Office Rent Processes:
The Case of U.S. Metropolitan Markets

Rena Mourouzi-Sivitanidou, Ph.D.

Office Rent Processes:
The Case of U.S. Metropolitan Markets

Abstract

This paper *synthesizes* elements of the traditional and contemporary theory of real estate markets to formulate an empirical framework for exploring metropolitan office rent processes. Such a framework is then applied to the analysis of office rents across eighteen U.S. office markets during 1986-1995. The empirical results underscore the sluggishness of rental adjustments, highlight the extent of rental disequilibria across markets, and uncover the role of office employment factors--size, diversity, spatial organization, growth rates, and volatility--, construction costs, interest rates, amenities, and zoning in shaping interarea differentials in the equilibrium component of office rents.

I. Introduction

Available data throughout the eighties and most of the nineties suggest that wide and persistent variations in office rents exist across U.S. metropolitan markets.[1] Such differentials have largely been overlooked by existing real estate research, which has already explored *interurban* differences in residential prices or *intraurban* variations in both residential and nonresidential rents. The paucity of empirical work on interurban variations in office markets may lie, at least in part, in the difficulty involved in applying traditional cross-section methodologies to the analysis of such variations. Based on either a-spatial, partial equilibrium supply-demand frameworks (Ozanne and Thibodeau 1983; Potepan 1996) or spatial equilibrium analyses (Roback 1982; Sivitanidou 1995), existing studies essentially rely on the assumption that *prevailing* rents reasonably proxy implicit long-run steady-state rents, that is the stable rental rates that would be established in a market at any point in time in the face of instantaneousmarket adjustments and stable values for all exogenous demand and supply variables (i.e. values equal those prevailing in the market at that point in time).[2] Such an assumption, however, may not apply to the analysis of contemporary metropolitan office markets.

---

[1] Expressed in constant 1982-1984 dollars, in 1990, for example, standardized office rents controlling for lease and other traits at "average" locations reached $9.82/sqft in Atlanta, $12.08/sqft in Boston, $12.68/sqft in Chicago, and $15.78/sqft in Los Angeles. Similar differentials are observed in other years for which data are available.

[2] Supply-demand frameworks are based on the notion that metropolitan areas are isolated, or "closed",

continued

It is well accepted by now that office markets are subject to persistent disequilibria that may be responsible for wide deviations of prevailing from implicit long-run steady-state equilibrium rents. Such deviations largely stem from continuous exogenous (demand or supply) shocks that tend to lead the market toward ever-changing steady-state rents and from slow market adjustments toward these steady-states. Several features of, or processes taking place within, office markets may be responsible for such sluggish adjustments. One of such features clearly involves institutional constraints in the form of long term leases that prevent tenants from swiftly adjusting their consumption to desired levels and landlords from adjusting rents to contemporaneously reflect (unexpected) changes in market realities. Another feature may involve delays inherent in the micro-economic process of tenant search and landlord wait (Arnott 1987, 1989; Wheaton 1990; Read 1993). As they may be imperfectly informed on the attributes or prices of available space, tenants desiring to adjust their space consumption may engage in lengthy, costly, and perhaps "unsuccessful" search. As they may also be imperfectly informed on the magnitude and nature of demand, landlords may need to observe tenants and experiment with rental rates, before adjusting them toward desired levels (Stull 1978; Rothchild 1981; Read 1988a).[3] *Lastly,* sluggish rental adjustments toward equilibrium may also be due to *slow* supply responses to changing market conditions. Upward stock adjustments in response to sudden surges in demand can only be gradual due to long construction lags, delayed entry by rational investors exercising their option to wait until expected benefits outweigh costs (McDonald and Siegel 1986), or investment phasing in light of rising supply schedules or internal adjustment costs (Topel and Rosen 1988). Downward stock adjustments may even be slower, as they can only be realized through depreciation or (often) prohibitively costly space conversions.

Crystallizing the problem of analyzing interarea office rent differentials using prevailing rents is the argument that deviations of prevailing from (implicit) long-run rents may not be uniform across markets. Metropolitan office markets may differ in the speed at which office rents adjust toward their long-run steady-state levels due to differences, for example, in the degree of market heterogeneity

---

entities, whose real estate prices or rents are determined by exogenous market size (e.g. population, employment), construction costs, and (occasionally) spatial variables. Spatial general equilibrium frameworks presume long-run interactions among "open" spatial units that eventually help determine endogenously real estate rents, market size (employment), and real estate stock in terms of both spatial and non-spatial influences.

[3] Exercising the option to wait in light of significant adjustment or turnover costs, rational landlords may be reluctant to easily commit space to new tenants before being "reasonably" convinced that tenant demand is sufficiently high to economize on the future costs of occupancy changes (see McDonald and Siegel 1986; Dixit 1989; Grenadier 1995).

that may affect matching rates and lease up times. Furthermore, office markets may differ in their time path of implicit long-run rents due to *local* idiosyncratic shocks or differences in sectoral mix which may help elicit different local responses to national macroeconomic cycles (see Coulson 1993; Goetzmann and Wachter 1995).

Against this background, this paper *synthesizes* elements from the contemporary theory of real estate markets to formulate an empirical modeling framework for exploring adjustments of office rental rates towards their implicit equilibrium levels and for identifying the determinants of the latter. Moving beyond the traditional long-run theory of metropolitan pricing and building on contemporary search theory, such a framework involves a rental adjustment mechanism and a series of behavioral relationships that describe in a simplified manner the operation of metropolitan office markets. Summarizing these features is a reduced-form function for a representative market's long-run steady-state rent, which, combined with a simple disequilibrium formulation for that market's prevailing rent, sets the stage for the empirical analysis.

The estimation of a time-series cross-section model uncovers several useful insights into office market behavior across U.S. metropolitan markets. First, the empirical results are consistent with propositions that interarea variations in implicit steady-state rents do exist and are largely shaped by intermarket differences in office employment factors--size, spatial organization, diversity, growth rates, and growth volatility; construction costs and interest rates; as well as area amenities and factors potentially shaping regulatory constraints. Second, the empirical findings are also consistent with the proposition that office rents *only slowly* adjust toward their implicit long-run steady-state levels and, most importantly, perhaps, with adjustment speeds that likely differ across markets. Such interarea differences in speeds of rental adjustment may (in part) be responsible for differing degrees of rent disequilibria across markets, thereby suggesting that the application of traditional cross-section methodologies to the analysis of interarea rent differentials may be misleading.

Placing this work into a broader context, Section II provides a brief review of empirical and theoretical perspectives regarding pricing mechanisms and rental adjustments in office markets. Section III outlines the modeling framework that motivated the empirical work. Section IV discusses the empirical model formulation, presents the variables used, and elaborates on the empirical results. Lastly, Section V discusses the conclusions of the paper and offers some directions for future research.

II. Real Estate Rents and Rental Adjustments: Empirical and Theoretical Perspectives

A growing volume of empirical studies in the last two decades has largely been the stimulus rather than the outcome of theoretical advances. Stemming from Rosen's and Smith's (1983) seminal analysis of the rental housing market is a substantial body of work focusing on the existence of disequilibria in office markets and associated rental adjustments. Such disequilibria are expressed in terms of deviations of (nominal) vacancy rates from some benchmark vacancy rate, referred to as normal or structural, and presumed to be either intertemporally constant (Rosen 1984; Shilling, Sirmans, and Corgel 1987) or intertemporally variable (Wheaton 1988; Sivitanides 1997).[4] In the face of such deviations, rents and vacancy rates must adjust until vacancy rates return back to their normal level. If, due to unexpected changes in office market conditions, office vacancy rates rise (fall) above (below) this level, office rents must subsequently start falling (rising), but *only* gradually, as lengthy leases impede swift adjustments.[5] Such a framework sets the stage for estimating speeds of rent-vacancy adjustments, computing normal vacancy rates, and analyzing their interarea determinants (Shilling, Sirmans, and Corgel 1987; Sivitanides 1997) but does *not* allow the estimation of a market's implicit long-run rent.

By demonstrating important stylized features of office markets, the empirical research just described has motivated theoretical work that takes a detailed look at the microeconomic processes underlying rental movements. Recognizing that the deterministic competitive model cannot explain the coexistence of equilibrium rents and positive vacancies or the pervasiveness of equilibrium rent dispersion, this theoretical work seeks to provide consistent explanations for the observed rent-vacancy relationships and rental adjustments by relaxing some of the assumptions of the competitive model. As such, it invariably builds on some notion of imperfect markets: heterogeneous products and incomplete markets, imperfect information and costly search on the part of tenants (or landlords), price-setting behavior by landlords, informational asymmetries, and substantial moving or transaction costs.[6]

---

[4] The typical rent adjustment equation takes the form below, where R denotes rents, V the nominal vacancy rate, V^* the normal vacancy rate, a the speed of rental adjustment, and t the time subscript.

$$(R_t - R_{t-1})/R_{t-1} = a(V^* - V_{t-1}); \quad a>0 \tag{f1}$$

The authors cited above suggest that a positive normal vacancy rate, V^*, is necessary in equilibrium. On the demand (tenant) side, it allows for lower search, information, and relocation costs. On the supply (landlord) side, it allows landlords facing uncertain demands to take advantage of unexpected increases in demand and subsequent increases in rental rates. The extent of such inventory holding depends on expected economic conditions as well as marginal inventory costs (Shilling, Sirmans, and Corgel 1987). For a critique of this standard empirical formulation see Wheaton (1994) and Hendershott (1996).

[5] Eppli and Shilling (1995) show that quantity adjustments in commercial markets are also slow, thereby casting doubt on the emphasis of these models on quantity adjustments as market clearers. Following Voith and Crone (1988), Grenadier (1995) estimates vacancy adjustment models that support the argument that vacancy rates are also sticky due to significant adjustment costs.

[6] Most, if not all, of these factors have been recognized in Rosen and Smith's (1983) original work but have not been incorporated, in any fashion, in empirical rental adjustment formulations.

Arnott (1989), Read (1988a, 1988b; 1993), and Wheaton (1990, 1994), among others, have all relied on models of imperfect markets to explain price determination mechanisms in modern residential markets. Central in Arnott's (1989) modeling framework is the analysis of tenant search and landlord behavior in a world with tenant idiosyncratic tastes. Given such idiosyncratic tastes, tenants search for their preferred unit and are willing to pay a premium for it. Landlords are thus facing downward demand curves which, in the short run, equip them with some monopoly or rent-setting power. In the longer run, given free entry and exit, excess profits eventually dissipate through vacancies so that, in equilibrium, gross rental income, $R(1-V)$, equals annualized replacement cost, P^c. In a similar model of monopolistic competition, Read (1993) shows how equilibrium distributions of rents and vacancies arise out of landlords' behavior in light of tenants with differential imperfect information or search costs.[7]

Providing a variation of this theme, Wheaton (1990) develops a search-theoretic model of the housing market where buyers and sellers are assumed to have symmetric information. Prospective buyers are households who, because of demographic or other changes, become mismatched with the unit they occupy and engage in costly search. At any point in time, the market's vacancy rate is shaped by the number of households holding two units, the newly bought and the old one available for sale. Buyers and sellers engage in a bargaining and negotiation process resulting in market prices that lie in-between buyer and seller reservation prices. Wheaton suggests that greater vacancy increases sales time, lowers seller reservation prices, speeds up search time, and leads to lower market prices.

Search theory seems to be particularly applicable to modern metropolitan office markets. Office space in these markets is highly heterogeneous, both in terms of location--which has long been thought to play a critical role in the cost minimizing calculus of office tenants-- and other property traits. Office tenants in contemporary decentralized office markets may thus be expending substantial search and negotiation efforts in order to secure their preferred space. Recognizing the importance of tenant search and negotiation processes in office markets, Wheaton and Torto (1994) have argued that such processes give rise to a "desired" or "equilibrium" rent, which is shaped by expected lease time, determined (in turn) by tenant flows and the vacancy rate. Given, however,

---

[7] In earlier work, Read (1988a) models the mechanism through which a rational profit-maximizing seller of an infrequently exchanged idiosyncratic good revises slowly his expectation of a unit's market value and, hence, his reservation price using sales succession information. This mechanism offers an explanation for price dispersion and vacancy duration in markets where search activities or consumer preferences change through time and/or markets where sellers are relatively out of touch with consumer preferences. Using a simple (partial equilibrium) model with *price-taking* landlords and searching tenants that fail to notify landlords as soon as they initiate search, Read (1988b) also shows how delays on the part of landlords in searching for new tenants lead to persistent vacancies.

market imperfections, involving information lags, prevailing rents may only *gradually* adjust toward this "desired" level (see Wheaton and Torto 1994). Rental adjustments can, therefore, be modeled in terms of deviations of prevailing from "desired" rent levels.[8] In contrast, then, to the traditional rental adjustment model, this model does allow for the estimation of "desired" or equilibrium rents. Placing the idea of a "desired" rent in a long-run framework, which accommodates supply responses but, for reasons explained later, does not allow for intermarket factor movements, sets the stage for defining the modeling setup adopted in this paper.

III. Metropolitan Rental Adjustments and Long-Run Steady-State Rents

Presented below is a simple modeling framework that sets the platform for, *first*, exploring adjustments of office rents toward their steady-state levels and, *second*, identifying empirically those factors that shape variations across metropolitan office markets in such levels. Synthesizing contemporary theory, this model builds largely on the work of, among others, Wheaton (1987, 1990) and Wheaton and Torto (1994).

Before proceeding with the modeling of rental adjustments, the spatial elements of the modeling framework used need to be clarified. *First*, the "national" office market is assumed to be composed of a number of metropolitan markets, each of which may be subject to exogenous economic influences. Considering, among other factors, the time horizon of the analysis (see Section IV), the study relies on the traditional assumption that these metropolitan office markets represent "closed" rather than "open" economies. As such, the number of office tenants, N, of given size, n, or, equivalently, office employment, nN, in each market is assumed to be exogenous, while tenant costs/profits and worker utilities within each of these markets are assumed to be determined endogenously.[9]

---

[8] The search-theoretic model takes the form below, where R denotes actual rents, R^* "desired" rents, ABS the gross absorption rate, V the nominal vacancy rate, and a and t the speed of rental adjustment and time subscript, respectively. In estimating such a model, Wheaton and Torto (1994) utilize net absorption due to the unavailability of data on gross absorption.

$$R_t - R_{t-1} = a\,(R^*(ABS_{t-n},\ V_{t-m}) - R_{t-1}); \quad 1 \geq a \geq 0 \qquad \text{(f2)}$$

[9] The answer to the question of whether metropolitan office markets should best be modeled as "open" or "closed" is still unclear, especially in light of casual empiricism which occasionally lends support to either the "closed" or "open" nature of metropolitan areas (Brueckner (1987). In placing this question into perspective and offering a rationale for the "closed" city assumption in this research, a few comments, starting with basic definitions, are in order. The "open" city paradigm postulates that worker (firm) migration occurs to erase any utility (cost) differentials across metropolitan markets, while the "closed" city paradigm assumes a "captive" workforce and allows such differentials to persist. As migration across markets is far from costless, utility differentials may be erased through migration only in the very long-run which, according to Brueckner (1987),

continued

Second, the office sector within each metropolitan market is assumed to be locationally diversified, thus allowing for polycentric spatial structures. Considering polycentricity is important for two reasons: first, available data involve hedonic rents at a market's "average" subcenter or location submarket; [10] second, as discussed later, polycentricity may play a role in tenant search processes. For the sake of analytical simplicity, the number of employment centers, *s*, characterizing these structures is assumed to be exogenously given.[11] Given subcenter and tenant differentiation, a *distribution* of rents, as opposed to a single rent, may be prevailing in each market. This distribution is not explicitly modeled by the aggregate approach followed, but rents and other variables could be thought of as averages of some distributions. Thus, for the sake of analytical simplicity, the focus is on each metropolitan office market's average subcenter, that is a subcenter housing average employment, nN/s, and subject to the area's average amenity levels or other spatial influences. It is acknowledged that focusing on the "average" subcenter of a metropolitan office market may mask potential differences in rent processes between CBD and suburban subcenters. The latter, for example may differ in tenant characteristics and project/location attributes that may elicit differential rent responses. Unfortunately, distinct time series of hedonic rents across CBD or suburban markets are not available.

1. Equilibrium Rents and Rental Adjustments

As already noted, emphasis is placed on each metropolitan office market's "average" subcenter. The latter is thought to be characterized by a vector of "average" office rents, $\{R, R^*\}$, where R denotes actual market rent prevailing at this "average" center, while R^* signifies that center's implicit

can be as long as one or two generations. For this reason, the "open" city model is considered a longer run model than the "closed" city one, and its appropriateness as analytical tool largely depends on the time horizon of the analysis. The choice between a "closed" and "open" economy may also depend on the nature of the problem being addressed (White 1978). The "closed" model may be more relevant for analysis of changes that occur simultaneously in all cities (e.g. energy crises). The "open" model may be more relevant in light of changes affecting an area or a number of areas differently than others and, as such, may induce utility differentials and migration. Despite assertions that office markets may be affected differentially by macroeconomic influences, depending, for example, on the structure of the metropolitan economy in question, they are often perceived as rather "insulated" from each other (Hekman 1985; Rosen 1984; Wheaton 1987). Given the unavailability of sufficiently long time series to conform with the "open" city model and noting that the assumption of exogenous workforce also fits nicely most search and matching models upon which the modeling framework adopted in this study is based, the "closed" city model is used.

[10] See the empirical section of the paper for a more detailed data description.

[11] This is a simplifying assumption, which would have been very unrealistic if a longer time horizon were utilized in the empirical analysis.

steady-state rent: the rent that would prevail at any point in time with instantaneous market adjustments and stable values for all exogenous demand and supply determinants. At any point in time, *t*, *R* may deviate from R^* due to incomplete market adjustments, attributed, among other factors, to long office leases, imperfect market information, and, from a longer run perspective, to slow supply responses to changes in demand. In light of such slow adjustments, a fraction ρ of any deviation ε between *R* and R^* in period *t* persists into the next, thus implying a speed of rental adjustment of $1-\rho$.[12] Such an adjustment speed may vary across metropolitan office markets due to varying metropolitan characteristics inducing differing degrees of inefficiency. Within this context, the following formulation of prevailing average rents may be pertinent, where the error term, ε, representing deviations from equilibrium, is assumed to follow an AR(1) process:

$$R_{jt} = R^*_{jt} + \varepsilon_{jt}$$

$$\varepsilon_{jt} = \rho_j \varepsilon_{jt-1} + \upsilon_{jt}, \qquad (1)$$

where:

R_{jt} : market *j*'s rent prevailing at time *t*
R^*_{jt} : market *j*'s implicit steady-state rent at time *t*
ρ_j : rate of persistence
υ_{jt} : independent random shocks

Deviating, then, from traditional rent-vacancy adjustment models, (1) essentially decomposes prevailing rents into an equilibrium and disequilibrium component. Notably, such an approach has already been used in the analysis of unemployment rates, vacancy rates, housing price appreciation, and office capitalization rates (see Marston 1985; Voith and Crone 1988; Gyourko and Voith 1992; Sivitanidou and Sivitanides 1999).

2. Determining R*: The Base Model

Completing the rent determination framework just described requires a formulation for R^*.
In modeling the latter, emphasis is first placed on tenant search activity and its role in the determination of short-run average market rents in light of fixed stock and a fixed number of office tenants. Subsequently, absorption, vacancy rate, asset price and supply responses are introduced, the steady-state conditions of the system are specified, (long-run) steady-state rents are

---

[12] As such, the rental adjustment speed determines the time required to elapse from the time a shock takes place until the market (in the absence of other disturbances) clears. The time, τ, for example, required for *x*% of the discrepancy between prevailing and equilibrium rents to dissipate can be proxied by

$$\tau = ln(1-x)/ln(\rho) \qquad (f3)$$

derived, and the model's comparative statics are discussed.

2.1. Tenant Search Activity and the Short-run Rent Function

At any point in time, tenant search activity, T, is triggered by a mismatch between space demanded (desired) by existing office tenants and the space they occupy. The "average" ex-ante demand for office space within an office subcenter is a derived demand for office service output. As such, it can be expressed as $D_t = D(R^e, Z(nN/s, X))$ where R^e, is the (expected) average market rent, such that $D_R < 0$; N/s is the exogenously determined number of office tenants of given average size n such that $D_N > 0$; and X is a vector of firm output (or its exogenous determinants) and metropolitan-specific productivity shifters, such that $D_X > 0$.[13] At any point in time, X may shift, thus generating a mismatch between space demanded (desired) by existing office tenants and the space they occupy. Such mismatch, however, may not easily be "corrected" due, for example, to long-term leases that prevent tenants from adjusting instantaneously their space consumption. Assuming that existing leases expire at an exogenous Poisson rate γ, only a fraction of office tenants have the opportunity to search the market for more suitable space.[14] Therefore, T, can be expressed as in (2), where $T_N > 0$, $T_\gamma > 0$, $T_X > 0$, $T_R < 0$:

---

[13] Demand for space is thought to derive from the demand for office services. Cost minimizing firms at the average subcenter are assumed to produce office services, Q^s, using office space, S, priced at R, and a fixed labor input, nN/s, priced at w. Production occurs according to a constant returns to scale production technology, $Q^s = Q(S, nN/s; A^f)$, where A^f is a Hicks neutral productivity shifter encompassing the effect of firm production amenities, that is location factors that directly affect firm costs (e.g. climate potentially affecting utility costs or even crime levels affecting the tenant budget share of expenses for safety). Assuming, as in standard microeconomic textbooks, that the fixed input's cost is determined through the interplay of its demand and fixed supply, $w = w(Q^s, R, nN/s; A^f)$. Furthermore, with long-run profits equal to zero, the long-run cost of service output can be determined as $p = p(w,R)$ or $p = (Q^s, R, nN/s; A^f)$. Cost minimization subject to the production technology yields the space input demand $S = S(Q^s, R, nN/s; A^f)$. Service output, Q^s, in turn, can be determined in two ways. First, it can be equated to the service output demanded by the area's households, Q^d, in which case, household service demand needs to be determined. To this end, the metropolitan area is thought of as a collection of residential villages developed around its fixed-location employment centers. Service firms at each center cater to the demands of the one-worker households within each residential village. Households demand services in a way that their utility is maximized. Assuming that households only derive utility from the consumption of services, priced at p, residential land, l, priced (endogenously) at p^r, and residential amenities, A^{res}, and that labor income, w, is their only source of income, service consumption, Q^d (as well as the embedded function for p^r), can be expressed in terms of all exogenous variables of the model: employment size, nN/s, transport costs, τ, the price of agricultural land, p^a, household incomes, w, service output price, p, as well as residential amenities, A^{res}. Thus, $Q^d = Q(nN/s, p, p^a, w, \tau, A^{res})$. Given the expressions for p and w, $Q = Q^s = Q^d$ can be expressed as $Q = Q(R, nN/s, p^a, A^f, \tau, A^{res})$, and $S = S(R, nN/s, p^a, A^f, \tau, A^{res})$ or $S = S(R, nN/s, X)$, where $X = X(p^a, \tau, A^f, A^{res})$. Alternatively, firm output can be assumed to be given exogenously, as is the case in this analysis.

[14] The rate γ depends on lease lengths that may be determined simultaneously with lease rates. However, for simplicity, γ is assumed to be exogenous. The hedonic rents utilized in the empirical analysis do control for

continued

$T_t = \gamma\, D(R^e_t, Z_t)$ (2)

Focusing on the Poisson matching probability, *m*, this can be expressed in terms of market rent, *R*, the probability of tenants finding suitable space, θ, and search costs, *c:*

$m_t = m\,[R_t, \theta\,(V_t, \phi_t), c\,(\phi_t, r_t)]$ (3)

This matching rate should obey $m_R>0$; simply, if average market rents are higher, the search effort may be higher, as the marginal benefits associated with savings that may be achieved by finding space at rents below this level may be greater. If market rents are higher, landlords may also face a greater opportunity cost of holding vacant units, which may motivate them to accommodate faster matching. If the probability θ of tenants finding suitable space is greater, the matching rate will also be higher, such that $m_\theta>0$. Notably θ may be shaped by the level of market vacancies, *V*, and the degree of market heterogeneity, ϕ. Market vacancies may facilitate search, so that $\theta_V>0$. Market heterogeneity, however, may reduce the probability of finding the "right" space, so that $\theta_\phi<0$. The probability of a tenant finding space of a given type may be smaller, for example, in markets with a more diverse tenant base/stock.[15] To the extent that spatial heterogeneity exemplifies tenant/stock heterogeneity, the same effect should apply. Finally, although higher search costs may lead to less effort and, hence, lower *m*, they may also render tenants sufficiently less demanding, thereby leading to faster matching, so that, ultimately, $m_c>0$. Marginal search costs may directly be related to the degree of market heterogeneity, ϕ, and the opportunity cost of search time or the rate of interest, *r*. Greater stock and locational heterogeneity may be associated with higher information and, hence, search costs, so that $c_\phi>0$. A greater number of *differentiated,* smaller and lower-density office nodes, for example, may impede information exchange and render search more spatially extensive, thus contributing to search costs.[16] Reflecting the opportunity cost of search time, the interest rate, *r*, may exert similar effects so that $c_r>0$.

(exogenous) lease lengths (Wheaton and Torto 1994).

[15] The underlying assumption here is that tenant heterogeneity signifies an equally diverse demand for and supply of space. This may be a reasonable assumption as differentiated demands should (in the long run) be accommodated through appropriate supply responses.

[16] Viewed from Arnott's (1989) perspective, the diversity of the existing inventory and tenants may signify thin markets. In light of tenant idiosyncratic tastes and willingness to pay a premium for their preferred space, landlords are able to exercise some monopoly power (in the short run) and charge higher rents.

As demonstrated by Wheaton (1990), tenant search activity, *T*, and the matching probability, *m*, along with the office vacant stock, *VS*, are instrumental in determining the short-run office rent, *R*. Determined through a negotiation process, and assuming symmetric information, the market rent of newly leased space must lie between tenant and landlord reservation rents.[17] Both are driven by the average expected lease up time, which is (in turn) inversely related to the tenant search activity, *T,* and matching probability, *m,* and directly related to the market's vacant stock, *VS.* Landlord reservation rents are lower with higher expected lease up time, as the opportunity cost (the rent and interest foregone) of not finding a suitable tenant increases with longer wait. Tenant reservation rents also fall with higher lease up time, as higher lease up time implies greater vacant stock per searching tenant and greater probability of finding a more suitable unit in a subsequent search. The tenant opportunity costs of not renting are, therefore, lower, thereby leading to lower tenant reservation rents:

$$R_t = R(m_t T_t,\ V_t S_t) \tag{4}$$

Focusing on partial effects, increases in tenant flows, *T*, due, for example, to expected employment growth or exogenous productivity shifts, must lead to higher market rent, such that $R_T > 0$, as higher search activity for given level of *V* and matching rate *m* implies shorter lease up time. Similarly, $R_m > 0$, as a higher matching rate will shorten expected lease up time and, as such, lead to higher market rents. Furthermore, assuming that the *vacancy rate* is not productive (*i.e.*, greater vacancy does not facilitate search), an inverse relationship must exist between rents and vacancies, such that $R_V < 0$, as higher vacancies are associated with longer lease up time. In contrast, however, if greater market vacancies render search more productive, the probability, *m*, of tenants finding suitable space within a given time period also increases, thereby rendering the overall (short term) effect on lease up time and, hence, rents uncertain.

2.2. Market Absorption and Vacancy Rates

As shown by (5), the new space absorbed at the market rent can be expressed as the difference between gross space absorption by successful (matched) searchers, $m\gamma D(R_t, Z_t)$, and the space they were previously occupying, $m\gamma OC_{t-1}$. This net absorption determines a new occupied stock which, as shown by (6), together with the total stock, determines the vacancy rate.

$$A_t = m_t \gamma [D(R_t\,,\, Z_t) - OC_{t-1}] \tag{5}$$

[17] Reservation rents are defined as those rents that leave the landlord and tenant indifferent between renting and not renting the space.

$$V_t = 1 - (OC_t \,/\, S_t) = 1 - [OC_{t-1}\,(1-m_{t\gamma}) + m_{t\gamma}(D(R_t\,,\,Z_t)]\,/\,S_t \qquad (6)$$

2.3 Asset Price Movements and Supply Responses

As shown by (7), the aggregate supply of office space, *S,* evolves in a stock-flow manner so that, in each period, new construction is added to the existing stock, which is assumed to depreciate at the rate δ. New construction, however, can only be realized as long as expected asset prices are higher than development costs.[18] When asset prices exceed development costs, excess profits accrue to land, and increases in land rents bring forth land for new construction. This relationship between construction, *C,* completed at time *t*, expected asset price, *P*, at the time of completion, and development costs, P^c, at the time the investment decision is made, *t-n*, is given by (8).[19]

$$S_t = S_{t-n}(1-\delta) + C_t \qquad (7)$$
$$C_t = C(P_t\,/(1+d)^n - P^c_{t-n}) \qquad (8)$$

Ignoring depreciation in value, expected asset price, *P*, at time *t* is determined by the well-known asset pricing formula in (9), where *g* is the expected growth of the rental income stream, *R(1-V)*, at the time of the investment decision, *t-n*, and *d* is the exogenous discount rate.[20]

$$P_t = \sum_{\lambda=1}^{4} \frac{R_t\,(1-V_t)\,(1+g)^{\lambda}}{(1+d)^{\lambda}}\;; \qquad R_t(1-V_t) = R_{t-n}\,(1-V_{t-n})\,(1+g)^{n} \qquad (9)$$

---

[18] This investment rule deviates from the one suggested by the new option theory (McDonald and Siegel 1986; Dixit and Pindyck 1994); however, as discussed in the empirical section, demand volatility, featuring prominently in this theory, enters the empirical model as a risk component of the capitalization rate.

[19] Following Gyourko and Voith (1993) and Alm and Follain (1994), among others, the new supply function assumes as simple a specification as possible. A more rigorous specification of the supply function could be derived from a supplier's multi-period optimization. Topel and Rosen (1988) present in some detail the derivation of such a function. They show that current prices alone are sufficient statistics for supply only if investment costs are not affected by the rate of change in investment output or, differently, only if short- and long-run investment supply elasticities coincide. Otherwise, current asset prices do not incorporate all information needed to make informed investment decisions, and expectations of future asset prices must be considered.

[20] Expectations in this model are assumed to be exogenous. Assumptions involving rational, forward-looking expectations will be examined in future research.

Notably, development costs, P^c, in this base model specification are assumed to be exogenous. An expanded specification in a later section accounts for the endogenous price of urban land and, by extension, development costs.

2.4. Steady States

Together with the steady-state conditions of the model, the prevailing values of all exogenous variables at any point in time *t* determine implicit steady-state solutions for the model's endogenous variables, including *R, V, P,* and *S*. These implicit solutions provide those stable values of these variables that would prevail if the market could reach its steady state instantaneously and if all exogenous variables maintained their values at time t. A change in the latter would invariably imply a different steady-state solution. With a nonzero rate of depreciation and the need for the depreciated stock to be replaced through a steady-state level of new construction, the steady-state solutions of the model differ somewhat from the long-run equilibrium solutions that correspond to the case with no depreciation. For the sake of analytical simplicity, a zero depreciation is thereafter assumed. In such a case, the steady-state level of new construction equals zero.[21]

The steady-state variant of (4), incorporating (2) and (3), is given by (10). Assuming for simplicity, *zero* depreciation of the existing stock, equation (5) implies that, at the market's steady-state, average gross absorption should equal the space vacated or, as shown by (11), that net absorption, *A*, equals zero. This ensures that the aggregate space demand is stable. It by no means implies that there is no search activity and, hence, no reason for vacancies to exist. The indivisibility of space and incompleteness of markets always ensures search and positive vacancies. Continuing with the steady-state of the system, (6) can be restated as in (12). Assuming $R^e_t = R_{t-1}$ and for $R_t = R_{t-n} = R^*$ and $V_t = V_{t-n} = V^*$, the asset price expression in (9) yields (13). Lastly, given (7)-(8) and assuming zero depreciation, yields (14). For the simplicity of exposition, all time subscripts are omitted from (10)-(14).

$$R^* = R[m\,(R^*, \theta\,(V^*, \phi,), c(\phi, r))\,\gamma D(R^*,Z), V^*S^*] \qquad (10)$$

$$A = 0 \qquad (11)$$

$$V^* = 1 - D(R^*, Z_t)/\,S^* \qquad (12)$$

$$R^*(1-V^*) = P^*u(d, g) \qquad (13)$$

$$P^* = P^c\ (C=0) \qquad (14)$$

---

[21] See, for example, Alm and Follain (1994). With nonzero depreciation, the steady-state level of new construction should be just sufficient to cover the depreciating stock or, more specifically, $C^* = \delta S^*$.

2.5. Steady-State Rent

Solving (10)-(14) for the steady-state rent, R^*, gives rise to the reduced-form (15). As shown, R^*, as well as the model's other endogenous variables, are driven by (aggregate) demand shifters, Z, exogenous matching rate shifters, M, construction costs, P^c, and capitalization rate components, u.[22]

$$R^* = R[\gamma,\ Z(nN/s, X),\ \ M(\theta(\phi), c(\phi, r)),\ \ P^c,\ \ u(d, g)] \qquad (15)$$

2.6. Comparative Statics

The comparative statics of the steady state of the system can be determined via total differentiation of (10)-(14). The final results are shown in Table 1, while the derivations and relevant conditions are explained in the Appendix. The effects of four exogenous variable groups--desired demand shifters, turnover and matching rate shifters, and development cost and capitalization rate shifters-- are first discussed.

Group 1. Desired Space Demand Shifters, Z(nN/s, X). Given a level of development costs, a shift in desired space demand will result in a higher number of office tenants searching the market. In the short run, rents must increase and vacancies must decrease. As rents increase and vacancies decrease, asset prices increase above development costs, thus triggering new construction. As new construction comes forth, rents start declining and vacancies start rising. The ultimate effect of increases in aggregate space demand on R^*, V^*, and S^* depends on how the rent response to changes in tenant flows compares to the rent response to changes in the vacant office stock. If rents respond more to tenant flows than to vacant stock changes, they should eventually be higher than their pre-shock levels (see Appendix). From (13) vacancies, V, should settle at those levels that will help asset prices revert back to the fixed replacement cost level. With higher R^*, for (13) to hold, V^* must rise as well. From (12), with higher V^* in light of a demand shift, S^* must rise as well.

Group 2. Matching Rate Shifters, M. As the matching rate *(m)* rises because of exogenous factors, M, short-run rents increase and the vacancy rate declines. As asset prices increase, new construction is triggered. This forces asset prices back to their original levels through higher vacancies. As shown in the Appendix, steady-state rents must eventually be higher than their pre-shock levels. From (13), with higher R^*, V^* must also be higher, while from (12), the change in S^* will depend on how the decrease in demand due to higher R^* compares to the increase in V^*. As shown in the Appendix, with demand being rather rent inelastic, S^* must rise as well. For given levels, then, of aggregate space demand shifters, Z, development costs, P^c and, hence, asset prices, P^*, a

[22] M is used to denote the exogenous shifters of the matching rate, m.

higher matching rate must also lead to higher steady-state rents and vacancies and, under certain conditions, a larger office stock.

Group 3. Development Cost Shifts, P^c. As replacement costs, P^c, decrease below the prevailing asset prices, profit-seeking developers respond, and new construction increases. This leads to increasing vacant stock, increasing lease up time, and lower rents. Given (13), such lower rents, R^*, and higher vacancies, V^*, ensure that asset prices, P^*, will eventually reach the lower replacement cost levels. From (12), both higher demand (due to lower rents) and higher vacancies ensure that the market's steady-state stock, S^*, will also be higher than its pre-shock levels (see Appendix).

Group 4. Capitalization Rate Shifts, u. In light of capitalization rate decreases, short-run asset prices increase and new construction is triggered. Vacancies rise, lease up time increases, and rents decrease. New construction halts, as declining asset prices return back to their replacement cost levels. As shown in the Appendix, at the market's new steady state, rents, R^*, are lower, while the vacancy rate, V^*, and office stock, S^*, are higher than their pre-shock steady- state levels, thus satisfying (10)-(14).

3. An Extended Model: Revisiting Development Costs

Replacement costs in models similar in spirit to the one just outlined are assumed to be exogenously given. However, this may not be a reasonable assumption. The cost of construction capital (labor and materials) and the cost of land may both be directly related to space and asset demand and, as such, may be determined endogenously. As, for example, asset demand rises, factor demands and respective factor prices may rise. While it may be hard to make the case for the endogeneity of construction costs in the context of a "closed" model such as the one described here, it is easier to demonstrate the endogeneity of land prices. In light of endogenous land prices, equilibrium condition (14) becomes:

$$P^* = P^c = P(p^*, k), \qquad (16)$$

simply indicating that development costs include the cost of commercial land, p^*, and commercial construction capital, k. The specification of the steady-state commercial land price function, p^*, used here draws from models of spatial development that recognize the durability of real estate capital (Arnott 1980; Wheaton 1982; Brueckner 1980; Capozza and Helsley 1989) but does not incorporate the effect of uncertainty on the pricing of urban land as in Capozza and Helsley (1990).[23] Recalling

[23] It needs to be emphasized that models of spatial growth within polycentric cities with both durable commercial and residential capital do not fully examine the dynamics of land rents or land prices. In

continued

the multicentric structure of metropolitan office markets, consider a center encircled by a residential village whose borders coincide with the metropolitan area's borders.

Focusing first on the edge of the commercial development or the border between commercial and residential development, it can be argued that, at the steady state of the system, a developer must be indifferent between maintaining a residential parcel into its current use and redeveloping it into commercial use. For this to be the case, commercial land *rents,* R_l^c at the edge of the commercial cluster must equal residential land rents, $R_l^{\,r}$, plus the cost of conversion, *rk*, of a parcel of residential into commercial use, so that $R_l^c = R_l(R_l^{\,r}, r, k)$.[24] Residential land rents at the edge of the commercial district, in turn, must equal rural land rent, R_l^a, at a sufficient long distance from the city border (see Capozza and Helsley 1989) plus the cost of conversion of agricultural into urban residential land, rk^{res}, plus the location rent due to the accessibility differential between the outer edge of the residential village and its edge to the commercial district. Given the focus on the "average" center employing *nN/s* workers, this location rent can be thought of as depending on transport costs per unit distance, τ, as well as the number of the center's workers. In sum, $R_l^{\,r} = R_l(R_l^{\,a}, r, k^{res}, \tau, nN/s)$ and $R_l^c = R_l(R_l^{\,a}, r, k^{res}, \tau, nN/s, k)$. Considering now that commercial land price is the capitalized value of expected land rents, and assuming a stream of benefits in perpetuity, p^* can be expressed as in (17), where *d* is the discount rate and *g* is the expected growth premium.

$$p^* = R_l(R_l^{\,a}, r, k^{res}, \tau, nN/s, k)/ d\text{-}g, \qquad (17)$$

The above land rent function omits the effect of barriers to entry, *z*, due, for example, to zoning constraints or growth controls that may disturb the relationship of adjoining residential and commercial land rents. It also omits the effect of any utility bearing urban amenities, A^{res}. Assuming that such amenities enter residential utility functions, they may also affect residential land rents. The extent, however, to which amenities are reflected in endogenous utility differentials vs land rent differentials cannot be determined a-priori. This ambiguity regarding the effect of amenities in "closed" city models has been extensively discussed by Polinsky and

---

examining a model with sequential firm and worker entry in a monopsonistic land market, Tabuchi (1990) assumes durable yet replaceable capital and does allow costly conversion of housing to office use--existing residential use around the city center is gradually replaced by denser commercial use. However, given monopsony, he ignores land rent throughout his analysis and rather focuses on the distribution of firms and workers. Henderson and Slade (1993) similarly explore on development patterns within cities with both residential and nonresidential use, without exactly focusing on land rent determination.

[24] Using simply *rk* to represent the cost of conversion implies that demolition costs are negligible.

Shavell (1976). Nevertheless, assuming that z and A^{res} may also be relevant (in a comparative analysis context), the land price function can be expressed as:[25]

$$p^* = p(R_l^{\,a}, r, k^{res}, \tau, nN/s, k, d, g, z, A^{res}) \tag{18}$$

In the case, therefore, of endogenous development costs, the steady-state of the system can be described by (10)-(13), as well as (16) and (17)-(18) in place of (14). The reduced-form R^* is now given by (19):

$$R^* = R[\gamma, Z, M(\theta(\phi), c(\phi, r)), p(R_l^{\,a}, r, k^{res}, \tau, nN/s, k, d, g, z, A^{res}), k] \tag{19}$$

Comparative statics analysis now needs to account for the fact that shifts in N, z, and A^{res} may positively affect development costs and, hence, R^*. The same applies to s, which as already discussed, may proxy spatial heterogeneity, ϕ, which may also affect the matching rate, m. All other exogenous variables in (17) or (18) shape P^c, whose effects on all endogenous variables of the system have already been discussed.

IV. Cross-Section Time-Series Analysis of Office Markets

Using cross-section time-series data from the largest U.S. office markets across the nation's four regions (e.g. Boston in the Northeast, Atlanta in the South, Los Angeles in the West, Chicago in the Midwest), the analysis in this section focuses on the estimation of two models. The first, referred to as Model I, is the base model, derived by incorporating into (1) the reduced-form steady-state rent specification depicted by (15); the second, referred to as Model II, is the expanded model derived by incorporating into (1) the expanded steady-state rent specification depicted by (19). Portrayed in general form by (20), both estimated models utilize the real rent index, $R_{j\,t}$ as the regressand.

$$R_{j\,t} = a + F(Z_{j\,t}, M_{j\,t}, P^c_{j\,t}, u_{j\,t}) + \rho_j\, \varepsilon_{j\,t-1} + \upsilon_{j\,t} \tag{20a}$$

$$E[\varepsilon^2_{j\,t}] = \sigma_{j\,j} \tag{20b}$$

$$Cov[\varepsilon_{j\,t}, \varepsilon_{k\,t}] = \sigma_{j\,k} \tag{20c}$$

where:

---

[25] The case of noncompetitive land markets has been studied by, among others, Markusen and Scheffman (1978) and, more recently, Turnbull (1986). They find that market power on the part of the landowner generates incentives for withholding land and delaying development.

a : a constant
Z_{jt} : exogenous (aggregate) office demand shifters
M_{jt} : exogenous matching rate shifters
P^{o}_{jt} : exogenous development cost shifters
u_{jt} : exogenous capitalization rate shifters
ρ_{jt} : serial correlation coefficient
ε_{jt} : autocorrelated, heteroskedastic, and cross-sectionally correlated error term
υ_{jt} : random iid error
j,t : metropolitan location and time index, respectively

Representing the TSCS model originally developed by Kmenta (1986) and later refined by Greene (1993), the model depicted by (20) accounts for *group-specific* autocorrelated (20a), heteroskedastic (20b), and cross-sectionally correlated (20c) error structures. As already hypothesized, error autocorrelation is an important component of (20), given the potentially slow demand and supply adjustments stemming from search and development processes in local office markets. Failure to account for its presence may result in inefficient parameters estimates. Similar estimation biases may be introduced by group-specific heteroskedasticity that may arise out of residuals that vary with the size of independent variables; often present in panel models, such heteroskedasticity should also be appropriately tested and accounted for. Finally, to the extent office markets are not perfectly segmented along metropolitan boundaries and are subject to common macroeconomic influences, shocks in one market may reverberate across markets thus giving rise to a contemporaneous correlation of metropolitan-specific shocks.

1. Data and Empirical Variable Proxies

Eighteen metropolitan office markets whose rent history is traced as far back as the first semester of 1986 (1986.1) and as recently as the second semester of 1995 (1995.2) are included in the sample used to estimate the TSCS model in (20) and its variants.[26] Relevant data on these markets were drawn from two datasets: (a) a CB Richard Ellis/Torto Wheaton Research cross-section time-series dataset on hedonic office rents and related office market variables; and (b) a set of complementary time-series cross-section data on the eighteen office markets collected from various sources by the author. Constructed from the above datasets are various variable proxies, as called for by (20).[27]

---

[26] An earlier version of this paper used a longer time series spanning eighteen years. Following a referee suggestion, this time frame has been shortened to more clearly conform with the "closed" city model adopted in this paper. For further discussion of this issue, refer to note 9.

[27] As already noted, lease lengths are controlled for by the hedonic rents used. Transportation costs per mile are assumed to not differ significantly across markets, while intermarket differences in conversion costs are continued

All such proxies are presented in Table 2, which offers detailed definitions, expected signs, and data sources, and in Table 3, which presents basic descriptive statistics. Given the detailed information portrayed in these tables, only a broad discussion of the relevance and noteworthy features of the variables used in empirical estimation is provided below.

Office Rents (R). "Average" rental rates, referred to by Wheaton and Torto (1994) as *hedonic indices of average consideration*, represent the average annualized gross rental payment per square foot, expressed in constant 1982-1984 dollars. Controlling, among other factors, for the starting date, size, and length of the lease, this index represents, in particular, the annualized average gross rental payment per square foot for a 10,000 square-foot lease, with a five-year term, associated with space in an existing (as opposed to new) building located within a subcenter/submarket of "average" location value. The detailed methodology used for its derivation is described more extensively by Wheaton and Torto (1994).

Group 1: Desired Demand Shifters (Z). Assuming that desired demand is shaped by expected, as opposed to current, employment, vector *Z* includes not only *EMPL*, representing office employment at each metropolitan area's "average" subcenter/submarket and proxying office sector output, but also *GROWTH,* intended to capture exogenous growth expectations and measured by average past rates of office employment growth. Furthermore, *Z* incorporates *RATIOF*, representing the ratio of office employment in FIRE over employment in other office sectors and intended to capture the higher space requirements that may characterize the more prestigious FIRE tenants. All these demand indicators are expected to exert a positive effect on office rents. In addition, to the extent firm amenities induce productivity effects through their influence on the cost of doing business, *CRIME* and *CLIMATE,* discussed below as development cost/land price shifters, may also be relevant. *CRIME*, representing a metropolitan crime index and potentially affecting business costs, is expected to induce negative influences on office rents, while *CLIMATE*, representing average temperature and potentially affecting utility costs, is expected to affect positively office rents.[28]

Group 2: Matching Rate Shifters (M). As already noted, matching rates *(m)* may be influenced by the probability of finding suitable space, which may, in turn, be shaped by market (spatial and tenant/stock) heterogeneity and search costs, which may also be influenced by market heterogeneity and the discount rate. The spatial heterogeneity of the office sector is proxied by *SUBCENT*,

assumed to be captured by construction cost differences. All other effects discussed in Section III are explicitly considered in the empirical formulation.

[28] The specification of *Z* is based on the simple input demand specification, $S=S(Q^s,R,\ nN/s;\ A^f)$, where Q^s represents exogenous service output. See note 13 for a more detailed discussion.

representing the number of each metropolitan area's homogeneous location markets as identified by Torto Wheaton Research.[29] Normalized by land area (square miles of developable land), *SUBCENT* may also affect steady-state rents on the assumption that it contributes to search costs.

Tenant/stock heterogeneity is measured by the office employment diversity index, *DIVERSE.* The latter reflects the *H*-Index or Shannon-Wiener Index, H_j, normalized by the maximum possible sectoral diversity, H_{max}. Referred to sometimes as the Shannon *evenness* index, this index of sectoral diversity was calculated as in (21), where E_{ij} reflects market *j*'s ratio of employment in detailed F.I.R.E and Service SIC *i (=1,2,...I)* over its total office employment and *ln(I)* reflects maximum possible diversity:

$$DIVERSE_j = H_j/H_{max} = -\sum (E_{ij}) \ln (E_{ij}) / \ln(I) \tag{21}$$

Given that *DIVERSE* and *SUBCENT* may affect negatively the probability of finding suitable space, thereby impeding matching, and positively search costs, thereby encouraging matching, their ultimate effect on rents is uncertain.

TENSIZE, measuring average tenant size, is intended to capture requirements by larger tenants for bigger, contiguous, and (perhaps) more prestigious space. To the extent such requirements render search more difficult and/or lower the probability of finding suitable space, *TENSIZE* is expected to exert a negative effect on office rents.

Lastly, it is worth noting that *DISCOUNT* (discussed below) may, to an extent, proxy the opportunity cost of search, which is expected to exert a positive impact on the matching rate and, hence, rents.

Group 3: Development Cost Shifters (P^c). Nonland development costs are proxied by *CCOST*, which mainly includes the cost of construction materials and labor. Land price effects are proxied by potential residential amenities, *CRIME* and *CLIMATE*, defined previously, and *ZONING*, measuring average land controlled by local governments and intended to capture regulatory influences on the land market. Assumed to affect the opportunity cost of commercial development, *CRIME* and *CLIMATE* are expected to exert negative and positive influences on office rents, respectively. According to the monopoly zoning hypothesis (Fischel 1980), *ZONING* may reflect the extent of land supply constraints and, as such, exert a positive effect on office rents.

---

[29] A number of alternative proxies of urban structure were used, including average worker commutes and the percent of office space or office employment within CBDs or central cities. *SUBCENT* appears to perform relatively better in the models presented in this paper.

Group 4: Capitalization Rate Shifters (u). Capitalization rates may be shaped by several factors: the real opportunity cost of commercial capital; expected growth in rental streams; and risk premia. The real opportunity cost of commercial capital is proxied by *DISCOUNT,* reflecting an inflation-adjusted constant maturity Treasury rate, which is expected to affect positively the capitalization rate and, hence, office rents. Expected growth in rental streams is proxied by *GROWTH*, which reflects past office employment growth rates and is expected to exert a negative impact on the capitalization rate and, hence, office rents. Such a negative effect counteracts the positive influence of *GROWTH* on rents through its impact on space demand, thereby rendering the net effect of this variable uncertain. Risk premia are proxied by growth volatility, *VOLAT,* capturing the effect of uncertainty on the part of the landlords regarding rental income streams and expected to exert a positive influence on office rents; [30] employment base diversity, *DIVERSE*, expected to exert a negative effect on office rents, as markets with a more diversified tenant demand base may be considered less risky; and several other variables intended to capture tenant-related risks. The latter include *GOVTEN*, representing the fraction of government tenants; *TENSIZE* (defined earlier); and *RATIOF* (also defined earlier). Such proxies are intended to respectively capture tenant risk aspects associated with the more stable income streams from government tenants, the financially stronger larger tenants, and the more volatile FIRE tenants.[31] As such, *GOVTEN* is expected to exert a negative influence on office rents, while *TENSIZE* and *RATIOF* are expected to exert effects that reinforce their previously discussed (negative and positive, respectively) influence on office rents.

In addition to the factors just discussed, attempts were made to extend (20) to explicitly account or the effect of changes through time in the degree of metropolitan decentralization. Attempts to proxy such effects through the use of a time (trend) variable did not produce sensible results. Further attempts to capture such changes through the use of "suburbanization" proxies, such as energy/transportation costs and household incomes (e.g. Brueckner 1987; Wheaton 1974), proved unsuccessful. In order to avoid overidentifying (20), such proxies were not included in the empirical model specifications that were finally adopted in this paper.

2. Empirical Estimation

[30] A growing volume of the investment literature focuses on the relevance of volatility in underlying demand movements in affecting irreversible investments (see, for example, McDonald and Siegel 1986; Dixit and Pindyck 1994). Given the more general scope of this paper, volatility simply enters the model as a risk component.

[31] Given the use of inflation-adjusted rents, inflation risk was not included in any of the estimated models.

The functional form of the estimated models relies on a nonlinear specification of *R**. Such a specification is intended to capture nonlinearities potentially introduced in the reduced-form rent function through the underlying demand, matching rate, or asset price equations (see Section III and Appendix, as well as Clapp, 1979 and 1980; and Wheaton 1990). Under the particular specification used all variables that do not take negative values or do not represent ratio/fraction or dummy variables were expressed in their natural logarithmic form. Two exceptions should be noted. The first includes *ZONING*, which both performed better *and* helped reduce multicollinearities when expressed in non-logarithmic form. The second includes *VOLAT*, to maintain consistency with *GROWTH* to which it refers; note that *GROWTH* takes negative values and, as such, is expressed in non-logarithmic form. Finally, it should also be noted that a three-semester lag, proxying the construction lag, was used for all variables influencing supply responses (see Eq. (8)-(9)).

The error structure of the estimated models follows (20), thus necessitating the use of the Time-Series Cross-Section (TSCS) estimation technique originally developed by Kmenta (1986) and later refined by Greene (1993) in LIMDEP 7.0 (Greene 1996). Involving a three-step Generalized Least Squared (GLS) estimation, the technique is described in detail by Greene (1993, 1996).[32] Lending support to the error specification and estimation process adopted are three sets of tests. The first set includes Lagrange Multiplier (LM), Wald, and (approximate) Likelihood Ratio (LR) tests for the presence of groupwise heteroskedasticity, all following a chi-squared distribution, $\chi^2(N-1)$, where N reflects the number of cross-section units, and all suggesting that the null hypothesis of homoskedastic disturbances be rejected at the 0.01 significance level. The second set includes LM and (approximate) LR tests for the presence of cross-section correlation, following a chi-squared distribution, $\chi^2[N(N-1)/2]$, and also suggesting that the null hypothesis of no cross-section correlation be rejected at the 0.01 level of significance. The third set of tests, to be discussed in more detail

---

[32] The TSCS estimation technique does provide for the incorporation of time-invariant local office market traits, thus allowing testing for the effects of fixed metropolitan characteristics included in the empirical model specification (20) and described in Table 2. In addition, and in contrast to traditional fixed- and random-effects models, TSCS estimation does allow for a spatially differentiated ρ and a cross-section correlation correction, which is necessary as office markets are subject to common influences that may result in the contemporaneous correlation of metropolitan-specific shocks. The Seemingly Unrelated Regression (SUR) technique has not been used in estimating any of these models. In addition to the provision for cross-sectionally correlated metropolitan-specific errors, SUR would only present advantages over the other formulations if variable coefficients across cross-section units were allowed. However, this is not possible given the relatively limited time series and the number of explanatory variables employed in this analysis. Moreover, employing the SUR specification with the restriction of equal coefficients across cross-section units would yield the same results as the TSCS model with one regression constant. Most importantly, a SUR formulation cannot be used to test for the effects of time-invariant local office market traits that are an important part of this analysis. See Chapters 16-17 in Greene (1993) for an extensive discussion of alternative panel data formulations.

continued

below, indicate the presence of serial correlation the magnitude of which varies across markets.

3. Empirical Results

Presented in Table 4 are the estimation results of Model I, which excludes metropolitan residential amenity and zoning effects, and Model II, which accounts for such amenity and regulatory influences.[33] In addition to the sets of regressors discussed in the previous subsection, both models incorporate regional location dummies *NORTHEAST*, *SOUTH*, and *MIDWEST,* which are intended to capture time-invariant regional economic influences that may not be adequately represented by the models' other regressors. Although approximate, relevant Likelihood Ratio tests have clearly indicated that model specifications accounting for regional effects are "superior" to those excluding them.[34]

Taken together, the empirical results point to two general conclusions, each elaborated on in the subsections that follow. *First*, the estimation results are *consistent* with the proposition that equilibrium rents are subject to multiple influences that are not simply limited to office employment and construction costs but also involve factors that potentially relate to search processes within local office markets. *Second,* as indicated by the market-specific serial correlation estimates, the empirical results are *consistent* with the argument that prevailing rents adjust slowly toward their (implicit) equilibrium levels and at speeds that vary across markets.

3.1. Equilibrium Rent Influences

The empirical results are robust and, by and large, consistent with the hypotheses regarding the influence of the four major variable groups featured in Section III, namely (aggregate) demand, matching rate, development cost, and capitalization rate shifters. Given that a number of the variables included in the model may exert effects through multiple channels, emphasis in the discussion of empirical results is placed on the effects of individual variables as opposed to variable groups.

Focusing first on office employment effects, *EMPL*, *GROWTH, VOLAT,* and *RATIOF* exert positive and statistically significant influences on office rents. The positive effect of *EMPL* exemplifies the role of office employment in influencing office space demand and equilibrium office

[33] Deviating slightly from (15), *CRIME* and *CLIMATE*, representing potential firm amenities, are excluded from Model I, as they also represent residential amenities. Both are incorporated in Model II.
[34] Likelihood Ratio (LR) tests are approximate as the estimators are not maximum likelihood due to the presence of serial correlation (see Greene 1993).

rents. The positive sign of *GROWTH* indicates, perhaps, that its demand side effect dominates the negative effect that such variable may exert on the office rent through its influence on the capitalization rate. The positive and statistically significant sign of *VOLAT* is consistent with the proposition that higher employment growth volatility is associated with higher capitalization rate requirements and, hence, higher (implicit) equilibrium rents. Employment composition, as reflected in *RATIOF*, hypothesized to affect space demand and/or matching probabilities, exhibits the expected positive sign.

Market heterogeneity, exemplified by *SUBCENT* and *DIVERSE,* may also be relevant, as indicated by the statistical significance of such variables. Measuring spatial heterogeneity, *SUBCENT* exhibits a positive and statistically significant sign, indicating, perhaps, that its effects on search costs and, hence, rents, prevail over its potentially negative effects on the probability of tenants finding suitable space. *DIVERSE*, intended to proxy tenant/stock heterogeneity, exhibits a negative and statistically significant sign. From a tenant search point of view, such an effect may indicate that the potentially negative effect on the probability of tenants finding suitable space prevails over its potential influence on search/ information costs. At the same time, such an effect is consistent with the hypothesis that more diverse metropolitan office markets may command lower capitalization rates, as they may be perceived by investors as less vulnerable to industry-specific shocks.

As expected, *CCOST,* exerts a positive and statistically significant effect on office rents. Mainly proxying capitalization rate influences, *DISCOUNT* exhibits the expected positive and statistically significant effect. Also intended to proxy such influences (together with *RATIOF*, *VOLAT*, and *DIVERSE*, all discussed previously) are *GOVTEN* and *TENSIZE*, both exhibiting the expected negative sign. Note that such a negative sign for *TENSIZE* may also reflect its influence on the matching rate and, hence, its negative effect on office rents.

As shown by the relevant results, amenity and regulatory effects are also important, as *CRIME*, *CLIMATE*, and *ZONING* exhibit the expected sign and are statistically significant at a reasonably high (a 90% or higher) level of confidence. The empirical relevance of the set of the three factors is reaffirmed by a Likelihood Ratio test indicating that Model II should be chosen over Model I (see Greene 1993). In sum, these results are consistent with propositions that such factors affect land and development costs and, eventually, long-run office rents.

Lastly, time-invariant regional effects, likely reflecting regional differences in economic base and regulatory environments that are not fully captured by the other regressors, also appear to be relevant. Such effects are exemplified by the statistical significance of regional dummies.

3.2. Disequilibrium Processes

The empirical results also shed light on disequilibrium processes as signified by the persistence of the error term, ρ, which, as already noted, may reflect the speed at which rents adjust toward their implicit equilibrium level, $1-\rho$.[35] Following Greene (1993, 1996), the statistical significance of metropolitan-specific autocorrelation estimates, ρ_j, was tested using the statistic $q_j = (\mu-1)\rho_j^2 / (1-\rho_j^2)$, where μ denotes the length of time series.[36] Such a statistic follows a χ^2 distribution with 1 degree of freedom, suggesting a critical value of q of 2.7 at the 10% level of significance. All but one of the q_j for Model II (as well as Model I) exceed this critical value, or alternatively all but one ρ_j exceed the value of 0.35 (which corresponds to the critical value of q), thus pointing to the significance of all but one autocorrelation coefficients at the 90% level of confidence. The exception is Philadelphia, whose autocorrelation coefficient is only statistically significant at the 87.3% confidence level.

The extent to which autocorrelation estimates and, by extension, adjustment speeds differ across markets was tested through a Likelihood Ratio test, involving a comparison of (restricted) models assuming a common autocorrelation coefficient across markets to (unrestricted) models allowing for market-specific autocorrelation estimates. Although only approximate, this test indicates consistently across models that autocorrelation estimates are different across markets (see note 34). Focusing, for example, on Model II's results, the Likelihood Ratio statistic, following a χ^2 *(17)* distribution, is estimated at $\lambda = -2(RLLF-ULLF) = 54.9$, which is clearly greater than the critical $\chi^2(17)$ value of 24.8 at the 10% level of significance.

As shown in Figure 1, presenting the autocorrelation coefficients based on Model II's results, the estimated market-specific autocorrelation coefficients are nontrivial, ranging from 0.34 in Philadelphia to 0.92 in Houston. Such estimates essentially imply that it could take between 0.8 and 9.7 years for 80% of the difference between prevailing and implicit equilibrium rents to dissipate (see note 12). With most autocorrelation coefficients rather sizable, it can be argued that prevailing office rents adjust slowly toward the ever-changing equilibrium rent levels dictated by prevailing market realities (e.g. *EMPL*, *GROWTH*, *DISCOUNT*). As such, at any point in time, prevailing rents likely

---

[35] It must be acknowledged that the presence of serial correlation may stem not only from sluggish adjustments to exogenous shocks but also from model misspecification associated, for example, with the omission of a relevant independent variable that is itself autocorrelated (see, for example, Kennedy 1992). For this reason, every effort was made here to avoid misspecification problems.

[36] LIMDEP does not provide the standard errors of the estimated autocorrelation coefficients.

deviate from these (implicit) equilibrium rent levels. In both 1990.2 (early nineties) and 1995.2 (mid-nineties), for example, as shown in Figure 2, percent deviations of the prevailing from the equilibrium rent are not only substantial but also vary noticeably in direction and, most importantly, magnitude across markets. In 1990.2, such deviations range from -25.1% in Houston, TX, where the prevailing rent is appreciably lower than the estimated equilibrium rent, to 12.1% in Los Angeles, CA, where the prevailing rent is higher than that market's estimated equilibrium rent. In 1995.2, such deviations range from -27.7% in New York, NY, to 14.1% in Denver, CO.

The variability of the disequilibrium deviations through time is also exemplified by Figure 3, portraying percent deviations of the prevailing from the equilibrium rent for the entire analysis period in four markets: [37] Atlanta, GA, in the south; Boston, MA, in the northeast; Chicago, IL, in the midwest; and Los Angeles, CA, in the west. Boston and Los Angeles exhibit the largest deviations. Prevailing rents in Boston during the first half of 1988 were by 25.9% above the equilibrium rent but, by the second half of 1991, they fell to a level as low as 15.0% below the equilibrium rent. In Los Angeles, prevailing rents reached their maximum deviation of 17.1% above the equilibrium rent in the second half of 1986, but they fell to a level as low as 8.6% below the equilibrium rent much later (second half of 1995). In Atlanta and Chicago, the respective maximum deviations above equilibrium--12.5% (first half of 1986) and 12.3% (second half of 1986)-- are smaller than those for Boston and Los Angeles, while the respective maximum deviations below equilibrium-- 8.9% (second half of 1993) and 12.7% (second half of 1993)-- are still smaller than Boston's but larger than those observed for Los Angeles.

Similar patterns are observed in all other markets. The maximum deviation of 21.4% above equilibrium was reached in Washington, DC, in the second half of 1987, and the maximum deviation of 34.7% below equilibrium was reached in New York, NY, in the second half of 1993; both markets exhibit small adjustment speeds. In contrast, the smallest absolute deviations are observed in the relatively smaller markets of Seattle, WA, and Sacramento, CA, both of which exhibit large adjustment speeds. Although fast (slow) adjustments may have contributed to small (large) deviations, the extent of movements in the exogenous determinants of equilibrium rents must

[37] For example, for western metropolitan markets, these were estimated as:

$$R^*_{jt} = \exp(13.026 + 1.919\ EMPL_{jt} + 4.080\ RATIOF_{jt} + 0.065\ GROWTH_{jt} + 2.385\ SUBCENT_j - 4.757\ DIVERSE_j - 3.852\ TENSIZE + 10.838\ CCOST_{jt} - 7.922\ CRIME_j + 3.734\ CLIMATE_j + 0.002\ ZONING + 0.979\ DISCOUNT_{jt} + 0.097\ VOLAT_{jt} - 47.187\ GOVTEN_j),$$

noting, again, that, with certain exceptions, all regressors that do not take negative values (all but *GROWTH*) or are not fraction or dummy variables (see Table 3) are expressed in logarithmic form. The exceptions include: *ZONING,* as it performed better in non-logarithmic form and helped mitigate multicollinearities; and

continued

have also played a role in shaping differences between prevailing and equilibrium rents.

3.3. Ignoring Sluggish Adjustments

In an effort to look into the empirical consequences of ignoring the extent of disequilibrium deviations due to sluggish rent adjustments, the counterparts of Models I and II, referred to as Models I' and II', were re-estimated on the assumption of zero serial correlation. Shown in Table 5, the empirical results reinforce the argument that ignoring sluggish adjustments and, by extension, the extent of disequilibrium deviations (that may differ across markets), may lead to misleading inferences regarding not only the magnitude but also the direction of the effect of certain variables on office rents. A comparison, for example, of the results of Models I' and II' to those of their presumably correctly specified counterparts (see Models I and II in Table 4) helps uncover substantial differences in coefficient sizes, as well as certain qualitative differences. More specifically, in contrast to what has been hypothesized and suggested by Model I's results, in Model I', *RATIOF* exhibits a *negative* effect. Furthermore, in contrast to what is suggested by the relevant theory and supported by Model I's and Model II's results, in *both* Model I' and Model II', *VOLAT* is shown to exert a statistically significant negative effect.

V. Concluding Remarks

Much of the existing literature on office markets has focused on rent-vacancy adjustments and the estimation and explanation of normal vacancies. This paper shifts attention to adjustments in office rents toward their implicit equilibrium levels and to the factors that determine such long run equilibrium rents.

Employing a time-series cross-section analysis of eighteen metropolitan office markets, this research presents empirical results that are consistent with the proposition that office rents *only* gradually adjust toward their implicit long-run equilibrium levels and that, as a result, prevailing rents *do* deviate from these *implicit* long-run levels. The empirical results also indicate that the latter may largely be determined by office employment factors--size, diversity, spatial organization, growth rates, and volatility-- construction costs, the opportunity cost of commercial capital, area amenities, and regulatory influences. Notably, ignoring sluggish rental adjustments and potential differences in adjustment speeds across markets may lead to misleading inferences on the relevance and/or the strength of the influence of some of these factors. Such a conclusion reinforces the argument that

---

VOLAT to maintain consistency with the specification of *GROWTH* to which it refers.

the application of traditional cross-section methodologies that implicitly assume that prevailing rents reasonably proxy equilibrium rents may not be appropriate in the case of office markets.

This paper has by no means exhausted issues related to office rent processes in metropolitan real estate markets. The spatial segmentation, if any, of these markets and the extent to which it influences the time path of implicit long-run rents and the rental adjustment process are some of the issues that need to be explored. Within this context, two propositions need to be empirically addressed. First, the proposition that continuing demand shifts away from central cities and toward the suburbs may be contributing to diverging paths of implicit long-run rents within metropolitan markets. Second, the proposition that rental adjustment speeds vary across CBD and suburban markets. It can be asserted that suburban adjustments may be faster, if suburban markets are mostly dominated by smaller tenants and smaller development projects; at the same time, however, it can be argued that development delays in wealthier outer suburbs may be more prohibitive, thereby slowing market adjustments. Empirical analysis is needed to clarify such potentially opposing effects.

Aknowledgements

I am grateful to Torto Wheaton Research for providing the data for this research and to an anonymous referee for useful comments and suggestions on an earlier version of this paper.

References

Alm, J. and J. Follain. 1994. Shocks and Valuation in the Rental Housing Market. *Journal of Urban Economics* 36: 117-142.

Arnott, R. 1980. A Simple Urban Growth Model with Durable Housing. *Regional Science and Urban Economics* 10: 53-76.

Arnott, R. 1987. Economic Theory and Housing, E. S. Mills, editor, *Handbook of Regional and Urban Economics*. North-Holland, New York, New York.

Arnott, R. 1989. Housing Vacancies, Thin Markets, and Idiosyncratic Tastes. *Journal of Real Estate Finance and Economics* 2: 5-30.

Board of Governors of the Federal Reserve System. Several Years. *Federal Reserve Bulletin,* Government Printing Office: Washington DC.

Brueckner, J. 1980. A Vintage Model of Urban Growth. *Journal of Urban Economics* 8: 389-402.

Brueckner, J. 1987. The Structure of Urban Equilibria. E. S. Mills, editor, *Handbook of Regional and Urban Economics*. North-Holland, New York, New York.

Capozza D. and R. Helsley. 1990. The Stochastic City. *Journal of Urban Economics* 28: 187-203.

Capozza D. and R. Helsley. 1989. The Fundamentals of Land Prices and Urban Growth. *Journal of Urban Economics* 26: 295-306.

Clapp, J. M. 1979. The Substitution of Land for Other Inputs, *Journal of Urban Economics* 6: 122-134.

Clapp, J. M. 1980. Production with Land and Nonland Inputs: Which Functional Form? *Journal of Urban Economics* 8: 32-46.

Coulson, N. E. 1993. The Sources of Sectoral Fluctuations in Metropolitan Areas. *Journal of Urban Economics* 33: 76-94.

Davidson, R. and J. G. MacKinnon. 1981. Several Tests for Model Specification in the Presence of Alternative Hypotheses. *Econometrica* 49: 781-793.

Dixit, A. 1989. Entry and Exit Decisions under Uncertainty. *Journal of Political Economy* 97: 620-638.

Dixit, A. and R. Pindyck. 1994. *Investment under Uncertainty.* Princeton University Press: Princeton, NJ.

Eppli, M. J. and J. D. Shilling. 1995. Speed of Adjustment in Commercial Real Estate Markets. *Southern Economic Journal* 61: 1127-1145.

Fischel, 1980. Zoning and the Exercise of Monopoly Power: A Re-evaluation. *Journal of Urban Economics* 8: 283-293.

Goetzmann, W. and S. Wachter. 1995. Clustering Methods for Real Estate Portfolios. *Real Estate Economics* 23: 271-310.

Greene, W. 1993. *Econometric Analysis* (second edition). Englewood Cliffs: New York, NY.

Greene, W. 1996. *LIMDEP 7.0.* Econometric Software Inc: Plainview, NY.

Grenadier, S. R. 1995. Local and National Determinants of Office Vacancies. *Journal of Urban Economics* 37: 57-71.

Gujarati, D. N. 1995. *Basic Econometrics.* McGraw-Hill, Inc: New York, NY.

Gyourko, J., and R. Voith. 1992. Local Market and National Components in House Price Appreciation. *Journal of Urban Economics* 32: 52-69.

Gyourko, J. and R. Voith. 1993. Leasing as a Lottery: Implications for Rational Building Surges and Increasing Vacancies. *Real Estate Economics* 21: 83-106.

Hekman, J. 1985. Rental Price Adjustment and Investment in Office Markets. *American Real Estate and Urban Economics Association Journal* 13: 32-47.

Hendershott, P. 1996. Rental Adjustments and Valuation in Overbuilt Markets, *Journal of Urban Economics* 39: 51-67.

Henderson, V. and E. Slade. 1993. Development Games in Non-monocentric Cities. *Journal of Urban Economics* 34: 207-229.

Kennedy, P. 1992. *A Guide to Econometrics*. MIT Press, Cambridge, Massachusetts.

Kmenta. 1986. *Elements of Econometrics. McMillan:* New York, NY.

Markusen, J. and D. Scheffman. 1978. The Timing of Residential Land Development: A General Equilibrium Approach. *Journal of Urban Economics* 5: 411-424.

Marston, S. 1985. Two Views of the Geographic Dispersion of Unemployment. *Quarterly Journal of Economics* 100: 57-79.

McDonald, R. and D. R. Siegel. 1986. The Value of Waiting to Invest. *Quarterly Journal of Economics* 101: 707-728.

Ozanne and Thibodeau. 1983. Explaining SMSA House Price Differentials. *Journal of Urban Economics* 13: 51-65.

Polinsky, A. M. and S. Shavell. 1976. Amenities and Property Values in a Model of an Urban Area. *Journal of Public Economics* 5: 119-129.

Potepan, M. 1996. Explaining Intermetropolitan Variation in Housing Prices, Rents, and Land Prices. *Real Estate Economics* 24: 219-245.

Read, C. 1988a. Price Strategies for Idiosyncratic Goods-The Case of Housing. *American Real Estate and Urban Economics Association Journal* 16: 379-395.

Read, C. 1988b. Advertising and Natural Vacancies in Rental Housing Markets. *American Real Estate and Urban Economics Association Journal* 16: 355-363.

Read, C. 1993. Tenant's Search and Vacancies in Rental Housing Markets. *Regional Science and Urban Economics* 23: 171-183.

Rothchild, M. 1981. Searching for the Lowest Price when the Distribution of Prices is Unknown. *Journal of Economic Theory* 25: 152-126.

Roback, J. Wages, Rents and the Quality of Life. 1982. *Journal of Political Economy,* 90: 1257-78.

Robert Snow Means Company. 1999. *Means Square Foot Costs*, R.S. Means Company, Inc: Kingston, MA.

Rosen, K. 1984. Toward a Model of the Office Building Sector. *American Real Estate and Urban Economics Association Journal* 12: 261-269.

Rosen, K. T. and L. B. Smith. 1983. The Price Adjustment Process for Rental Housing and the Natural Vacancy Rate. *American Economic Review* 73: 779-786.

Shilling, J. D., C. F. Sirmans, and J. B. Corgel. 1987. Price Adjustment Process for Rental Office Space. *Journal of Urban Economics* 22: 90-100.

Sivitanidou, R. 1995. Urban Spatial Variations in Commercial Rents: The Role of Spatial Amenities and Commercial Zoning. *Journal of Urban Economics* 38: 23-49.

Sivitanides, P. 1997. The Rent Adjustment Process and the Structural Vacancy Rate in the Commercial Real Estate Market. *Journal of Real Estate Research* 13: 195-209.

Sivitanidou, R. and P. Sivitanides. 1999. Office Capitalization Rates: Real Estate and Capital Market Influences. *Journal of Real Estate Finance and Economics* 18(3): 297-322.

Stull, W. 1978. The Landlord's Dilemma: Asking Rent Strategies in a Heterogeneous Housing Market. *Journal of Urban Economics* 5: 101-115.

Tabuchi, T. 1990. Dynamics of Urban Land Use: Sequential Location of an Office Firm and Residence. *Journal of Urban Economics* 28: 87-102.

Topel, R. and S. Rosen. 1988. Housing Investment in the United States. *Journal of Political Economy* 77: 795-816.

Turnbull, G. 1986. Market Structure, Location Rent, and the Land Development Process. *Journal of Urban Economics* 23: 261-277.

U.S. Department of Justice, Federal Bureau of Investigation. 1991. *Uniform Crime Reports*, Government Printing Office: Washington DC.

U.S. National Oceanic and Atmospheric Administration. 1991. *Climatography of the United States*, No. 81, Government Printing Office: Washington DC.

U.S. Bureau of the Census. 1992. *Census of Governments*, Government Printing Office: Washington DC.

Voith, R. and T. Crone. 1988. National Vacancy Rates and the Persistence of Shocks in U.S. Office Markets. *American Real Estate and Urban Economics Association Journal* 16: 437-458.

Wheaton, W. C. 1974. A Comparative Static Analysis of Urban Spatial Structure. *Journal of Economic Theory* 9: 223-237.

Wheaton, W. C. 1982. Urban Spatial Development with Durable but Replaceable Capital. *Journal of Urban Economics* 12: 53-67.

Wheaton, W. 1987. The Cyclic Behavior of the National Office Market. *American Real Estate and Urban Economics Association Journal* 15: 281-299.

Wheaton, W. C. 1990. Vacancy, Search, and Prices in a Housing Market Matching Model. *Journal of Political Economy* 98: 1270-1292.

Wheaton, W. C. and R. G. Torto. 1988. Vacancy Rates and the Future of Office Rents. *American Real Estate and Urban Economics Association Journal* 16: 430-436.

Wheaton, W. C. and R. G. Torto. 1994. Office Rent Indices and their Behavior through Time. *Journal of Urban Economics* 35: 121-139.

White, M. 1978. On the Short-Term Effects of Long-Term Change in Cities: An Efficient Land Markets Model. *Journal of Urban Economics* 5: 485-504.

FIGURE 1

Autocorrelation Coefficient Estimates

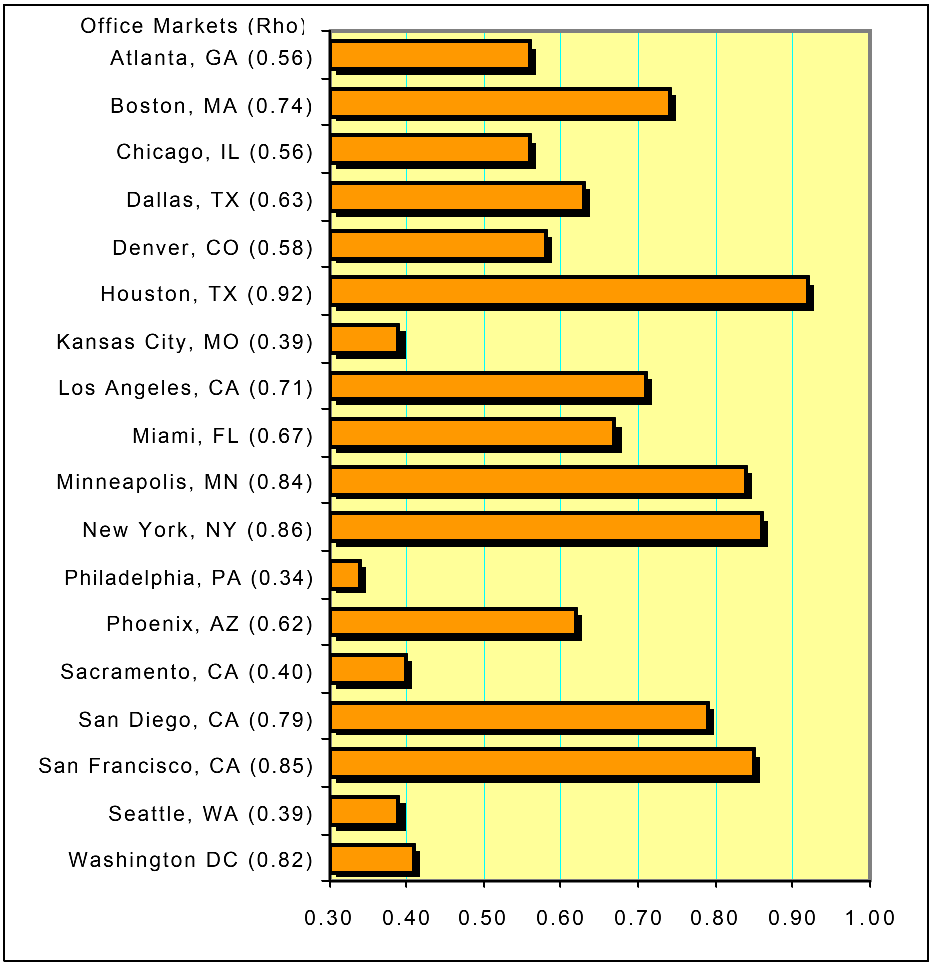
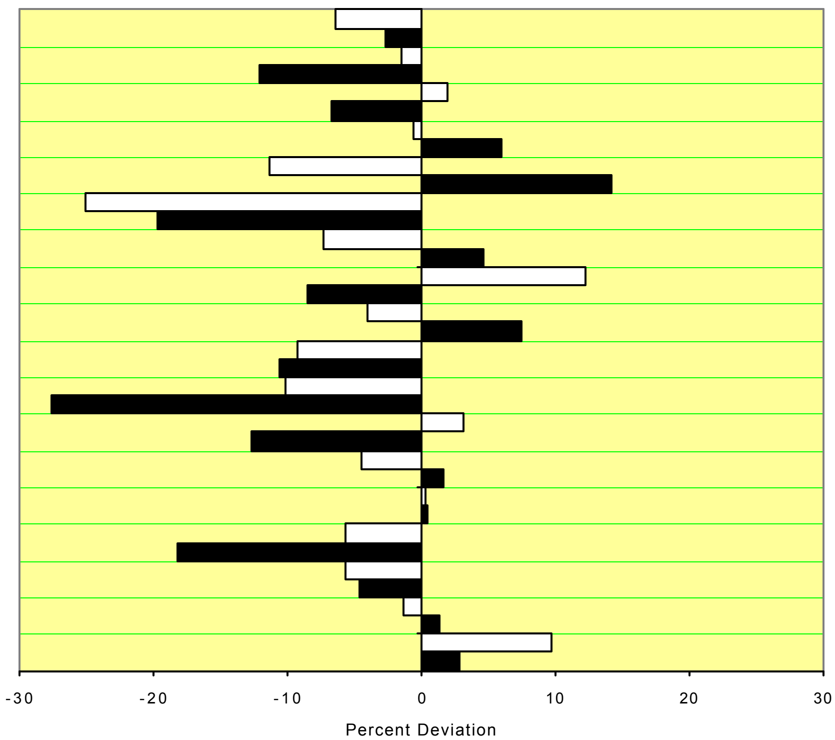


FIGURE 2
Percent Deviations of Prevailing from Equilibrium Rent, 1990.2 and 1995.2

Office Market	Percent Deviation 1990.2	1995.2
Atlanta, GA	-6.40	-2.67
Boston, MA	-1.56	-12.14
Chicago, IL	1.83	-6.84
Dallas, TX	-0.63	5.90
Denver, CO	-11.31	14.09
Houston, TX	-25.11	-19.67
Kansas City, MO	-7.36	4.53
Los Angeles, CA	12.12	-8.59
Miami, FL	-4.12	7.45
Minneapolis, MN	-9.27	-10.60
New York, NY	-10.14	-27.71
Philadelphia, PA	3.17	-12.76
Phoenix, AZ	-4.48	1.61
Sacramento, CA	0.20	0.35
San Diego, CA	-5.75	-18.26
San Francisco, CA	-5.63	-4.73
Seattle, WA	-1.35	1.30
Washington DC	9.69	2.73



Legend: 1990.2 (white) 1995.2 (black)

FIGURE 3

Percent Deviations of Prevailing from Equilibrium Rent, 1986.1-1995.2

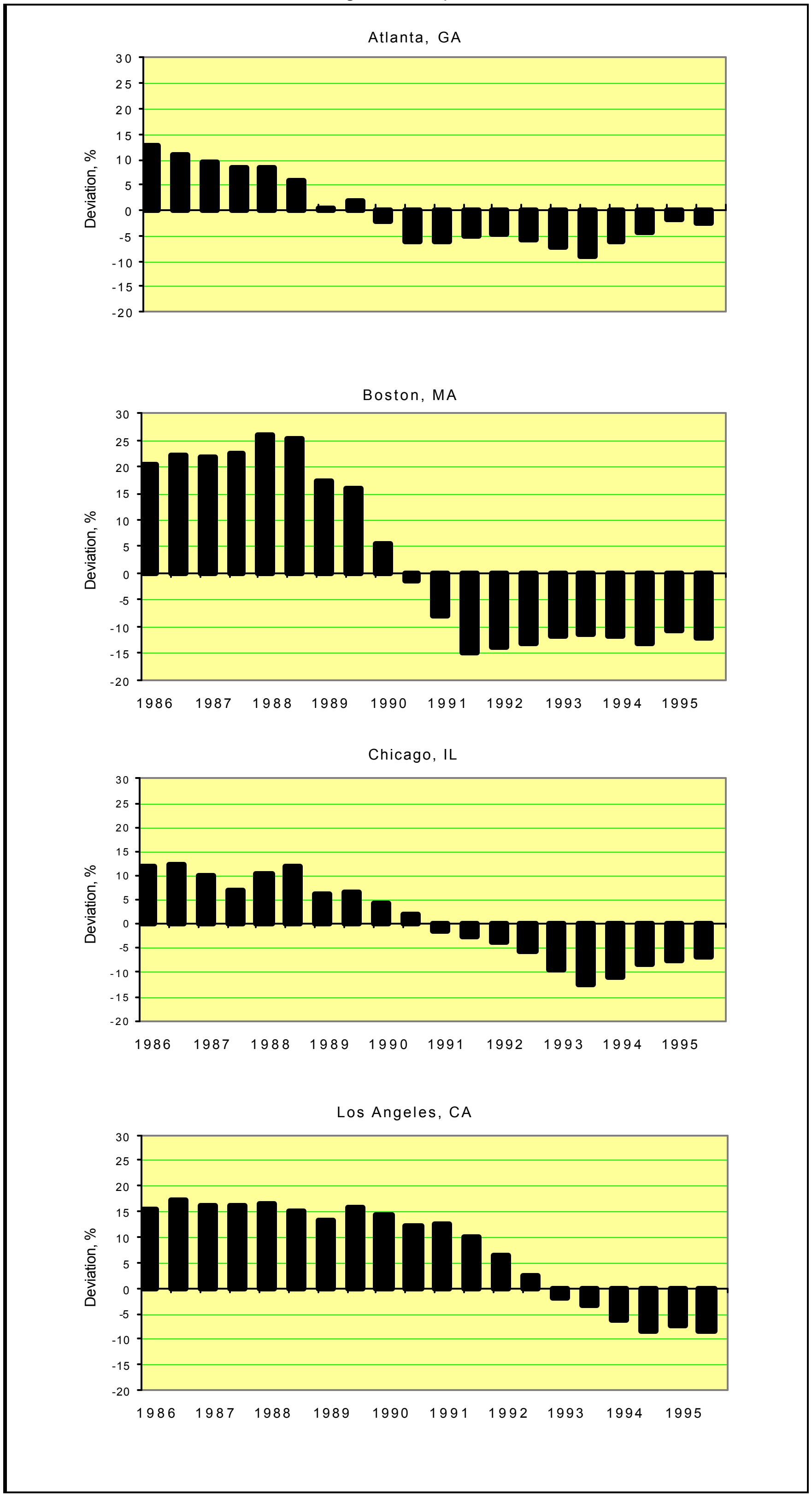


TABLE 1

Summary of Comparative Statics [a/]

Variable Groups	Variable Group Effects		
	dR/( )	*dV/( )*	*dS/( )*
Group1: Exogenous Demand Shifters, Z	*> 0*	*> 0*	*> 0*
Group 2: Exogenous Matching Rate Shifters. *v*	*> 0*	*> 0*	*> 0*
Group 3: Exogenous Development Cost Shifters. P^C	*> 0*	*< 0*	*< 0*
Group 4: Exogenous Capitalization Rate Shifters, *u*	*> 0*	*< 0*	*< 0*

Notes:

[a/] See Appendix for derivations

TABLE 2
Variable Definitions, Sources, and Expected Effects

Variable Groups	Variables	Explanation	Data Source [a]	Expected Effects
Dependent Variable	*R(RENT)*	Hedonic rent index, 1986.1-1995.2	Torto Wheaton Research	NA
Group1: [b]				
Exogenous Demand Shifters	*EMPL*	Average subcenter employment in office-using sectors, 1986.1-1995.2	Torto Wheaton Research	+
	GROWTH	Office employment growth rate, 1986.1-1995.2	Torto Wheaton Research	+
	RATIOF	Office employment in FIRE over office employment in other office sectors, 1986.1-1995.2	Torto Wheaton Research	+
Group 2: [c]				
Exogenous Matching Rate Shifters	*SUBCENT*	Number of office subcenters per area of land, proxying spatial heterogeneity, 1990	Torto Wheaton Research U.S. Bureau of the Census, 1990	+/-
	DIVERSE	Tenant diversity index, 1986.1-1995.2	Torto Wheaton Research	+/-
	TENSIZE	Average tenant size, 1990	Torto Wheaton Research	-
Group 3:				
Exogenous Development Cost Shifters	*CCOST*	Inflation-adjusted construction cost index; covers labor and materials, 1986.1-1995.2	R.S. Means Company, 1999	+
	CRIME	Metropolitan crime index, 1990 [d]	U.S. Department of Justice, 1991	-
	CLIMATE	Average temperature based on [d] a 30-year period, 1990	U.S. National Oceanic and Atmospheric Administration, 1991	+
	ZONING	Average land controlled by local governments, 1992 [d]	U.S. Bureau of the Census, 1992	+
Group 4:				
Exogenous Capitalization Rate Shifters	*DISCOUNT*	Real five-year Treasury constant maturity rate, 1986.1-1995.2	Board of Governors of the Federal Reserve System, 1987-1997	+
	GROWTH	See above	See above	-
	VOLAT	Standard deviation of semi-annual office employment growth rates during the preceding five semesters, 1986.1-1995.2	Torto Wheaton Research	+
	DIVERSE	See above	See above	-
	GOVTEN	Fraction of government tenants, 1990	Torto Wheaton Research	-
	TENSIZE	See above	See above	-
	RATIOF	See above	See above	+

Notes:

[a] Complete references are provided in the Reference section of the paper

[b] To the extent *CRIME* and *CLIMATE* affect business costs, they should also be included in Group 1 (see text)

[c] To the extent *DISCOUNT* also captures the opportunity cost of search, it should also be included in Group 2 (see text)

[d] These variables have been added to explore the specification that accounts for land costs

TABLE 3
Basic Descriptive Statistics

Variables [a/]	Mean	Standard Deviation
R (hedonic rent index, in $/sqft)	11.589	2.943
EMPL (average number of office workers, in tens of thousands)	3.550	2.086
GROWTH (office employment growth, %)	1.804	2.020
RATIOF (ratio of workers in FIRE over other office sectors)	0.651	0.170
SUBCENT (number of subcenters per thousand square miles)	3.697	4.524
DIVERSE (tenant diversity index)	0.811	0.024
TENSIZE (average tenant floor area)	7,567	2,691
CCOST (construction cost index)	78.191	9.703
CRIME (crime incidents per thousand persons)	72.722	19.076
CLIMATE (average temperature, in degrees Fahrehneit)	54.130	8.120
ZONING (square miles of land per local government)	97.580	119.690
DISCOUNT (interest rate, %)	6.070	1.537
VOLAT (standard deviation of office employment growth)	1.196	0.336
GOVTEN (ratio of government over all office tenants)	0.033	0.013

Notes:

[a/] For complete variable definitions, data sources, and expected effects, see Table 2

TABLE 4

Time-Series Cross-Section Modeling of Office Market Rents [a/, b/]

	Model I	Model II
Constant	-2.861 *	13.026 **
	(1.605)	(2.017)
EMPL	2.178 **	1.919 **
	(0.079)	(0.071)
GROWTH	0.052 **	0.065 **
	(0.003)	(0.002)
RATIOF	4.043 **	4.080 **
	(0.217)	(0.128)
SUBCENT	2.005 **	2.385 **
	(0.081)	(0.050)
DIVERSE	-1.821 *	-4.757 **
	(1.080)	(0.622)
TENSIZE	-4.543 **	-3.852 **
	(0.145)	(0.140)
CCOST	10.836 **	10.838 **
	(0.333)	(0.183)
CRIME	-	-7.922 **
		(0.249)
CLIMATE	-	3.734 **
		(0.348)
ZONING	-	0.002 **
		(0.0003)
DISCOUNT	0.827 **	0.979 **
	(0.054)	(0.033)
VOLAT	0.204 **	0.097 **
	(0.022)	(0.013)
GOVTEN	-11.540 **	-47.187 **
	(2.773)	(2.370)
NORTHEAST	1.836 **	-0.581 **
	(0.143)	(0.197)
SOUTH	1.573 **	3.587 **
	(0.089)	(0.075)
MIDWEST	0.638 **	1.418 **
	(0.106)	(0.081)
N	*360*	*360*
Rho [c/]	*0.72*	*0.65*
Log Likelihood	*119.25*	*149.92*
Test statistics: [d/]		
LR test (CSC)	*661.98* **	*747.57* **
LR test (H)	*92.41* **	*90.45* **
LM (CSC)	*506.84* **	*586.17* **
LM(H)	*90.47* **	*106.88* **
Wald (H)	*301.35* **	*255.18* **

Notes:

[a/] Asymptotic standard errors are in parentheses below the coefficients; one and two asterisks next to the coefficients denote statistical significance at the 10% and 5% levels, respectively

[b/] See Table 2 for variable definitions, sources, and expected effects, and Table 3 for basic statistic

[c/] This reflects the average of market-specific *rhos*

[d/] The critical Wald, LR, and LM test statistics for homoskedasticity at the 1% significance level is 33.41; the critical LR and LM test statistics for cross-section correlation at the 1% significance level is 195.83.

TABLE 5

Time-Series Cross-Section Modeling of Office Market Rents Assuming *Rho= 0* [a/, b/]

	Model I'	Model II'
Constant	0.274	15.386 **
	(1.450)	(2.701)
EMPL	1.878 **	2.297 **
	(0.073)	(0.081)
GROWTH	0.285 **	0.276 **
	(0.003)	(0.006)
RATIOF	-0.016	2.245 **
	(0.130)	(0.182)
SUBCENT	2.412 **	2.650 **
	(0.049)	(0.052)
DIVERSE	-12.172 **	-14.755 **
	(0.647)	(1.121)
TENSIZE	-3.393 **	-3.165 **
	(0.088)	(0.145)
CCOST	9.410 **	7.455 **
	(0.256)	(0.310)
CRIME	-	-5.947 **
		(0.221)
CLIMATE	-	4.232 **
		(0.261)
ZONING	-	0.002 **
		(0.0005)
DISCOUNT	3.415 **	3.293 **
	(0.032)	(0.061)
VOLAT	-0.305 **	-0.365 **
	(0.016)	(0.033)
GOVTEN	-20.626 **	-18.082 **
	(2.842)	(4.659)
NORTHEAST	1.013 **	-1.148 **
	(0.102)	(0.139)
SOUTH	1.168 **	2.163 **
	(0.054)	(0.093)
MIDWEST	0.686 **	1.467 **
	(0.056)	(0.112)
N	*360*	*360*
Log Likelihood	*-97.38*	*-111.93*
Test statistics: [c/]		
LR test (CSC)	*888.69* **	*766.13* **
LR test (H)	*131.97* **	*135.27* **
LM (CSC)	*626.13* **	*585.15* **
LM(H)	*95.88* **	*109.12* **
Wald (H)	*527.82* **	*494.41* **

Notes:

[a/] Asymptotic standard errors are in parentheses below the coefficients; one and two asterisks next to the coefficients denote statistical significance at the 10% and 5% levels, respectively

[b/] See Table 2 for variable definitions, sources, and expected effects, and Table 3 for basic statistics

[c/] The critical Wald, LR, and LM test statistics for homoskedasticity at the 1% significance level is 33.41; the critical LR and LM test statistics for cross-section correlation at the 1% significance level is 195.83.