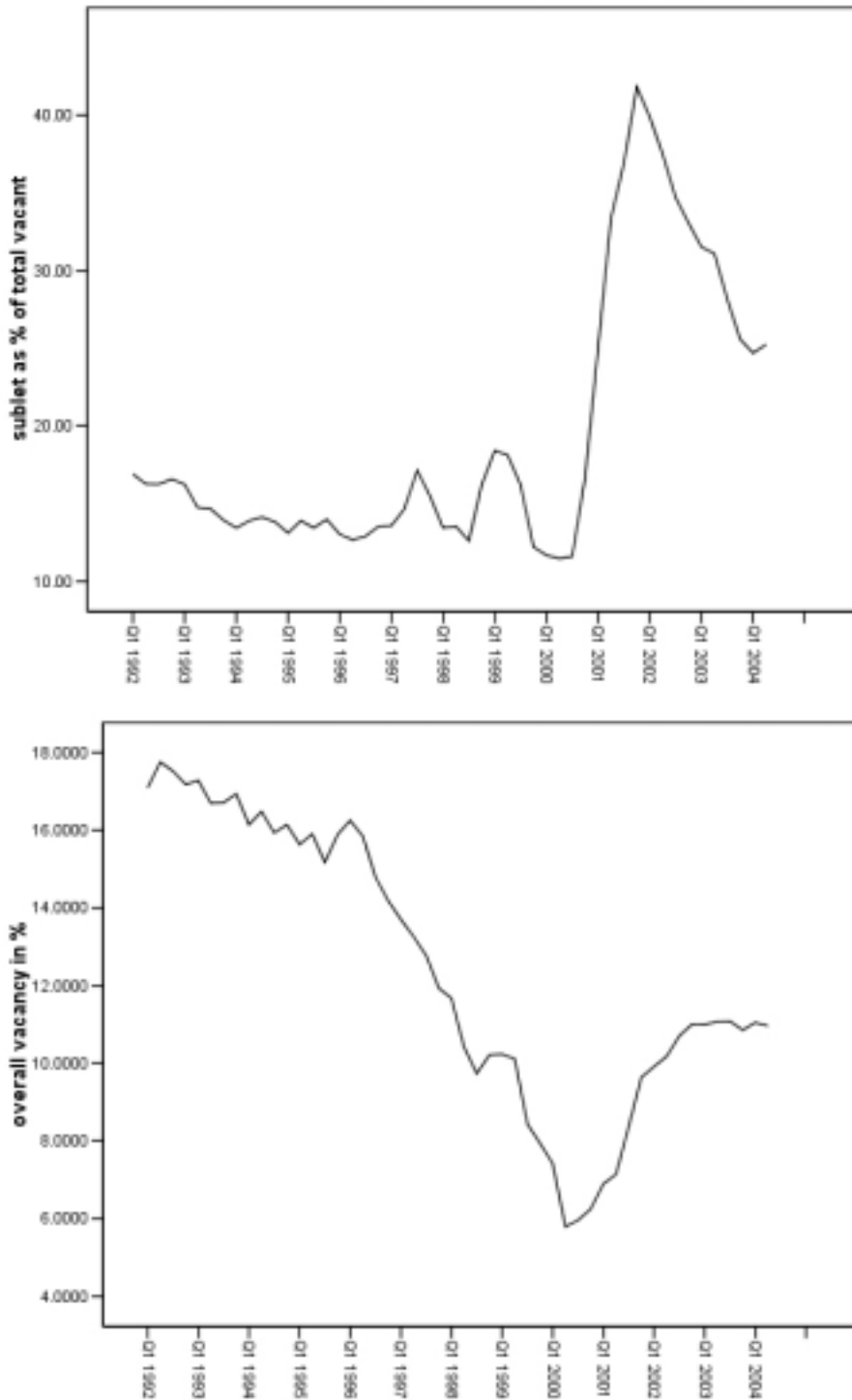


Figure A-1: Sublet space as a percentage of total vacant space (above) and overall vacancy in percent (below).



Figure A-2: Snapshot of locations of geocoded office buildings in Manhattan used to derive aggregate market indicators



Figure A-3: Submarkets of the Manhattan office market

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ⁱ Because of a lack of reliable data on the actual rate of buildings demolished or permanently taken off the market for the New York market, it is assumed that the change in supply is net of a depreciation rate which is probably below 0.1% of the total stock.

iii 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.

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

^{iv} The Jarque-Bera/Salmon-Kiefer test of the null hypothesis that the model errors u_j are $N(0, \sigma^2)$ 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 $N(0, \sigma^2)$ 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.

^v Test for ARCH(p) of $u(t) = \text{True value of OLS Residual of } r_diff1$
Null hypothesis: $u(t)$ is Gaussian white noise
Alternative hypothesis: $V(t) = a(0) + a(1)u(t-1)^2 + \dots + a(p)u(t-p)^2$,
where $V(t)$ is the conditional variance of $u(t)$.
The ARCH test is the LM test of the joint hypothesis
 $a(1) = \dots = a(p) = 0$
 $p = 1$
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

^{vi} Test for ARCH(p) of $u(t)$ = True value of
OLS Residual of r_diff1
Null hypothesis: $u(t)$ is Gaussian white noise
Alternative hypothesis: $V(t) = a(0) + a(1)u(t-1)^2 + \dots + a(p)u(t-p)^2$,
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The ARCH test is the LM test of the joint hypothesis
 $a(1) = \dots = a(p) = 0$
 $p = 1$
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

^{vii} The ARCH test is the LM test of the joint hypothesis
 $a(1) = \dots = a(p) = 0$
 $p = 1$
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