

SPACE RENT AND WAGE CAPITALIZATION IN THE
COMMERCIAL REAL ESTATE MARKET

by

RENA MOUROUZI-SIVITANIDOU

Diploma in Architectural Engineering
National Technical University of Athens, Greece
(1982)

M.C.P. Georgia Institute of Technology
(1985)

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Signature of Author

Department of Urban Studies and Planning
September 28, 1990

Certified by

William C. Wheaton
Associate Professor of Economics
and Urban Studies and Planning
Dissertation Supervisor

Accepted by

Langley Keyes
Chair, Ph.D. Committee

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Rena Mourouzi-Sivitanidou

Submitted to the Department of Urban Studies and Planning
on September 28, 1990 in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy.

ABSTRACT

The dissertation presents an attempt to extend the capitalization debate to the case of the decentralized--and often regulated--commercial land and real estate market. It asks whether and to what extent variations across centers in commercial land rents, space rents, and wages reflect locational value, and thoroughly examines the role that local development restrictions play in affecting the magnitude of these variations.

Previous work on capitalization has been inadequate in addressing these issues. Assuming mobile households but immobile firms, early analyses concluded that differences in amenity levels are perfectly capitalized by land values, creating thus the misconception that only land prices are affected by amenities. Subsequent analyses on the intercity or intracity level have cleared up this fallacy by compellingly showing that, with both mobile households and firms, not only land prices, but also wages have to some extent capitalize locational value. Yet, these analyses are not explicitly spatial; they do not fully account for the commercial land and real estate market; and they do not explore capitalization effects in markets which are not necessarily competitive.

Capitalization is theoretically examined here in the context of four spatial models of a two-center, two-sector metropolis, fully incorporating land and space consumption by firms. The first examines capitalization under the assumption of perfectly competitive markets. The other three study capitalization under conditions of a constrained supply of land and/or a regulated commercial density. The analysis of these models clearly shows that in a competitive land market, intercenter differences in production amenities are mostly capitalized by labor wages (and land rents) rather than commercial space rents. Once, however, development restrictions, either in the form of zoning limits or density regulations, are introduced at the most advantageous location, amenity differences are shifted toward higher space rent and lower wage differences between centers.

This analysis has set the stage for appropriately studying capitalization from the empirical perspective. Utilizing an extensive database on space rents, census data on housing prices and locational advantages, as well as data on development controls in the greater Los Angeles area, a number of empirical models have been developed. Their estimation results confirm the presence of binding development controls in the greater Los Angeles area and validate their hypothesized role in the amenity capitalization process. In short, in the presence of land constraints, density regulations or both, space rents are shown to capitalize more locational value. In addition, land and density constraints are found to

significantly increase the positive effect of production amenities on floor space rents.

Despite the simplifying assumptions of the theoretical models and the deficiencies of the data employed in the empirical study, these analyses shed considerable light to the process through which compensating price differentials across centers are established in contemporary multinodal metropolises. Most importantly, perhaps, they elucidate the role that institutional rigidities, often characterizing the commercial land market, play in this pricing and capitalization process.

Dissertation Supervisor: William C. Wheaton

Title: Associate Professor of Economics and Urban Studies and Planning

TABLE OF CONTENTS

	Page
INTRODUCTION.....	9
1. The Capitalization Question.....	9
2. Objectives and Methodology.....	12
2.1 <i>The Theoretical and Modeling Approach</i>	12
2.2 <i>Empirical Modeling</i>	13
3. Organization and Outline.....	14
3.1 <i>Part 1. Rent and Wage Capitalization: A Theoretical Analysis</i>	16
3.2 <i>Part 2. Space Rent Capitalization: The Case of Greater LA</i>	16
PART 1. Rent and Wage Capitalization: Theory and Modeling	
I. RENT AND WAGE CAPITALIZATION IN THE LITERATURE.....	19
1. Land and Space Rent Capitalization: Intracity Models.....	19
1.1 <i>Standard Monocentric Models</i>	19
1.2 <i>Hedonic Models of Urban Markets</i>	21
1.3 <i>Interjurisdictional Models in the Local Public Finance Literature</i>	23
2. "Dual" Capitalization: Intercity Models.....	24
3. Spatial Multicentric Models.....	27
4. The Capitalization Literature: Concluding Remarks.....	30
II. A SIMPLIFIED MODEL OF A TWO-CENTER, TWO-SECTOR CITY.....	32
1. The General Model.....	33
2. The Residential Sector.....	35
3. The Commercial Sector.....	38
3.1 <i>The Market for Service Output</i>	38
3.2 <i>The Labor Market</i>	39
3.3 <i>The Commercial Property Market</i>	40
3.4 <i>The Commercial Land Market</i>	41
4. Market Interactions.....	42
III. ALTERNATIVE LAND MARKETS.....	45
1. Model I : A Competitive Land Market.....	46
2. Model II : A Segmented Land Market.....	53
3. Model III: A Regulated Market.....	63
4. Model IV : A Segmented and Regulated Market.....	72

IV. MODEL SIMULATIONS.....	80
1. Common Exogenous Parameters.....	81
2. Simulated Examples.....	82
2.1 <i>Model I : A Competitive Land Market</i>	84
2.2 <i>Model II : A Segmented Land Market</i>	85
2.3 <i>Model III: A Regulated Market</i>	86
2.4 <i>Model IV : A Segmented and Regulated Market</i>	88
3. Model Simulations: Concluding Remarks.....	89
PART 1: AN OVERVIEW AND CONCLUSIONS.....	90
1. The Modeling Approach.....	91
2. Capitalization in Alternative Land Markets.....	92
2.1 <i>Capitalization in Competitive Markets</i>	93
2.2 <i>Capitalization in Segmented Markets</i>	93
2.3 <i>Capitalization in Regulated Markets</i>	94
2.4 <i>Capitalization in Segmented and Regulated Markets</i>	94
3. Concluding Remarks.....	95
PART 2. Space Rent Capitalization: The Case of Greater Los Angeles	
V. ANALYZING CAPITALIZATION IN THE COMMERCIAL REAL ESTATE MARKET.....	97
1. Analyzing Capitalization: Theoretical Implications.....	97
2. Past Empirical Studies: A Review and Criticism.....	101
2.1 <i>Wage Capitalization</i>	101
2.2 <i>Space Rent Capitalization</i>	103
2.3 <i>Past Empirical Studies: Concluding Remarks</i>	107
2. The Empirical Analysis: An Overview.....	108
VI. THE LOS ANGELES-LONG BEACH-ANAHEIM SCSA: URBAN SUBCENTERS.....	110
1. The Los Angeles-Long Beach-Anaheim SCSA.....	110
2. Urban Subcenters in Greater Los Angeles.....	115
VII. ESTIMATING "EFFECTIVE" SUBCENTER RENTS.....	121
1. Hedonic Price Equations.....	122
2. The Hedonic Model.....	125
2.1 <i>The General Model, Variables, and Data</i>	125
2.2 <i>Functional Form(s)</i>	129
2.3 <i>Estimation Results</i>	129
VIII. ANALYZING THE PATTERN OF EFFECTIVE SUBCENTER RENTS.....	133
1. Testing for the Presence of Development Constraints.....	133
1.1 <i>The Variables and Data</i>	135
1.2 <i>Statistical Models</i>	140
1.3 <i>Estimation Results</i>	140
2. Testing the Capitalization Hypothesis.....	142
2.1 <i>The Variables and Data</i>	143
2.2 <i>Statistical Models</i>	146
2.3 <i>Estimation Results</i>	148

PART 2. SPACE RENT CAPITALIZATION IN GREATER LOS ANGELES.....	156
1. The Methodological Approach.....	156
2. Empirical Findings.....	157
AN OVERVIEW AND EXTENSIONS.....	160
1. The Theoretical Analysis.....	160
1.1 <i>Modeling Refinements</i>	161
1.2 <i>Theoretical Reformulations</i>	167
2. The Empirical Research.....	170
3. Final Remarks.....	173
REFERENCES.....	175
APPENDIX I : The Model Specification.....	181
APPENDIX II : Simulation Solutions.....	186
APPENDIX III: Estimating "Effective" Subcenter Rents: Semilogarithmic Equations.....	200

LIST OF TABLES, FIGURES, AND MAPS

TABLES	Page
IV-1: Computer Simulations: Values of Exogenous Parameters.....	81
IV-2: Computer Simulation Examples.....	83
VI-1: Commercial Submarkets in Greater Los Angeles.....	112
VI-2: Commercial Building Data.....	116
VI-3: Greater Los Angeles: "Average" Subcenter Characteristics.....	119
VII-1: Commercial Space Rent Estimates.....	131
VIII-1: Empirical Data: Definition of Variables.....	136
VIII-2: Regression Results: Testing for the Presence of Development Constraints.....	141
VIII-3: Development Restrictions: Definition of Variables.....	144
VIII-4: Linear Regression Results1: Testing the Capitalization Hypothesis.....	150
VIII-5: Linear Regression Results2: Testing the Capitalization Hypothesis.....	152
VIII-6: Nonlinear Regression Results: Testing the Capitalization Hypothesis.....	154

FIGURES

I-1 : The Roback Model.....	26
II-2 : Multicentric Models: "Dual" Capitalization of Transport Costs.....	28
II-1 : A Simplified Two-Center City.....	34
III-1 : Competitive Land Rents; $C_A=0$	47
III-2 : Competitive Land Rents; $C_A>0$	49
III-3 : Competitive Land Rents; $C_A=C_{Amax}$	53
III-4 : Segmented Land Rents; $C_A=0$; $rl<L_1$	55
III-5 : Space Rent and Wage Capitalization in a Segmented Land Market.....	58
III-6 : Segmented Land Rents; $C_A>0$, $rl<rlc$	61
III-7 : Regulated Land Rents; $C_A=0$	64
III-8 : Space Rent and Wage Capitalization in a Regulated Market.....	67
III-9 : Regulated Land Rents; $C_A>0$; $cl_1=cl_{1min}$	70
III-10: Land Rents in a City with a Segmented and Regulated Market; $C_A=0$; $N_1<N_1^*$	73
III-11: Space Rent and Wage Capitalization in a Segmented and Regulated Market.....	75
III-12: Land Rents in a Segmented and Regulated Market; $C_A>0$, $N_1<N_{1c}$	78
VII-1 : "Effective" Vs Average Subcenter Rents.....	130
A-1 : A Simplified Two-Center City.....	181
A-2 : The Newton-Ramphson Method: Graphic Illustration.....	187

MAPS

VI-1 : The Los Angeles-Long Beach-Anaheim SCSA.....	111
VI-2 : The Los Angeles-Long Beach-Anaheim SCSA: Selected Subcenters....	117

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INTRODUCTION

The dissertation extends the capitalization debate to the case of the decentralized and often regulated commercial land and real estate market. It asks whether and to what extent variations across commercial nodes in commercial land rents, space rents, and wages capitalize locational value, and thoroughly explores the role that local development restrictions play in affecting the magnitude of these variations.

These issues are accentuated by the relative gap in the existing capitalization literature and the need to better understand the mechanism through which the seemingly large and systematic differences in commercial land rents, space rents, and wages are established in today's decentralized markets. The issue is important, as relative factor and market prices play a significant role in the intrametropolitan distribution of jobs and, consequently, the relative economic vitality of downtown and suburban markets.

1. Capitalization and Pricing Issues

Since the early sixties American cities began to decentralize increasingly. Fiscal and racial externalities have spurred the suburbanization of higher income households [Bradford and Kelejian, 1973], while the scarcity of centrally located land and the slow process of central city redevelopment have encouraged the horizontal spread of older, more densely developed metropolises [Wheaton, 1982].

The rapid decentralization of households has greatly encouraged the decentralization of jobs, which began to move rapidly out of central cities to take advantage of large suburban concentrations of white collar labor or cheaper land [Archer, 1981; Black, 1980; Erickson and Wasylenko, 1980; Mills, 1964; Moses, 1961; Steinnes, 1978; White, 1976; Wheaton, 1984; Struyk and James, 1975]. As a result, metropolitan markets have increasingly begun to exhibit a multinodal structure. Agglomeration advantages or external scale economies, co-location benefits emanating out of the close interdependency of firms, and other production amenities associated with better accessibility or lower tax rates might have encouraged the concentration rather than the dispersion of commercial development in suburban locations [Ogawa and Fujita, 1980].

Notably, the spatial "segmentation" of the commercial sector has been accompanied by a price "segmentation" as well. Casual observations and existing empirical studies alike have uncovered large and systematic differences across commercial nodes in land prices, space rents [Clapp 1983; Wheaton 1984], and labor wages [Eberts, 1981]. Such price variations across locations raise the important question of the mechanism through which these are generated and, most importantly, sustained in the market.

It has traditionally been assumed that the capitalization of local amenities is in the heart of such price variations across space. Focusing on markets where only demand forces are assumed to operate, the literature has convincingly described intercenter variations in (residential) land prices and wages as the result of the "dual" capitalization of differences in transport costs or other amenities into both the residential and labor markets of urban areas. Differences in transport costs within cities, for example, must perfectly be capitalized by residential land prices [Alonso, 1964; Muth, 1969; Mills, 1972; Wheaton, 1974]; between cities of varying sizes, however, wages

must also vary to compensate marginal workers for higher commuting [Moses, 1961; White, 1976; Roback, 1982; Blomquist et. al., 1988]. Emanating out of the close interaction between the labor and residential land market, this process is consistent with Rosen's [1974] "equalizing differences" hypothesis, postulating that such variations are necessary to ensure that workers enjoy equivalent welfare, irrespective of location. By compellingly establishing this dual capitalization process, the literature cleared up the misconception of partial equilibrium analyses (i.e., monocentric models) that only land prices capitalize locational value, and gave credence to the argument that urban locations must best be viewed as diverse bundles of rents, wages, and urban amenities.

While, however, the literature has altogether acknowledged the presence of mobile households and the mechanism through which residential values are determined, it has not fully considered the active presence of mobile firms in the land market, the way they use land and consume space, and, most importantly, the role they play in the capitalization process. As a result, many closely related questions remain largely unaddressed. Just, how does the capitalization of production amenities work in the commercial land market of multinodal metropolises? How are *variations* across nodes in commercial land and floor space rents determined? To what extent do such components of the firm production costs as floor space rents or wages capitalize locational value? What role do such institutional rigidities, as zoning limits or density regulations, which invariably operate in the commercial land market, play in the capitalization process?

The lack of compelling answers to these questions may largely be attributed to the lack of a sufficiently complete analytical framework within which to examine how commercial land and real estate prices are determined and how pricing in the commercial land market relates to pricing in the

residential and labor markets to which this is so closely linked. Such a framework is necessary to tie together the role that spatial differentiations from both the demand (production amenities) and the supply side of commercial land (development restrictions) play in the pricing process.

2. Objectives and Methodology

Against this background, the dissertation has two distinct, yet closely interrelated, objectives. First, to provide a theory of how the capitalization of production amenities works within the contemporary multinodal metropolis, and illustrate how this eventually generates compensating variations across centers in commercial rents and wages. Second, to empirically analyze the pattern of commercial pricing within a multinodal metropolitan area, in order to substantiate or contradict some of the theory's implications.

1.1 The Theoretical and Modeling Approach

The general conceptual and methodological framework adopted in this study originates in the traditional land market theory and the general equilibrium principles underlying the new generation of multicentric city models [i.e., Clapp, 1983]. Building on such past modeling efforts in the field, four simplified models of the land market within a two-center metropolis were developed to examine capitalization. The first models long run equilibria in a competitive land market. The other three examine spatial price equilibria under a constrained supply of land and/or a regulated commercial density. Together, they help explicitly address the following questions:

[1] How do differences across centers in some exogenous advantages to the firm affect pricing in the commercial land market, the commercial property market, and the labor market of a multinodal area? To what extent do variations in commercial land rents, space rents, and wages capitalize differences in locational value?

[2] How do local development restrictions, either in the form of zoning limits or density regulations, affect commercial pricing, and what role do they play in the capitalization process?

Summarized in a number of theoretical propositions and demonstrated through a series of simulated examples, the answers to these questions shed considerable light to the mechanism through which variations across centers in commercial land and real estate prices are determined within multicentered metropolises. Most importantly, perhaps, they elucidate the role that institutional rigidities, often characterizing the commercial land market, play in the capitalization process.

1.2 Empirical Modeling

The empirical analysis provides for direct tests of some of the theoretical propositions and, hence, an indirect test of the empirical validity of their underlying theory. Following a long run equilibrium framework, the empirical study employs standard econometric techniques to estimate and model differences in "effective" space rents across a number of office-commercial nodes in the Los Angeles-Long Beach-Anaheim SCSA (Standard Consolidated Statistical Area). The models were explicitly designed to test for the presence of development constraints in the greater Los Angeles area and to analyze the role they play in the capitalization process.

As such, the models utilize an extensive database on space rents from Coldwell banker and a set of data on housing prices, locational advantages,

and land and density restrictions across 33 nodes within the study area. These data are not without limitations. Asking rents instead of contract rents are available; building quality variables are insufficient; housing price data are urban aggregates rather than more localized data; data on land availability could be translated into dummy rather than numeric variables. Yet, despite these data deficiencies, the empirical results seem to provide considerable support to the relevant theoretical propositions.

3. Organization and Outline

The dissertation is organized into two major parts. Part 1 includes chapters I through V, which cover the theoretical and modeling approach employed to address the central questions of this dissertation. Part 2, includes chapters VI through IX, which discuss the empirical work that stemmed out of the theoretical analysis. A brief outline of the contents of each is provided below.

3.1 PART 1. Rent and Wage Capitalization: A Theoretical Analysis

Chapter I, an introductory to the theoretical part, discusses the implications of a number of intracity and intercity models with respect to capitalization. It suggests that existing models do not fully account for the commercial land and property markets and do not examine capitalization effects in markets which are not necessarily competitive. Thus, it concludes, to appropriately study capitalization in the decentralized commercial land and real estate market, an explicitly spatial, nonmonocentric model must be developed. This model, it suggests, must incorporate land and space consumption by firms and provide for differences across centers in land supply and development densities.

Chapter II, then, builds on this conclusion to outline the general model of a two-center, two-sector metropolis. It discusses in detail household and firm equilibrium and analyzes the basic interactions between the city's residential market, labor market, and the market for service output. The analysis of the model establishes the positive response of residential land rents and wages to changes in employment and reaffirms the "dual" capitalization of intercenter differences in transport costs by both labor wages and residential land rents. At this stage, however, this general model is incomplete, in that it does not exactly specify how the commercial land and real estate markets operate.

Chapter III, then, provides an analysis of four alternative models of the commercial land market, especially designed to examine how the capitalization process works in each: Model I, portraying a perfectly competitive land market at both of the city's subcenters; Model II, portraying a land market segmented by a binding zoning limit at one of the city's subcenters; Model III, featuring a land market with regulated commercial density; and Model IV introducing both a zoning limit and a density regulation, combining thereby features from both Model II and Model III. The examination of long run equilibria in these models shows that in a competitive land market, wage differences are likely to capitalize the bulk of any advantage difference to the firm. As, however, increasingly binding zoning limits and/or density regulations are applied to the more advantageous center, differences in floor space rents start capitalizing more (and wage differences less) locational value.

Chapter IV presents a series of numerical simulated examples of each of the four models discussed in the previous chapter. In addition to providing considerable support to the theoretical propositions, the simulations shed some light to the magnitude of space rent and wage capitalization. In

particular, they show that, under quite general conditions, restrictions must be very restraining for space rents to capitalize the bulk of the locational advantage to the firm, if only one of the two constraints is applied to the commercial land market.

Finally, the concluding section of Part 1 summarizes the theoretical and modeling approach and highlights the most important conclusions advanced in the first four chapters of the dissertation. This sets the basis for the discussion in Chapter V, which follows.

3.2 PART 2. Space Rent Capitalization: The Case of Greater Los Angeles

Chapter V is an introductory to the empirical part. It discusses the most important empirical implications of the theory developed and critically evaluates past empirical studies on intrametropolitan commercial pricing. Concluding that existing empirical studies may be flawed for they do not fully account for the supply side of the commercial land market, it proceeds with outlining the present empirical study, which attempts to rectify the problems characterizing prior empirical work.

Chapter VI describes the study area, identifies its broader commercial submarkets, and discusses the selection of a number of commercial nodes within their boundaries. Finally, it presents the selected subcenters' "average" building attributes and asking rents to conclude that the former considerably vary across centers; thus, it suggests, average rents cannot be used as the basis for intercenter price comparisons.

Chapter VII builds on this conclusion to present alternative hedonic models designed to estimate "effective" subcenter rents for a building of constant "quality" and other attributes such as age, size, and height. Projecting a somewhat different picture of rent differentials than what the

"average" rents reflect, "effective" rents appear to significantly vary across centers, setting thus the stage for the analysis that follows.

Chapter VIII, then, draws from the conclusions of the theoretical part to statistically analyze this pattern of "effective" rents in order to address the relevant theoretical propositions. To test for the presence of binding development restrictions and investigate the role they play in the capitalization process, a number of linear and nonlinear statistical model specifications are presented, and the data employed to estimate them are discussed. The econometric estimation of these models confirms the presence of development constraints and validates their hypothesized role in the capitalization process.

Part 2's concluding section briefly summarizes the methodology and highlights the main conclusions of the empirical work presented in the last four chapters of the dissertation.

Finally, the concluding chapter of the dissertation provides a brief overview of the theoretical and empirical analysis and discusses extensions and refinements of the theoretical and empirical models that these analyses have utilized.

P A R T I

**RENT AND WAGE CAPITALIZATION:
THEORY AND MODELING**

Chapter I.

RENT AND WAGE CAPITALIZATION IN THE LITERATURE

With its direct implications for urban pricing, amenity capitalization has been a central focus for academic research in the field of urban economics and other related strands of economic analysis. Price differences across space in this literature are often viewed as equalizing differences for the different attributes or amenities/disamenities (advantages/disadvantages) that different urban locations embody. This hedonic "hypothesis" underlies both the simple intracity location and spatial pricing models, a number of more elaborate intercity models, and, to a certain extent, the newly developed multicentric city models. This chapter reviews in detail the theoretical advances to date with respect to the amenity capitalization issue.

1. Land and Space Rent Capitalization: Intracity Models

1.1 Standard Monocentric Models

Capitalization effects within single, monocentric and well defined urban areas were first examined in the context of the traditional land market models of Alonso [1960], Muth [1969], Mills [1972] and Wheaton [1974]. Notably, these theoretical models are based on the a priori assumption that households are mobile, but that employment is exogenous and firms are immobile. Concentrated in the city's spaceless central business district, the latter are not supposed to consume land or face any intracity location choices. Thus,

such and similar analyses of the land market have ignored the firm equilibrium and have solely been confined to the examination of household equilibrium and the way residential land prices vary with locational amenities across space.

The amenity originally considered was access, as represented by the distance of residential locations from the area's single employment center and the transport costs involved. As all models clearly demonstrate, residential land values do perfectly capitalize variations across space in transport costs. Obviously, differences in land prices represent the compensating variation which makes less or more attractive sites provide urban land consumers with the same level of utility.

Subsequently, these standard monocentric models, focusing on one-dimensional distance gradients, were extended to include other amenities also defined by their distance from the city center. The case of air quality is, perhaps, the most representative in this class of models [i.e., Stull, 1974; Henderson, 1985]. Henderson [1985], for example, assumes air quality to worsen with smaller distance from the city center, the site of pollution. Assuming that the rate at which this disamenity declines with distance from the city center may well exceed the effects of change in accessibility, he suggests that a positive land rent gradient may be established in the city.

In somewhat more complex adaptations of the monocentric model, urban space is characterized by a vector of amenities or neighborhood attributes [Polinsky and Shavell, 1976]. In these location models, household equilibrium still requires that the price of land be computed as the compensatory variation necessary to ensure that household utilities remain spatially invariable.

Polinsky and Shavell [1976] caution to a potential application problem arising when household utilities are assumed to be endogenously rather than exogenously determined. The former assumption is adopted by "closed" city

models, portraying cities where in-migration from, or out-migration toward, a larger urban area is limited. The latter assumption is adopted by "open" city models, in which the city is assumed to be a part of a larger urban area throughout which households are perfectly mobile.

As Polinsky and Shavell note, the validity of cross-section results to predict property value adjustments in response to changes in amenity schedules depends on this assumed degree of mobility. In the small open model, the results of cross-section analyses may unquestionably be used to predict changes in residential rent schedules. In closed city models, however, the use of these results to predict property value changes is debatable, for property values at any location depend on the distribution of amenities throughout the city. The clear implication is that a general equilibrium model is needed to derive the overall pattern of intracity property values and suggest appropriate statistical models for empirical verification.

These simple models, mostly stressing the effect of accessibility, have stimulated a number of empirical studies which have substantiated to some extent the assertion that access (among other factors) is a locational *amenity* or, equivalently, an attribute that is valued *positively* by urban land consumers [Kain, 1964]. Studies of property values, however, tend to conclude that, in general, the effect of accessibility is weak compared to the effect of structural, qualitative and other locational characteristics of housing [Quigley, 1979].

1.2 Hedonic Models of Urban Markets

The recognition of the differentiated character or heterogeneity of built capital, its locational fixity, and its durability (at least in the short run) led to the development of the alternative but equivalent discrete

choice [Sweeney, 1974; Quigley, 1976] and bid-rent approaches [Wheaton, 1977]. Models based on such approaches have quite often been employed to establish or evaluate "amenity" effects in property markets. Although these were first developed to facilitate empirical applications in the residential property market, they can readily be applied to the analysis of any other hedonic market, such as the market for office space [Clapp, 1981; Wheaton, 1984].

According to the conventional hedonic approach, households or firms are assumed to have a utility function, which depends on the location and qualitative features of housing or office space. Suppliers provide different buildings in different locations to suit tenants in a profit maximizing fashion. Housing consumers or office tenants compare rents with attributes and seek the best location. According to the bid-rent version of the model, rather than taking prices as given, consumers of housing or office space establish bids for units, characterized by an array of attributes related to locational or structural unit characteristics. Ultimately, units are occupied by those households or office tenants offering the highest bid.

The two conceptual approaches are equivalent; in equilibrium, rents should always be positively related to desirable attributes, in a way that yields equal utility to housing consumers or office tenants and equal profits to the suppliers of housing or office space [Wheaton, 1977].

Once again, analyses based on such approaches [Quigley, 1976; Wheaton, 1977] suggested that intraurban differences in such amenities as access, crime, school quality, or quality of environment *do* influence residential location and residential land and property values. Most importantly, applications in the case of office markets, such as Clapp's [1983] or Wheaton's [1984], have uncovered the importance of a number of locational attributes, such as access to labor and other accessibility advantages related to highway systems, in influencing nonresidential location and pricing. At

the same time, however, Wheaton's [1984] empirical study rejected the hypothesis that variations across Boston's communities in effective tax rates significantly influence variations across space in commercial space rents.^{1/}

1.3 Interjurisdictional Models in the Local Public Finance Literature

The realization that amenity packages, including tax rates and public services, widely vary across jurisdictions extended the amenity capitalization debate into the realm of public finance [Oates, 1969; Edel and Sclar, 1974; Hamilton, 1975; Yinger, 1982]. Yinger's [1982] is perhaps the most refined of these analyses. Arguing that past analyses are incomplete because they do not fully account for the markets for housing and local services, Yinger draws from the Tiebout literature to examine the household location decision and resident voting in an urban area with diverse local governments. He shows that capitalization is a feature of a long run equilibrium; perfect capitalization of amenity differences between jurisdictions by land prices, he suggests, *should* occur and be sustained in the long run [Yinger, 1982]. He disqualifies previous arguments [i.e., Edel and Sclar, 1974; Hamilton, 1975] that capitalization can be eliminated through supply responses because, he argues, nonfiscal variables *do* impact housing prices. Thus, if consumers have preferences over the goods produced by local governments and if mobility is sufficiently high, property values should be expected to be higher in communities with more attractive packages of public goods.^{2/}

^{1/} These studies are in some more detail reviewed in Part 2 (Chapter V) of this dissertation.

^{2/} Pogodzinski [1988] argues that Yinger's proposition is misdirected, because complete capitalization occurs regardless of the presence or the absence of amenities.

2. "Dual" Capitalization: Intercity Models

The models above implicitly assume that location decisions take place within a single city or metropolitan area. The recognition that households and urban firms are free to choose among alternative locations not only *within* but also *between* cities or metropolitan areas has complicated the capitalization question and the way analysts should go about addressing it.

Equilibrium within a system of cities now involves at least two basic factor markets--the market for urban land and the labor market. The capitalization question now is which factor market capitalizes variations in amenity values and, if both do, what the relative capitalization magnitudes are. Rosen [1979], Henderson [1982], Roback [1982] and Blomquist et. al. [1988] have all developed simple models to address these newly emerged questions. Mostly, their analyses focused on the issue of how amenity differences between cities or metropolitan areas are capitalized by interarea differences in labor wages and/or residential land prices. Although these analyses considerably improved the way analysts have been thinking about capitalization, their modeling approaches often appear to be somewhat problematic.

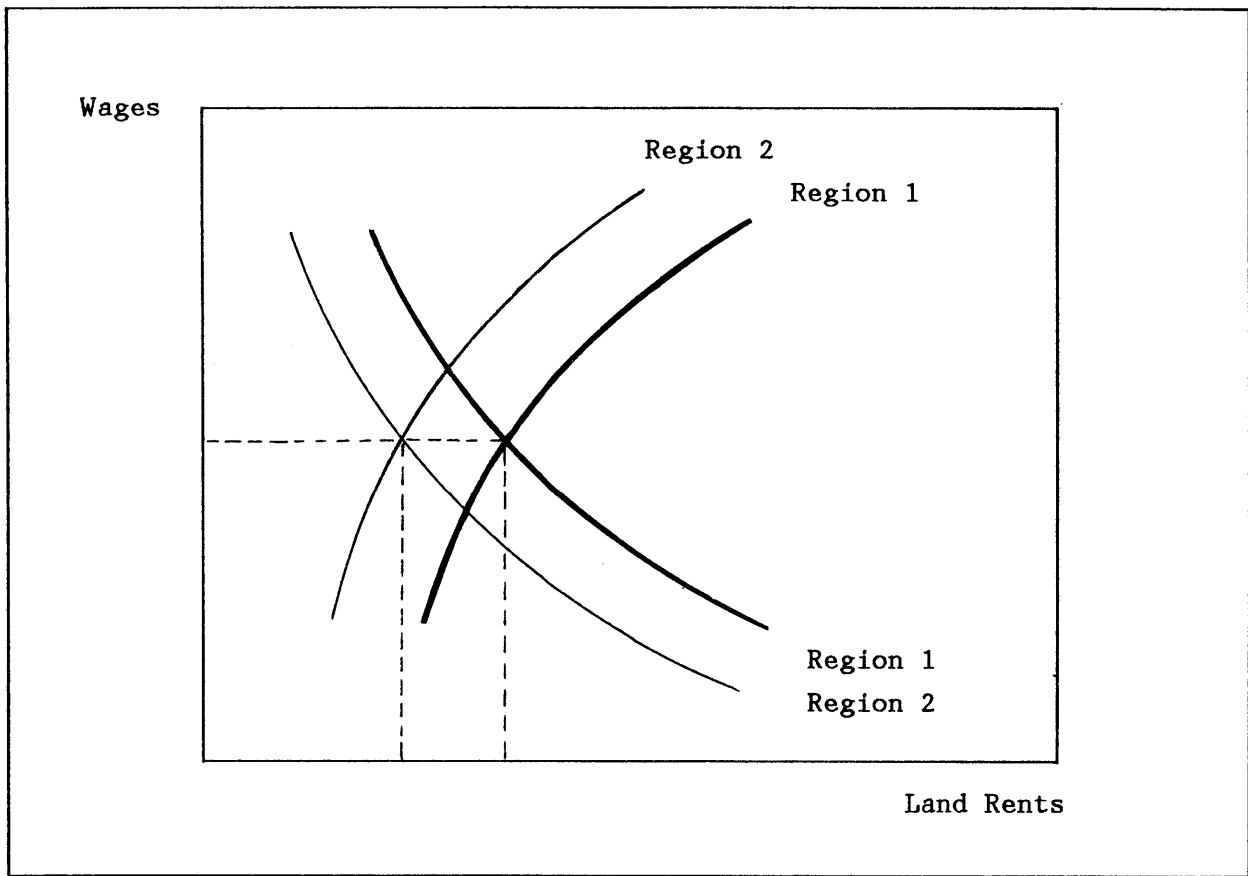
In examining equilibrium in the labor market without, however, fully accounting for the demand for labor, Henderson [1982] has shown that interurban variations in labor wages must capitalize to some extent differences in amenity levels or cost of living. Rosen [1979], Roback [1982] and Blomquist et. al. [1988], on the other hand, have examined in detail equilibrium not only in the labor, but also in the (residential) land market. They concluded that intercity differences in amenity levels must be capitalized into *both* the land and the labor market of urban areas. The clear implication here is that land prices and wages alike have to vary between

cities or metropolitan areas so that workers/households enjoy equivalent welfare and firms produce at equal costs across space. Analyses of such equilibria justified Rosen's [1974] contention that urban locations must best be viewed as tied bundles of rents, wages, and spatial amenities. Most importantly, perhaps, these analyses have largely proven that the conventional wisdom that only land prices are affected by local amenities may be quite misleading [Roback, 1982].

Roback's model has gone beyond this general conclusion to look at the decomposition of amenity values into land rents and wages. Her conclusions can best be illustrated by Figure I-1. The upward slopping lines represent wage and land rent combinations equalizing household utilities at given amenity levels. The downward slopping lines are those wage and land rent combinations that equalize unit production costs, again at given values of the amenity. In Figure I-1, it is assumed that Region 1 is more amenable both to households and firms. In this case, Region 1 will have higher land rents but not necessarily higher wages than Region 2. It can easily be inferred that if Region 1 is more amenable to households but less amenable to firms than Region 2, then Region 1 will have lower wages but not necessarily lower land rents than Region 2.

Roback's model [1982] refined Henderson's [1982] analysis by fully accounting for the demand for labor. Yet firms in her model still consume land and not space and, unlike Henderson's model, amenities, commuting costs and, consequently, land prices are not allowed to vary within urban areas. The Blomquist et. al. [1988] model presents an improvement over the Roback model in that it allows amenities to vary both within and across urban areas. Similarly to what happens between urban areas, Blomquist et. al. suggested, for a complete equilibrium in the residential and labor markets, amenity differences across locations (counties) within metropolitan areas must be

FIGURE I-1:
The Roback Model



capitalized by both residential land rents and labor wages.

These and similar analyses have given rise to a number of applied econometric studies uncovering significant variations in real wages and residential rents between urban counties or metropolitan areas [Hoch, 1974; Israeli, 1977; Rosen, 1979; Henderson, 1982; Blomquist et. al., 1988]. Such differences are mostly accounted for by differences in such amenities or disamenities as air quality, climate, crime, and, to a smaller extent, quality of schools and education. Most recently, Gyourko and Tracy [forthcoming] have empirically demonstrated the role that variations across cities in local

fiscal conditions play in creating compensating wage differences across urban areas.

3. Spatial Multicentric Models

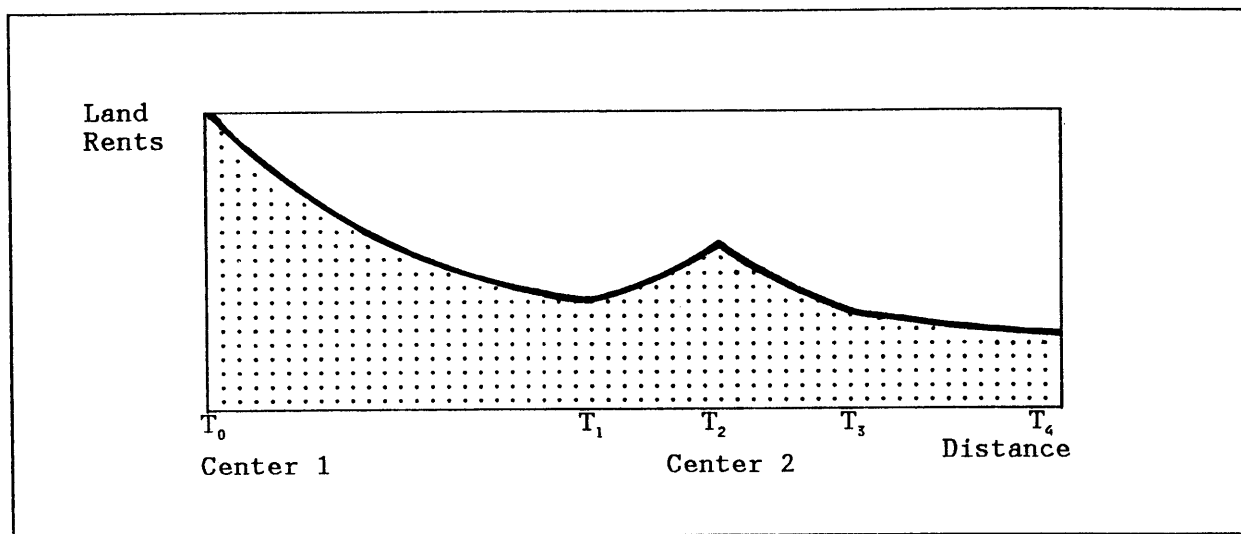
The models just reviewed share a number of common deficiencies that render them inappropriate to be used as analytical tools for thoroughly addressing the questions posed in this dissertation. They do not fully account for mobile firms which consume land and use space, they do not explore capitalization effects in markets which are not necessarily competitive, and, most importantly, they do not reflect the multinodal structure of the modern metropolis.

The new generation of multicentric models, on the other hand, reflect irrefutably the spatial structure of the contemporary city [White, 1976; Sullivan, 1986; Wieand, 1987; Papageorgiou and Casetti, 1971; Hartwick and Hartwick, 1974; Romanos, 1977; Clapp, 1983; Capozza, 1971; Ogawa and Fujita, 1979]. Yet, although explicitly designed to address multicentricity phenomena, this new generation of urban models have not appropriately been expanded to deal explicitly with capitalization and commercial pricing issues within decentralized metropolises [Stahl, 1987].

On the demand side, these models have examined the decentralization phenomenon and the resultant urban spatial structure. Their focus and modeling structures may often differ, but the "dual" capitalization of transport cost differentials into both the residential land and the urban labor market is a common feature of their derived equilibria.^{3/}

^{3/} In one of the first of such modeling efforts, White [1976] developed a simple model to analyze the long run equilibrium adjustments associated with the transition from a monocentric to a two-center city. Her analysis focuses principally on manufacturing firms dependent heavily on export terminals and (continued...)

FIGURE I-2:
Multicentric Models: "Dual" Capitalization of Transport Costs



This "dual" capitalization can best be illustrated using Figure I-2. Center 1 is the central business district, while Center 2 represents a small employment center developed around a suburban transport node. The residential land rents paid by Center 1 workers should still capitalize differences in

³(...continued)
often facing labor scarcity problems. More recently, Sullivan [1986] and Wieand [1987] have developed similar, but more elaborate models of a circular two-center city. Sullivan [1986] has introduced a three-sector economy with households, office activity, and industrial production in an open city. Weiand [1987] developed a more elaborate closed model to analyze not only the long run but also the short run equilibrium adjustments that firm decentralization brings about in urban areas. To this end, he used a two-period planning horizon and fully accounted for the intertemporal behavior of the suppliers of office and industrial space.

Papageorgiou and Casetti [1971], Hartwick and Hartwick [1974], Romanos [1977], and Clapp [1983], on the other hand, have constructed more general multicentric models with more than two centers present in urban areas, but with the location of these centers being exogenously determined. Capozza [1971], Ogawa and Fujita [1979], as well as others, have further generalized such nonmonocentric models, by abandoning the assumption of a prespecified number and location of urban subcenters. In their models the number and location of centers are endogenously derived. In particular, Ogawa and Fujita [1979] have examined how different types of nonmonocentric cities may be formed on the basis of different locational and linkage requirements by the office firms. Interestingly enough, they concluded that if the bid rent gradient of firms is as steep as the bid rent gradient of households, it is quite possible that urban firms be as dispersed in the city as households are.

commuting costs, as the simple monocentric model would require. For the marginal workers at T_1 , however, who commute different distances but have identical land expenses, wages between centers must also vary to provide them with equivalent welfare. This wage variation, on the other hand, must be accompanied by a land rent variation between centers as well. Center 1 is bigger and, as such, it must in equilibrium have higher residential land rents at its borders than Center 2.

On the supply side, and similarly to the intercity models just reviewed, these models have assumed a perfectly elastic supply of commercial land. As such, they can be used to explain commercial or firm pricing patterns only if perfectly competitive market conditions are assumed. More specifically, they can explain intrametropolitan nonresidential rent differentials only to the extent that it can safely be assumed that nonresidential land rents equal their neighboring residential land rents and space rents are positively related to housing prices; and they can explain nonresidential space rent differentials, only to the extent that these move in a parallel fashion with land rent differentials. This may hardly be the case if restrictions on nonresidential development are present in urban areas.^{4/}

Assuming an open city model, Sullivan [1986] made the first attempt to evaluate the general equilibrium adjustments necessitated by the imposition of FAR (Floor Area Ratio) restrictions on the central business district of a

^{4/} Most of the interest in and research on development constraints has been directed toward its distributional and price effects [see Ohls et. al., 1974; White, 1975; Grieson and White, 1981; Elliot, 1981; Rosen and Katz, 1981; Mark and Goldberg, 1986; Sherman-Rolleston, 1987; Rose, 1989]. Analysts have studied its effects on urban land and property markets, in general, to conclude that land use zoning inflates land and property prices and that density zoning distorts similarly property markets. However, the effects of zoning have not yet been studied in the context of a general equilibrium model, involving both households and firms. Given its documented effects on land and property pricing, it can be very well hypothesized that zoning must play a major role in the amenity capitalization process.

circular city. In his model, he introduced a three-sector economy with households, office activity and industrial production. Office activity, however, was assumed to be exclusively concentrated in the central business district, while manufacturing activity was assumed to exclusively take place in a suburban subcenter. Hence, the model did not exactly deal with a single decentralized activity and its intracity distribution as dictated by the government-imposed density regulation.

4. The Capitalization Literature: Concluding Remarks

Obviously, most of the interest in and research on capitalization has been directed toward the residential land market, with the commercial land and property markets receiving only a marginal, if any, attention. Within this context, the literature has well established the capitalization of transport costs and other amenities across space within *monocentric* cities, the "dual" capitalization of amenity differences by both residential land rents and labor wages within a *system* of cities, and the "dual" capitalization of transport costs by both residential land rents and labor wages across centers within *multinodal* metropolises.

What seems, however, to be missing from this literature is a much more thorough look at the capitalization process, which takes into account the way commercial land markets operate and linked to the residential and labor markets of urban areas. To study capitalization in such a context, an explicitly spatial model, incorporating land and space consumption by firms and allowing for a variety of supply conditions in the commercial land market, must be developed.

Chapters II, III, and IV discuss in detail and Appendix I summarizes such a model, especially designed to thoroughly address capitalization issues within multicentric metropolises.

Chapter II.

A SIMPLIFIED MODEL OF A TWO-CENTER, TWO-SECTOR CITY

To set the basis for analyzing capitalization within nonmonocentric city settings, a simple theoretical model of a two-center, two-sector metropolis, fully incorporating land and space consumption by firms was developed. Similarly to its monocentric counterparts [i.e., Muth, 1969; Mills, 1972; Wheaton, 1974], the model provides a static rather than a dynamic theory [Wheaton, 1982, 1983] and a theory of long run rather than short run adjustments in the market [Sullivan, 1986; see note 3].

Being an analytic or explanatory [Wheaton, 1979] rather than a policy-oriented model [Lowry, 1965; Ingram, 1979; Kain, 1987], its underlying objective is not to replicate a realistic city, but to provide an easily comprehensible and analytically tractable framework within which to address the issue(s) at hand. As such, the model simplifies behavioral relationships and ignores a number of real world complexities, which, at the same time, are sources of analytical inconveniences: the presence of a variety of household and firm types within urban areas; the variety of trips made toward employment districts; the presence of agglomeration economies or external economies of scale in production; the locational interdependency of firms and the presence of a variety of externality effects in the urban land market.^{5/}

^{5/} The extent to which the relaxation of some of these and other more specific assumptions is likely to affect the theoretical conclusions is discussed in the concluding section of the dissertation, which explores avenues for future research.

Yet, despite its simplifying assumptions, the model sheds considerable light to the way the capitalization of production amenities works and to the magnitude of the compensating variations across centers in commercial rents and wages it eventually produces. This chapter describes the two-center city featured in the general model, discusses household and firm equilibrium in the city's residential and commercial sectors, and highlights the basic interactions between the output market, the labor market, and the market for residential land.

1. The General Model

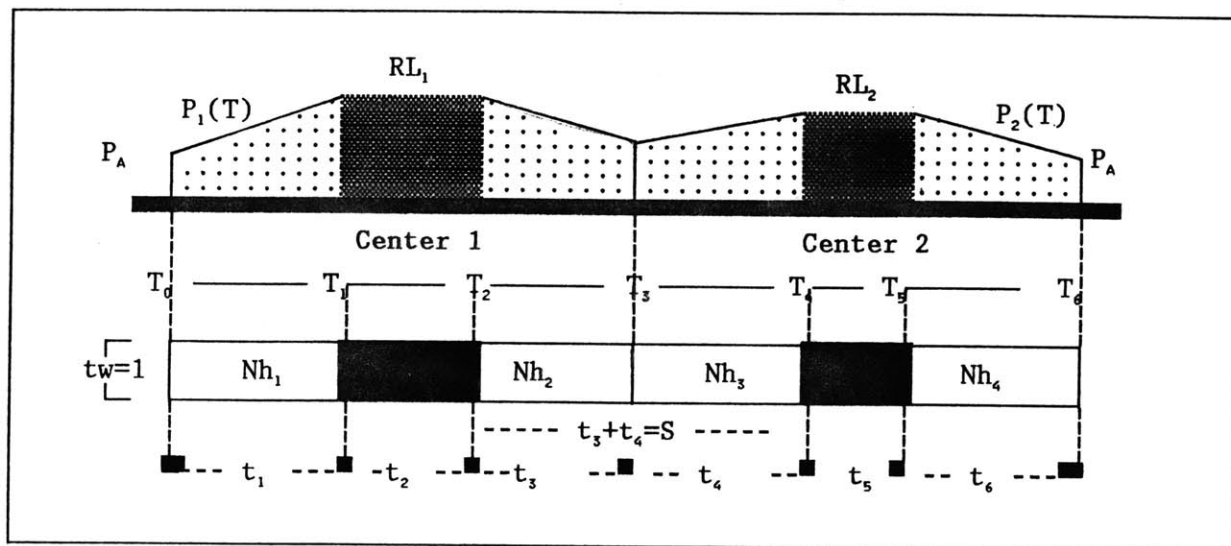
The model features a simplified, linear city of a unit's distance width, built on a homogeneous plain (Figure II-1). The city's land is allocated to N_h identical, one-worker households and two commercial centers--Center 1 and Center 2--developed at prespecified locations, with a fixed distance S from each other's edges.⁶ The two centers are specialized in the production of service output, which is sold outside the city. In equilibrium, they are assumed to employ fully the city's labor force.

In the absence of cross commuting, the labor demanded for production in each subcenter is provided by those households located in each subcenter's labor market area.⁷ Firms, then, located at Center 1 draw their workers from that subcenter's adjoining residential areas spanning from T_0 to T_1 and from T_2 to T_3 . Similarly, firms located at Center 2 draw their workers from

⁶ The assumption of a fixed distance between the two subcenter's edges (rather than between the two subcenter's midpoints) reduces the number of nonlinear equations and hence facilitates the derivation of numerical solutions to the model (see Chapter IV).

⁷ The conditions under which cross commuting patterns may prevail are incorporated in the discussion of Model II in Chapter III.

FIGURE II-1
A Simplified Two-Center City



their neighboring residential areas, spanning from T_3 to T_4 and from T_5 to T_6 . Workers are assumed to commute daily toward their respective employment locations. Intracenter commuting, however, is ignored, so that the distance traveled by the workers does not include any commuting beyond the edges of the two commercial sites.

A general long run equilibrium in the city requires that its residential land market, labor market, and commercial land and property markets be cleared simultaneously through appropriate rent and wage adjustments. The number of households (Nh) and their consumption characteristics, the production characteristics of firms, and the base wage in Center 2 (W_2) are given exogenously. The city's residential land rents ($P_i(T)$), the two subcenters' commercial land rents (RL_i), those subcenters' floor space rents (R_i), and Center 1's labor wages (W_1) are determined by the model. Household and firm equilibrium in the city's various markets is in detail discussed below.

2. The Residential Sector

In such a simplified model, the city's N_h identical households derive utility from the consumption of land (q) and other nonland goods (X) bought at a unit price. To facilitate the analysis, these households are assumed to consume the same amount of land across locations. Their underlying economic objective, then, is to choose their other, nonland consumption in a way that will maximize their utility, $U(X, q)$, subject to their budget constraint. Assuming for simplicity that those households' wage earnings are their only source of income, demand for nonland goods can be expressed as:

$$X = W_i - P_i(T)q - kT > 0 \quad (\text{II.1})$$

where:

- W_i : households' yearly wage earnings at employment center i ;
- $P_i(T)$: yearly rental expenses on residential land per unit of this land;
- k : yearly transport costs per unit T , the distance traveled by the workers.

The households' nonland demands, as well as the city's residential land rents and subcenter wages that determine these demands, must comply with a number of equilibrium conditions in the urban residential market. Free competition between the city's residential land and its neighboring rural locations ensures first that the annual land rents that those households located at the city's outer borders pay ($P_1(T_0)$, $P_2(T_0)$) be equal to the annual rent that the rural land commands (P_A). Assuming for simplicity equal agricultural rents at both of the city's outer borders, the following condition(s) must hold:

$$P_1(T_0) = P_2(T_0) = P_A \quad (\text{II.2})$$

In the long run, the residential land rents ($P_1(T)$) prevailing within these borders should adjust in a way that the city's identical households achieve the same level of welfare, independently of where they locate or where they are employed. Otherwise, utility maximizing consumers would have an incentive to move to a higher utility location, and equilibrium would be disrupted. Given the households' fixed land consumption across locations, the equal utility condition clearly requires that households also consume the same amount of nonland goods across space. Given the nonland consumption expression in (II.1) and condition (II.2) above, two sets of equilibrium conditions are then derived.

The first set of these conditions require that the pattern of residential land rents across a subcenter's supporting residential area reflect fully the transport cost differentials of workers employed at that subcenter. This is signified in the following relationships, derived by applying the equal nonland consumption condition first to workers employed at C_1 and located at T_0 , T_2 , and T_3 , and then to workers employed at C_2 and located at T_3 , T_4 , and T_5 :

$$\begin{aligned} P_1(T_1) &= P_1(T_2) \\ P_1(T_1)q &= P_Aq + kt_1 \\ P_1(T_2)q &= P_1(T_3)q + kt_3 \end{aligned} \tag{II.3}$$

$$\begin{aligned} P_2(T_4) &= P_2(T_5) \\ P_2(T_4)q &= P_2(T_3)q + kt_4 \\ P_2(T_5)q &= P_Aq + kt_6 \end{aligned} \tag{II.4}$$

The t_n are defined as in Figure II-1. $P_1(T_3)$ in (II.3) and $P_2(T_3)$ in (II.4) denote the residential land rents that households employed at Center 1

and Center 2, respectively, and located in the city's middle border (T_3) pay. To ensure the stability of this border and the continuity of development in the city's inner residential zone, the following complementary condition(s) must hold:

$$P_1(T_3) = P_2(T_3) \geq P_A \quad (\text{II.5})$$

A second set of equilibrium conditions require that the wage differences between the city's two commercial subcenters reflect fully the transport cost differentials of the more distant households employed in each of these subcenters. Alternatively, this requires that wage differences between centers reflect fully differences in the land expenses of those households located at the two subcenters' edges. These conditions are signified in the following relationships, derived by applying the equal nonland consumption condition first to workers located at T_3 and employed at Center 1 and Center 2, and then to workers located at T_0 , T_6 , or T_1 , T_4 and employed at Center 1 and Center 2, respectively:

$$W_1 - W_2 = k(t_3 - t_4) \quad (\text{II.6})$$

$$W_1 - W_2 = k(t_1 - t_6) \quad (\text{II.7})$$

$$W_1 - W_2 = [P_1(T_2) - P_2(T_4)]q \quad (\text{II.8})$$

Finally, for the urban consumers and the residential market to achieve their long run equilibrium, the city's residential land rents should adjust in a way that the households' land demands in each residential zone be equal to the supply of this land (Figure II-1). Given the city's unitary width and the households' fixed land consumption across space, the following relationships must then in the long run hold:

$$Nh_1 = \frac{1}{q} \int_{T_1}^{T_0} TdT = \frac{t_1}{q}; \quad Nh_2 = \frac{1}{q} \int_{T_2}^{T_3} TdT = \frac{t_3}{q}; \quad (II.9)$$

$$Nh_3 = \frac{1}{q} \int_{T_3}^{T_4} TdT = \frac{t_4}{q}; \quad Nh_4 = \frac{1}{q} \int_{T_5}^{T_6} TdT = \frac{t_6}{q}; \quad (II.10)$$

where:

$$Nh_1 + Nh_2 + Nh_3 + Nh_4 = Nh. \quad (II.11)$$

3. The Commercial Sector

The city's firms participate in four closely linked submarkets: the market for service output and the labor, property and land markets, which provide direct (labor, floor space) and indirect (commercial land) inputs for the production of service output. The market for commercial capital, assumed to be abundant and mobile, is a national market and, as such, exogenous to this model.

3.1 The Market for Service Output

Service output is marketed nationally in a perfectly competitive market. Such services in the two commercial subcenters are produced through a simple, constant returns production process involving the use of fixed proportions of labor (N_1) and floor space (Qs_1) to firm output. In such a case, then:

$$\frac{Qs_1}{N_1} = \frac{a_s}{a_n}, \quad (II.12)$$

where a_s and a_n denote the fixed floor space and labor demanded per unit of the service output produced. The total production costs at each alternative site are then the sum of labor wages, floor space rents, and some other production costs, assumed to be exogenously determined. Such exogenously determined costs may be transport costs related to highway accessibility, or tax payments and other costs related to the use of local public services. In a long run equilibrium in the city's output market the total production costs per worker employed should be equal across the city's alternative commercial locations. Otherwise, cost minimizing employers would have a incentive to move to the least cost location, and a disequilibrium situation would prevail. Therefore:

$$W_1 + R_1 \frac{Qs_1}{N_1} + CE_1 = W_2 + R_2 \frac{Qs_2}{N_2} + CE_2 \quad (II.13)$$

where:

- W_i : wage level at employment center i ;
- R_i : equilibrium rents per unit of floor space at center i ;
- CE_i : exogenous production costs per worker at center i ;
- Qs_i : floor space demand at center i ;
- N_i : labor demand at employment center i .

3.2 The Labor Market

The service market's labor basis consists of the city's N_h identical, one-worker households. In a long run equilibrium in each subcenter's and the city's labor market, the labor demanded for the production of service output at each subcenter should equal the number of households located in each subcenter's labor market area. Likewise, the total labor demanded in the city should equal the city's total number of households. Assuming a normal location pattern without cross commuting on the part of workers employed in

either of the city's subcenters and given the configuration of the two-center city pictured in Figure II-1, the following conditions must hold:

$$N_1 = Nh_1 + Nh_2 = (t_1 + t_3)/q \quad (II.14)$$

$$N_2 = Nh_3 + Nh_4 = (t_4 + t_6)/q \quad (II.15)$$

$$N_1 + N_2 = Nh = (t_1 + S + t_6)/q \quad (II.16)$$

where:

N_i : labor demand at center i ;
 Nh_n : number of households located in each of the city's residential zones;
 t_n : distances between the center's edges and residential borders;
 S : linear distance between the two subcenters' inner edges;
 q : household land consumption.

3.3 The Commercial Property Market

Each subcenter's property market is assumed to be perfectly competitive. In such a market, the floor space needed for the production of service output is produced according to a simple, constant returns to scale Cobb Douglas function. In such a case, then:

$$Qs_i = K_i^b L_i^{1-b}; \quad 0 < b < 1 \quad (II.17)$$

where:

K_i : the capital demanded at center i ;
 L_i : the commercial land demanded at center i .

Given the competitive market conditions under which this space is produced, long run profits (π) should be spatially invariable and equal to zero. Therefore:

$$\pi = R_i Q_{s_i} - R L_i L_i - r K_i = 0,$$

or:

$$R_i = \left[R L_i L_i + r K_i \right] / Q_{s_i}, \quad (\text{II.18})$$

where:

R_i : annual equilibrium rents per unit of floor space at center i ;
 $R L_i$: annual commercial land rents per unit of land at center i ;
 r : the exogenously determined, annual rental cost of capital.

Cost minimization yields the demand functions for capital and land (II.19) and (II.20), respectively. Incorporating these demand functions into the zero profit condition (II.18) yields the long run rental cost for floor space (II.21):

$$K_i = \frac{a_s}{a_n} N_i \left[\frac{b R L_i}{(1-b)r} \right]^{1-b} \quad (\text{II.19})$$

$$L_i = \frac{a_s}{a_n} N_i \left[\frac{(1-b)r}{b R L_i} \right]^b \quad (\text{II.20})$$

$$R_i = C_0 R L_i^{1-b}$$

where:

$$C_0 = r^b b^{-b} (1-b)^{b-1} \quad (\text{II.21})$$

3.4 The Commercial Land Market

Each subcenter's commercial land market is assumed to be homogeneous. In the absence of intracenter differentiations, the firms' rent for commercial land ($R L_i$) and, consequently, commercial space rents (R_i) should not vary within each center (Figure II-1). In the long run, commercial land rents

(RL_1) should be such so that the land demanded (L_1) for production at each subcenter equals its supply. Given the city's unitary width, the following conditions must then hold in equilibrium:

$$L_1 = t_2 \quad (II.22)$$

$$L_2 = t_5 \quad (II.23)$$

4. Market Interactions

The equilibrium conditions discussed so far establish some basic relationships among the output market, the labor market, and the market for residential land. Taken together, equilibrium conditions (II.14)-(II.16) clearly require that a higher demand for labor by either of the city's subcenters be associated with a larger residential area supporting that center and higher commuting costs for its most distant worker. In turn, as (II.3) and (II.4) indicate, such higher commuting costs should always result in greater residential land rents at that subcenter's edges and, as evident from (II.6) and (II.7), higher relative labor wages.

These effects are formally derived by solving equations (II.14)-(II.16) and (II.6)-(II.7) for t_1 , t_3 , W_1 each as a function of N_1 , and t_4 , t_6 , each as a function of N_2 :

$$t_1 = q \left[\frac{N_1 \quad Nh \quad S}{2 \quad 4 \quad 2q} \right]; \quad t_3 = q \left[\frac{N_1 \quad Nh \quad S}{2 \quad 4 \quad 2q} \right];$$

$$t_4 = q \left[\frac{N_2 \quad Nh \quad S}{2 \quad 4 \quad 2q} \right]; \quad t_6 = q \left[\frac{N_2 \quad Nh \quad S}{2 \quad 4 \quad 2q} \right];$$

$$W_1 = W_2 + \frac{kq}{2}(N_1 - N_2) = W_2 + kq \left[N_1 - \frac{Nh}{2} \right] \quad (\text{II.24})$$

Using then (II.24) together with (II.3)-(II.4), the response of the two subcenter's adjoining residential land rents and Center 1's labor wages to changes in center employment can be derived:

$$\frac{\partial P_1(T_2)}{\partial N_1} = \frac{\partial \left[\begin{matrix} k \\ P_A + t_1 \\ q \end{matrix} \right]}{\partial N_1} = \frac{k}{2} > 0; \quad \frac{\partial P_2(T_4)}{\partial N_2} = \frac{\partial \left[\begin{matrix} k \\ P_A + t_6 \\ q \end{matrix} \right]}{\partial N_2} = \frac{k}{2} > 0; \quad \frac{\partial W_1}{\partial N_1} = kq > 0 \quad (\text{II.25})$$

Furthermore, given the city's fixed workforce in (II.16), the greater Center 1's (Center 2's) employment, the smaller the employment at Center 2 (Center 1). It can then be argued that the greater the labor size differential between the two subcenters, the greater the differential between the residential land rents at those subcenters' edges, and the greater their wage differential will be. These effects are signified in (II.26) below:

$$\frac{\partial (P_1(T_2) - P_2(T_4))}{\partial (N_1 - N_2)} = \frac{k}{2} \frac{\partial (N_1 - N_2)}{\partial (N_1 - N_2)} = \frac{k}{2} > 0, \quad \frac{\partial (W_1 - W_2)}{\partial (N_1 - N_2)} = \frac{kq}{2} \frac{\partial (N_1 - N_2)}{\partial (N_1 - N_2)} = \frac{kq}{2} > 0 \quad (\text{II.26})$$

The equilibrium conditions, then, discussed in this chapter establish some basic relationships among labor size, labor wages, and residential land rents. They are clearly insufficient, however, for completely determining the

equilibrium pattern of commercial land and space rents across the city's subcenters.

To determine a complete spatial equilibrium in the city, the model must incorporate the factor demand functions in the commercial property market and must specify the exact relationship between each subcenter's commercial and adjoining residential land. Such specifications, however, depend on how the commercial land and property markets operate. For this reason they are incorporated in the discussion of Chapter III, where a number of alternative land market specifications are adopted to complete the model and, at the same time, address the central questions of the dissertation.

Chapter III.

ALTERNATIVE LAND MARKETS

Four alternative models of the commercial land market are discussed in this chapter to address the central questions of the dissertation: how the capitalization of production amenities works within multinodal metropolises, and what role local development constraints play in this process.

Model I portrays a perfectly competitive land market, with equal commercial and residential land rents at both subcenters' edges. In Model II, binding land constraints are introduced at Center 1, creating thereby a segmented land market and unequal residential and commercial land rents at the constrained center's edges. In Model III, a density regulation in the form of a limit on Center 1's capital/land ratio is assumed, creating thus a regulated and, hence, an inefficient commercial land market. Model IV, introducing both land constraints and a density regulation at Center 1, features a commercial land market constricted by development moratoria.

In each of these models, firms and households choose between centers on the basis of the intercenter distribution of amenities, but in the light of institutional rigidities in the commercial land market their choice may not be unrestricted. In the absence of other differentiations between centers, development restrictions interact closely with production amenities to determine the pattern of firm location and spatial price equilibria in the city. In examining these derived equilibria, inferences are made with respect to the relative impact of production amenities on the resultant pattern of

intercenter rent and wage differences and, whenever applicable, the exact role that development restrictions play in influencing the capitalization process.

1. Model I: A Competitive Land Market

Model I features a two-center city with perfectly competitive, nonsegmented and nonregulated land market, where households and firms freely bid for a share of the city's land. This unconstrained competitiveness of the land market is signified in the following relationships, suggesting that neighboring commercial and residential rents be equal at the subcenters' edges:

$$RL_1 = P_1(T_1) = P_1(T_2) \quad (III.1)$$

$$RL_2 = P_2(T_4) = P_2(T_5) \quad (III.2)$$

In the absence of regulatory controls over the city's commercial land market, the production of floor space at each center must obey the demand functions (II.19) and (II.20), and the long run rental cost of floor space must comply with (II.21). Together with the "border" conditions (III.1)-(III.2), the model's equilibrium conditions now form a system of 17 equations with 17 unknowns, rendering it thereby mathematically solvable.

Assuming at first equal or no exogenous production costs at the city's subcenters ($CE_1 - CE_2 = 0$), a perfectly "symmetrical" city with no land rent, space rent, or wage differentials across its commercial subcenters will result. Given the assumption of a spatially homogeneous land and conditions (II.12) and (II.24), the equal cost condition (II.13) can now be modified as:

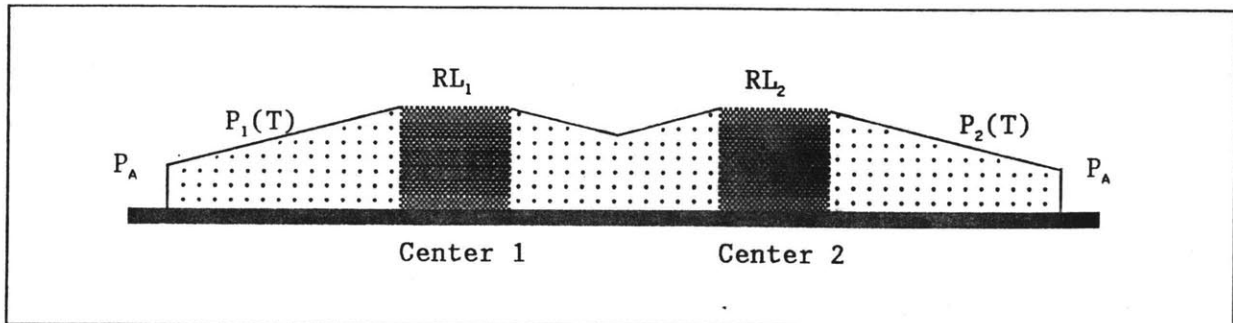
$$\frac{a_s}{a_n}(R_1 - R_2) + (W_1 - W_2) = 0;$$

or:

$$\frac{a_s}{a_n}(R_1 - R_2) + \frac{kq}{2}(N_1 - N_2) = 0 \quad (\text{III.3})$$

The above condition alone precludes employment size and commercial space rent differences of the same sign between the city's subcenters. Yet, this condition may support both equal employment sizes and floor space rents, or labor size and floor space rent differentials of an opposite sign between the two centers. This latter solution would, however, suggest that larger (smaller) subcenters must in equilibrium command lower (higher) space rents, and would thus contradict (III.1), (III.2), (II.21), and the summary conditions (II.24)-(II.26). By contradiction, then, the only feasible equilibrium solution is that of equal employment size and commercial space rents at the two centers. Given the equilibrium conditions just mentioned, equal employment sizes at the two subcenters imply, in turn, equal residential and commercial land rents and equal wages. This case of the simple symmetrical city, portrayed in Figure III-1 and summarized in Proposition 1 below, constitutes the base case of this analysis against which alternative models will be examined.

FIGURE III-1
Competitive Land Rents; $C_A=0$



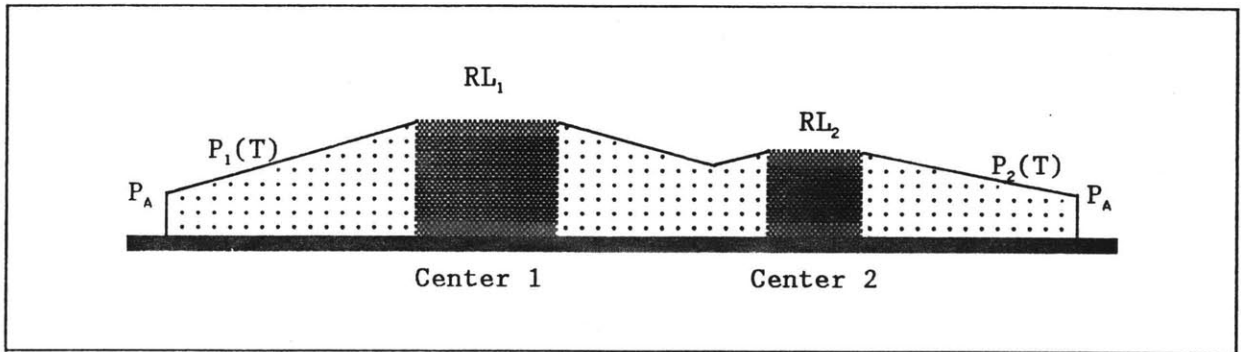
Proposition 1: *In a perfectly competitive city without any land supply restrictions, regulatory controls, or production cost differentials across centers, no variations in land rents, commercial floor space rents, or wages should in equilibrium prevail.*

To examine the amenity capitalization process, Center 1 is now assumed to present an exogenous production cost advantage, $C_A (=CE_2 - CE_1 > 0)$, over Center 2, so that in equilibrium:

$$\frac{a_s}{a_n}(R_1 - R_2) + (W_1 - W_2) = C_A \quad (\text{III.4})$$

The presence of such a production cost advantage at Center 1 disturbs the symmetry in the locational and pricing patterns observed in the base case just examined. As shown in Figure III-2, locational demand for the endowed center in this case is higher, exerting thereby an upward pressure on its employment size, its adjoining residential land rents, its commercial land and space rents, and its labor wages. As Center 1 expands at the expense of Center 2 and its supporting residential area, the commuting costs of the most distant worker employed at Center 2 decrease, exerting thereby a downward pressure on its residential land rents, commercial land rents, and floor space rents. Center 1 will continue to expand at the expense of Center 2, but only until increases in its space rents and wages erode its initial advantage. In the long run, such a demand imbalance between the two centers is likely to result in higher land rents, higher space rents, and higher wages at Center 1, and lower commercial land and floor space rents at Center 2. The higher the advantage differential between the city's subcenters, the higher Center 1's labor size, commercial land and space rents, the lower Center 2's labor size and respective equilibrium prices, and, consequently, the higher the price

FIGURE III-2
Competitive Land Rents; $C_A > 0$



differentials between the two centers.

To formally demonstrate the equilibrium effects of the production amenity, (II.3), (II.4), (II.21), (II.24), (II.25), and (III.1)-(III.2) are incorporated into the equal cost condition (III.4) to yield implicit function (III.5):

$$\frac{a_s}{a_n} C_0 P_1(T_2)^{1-b} - \frac{a_s}{a_n} C_0 P_2(T_4)^{1-b} + \frac{kq}{2} (N_1 - N_2) = C_A;$$

or:

$$\frac{a_s}{a_n} C_0 \left[P_A + k \left[\frac{N_1}{2} + \frac{Nh}{4} - \frac{S}{2q} \right] \right]^{1-b} - \frac{a_s}{a_n} C_0 \left[P_A + k \left[\frac{3Nh}{4} - \frac{S}{2q} - \frac{N_1}{2} \right] \right]^{1-b} + kq \left[N_1 - \frac{Nh}{2} \right] - C_A = 0 \quad (III.5)$$

Differentiating (III.5) implicitly yields the effect of Center 1's advantage on the two subcenters' employment size:

$$\frac{dN_1}{dC_A} = \frac{2}{\frac{a_s}{a_n} C_0 k (1-b) [P_1(T_2)^{-b} + P_2(T_4)^{-b}] + 2kq} > 0; \quad \frac{dN_2}{dC_A} = - \frac{dN_1}{dC_A} < 0$$

(III.6)

The associated changes in those subcenters' commercial land and space rents, as well as Center 1's labor wages can now easily be determined. Using again (II.21) and (II.25):

$$\frac{dRL_1}{dC_A} = \frac{dP_1(T_2)}{dC_A} = \frac{k}{2} \frac{dN_1}{dC_A} > 0; \quad \frac{dRL_2}{dC_A} = \frac{dP_2(T_4)}{dC_A} = \frac{k}{2} \frac{dN_2}{dC_A} < 0;$$

$$\frac{dR_1}{dC_A} = \frac{C_0 k (1-b)}{2P_1(T_2)^b} \frac{dN_1}{dC_A} > 0; \quad \frac{dR_2}{dC_A} = \frac{C_0 k (1-b)}{2P_2(T_4)^b} \frac{dN_2}{dC_A} < 0;$$

$$\frac{dW_1}{dC_A} = kq \frac{dN_1}{dC_A} > 0$$

(III.7)

Therefore:

$$\frac{d(RL_1 - RL_2)}{dC_A} = \frac{d(P_1(T_2) - P_2(T_4))}{dC_A} = k \frac{dN_1}{dC_A} > 0;$$

$$\frac{a_s}{a_n} \frac{d(R_1 - R_2)}{dC_A} = \frac{a_s}{a_n} \frac{1-b}{2} \left[\frac{R_1}{P_1(T_2)} + \frac{R_2}{P_2(T_4)} \right] \frac{dN_1}{dC_A} > 0;$$

$$\frac{d(W_1 - W_2)}{dC_A} = kq \frac{dN_1}{dC_A} > 0,$$

(III.8)

where:

$$\frac{a_s}{a_n} \frac{d(R_1 - R_2)}{dC_A} + \frac{d(W_1 - W_2)}{dC_A} = 1 \quad (\text{III.9})$$

Given (III.6)-(III.7) and assuming that $q > \frac{a_s (1-b)}{a_n} \left[\frac{R_1}{P_1(T_2)} + \frac{R_2}{P_2(T_4)} \right]$,

(III.10) must hold:^{8/}

$$\frac{a_s}{a_n} \frac{d(R_1 - R_2)}{dC_A} < q \frac{d(P_1(T_2) - P_2(T_4))}{dC_A} = q \frac{d(RL_1 - RL_2)}{dC_A} = \frac{d(W_1 - W_2)}{dC_A} < 1 \quad (\text{III.10})$$

Moreover, since there are no rent or wage differentials between the two centers when $C_A = 0$, and (III.4)-(III.5) and (III.9) hold unconditionally for all $C_A > 0$, (III.11) must also be valid:

$$\frac{a_s}{a_n} (R_1 - R_2) < q(P_1(T_2) - P_2(T_4)) = q(RL_1 - RL_2) = (W_1 - W_2) < C_A \quad (\text{III.11})$$

Hence:

Proposition 2: *Under competitive market conditions, differences in production amenities between centers are exactly capitalized into the sum of those centers' floor space rent and wage differences. Differences in floor space rents do reflect differences in commercial land rents, while wage differences equal differences in the residential land expenses of those households located at the subcenter edges. Under normal conditions, wage differences will likely exceed differences in space rents per worker; thus, wages capitalize a larger share of the production amenity than space rents.*

^{8/} Given (II.12), (II.20), and (III.1)-(III.2), when the centers are of equal size, the inequality above becomes $q > L_i/N_i$. This condition requires that residential land consumption be greater than the land per worker needed for production at each center. Empirically q ranges from 20,000 to 40,000 square feet, while L_i/N_i may not exceed the 2,000 square feet. Thus, under normal conditions, the inequality holds.

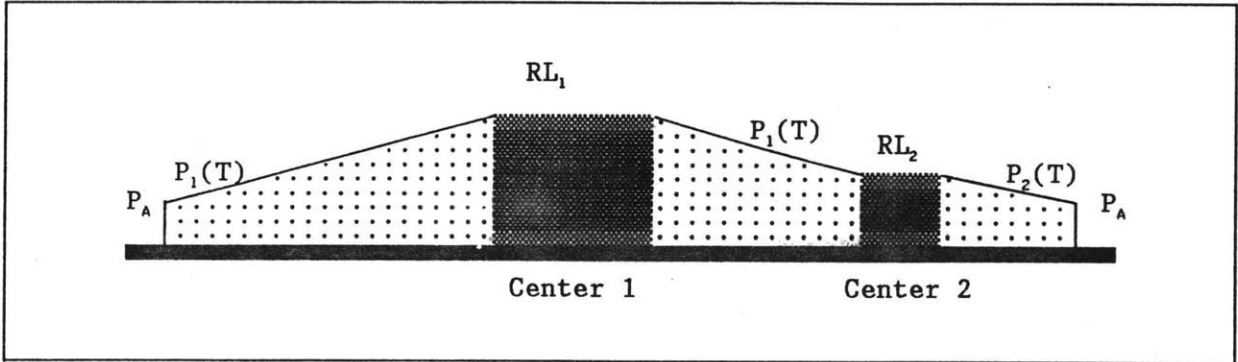
Evidently, then, the assumed difference in production amenities between the city's subcenters *does* produce compensating variations in land rents, floor space rents, and wages. The expressions in (III.8) validate the assertion that the higher the production cost differential between the city's subcenters, the higher these compensating variations will be. In this two-center city, however, there is a limit to how large Center 1's cost advantage and, consequently, how high these price differences can be. Given the fixed distance, S , between the two centers, if Center 1 becomes too advantageous (and hence too large), then Center 1 workers would pay a higher price for land at Center 2's inner edge than Center 2 workers. Center 2 would thus cease to exist. To justify, then, the existence of the less advantageous subcenter in this model, Center 1's advantage must be such that:

$$P_1(T_4) \leq RL_2 = P_2(T_4) \quad (III.12)$$

The equality in (III.12) will hold in the extreme case Center 1 is endowed with its maximum advantage. In such a case, Center 1 workers will occupy entirely the city's inner residential strip, while Center 2 workers will be confined to that subcenter's outer residential area. The resultant city will then be as portrayed in Figure III-3. As also shown in this figure, $t_3 = S$ and $t_4 = 0$. Applying these boundary solutions to (II.24) determines Center 1's employment size, which, when incorporated into the equal cost condition (III.5), yields Center 1's maximum advantage in (III.13):

$$C_{Amax} = kS + C_0 \frac{a_s}{a_n} \left[P_A + k \frac{Nh}{2} \right]^{1-b} \frac{aS}{a_n} - C_0 \left[P_A + k \frac{Nh}{2} \frac{S}{q} \right]^{1-b} \quad (III.13)$$

FIGURE III-3
Competitive Land Rents; $C_A = C_{Amax}$



Using, then, (II.3)-(II.4), (II.8), as well as (III.1)-(III.2), the associated maximum land rent, space rent, and wage differentials between the two centers are derived:

$$\max(RL_1 - RL_2) = kS/q > 0;$$

$$\frac{a_s}{a_n}(R_1 - R_2) = C_{Amax} - kS; \quad \max(W_1 - W_2) = kS > 0 \quad (III.14)$$

Hence:

Proposition 3: Under competitive market conditions, there is a maximum cost advantage that more advantageous subcenters can command without threatening the existence of less advantageous subcenters. In equilibrium, such an advantage ultimately results in the maximum positive land rent, floor space rent, and labor wage differentials across a city's commercial subcenters.

2. Model II: A Segmented Land Market

In Model II, Center 1 is assumed to be segmented by a binding constraint on its commercial land area, such that $L_1 = rl < L_1^*$. The term rl denotes the exogenously determined maximum land area that Center 1 can occupy, while L_1^*

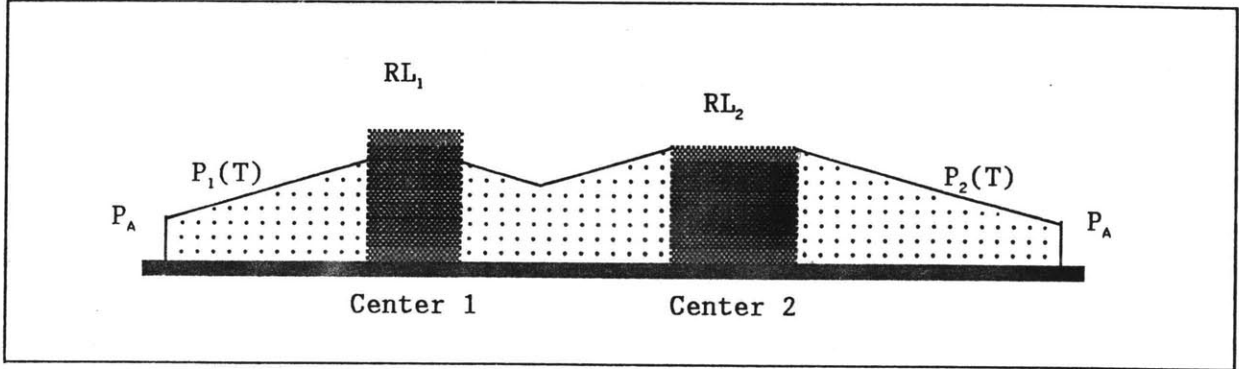
denotes the land area that this subcenter would occupy in the absence of any development restriction.

The presence of such a constraint at Center 1 does not affect the production of floor space at Center 1, but does affect the competitive relationship between that subcenter's commercial and its adjoining residential land. Since Center 1's outer edge is no longer the result of free competition between the city's commercial and residential sectors, "neighboring" rents at that subcenter's edges need not be equal. Thus, border condition (III.1) need not hold. Model II can then be solved using the general equilibrium conditions already discussed in Chapter II and the "border" condition (III.2). Given Center 1's exogenously determined land area, these equilibrium conditions now form a solution system of 16 equations with 16 unknowns.

To examine the effects of the development restriction, consider again the competitive city in Model I (Figure III-1) and assume that a binding constraint, confining that subcenter's total land area to r_1 , is imposed. Such a constraint ultimately causes Center 1's labor size to fall and Center 2's labor size to rise. As Center 1 shrinks, its residential land rents and labor wages fall. As Center 2 grows, its residential land rents, commercial land rents, and floor space rents rise. Subsequently, such adjustments create a production cost differential and, therefore, a demand imbalance between the city's subcenters. Given, then, Center 2's increased production costs, for equilibrium to be restored in the city, Center 1's commercial land and space rents have to rise both above their competitive equilibrium level and above Center 2's respective equilibrium prices.

Figure III-4 below portrays this spatial equilibrium. To formally derive the adjustments portrayed in this figure, the price of land needed to equate land demand in (II.20) with the constrained supply (r_1) at Center 1 is

FIGURE III-4
Segmented Land Rents; $C_A=0$; $rl < L_1^*$



first derived. Incorporating this along with (II.3)-(II.4), (II.21), (II.24), and (III.2) into the equal cost condition (III.3) yields (III.15):

$$\frac{a_s}{a_n} C_0 RL_1^{1-b} - \frac{a_s}{a_n} C_0 P_2(T_4)^{1-b} + \frac{kq}{2} (N_1 - N_2) = 0;$$

or:

$$C_0 \left[\frac{a_s}{a_n} \right]^{\frac{1}{b}} \left[\frac{N_1}{rl} \right]^{\frac{1-b}{b}} \left[\frac{1-b}{r} \right]^{\frac{1-b}{b}} - \frac{a_s}{a_n} C_0 \left[P_A + k \left[\frac{3Nh}{4} \frac{S}{2q} \frac{N_1}{2} \right] \right]^{1-b} + kq \left[N_1 \frac{Nh}{2} \right] = 0 \quad (III.15)$$

The effects of an increasingly binding constraint, effectively limiting rl , on the two subcenters' employment basis can then be determined by implicitly differentiating (III.15) to yield (III.16):

$$\frac{dN_1}{dr1} = \frac{\frac{N_1}{r1}}{1 + \left[\frac{\left[\frac{a_s}{a_n} C_0 \frac{k(1-b)}{2P_2(T_4)^b} + kq \right] / C_0 r^{1-b} \left[\frac{1-b}{b} \right]^{2-b} \left[\frac{a_n}{a_s} \right]^b r1^{\frac{b-1}{b}} N_1^{\frac{1-2b}{b}}}{\right]} > 0$$

Therefore:

$$\frac{dN_2}{dr1} = - \frac{dN_1}{dr1} < 0. \quad (\text{III.16})$$

Using again (II.20), (II.21), (II.25), and (III.3), the associated changes in the two subcenters' adjoining residential land rents, their commercial land and space rents, and Center 1's labor wages can be determined as follows:

$$\begin{aligned} \frac{dP_1(T_2)}{dr1} &= \frac{\partial P_1(T_2)}{\partial N_1} \frac{dN_1}{dr1} > 0; & \frac{dP_2(T_4)}{dr1} &= \frac{\partial P_2(T_4)}{\partial N_2} \frac{dN_2}{dr1} < 0; \\ \frac{dRL_1}{dr1} &= \frac{\partial RL_1}{\partial r1} + \frac{\partial RL_1}{\partial N_1} \frac{dN_1}{dr1} = \frac{1-b}{b^2} r \left[\frac{a_s N_1}{a_n} \right]^{\frac{1}{b}} \left[\frac{r1}{N_1} \frac{dN_1}{dr1} - 1 \right] r1^{-\frac{(1+b)}{b}} < 0; & \frac{dRL_2}{dr1} &= \frac{dP_2(T_4)}{dr1} < 0; \end{aligned}$$

$$\frac{dR_1}{dr1} = \frac{dR_2}{dr1} - \frac{a_n}{a_s} \frac{dW_1}{dr1} < 0, \quad \text{since:} \quad \frac{dR_2}{dr1} = \frac{C_0(1-b)}{RL_2^b} \frac{dRL_2}{dr1} < 0;$$

$$\text{and:} \quad \frac{dW_1}{dr1} = \frac{\partial W_1}{\partial N_1} \frac{dN_1}{dr1} > 0. \quad (\text{III.17})$$

In summary, then, the equilibrium adjustments described in (III.16)-(III.17) clearly suggest that:

$$\frac{d(RL_1 - P_1(T_2))}{drl} < 0; \frac{d(P_1(T_2) - P_2(T_4))}{drl} > 0; \frac{d(RL_1 - RL_2)}{drl} < 0; \frac{d(R_1 - R_2)}{drl} < 0; \frac{d(W_1 - W_2)}{drl} > 0$$

(III.18)

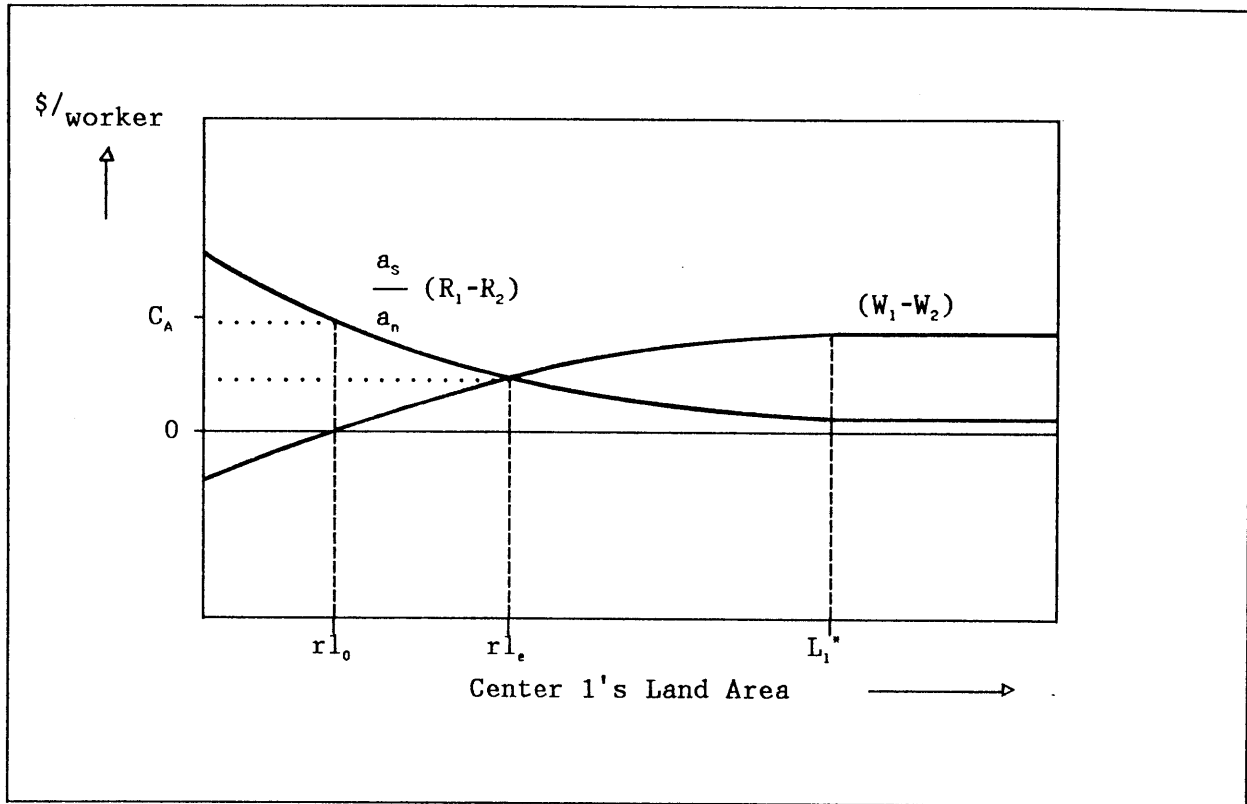
Hence:

Proposition 4: *As a constraint on a subcenter's commercial land area increasingly binds, the higher the positive rental gap between its commercial and adjoining residential land, the larger the positive commercial land rent and space rent differences, and the higher the negative wage differences between this and an otherwise similar but nonconstrained subcenter in the same metropolitan market.*

To examine now how the amenity capitalization process works in the presence of land constraints, a production cost differential ($C_A = CE_2 - CE_1 > 0$) is assumed to exist between the city's subcenters.

As already documented, in the absence of the constraint, positive differentials in residential and commercial land rents, space rents, and labor wages are sustained between the two centers. Yet, as a constraint is imposed on Center 1, the more advantageous of the two centers, rents and wages at both centers have to appropriately adjust to restore equilibrium in the city. These adjustments are still given by (III.18), which holds for all $C_A > 0$. Following, then, (III.18), as an increasingly binding constraint is imposed on Center 1's commercial land, the positive commercial land and space rent differences between the city's subcenters are reinforced, while their wage (and residential land rent) differences are clearly weakened. Given the equal cost condition in (III.4), it can then easily be inferred that the development restriction shifts capitalization away from wage (and residential land rent) and toward floor space rent (and commercial land rent) differences in the

FIGURE III-5
Space Rent and Wage Capitalization in Segmented Land Markets



city. Yet, the magnitude of space rent and wage capitalization in the presence of land constraints is highly conditional, depending on the restrictiveness of these constraints.

As Figure III-5 clearly illustrates, for mild enough constraints, wage differences between centers still capitalize most of the advantage to the firm. Yet, as the constraint reaches a certain threshold value, designated rl_e , the fixed advantage difference between the two centers is equally capitalized by space rent and wage differences. By incorporating this equality into (III.4), solving for N_1 , and substituting this into (III.15), it follows that rl_e must fulfill (III.19) below:

$$rl_e = \frac{\left[\frac{Nh}{2} + \frac{C_A}{2kq} \right] \left[\frac{1-b}{r} \right]^b \left[\frac{a_s}{a_n} C_0^b \right]^{\frac{1}{1-b}}}{\left[\frac{C_A}{2} + \frac{a_s}{a_n} C_0 \right] \left[\frac{Nh}{P_A + k} + \frac{S}{2} - \frac{C_A}{2q} \right]^{1-b} \left[\frac{a_s}{a_n} C_0^b \right]^{\frac{b}{1-b}}} \quad (III.19)$$

As rl falls below rl_e but without yet reaching another threshold value, designated rl_0 , space rent differences begin capturing more and wage differences less of the difference in locational value between centers. Once rl reaches rl_0 , wage differences dissipate, and space rent differences capitalize the full amount of the cost advantage difference between centers. Incorporating this into the wage expression in (II.24), solving for N_1 , and substituting this into (III.15), yields rl_0 in (III.20) below:

$$rl_0 = \frac{\left[\frac{Nh}{2} \right] \left[\frac{1-b}{r} \right]^b \left[\frac{a_s}{a_n} C_0^b \right]^{\frac{1}{1-b}}}{\left[\frac{C_A}{2} + \frac{a_s}{a_n} C_0 \right] \left[\frac{Nh}{P_A + k} + \frac{S}{2} - \frac{C_A}{2q} \right]^{1-b} \left[\frac{a_s}{a_n} C_0^b \right]^{\frac{b}{1-b}}} \quad (III.20)$$

With yet more binding restrictions rendering rl lower than rl_0 , wage differences will become negative, and space rent differences will exceed the value of the two subcenters' initial advantage differential. The more stringent Center 1's land restriction, the more pronounced the negative wage and positive space rent differences between the two centers.

Hence:

Proposition 5: *Advantage differentials between constrained and otherwise similar but nonconstrained subcenters are always capitalized into positive commercial land and space rent differences between centers. Commercial land rent differences are always higher than wage (or residential land rent) differences, but the magnitude of space rent capitalization as well as the extent and sign of wage (or residential land rent) capitalization are highly conditional, depending on the degree to which land constraints bind. In particular (Figure III-5; (III.19)-(III.20)):*

$$\begin{aligned}
 \text{if } rl_e < rl < L_1^* \quad 0 < \frac{a_s}{a_n} (R_1 - R_2) < (W_1 - W_2) < C_A; \\
 \text{if } rl_0 < rl < rl_e \quad 0 < (W_1 - W_2) < \frac{a_s}{a_n} (R_1 - R_2) < C_A; \\
 \text{if } rl < rl_0 \quad (W_1 - W_2) < 0 < C_A < \frac{a_s}{a_n} (R_1 - R_2). \quad (III.21)
 \end{aligned}$$

In the presence, then, of increasingly binding land constraints, space rents are seen to capitalize more, and wage differences less, locational value. When evaluated at the selective and increasingly restrictive zoning limits of rl_e and rl_0 , the marginal effect of the advantage on space rents (wages) is also seen to increase (decrease), suggesting that zoning limits may have nontrivial second-order effects in the capitalization process.^{9/}

The marginal advantage effects exceed unity, and space rent differences between centers always exceed the value of the two subcenters' initial advantage difference when a cross commuting situation prevails in the city.

^{9/} At rl_e , $\frac{a_s}{a_n} (R_1 - R_2) = 0.5C_A$, and thus $\frac{a_s}{a_n} \frac{d(R_1 - R_2)}{dC_A} = 0.5$. At rl_0 , $\frac{a_s}{a_n} (R_1 - R_2) = C_A$, and thus $\frac{a_s}{a_n} \frac{d(R_1 - R_2)}{dC_A} = 1$. A general, formal proof of such effects, however, requires the evaluation of the following derivative:

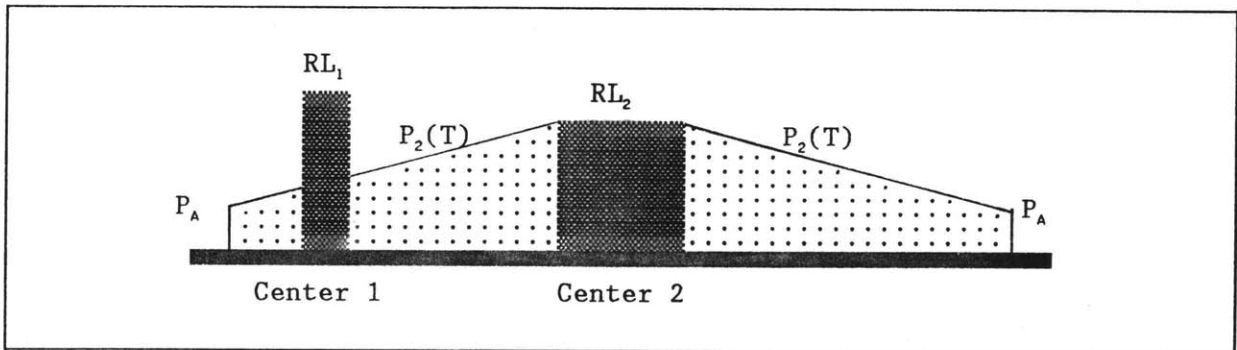
$$\frac{a_s}{a_n} \frac{d^2(R_1 - R_2)}{dC_A drl}$$

In particular, for any $C_A \geq 0$ in this model, there is a "sufficiently" binding land constraint, rlc , beyond which the rent offer of Center 2 worker for residential land at Center 1's inner edge exceeds the rent offer of Center 1 workers for these locations, such that:

$$P_2(T_1) \geq P_1(T_1) \quad (III.22)$$

In such a case, the residential area between the two centers will be occupied by Center 2 workers, while Center 1's outer residential zone will be occupied by both Center 1 workers and those workers employed at Center 2 who cannot be accommodated elsewhere. A unidirectional commuting for Center 1 workers and a cross commuting situation for Center 2 workers will thus prevail.

FIGURE III-6
Segmented Land Rents; $C_A \geq 0$, $rl < rlc$



The resultant city will be as portrayed in Figure III-6. To reflect its structure, the equilibrium conditions discussed so far have to only slightly be modified. Conditions (II.14)-(II-15), (II.6), and (II.8) need not hold, while, given (II.7) and noting that $t_s=0$, the boundary solutions and the wage expression in (II.24) have to be replaced by the following:

$$t_1 = \frac{Nh}{2}q - S - \frac{rl}{2}; \quad t_3 = 0; \quad t_4 = S; \quad t_6 = \frac{Nh}{2}q + \frac{rl}{2}$$

$$W_1 - W_2 = -k(rl + S) \quad (III.23)$$

To derive the critical value of rl , rlc , beyond which (III.22) and (III.23) hold, it suffices to note that, at rlc , $t_1 = N_1/q$. Applying this to (II.24), incorporating the resultant N_1 into (III.15), and solving for rlc yields (III.24):

$$rlc = \frac{1}{2q} \frac{C_0(Nhq - 2S) \left[\frac{1-b}{r} \right]^b \left[\frac{a_s}{a_n} \right]^{\frac{1}{1-b}}}{\left[\frac{a_s}{a_n} C_0 \left[P_A + k - \frac{Nh}{2} \right]^{1-b} + kS + C_A \right]^{\frac{b}{1-b}}} \quad (III.24)$$

Using, in addition, (II.20), (II.3)-(II.4), (II.8), and (III.4), it follows that for any $rl < rlc$, the resultant compensating differentials in land rents, floor space rents, and labor wages must satisfy the inequalities below:

$$RL_1 - RL_2 > \left[\frac{a_s}{a_n rlc} \left[\frac{Nh}{2} - \frac{S}{q} \right] \right]^{\frac{1}{b}} \left[\frac{1-b}{r} \right]^b - \left[P_A + k - \frac{Nh}{2} \right]$$

$$\frac{a_s}{a_n} (R_1 - R_2) > C_A + kS; \quad W_1 - W_2 < -kS \quad (III.25)$$

Hence:

Proposition 6: *If sufficiently binding, constraints on a subcenter's commercial land may necessitate cross commuting on the part of workers employed at the city's unconstrained subcenter(s). Compared to their levels under a normal commuting pattern, commercial land and space rent differences must be higher, while wage differences must be smaller. Most importantly, under such a cross-hauling pattern, the compensating space rent differential between centers must always be greater than those subcenters' initial advantage difference.*

3. Model III: A Regulated Land Market

In Model III, Center 1 is assumed to be regulated by a binding constraint on its capital/land ratio, such that $cl_1 < cl_1^*$. The term cl_1 denotes the exogenously determined maximum allowable density at Center 1, while cl_1^* denotes the density at which commercial development would occur in the absence of any regulation.

This restriction does not alter the competitive relationship between the regulated subcenter's commercial and its adjoining residential land, but does constrain the demand for capital and land at this center. Floor space at Center 1 is still produced according to (II.17), but factor intensities need not comply with the demand functions (II.19)-(II.20). Given the regulation and the production function (II.17), the constrained demands for capital and land at Center 1 are now given by (II.26) and (II.27). Combining them with (II.18) gives (III.28) in place of the competitive market condition (II.21):

$$K_1 = cl_1^{1-b} Qs_1 \quad (III.26)$$

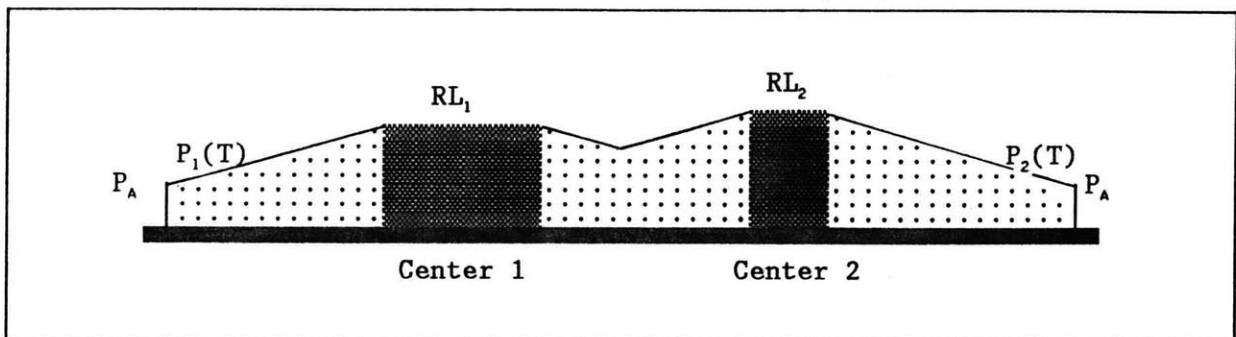
$$L_1 = cl_1^{-b} Qs_1 \quad (III.27)$$

$$R_1 = rcl_1^{1-b} + RL_1 cl_1^{-b} \quad (III.28)$$

Model III can then be solved using the general equilibrium conditions presented in Chapter II, the border conditions (III.1)-(III.2), the constrained demand functions (III-26)-(III.27), and the long run cost function of floor space (III.28), as applied to Center 1 locations. Together with the exogenous regulation, these conditions now form a system of 16 equations with 16 unknowns.

To trace now the impact of the regulation, a binding density limit, cl_1 , on Center 1 of the competitive city is assumed. Given that factor intensities at Center 1 no longer represent the optimum, least cost combination of capital and land inputs, floor space at this center is produced at a higher cost and, as a result, firms prefer Center 2's nonregulated locations. Consequently, Center 1's employment size falls and Center 2's rises. As Center 1 shrinks, its commercial and residential land rents, as well as its labor wages must fall, while as Center 2 grows its land and space rents must rise. This produces a production cost differential between the two centers and, for equilibrium to be restored, Center 1's space rents must rise above those prevailing at Center 2. The resultant city is portrayed in Figure III-7 below.

FIGURE III-7
Regulated Land Rents; $C_A=0$, $cl_1 < cl_1^*$



To formally demonstrate the impact of the regulation, the equal cost condition (III.3) is combined with (II.21), (III.28), (II.24), (II.3)-(III.4), and (III.1)-(III.2) to yield implicit function (III.29):

$$\frac{a_s}{a_n} \left[r c l_1^{1-b} + R L_1 c l_1^{-b} \right] - \frac{a_s}{a_n} C_0 R L_1^{1-b} = 0$$

or:

$$\frac{a_s}{a_n} c l_1^{1-b} \left[r c l_1 + P_A + k \left[\frac{N_1}{2} + \frac{N_h}{4} - \frac{S}{2q} \right] \right] - \frac{a_s}{a_n} C_0 \left[P_A + k \left[\frac{3N_h}{4} - \frac{S}{2q} - \frac{N_1}{2} \right] \right]^{1-b} + k q \left[\frac{N_1}{2} - \frac{N_h}{2} \right] = 0$$

(III.29)

The effects of an increasingly binding constraint, effectively limiting $c l_1$, on the two subcenters' employment size can now easily be determined. Differentiating (III.29) implicitly yields (III.30):

$$\frac{dN_1}{dc l_1} = \frac{b P_1(T_2) - r(1-b) c l_1}{c l_1 \frac{k}{2} + C_0 \frac{k(1-b)}{2 P_2(T_4)^b} c l_1^{1+b} + \frac{a_n}{a_s} k q c l_1^{1+b}} > 0$$

$$\frac{dN_2}{dc l_1} = - \frac{dN_1}{dc l_1} < 0 \quad (III.30)$$

Using then (III.30) along with (II.21), (II.25), and (III.3), the parallel changes in the two subcenters' commercial and residential land rents, space rents, and Center 1's labor wages can be determined as follows:

$$\frac{dRL_1}{dcl_1} = \frac{dP_1(T_2)}{dN_1} \frac{dN_1}{dcl_1} > 0; \quad \frac{dRL_2}{dcl_1} = \frac{dP_2(T_4)}{dN_1} \frac{dN_1}{dcl_1} < 0;$$

$$\frac{dR_1}{dcl_1} = \frac{dR_2}{dcl_1} - \frac{a_n}{a_s} \frac{dW_1}{dcl_1} < 0, \quad \text{since: } \frac{dR_2}{dcl_1} = \frac{C_0(1-b)}{P_2(T_4)^b} \frac{dRL_2}{dcl_1} < 0;$$

$$\text{and: } \frac{dW_1}{cl_1} = \frac{dW_1}{dN_1} \frac{dN_1}{dcl_1} > 0 \quad (\text{III.31})$$

Consequently:

$$\frac{d(RL_1 - RL_2)}{dcl_1} > 0; \quad \frac{d(R_1 - R_2)}{dcl_1} < 0; \quad \frac{d(W_1 - W_2)}{dcl_1} > 0; \quad (\text{III.32})$$

Hence:

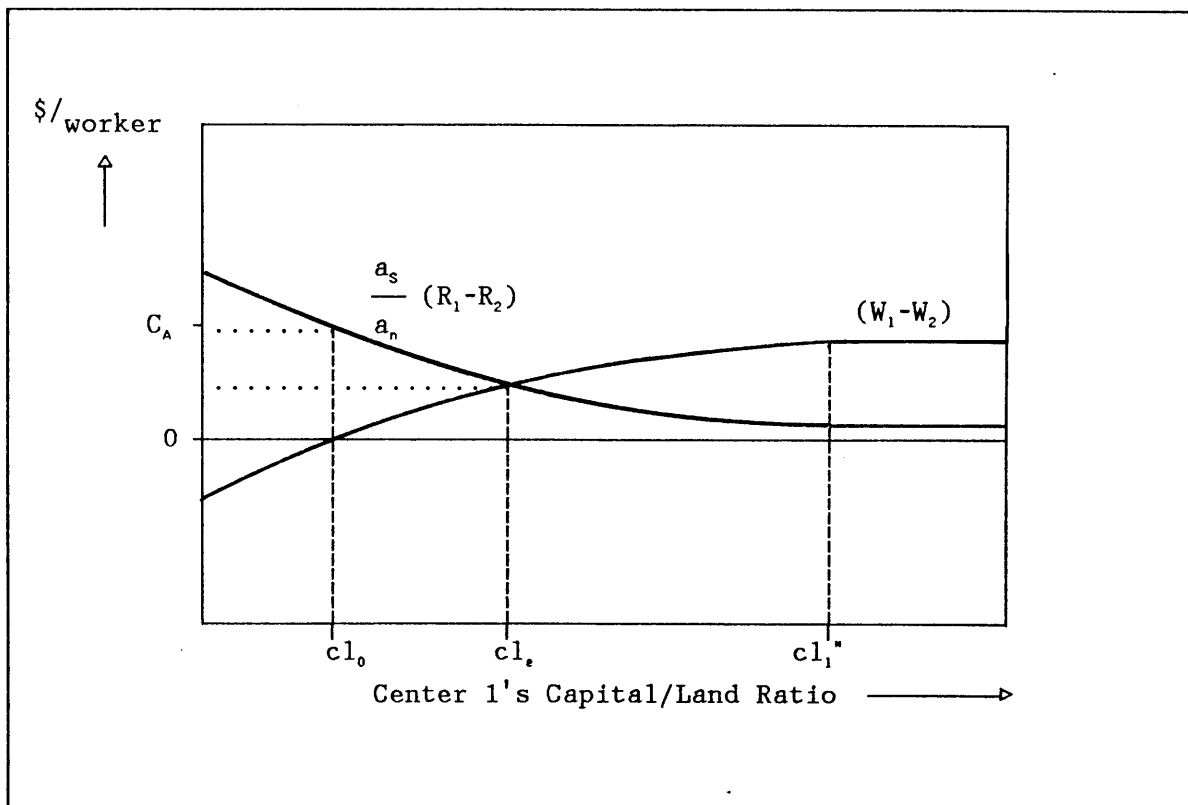
Proposition 7: *As a constraint on a subcenter's capital/land area ratio increasingly binds, the higher the negative land rent and wage differentials and the larger the positive commercial space rent differences between this and an otherwise similar but nonregulated subcenter in the same metropolitan market.*

To examine now how the capitalization process works in this model, Center 1 is assumed to have a production cost advantage ($C_A = CE_2 - CE_1 > 0$) over Center 2. Under competitive market conditions, a pattern of positive compensating differences in commercial land rents, space rents, and wages would prevail in the city. Once, however, Center 1 becomes regulated, the two subcenters' land rents, space rents, and labor wages have to adjust accordingly, to equalize production costs between centers. These adjustments are still given by (III.32), which obviously holds for all $C_A \geq 0$.

Following, then, (III.32), it can clearly be inferred that the density regulation strengthens the effects of the advantage on the two subcenters'

space rent differences, but at the same time weakens its effects on those subcenters' land rent and labor wage differences. By reinforcing the positive compensating differential in space rents and by narrowing down the wage (and land rent) differential, the development regulation increases in effect the share of the advantage that is capitalized by the former and, at the same time, decreases the share of the advantage that is capitalized by the latter. Thus, in contrast to what happens in the absence of regulatory limits, and depending on how restrictive Center 1's regulation is, a range of different capitalization magnitudes may prevail in the city. These capitalization outcomes can best be illustrated using Figure III-8.

FIGURE III-8
Space Rent and Wage Capitalization in Regulated Land Markets



As this figure clearly shows, when cl_1 is regulated to be below a certain threshold density limit, designated cl_e , wage differences between centers must still capitalize a higher share of the advantage than that capitalized by those centers' floor space rent differences. As, however, the density limit reaches this threshold value (cl_e), the fixed advantage difference between the two centers gets equally capitalized by space rent and wage differences. Incorporating this equality into the equal cost condition in (III.4), solving for N_1 , and substituting this into (III.29) gives the following implicit function to be solved for cl_e :

$$\frac{a_s}{a_n} \left[r cl_e^{1-b} + \left[P_A + k \frac{Nh}{2} - k \frac{S}{2q} + \frac{C_A}{4q} \right] cl_e^{-b} \right] - \frac{a_s}{a_n} C_0 \left[P_A + k \frac{Nh}{2} - k \frac{S}{2q} + \frac{C_A}{4q} \right]^{1-b} = \frac{C_A}{2} \quad (III.33)$$

As cl_1 falls below cl_e but without yet reaching another threshold value, designated cl_0 , space rent differences begin capturing more, and wage differences less, of the difference in locational value between centers. Once cl_1 reaches cl_0 , wage differences dissipate, and space rent differences capitalize the full amount of the two subcenters' advantage difference. Incorporating this into the wage expression in (II.24), solving for N_1 , and substituting this into (III.29) yields the following implicit function of cl_0 :

$$\frac{a_s}{a_n} \left[r cl_0^{1-b} + \left[P_A + k \frac{Nh}{2} - k \frac{S}{q} \right] cl_0^{-b} \right] - \frac{a_s}{a_n} C_0 \left[P_A + k \frac{Nh}{2} - k \frac{S}{q} \right]^{1-b} = C_A \quad (III.34)$$

Finally, as Figure III-8 clearly illustrates, once Center 1's regulatory limit falls below cl_0 , the two subcenters' wage differences become negative, and space rent differences exceed the value of the initial intercenter advantage differential in the city.

This analysis leads to Proposition 8 below.

Proposition 8: *Advantage differentials between regulated and otherwise similar but nonregulated subcenters are always capitalized into positive space rent differences between these subcenters. Yet, the magnitude of space rent capitalization, as well as the extent and sign of wage (or residential and commercial land rent) capitalization are highly conditional, depending on the degree to which the density regulation binds. In particular (Figure III-8; (III.33)-(III.34)):*

$$\begin{aligned}
 \text{If } cl_e < cl_1 < cl_1^* \quad 0 < \frac{a_s}{a_n}(R_1 - R_2) < (W_1 - W_2) < C_A; \\
 \text{if } cl_0 < cl_1 < cl_e \quad 0 < (W_1 - W_2) < \frac{a_s}{a_n}(R_1 - R_2) < C_A; \\
 \text{if } cl_1 < cl_0 \quad (W_1 - W_2) < 0 < C_A < \frac{a_s}{a_n}(R_1 - R_2) \quad (III.35)
 \end{aligned}$$

As shown in Figure III-8 and documented by (III.31)-(III.32), the more stringent the constraint for a given production cost advantage at Center 1, the higher the positive space rent and the smaller the negative land rent (both residential and commercial) and wage differentials between the city's subcenters. The increase (decrease) in the share of the advantage capitalized by space rents (labor wages) tends to suggest that, similarly to zoning limits, density regulations may also have second-order effects in the capitalization process. When, again, evaluated at selective and increasingly binding density limits, the marginal effects of the advantage on space rents

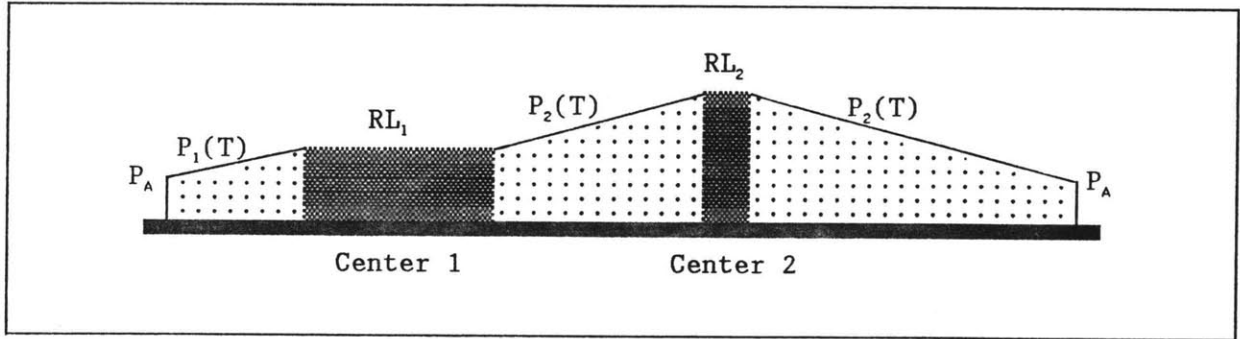
(wages) are seen to increase (decrease).^{10/}

There is, however, a limit to how stringent Center 1's regulation and, consequently, how high these compensating land rent, space rent, and wage differences can be. If Center 1's regulation becomes too rigid, and hence Center 1 too small, Center 2 workers will pay a higher price for land at Center 1's inner edge and, as a consequence, Center 1 would cease to exist. To justify, then, the existence of Center 1 in this case, Center 1's predetermined capital/land area ratio must be such so that in equilibrium:

$$P_1(T_2) = RL_1 \geq P_2(T_2) \quad (\text{III.36})$$

In the extreme case in which the equality in (III.36) holds, Center 1's capital/land area ratio will presumably be set at its minimum, and the resultant city will be as portrayed in Figure III-9.

FIGURE III-9
Regulated Land Rents; $cl_1 = cl_{min}$



^{10/} At cl_1 , $\frac{a_s}{a_n} (R_1 - R_2) = 0.5C_A$, and thus $\frac{a_s}{a_n} \frac{d(R_1 - R_2)}{dC_A} = 0.5$. At cl_0 , $\frac{a_s}{a_n} (R_1 - R_2) = C_A$, and thus $\frac{a_s}{a_n} \frac{d(R_1 - R_2)}{dC_A} = 1$. A general, formal proof of such effects, however, requires the evaluation of the following derivative:

$$\frac{a_s}{a_n} \frac{d^2(R_1 - R_2)}{dC_A dcl_1}$$

In such a city, $t_3=0$ and $t_4=S$. Applying these boundary solutions to (II.24) yields Center 1's threshold employment size, which, when incorporated into (III.29), gives rise to implicit function (III.37) through the solution to which cl_{min} can be determined:

$$\frac{a_s}{a_n} \left[r cl_{min}^{1-b} + cl_{min}^{-b} \left[P_A + k \frac{Nh}{2} - k \frac{S}{q} \right] \right] - \frac{a_s}{a_n} C_0 \left[P_A + k \frac{Nh}{2} \right]^{1-b} - kS - C_A = 0 \quad (III.37)$$

Using (II.8), (II.24), (III.1)-(III.2), and (III.4), the resultant minimum negative land rent and wage differences and the maximum positive space rent differences in the city can be determined as follows:

$$\begin{aligned} \min(RL_1 - RL_2) &= -kS/q; \\ \max \frac{a_s}{a_n} (R_1 - R_2) &= C_A + kS; \quad \min(W_1 - W_2) = -kS. \end{aligned} \quad (III.38)$$

This analysis gives rise to Proposition 9 below.

Proposition 9: *There is a limit to the maximum regulation that can be imposed on the capital/land area ratio of an advantageous center without threatening its existence. If imposed, such a regulation will result in the maximum positive floor space rent and minimum negative land rent and wage differential between this and other nonadvantageous and nonregulated subcenters.*

4. Model IV: A Segmented and a Regulated Market

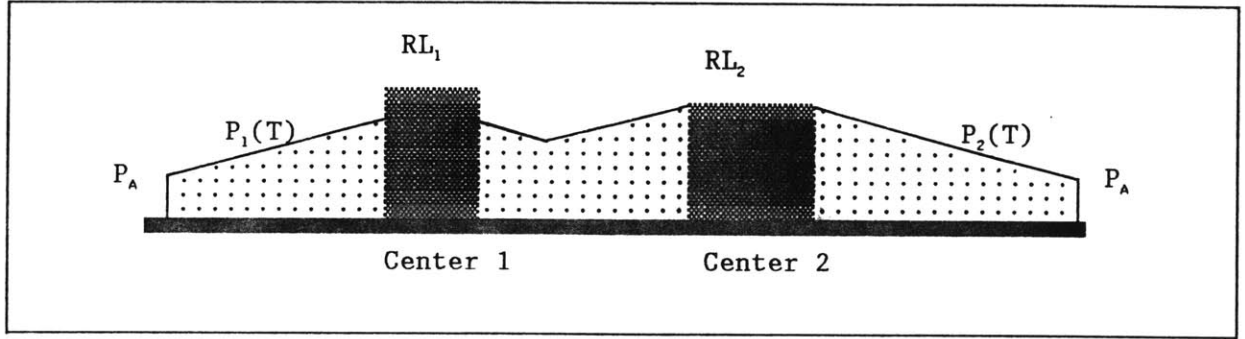
In Model IV, Center 1 is assumed to be both regulated and segmented by binding constraints on its commercial land and development density. Taken together, Center 1's restrictions determine in effect exogenously that subcenter's building capacity, Q_{s_1} , and, consequently, its employment size, N_1 . Using (II.12) and (II.17), these are given by (III.39):

$$\begin{aligned} Q_{s_1} &= r_l c l_1^b < Q_{s_1}^* \\ N_1 &= \frac{a_n}{a_s} r_l c l_1^b < N_1^* \end{aligned} \quad (III.39)$$

The two restrictions, then, also mirror the effect of building moratoria often imposed on "congested" centers. Given the exogenously determined values of these restrictions, Model IV can easily be solved using the general equilibrium conditions applied to Model III but border condition (III.1). These conditions now form a system of 15 linear equations with 15 unknowns.

To analyze the combined effect of these constraints, consider the base city in Model I (Figure III-1) and assume that binding ceilings on both Center 1's commercial land area and capital/land ratio are imposed, such that $r_l < L_1^*$ and $c l_1 < c l_1^*$. From (III.39), such constraints limit Center 1's labor size and increase Center 2's employment basis. As Center 1 shrinks, its labor wages and its residential land rents must fall, while as Center 2 grows, its commercial and residential land rents and floor space rents must rise. Given, then, Center 2's increased production costs, for equilibrium to be restored in the city Center 1's space rents have to rise above their competitive equilibrium level and above Center 2's floor space rents. Whether, however, commercial land rents at Center 1 will ultimately fall or rise depends on

FIGURE III-10
Segmented and Regulated Land Rents; $C_A=0$; $r_1 < L_1'$; $c_1 < c_1'$



whether the effect of the land or density constraint on Center 1's land rents prevails. Figure III-10 depicts the resultant city on the assumption that the effect of the zoning constraint on commercial land rents overshadows the effect of the density regulation on these rents.

To formally demonstrate these adjustments, (III.18) and (III.32) from Model II's and Model III's analysis are utilized. It is important to note at this point that the sign of the differentials below signify the adjustments occurring as both r_1 and c_1 are increased or, equivalently, as both the zoning limit and the density regulation are relaxed.

$$dRL_1 = \frac{\partial RL_1}{\partial r_1} r_1 + \frac{\partial RL_1}{\partial c_1} c_1 \begin{matrix} < 0 \\ > 0 \end{matrix}; \quad dRL_2 = \frac{\partial RL_2}{\partial r_1} r_1 + \frac{\partial RL_2}{\partial c_1} c_1 < 0;$$

$$dR_1 = \frac{\partial R_1}{\partial r_1} r_1 + \frac{\partial R_1}{\partial c_1} c_1 < 0; \quad dR_2 = \frac{\partial R_2}{\partial r_1} r_1 + \frac{\partial R_2}{\partial c_1} c_1 < 0;$$

$$dW_1 = \frac{\partial W_1}{\partial r_1} r_1 + \frac{\partial W_1}{\partial c_1} c_1 < 0; \quad (III.40)$$

Thus, the following adjustments occur as both Center 1's zoning limit and density regulation increasingly bind:

$$d(RL_1 - RL_2) \begin{matrix} < \\ > \end{matrix} 0; \quad d(R_1 - R_2) > 0; \quad d(W_1 - W_2) < 0 \quad (III.41)$$

Hence:

Proposition 10: *As restrictions on a subcenter's commercial land and capital/land ratio increasingly bind, the smaller the negative labor wage and residential land rent differences and the higher the positive space rent differences between this subcenter and other unconstrained and nonregulated centers. The sign of the commercial land rent differences between centers is ambiguous because of the opposite effects that the two restrictions have on the constrained subcenter's commercial land rents.*

Proposition 10 and (III.40)-(III.41), upon which this is based, hold for all $C_A \geq 0$. This sets the basis for examining how zoning limits and density regulations interact to influence the capitalization process.

In the absence of these restrictions, advantage differences between the two centers would still be capitalized by both space rent and wage differences between the two centers, with the latter likely to absorb the bulk of any advantage difference to the firm. Following (III.40)-(III.41), however, as both binding zoning limits and density regulations are imposed on the city's more advantageous center (Center 1), compensating space rent differences will further be reinforced, while wage (and residential land rent) differences will further be weakened. It should be noted here that (III.40) makes clear that the effect of both constraints on space rents and wages will be more pronounced than the effect of either land on density limits operating alone in the commercial land market.

FIGURE III-11
Space Rent and Wage Capitalization in
Segmented and Regulated Land Markets

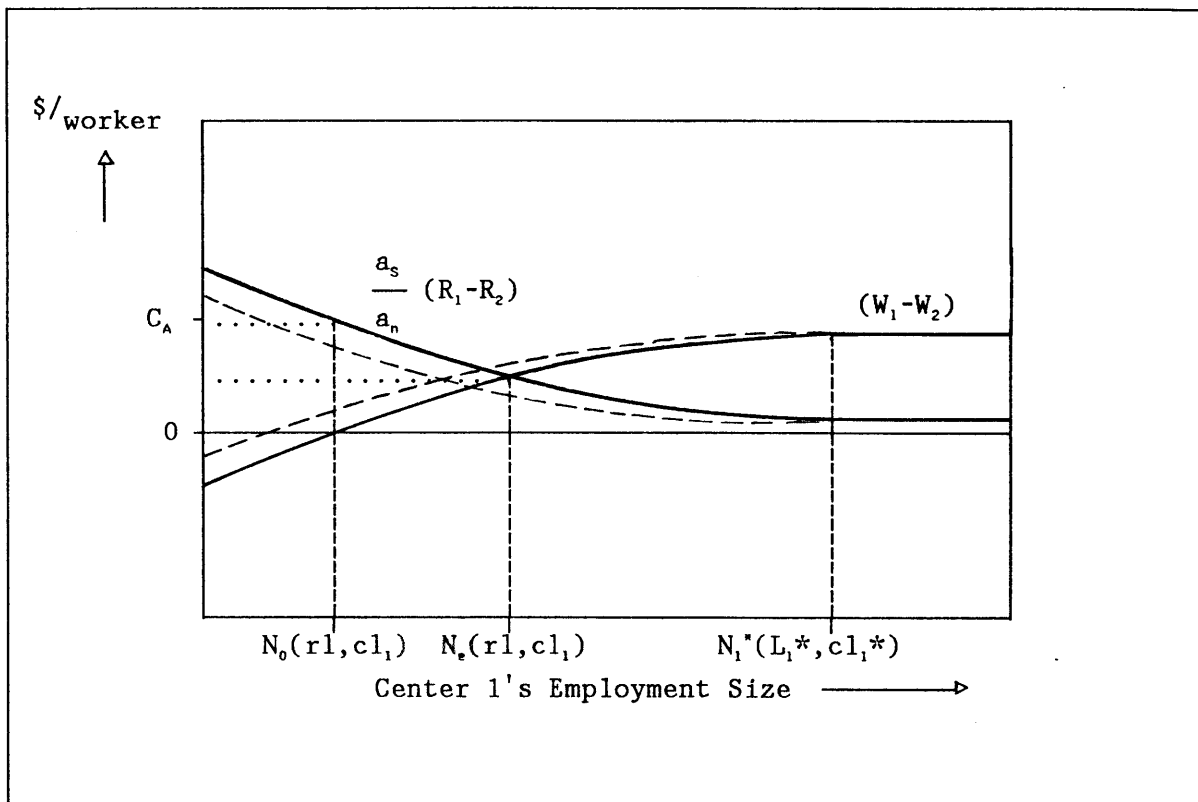


Figure III-11 depicts the range of resultant capitalization magnitudes and at the same time compares them with the results of Model II (or Model III), where only one of the two constraints is imposed on Center 1's land market (perforated line). Following Figure III-11, once the two constraints become binding (i.e., restrict Center 1's employment size below its competitive equilibrium level), they are again seen to shift capitalization away from wage (and residential land rent) and toward space rent differences in the city. As the two constraints become rigid enough so that N_1 reaches some critical value, designated N_s , advantage differences are equally capitalized by space rent and wage differences between centers. N_s

can then be determined by (III.42) below, derived by equating space rent with wage differences, inserting this equality in the equal cost condition (III.4), and subsequently solving the latter for N_e .

$$N_e = \frac{C_A}{kq} + \frac{Nh}{2} \quad (\text{III.42})$$

As the constraints become even more restraining so that N_1 falls below N_e but does not yet reach some lower value of N_1 , designated N_0 , the fixed cost advantage difference between the two centers is capitalized by higher space rent and lower wage differences. At N_0 , this is fully absorbed by space rent differences. N_0 can then be determined by (III.43), derived by equating wage differences to zero.

$$N_0 = \frac{Nh}{2} \quad (\text{III.43})$$

Finally, as Figure III-11 again shows, land and density constraints that render Center 1 smaller than its critical size in (III.43) will result in negative wage differences and space rent differences that exceed the value of the two subcenters' initial cost advantage difference. This is the inevitable result of over-restricting Center 1. As its wages shrink relative to Center 2's, its space rents must sufficiently rise to compensate for its lower wages.

This analysis leads to Proposition 11 below.

Proposition 11: *Cost advantage differences between centers that are both segmented and regulated and otherwise similar but nonrestricted centers are always capitalized by positive space rent differences between these centers. Yet the magnitude of space rent capitalization, as well as the extent and sign of wage (or residential and commercial land rent) capitalization are highly conditional, depending on the degree to which development constraints bind. In particular (Figure III-11; (III.42)-(III.43)):*

$$\text{if } N_e < N_1 < N_1^* \quad 0 < \frac{a_s}{a_n} (R_1 - R_2) < (W_1 - W_2) < C_A;$$

$$\text{if } N_0 < N_1 < N_e \quad 0 < (W_1 - W_2) < \frac{a_s}{a_n} (R_1 - R_2) < C_A;$$

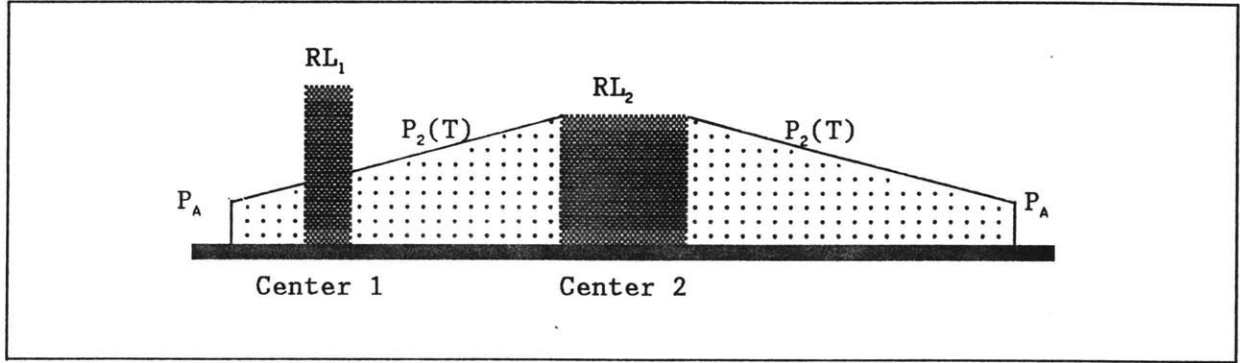
$$\text{if } N_1 < N_0 \quad (W_1 - W_2) < 0 < C_A < \frac{a_s}{a_n} (R_1 - R_2). \quad (\text{III.44})$$

Similarly to what happens in Model II, space rent differences will always be higher than the two subcenters' initial advantage difference when a cross commuting situation prevails in the city. Such a location and pricing pattern can be triggered by constraints stringent enough to ensure that the rent offer of Center 2 workers for land at Center 1's inner edge will be higher than the rent offer of Center 1 workers for this land:

$$P_2(T_1) > P_1(T_1) \quad (\text{III.45})$$

In such a case, the residential area between the two centers will be occupied by Center 2 workers, while Center 1's outer residential strip will be occupied by both Center 1 workers and those workers employed at Center 2 that cannot be accommodated elsewhere. A unidirectional commuting for Center 1 workers and a cross commuting situation for Center 2 workers will thus prevail in the city, which will be as portrayed in Figure III-12.

FIGURE III-12
Segmented and Regulated Land Rents; $C_A \geq 0$, $N_1 < N_{1c}$



Equilibrium in such a city need not comply with (II.14)-(II.15), (II-6), and (II.8), while (II.24) needs to be replaced by (III.23). Given (II.24) and noting that at N_{1c} , $N_1 = t_1/q$, the critical value of N_1 , N_{1c} , beyond which cross commuting prevails can be obtained as follows:

$$N_{1c} = \frac{Nh}{2} - \frac{S}{q} \quad (\text{III.46})$$

It follows, then, that for any $N_1 < N_{1c}$ commercial space rent and wage differences must satisfy conditions (III.47):

$$\frac{a_s}{a_n}(R_1 - R_2) > C_A + kS; \quad W_1 - W_2 < -kS \quad (\text{III.47})$$

This special case is summarized in Proposition 12 below.

Proposition 12: *If sufficiently binding zoning limits and density regulations are imposed on a subcenter with a cost advantage, then cross commuting on the part of some workers employed at the unconstrained subcenter becomes necessary in equilibrium. Under such a cross commuting situation, the space rent and wage differentials between the two commercial locations are likely to be higher than they would be if a more "normal" locational pattern prevailed. Furthermore, the compensating space rent differences between these centers are likely to exceed the value of any initial advantage difference between them.*

Chapter IV.

MODEL SIMULATIONS

Simulation techniques have traditionally been used as a means to provide numerical solutions to models that cannot be analytically solved or provide additional numerical support to analytical solutions. In such a case, simulated examples can make the structure of explanatory models more easy to understand, highlight behavioral relationships, and better demonstrate their underlying premises [Ingram, 1979].

The simulation examples presented here are merely intended to lend numerical support to the propositions advanced in the previous chapter and to shed some light to the magnitude of capitalization effects. To illustrate the propositions, four simulation series of a competitive (Model I), a segmented (Model II), a regulated (Model III) and, finally, a segmented and regulated land market (Model IV) within a two-center city were developed. Similarly to the theoretical models just discussed, the simulated examples presented here do not attempt to replicate any specific, real world city; they just provide a numerical interpretation of the simplified, two-center metropolises modeled in Chapter III.

This chapter discusses the common exogenous parameters and different assumptions underlying these simulations, briefly discusses the computation techniques employed, and links the simulation results to the propositions they were intended to illustrate.

1. Common Exogenous Parameters

Naturally, the four simulation series differ in the basic assumptions inherently built in each model, but they are comparable in the assumed values of common exogenous variables. These are presented in Table IV-1. As the table shows, the two-center city simulated each time was assumed to be inhabited by 1,000,000 identical, one-worker households. To avoid lengthy commuting, the city's width has been adjusted to 2 miles, while the distance between the inner edges of its subcenters was set to 6 miles.

TABLE IV-1
Values of Exogenous Parameters

1. General Characteristics of the City			
Number of households, N_h	:	1,000,000.00	
Distance between the centers' inner edges, S , in miles	:	6.00	
City width, tw'' , in miles	:	2.00	
2. Household Equilibrium			
Household utility function, $X^a q^{1-a}$; a	:	0.50	
Household land consumption, q , in acres	:	0.07	
Agricultural land rent, P_a , \$/acre	:	7,500.00	
Annual commuting cost, K , in \$/mile	:	350.00	
Annual base wage at Center 2, W_2	:	20,000.00	
3. Firm Equilibrium			
Firm production function, $Qs_i = K_i^b L_i^{1-b}$; b	:	0.77	
Commercial floor space/worker, in sq.ft	:	250.00	
Annual rental of capital, r , in \$/sq.ft	:	7.00	

^{a/} For the sake of analytical simplicity, tw in Chapter II and Chapter III was assumed to equal unity.

Household utility was assumed to be of a simple Cobb Douglas form with a land coefficient of 0.5. Each household was assumed to consume 0.07 acres of residential land and spend annually \$350 per mile for commuting. The annual agricultural land rent or, equivalently, the opportunity cost for residential development was assumed to be \$7,500 per year at both of the city's outer

borders. Households employed at Center 2 were assumed to earn \$20,000 yearly.

For the production of service output in the two commercial centers, 250 square feet per worker were assumed to be needed. The capital used for the production of this space was assumed to be more productive than land. Thus, the capital coefficient in the simple Cobb Douglas production function for floor space was set to 0.77. The exogenous annual rental cost of capital was set to \$7 per square foot.

2. Simulated Examples

The assumptions underlying the simulated cities and a summary of the simulation results are presented in Table IV-2. The endogenous variables in each model were computed with the aid of simple computer algorithms, which provided for the solution of nonlinear equations (i.e., III.5) through the Newton-Ramphson iterative method. The error margin in these algorithms was set to $1d-12$, and in most cases 6-10 iterations proved enough for converging the solution to the models with such a high precision.^{11/}

The simulation results demonstrate the distinct features of the four alternative models and exemplify the way the "dual" capitalization process works in each. *Simulations 1-3* refer to Model I, *Simulations 4-6* to Model II, *Simulations 7-9* to Model III, and *Simulations 10-12* to Model IV. Each of these simulations is briefly discussed and linked to the theoretical proposition it exemplifies.

^{11/} The computer algorithms were written in BASIC. Dvorak and Musset [1984] discuss in detail the use of the language in the "small computer field" and the application of the Newton-Ramphson iterative method to the solution of nonlinear equations. See Appendix II for a brief discussion of the procedure. Appendix II also presents the complete computer simulation outputs, which, in addition to the summary results presented and discussed in this chapter, include boundary solutions.

TABLE IV-2
Computer Simulation Examples

Endogenous Variables ^{a/}											
MODELS	SIM #	Centers	Exogenous Cost Advantage /worker /year	Exogenous Restriction on Capital Land /Land	Commercial Land in sq. miles	Capital /Land Ratio	Labor Supply	Annual Residential Land Rents /acre	Annual Commercial Land Rents /acre	Annual Commercial Space Rents /sq.ft	Yearly ^{c/} Wages
I.	1.	Center 1	-	-	3.42	1.42	500,000	\$129,385.00	\$129,385.00	\$9.85	\$20,000.00
		Center 2	-	-	3.42	1.42	500,000	129,385.00	129,385.00	9.85	-
	2.	Center 1	\$1,000	-	3.62	1.49	549,108	136,107.09	136,107.09	9.97	20,941.09
		Center 2	-	-	3.22	1.35	450,892	122,662.92	122,662.92	9.73	-
	3.	Center 1	\$2,229 ^{d/}	-	3.84	1.58	609,445	144,366.96	144,366.96	10.11	22,097.39
		Center 2	-	-	2.94	1.26	390,555	114,403.65	114,403.65	9.58	-
II.	4.	Center 1	-	1.20	-	4.95	458,478	123,701.27	451,397.19	13.13	19,204.28
		Center 2	-	-	3.58	1.48	541,522	135,068.73	135,068.73	9.95	-
	5.	Center 1	\$1,000	1.20	-	5.60	504,302	129,973.86	510,844.35	13.51	20,082.44
		Center 2	-	-	3.40	1.41	495,698	128,796.15	128,796.15	9.84	-
	6.	Center 1	\$1,000	0.02	-	51.62	46,459	114,360.00	4,705,623.07	22.52	17,896.50
		Center 2	-	-	6.00	1.58	953,541 ^{e/}	144,410.00	144,410.00	10.11	-
III.	7.	Center 1	-	-	0.30	10.56	466,035	124,735.68	124,735.68	12.54	19,349.10
		Center 2	-	-	3.56	1.47	533,965	134,034.32	134,034.32	9.93	-
	8.	Center 1	\$1,000	-	0.30	11.60	512,029	131,031.60	131,031.60	12.90	20,230.52
		Center 2	-	-	3.38	1.40	487,971	127,738.41	127,738.41	9.82	-
	9.	Center 1	\$1,000	-	0.08 ^{f/}	24.84	390,493	114,395.09	114,395.09	22.50	17,901.41
		Center 2	-	-	3.84	1.58	609,507	144,374.92	144,374.92	10.11	-
IV.	10.	Center 1	-	1.20	4.20	-	403,855	116,224.17	1,014,569.44	17.45	18,157.48
		Center 2	-	-	3.80	1.56	596,145	142,545.83	142,545.83	10.08	-
	11.	Center 1	\$1,000	1.20	4.20	-	403,855	116,224.17	1,541,055.64	21.45	18,157.48
		Center 2	-	-	3.80	1.56	596,245	142,545.83	142,545.83	9.82	-
	12.	Center 1	\$1,000	1.20	3.00	-	311,678	112,885.14	1,458,396.82	23.37	17,690.00
		Center 2	-	-	4.30	1.60	688,322 ^{g/}	145,885.87	145,885.00	10.13	-

^{a/} All numbers have been rounded up to two decimal points;

^{b/} These were evaluated at the subcenters' edges;

^{c/} Center 2's base wage was set exogenously to \$20,000 per year;

^{d/} This represents the maximum advantage that Center 1 can command;

^{e/} In this simulation, 348,940 of these workers must cross commute;

^{f/} This represents the maximum constraint that can be imposed on Center 1;

^{g/} In this simulation, 73,261 of these workers must cross commute.

2.1 Model I: A Competitive Land Market

Simulations 1-3, portray the perfectly competitive city, where households and firms freely bid for a share of the city's land. Equal neighboring residential and commercial land prices at the subcenters' edges present a distinctive feature of the simulated cities.

Simulation 1, in particular, portrays the symmetrical city which results if no production cost differentials, land supply restrictions or regulatory controls are assumed at any of the city's commercial locations. As such, the simulation clearly demonstrates Proposition 1.

Simulation 2, introducing a production cost differential of \$1,000 per worker at Center 1, shows how capitalization works in the absence of institutional rigidities in the city's land market. Center 1, the more advantageous center, commands higher commercial space rents and higher wages than Center 2, simply because it becomes larger, induces higher commuting and ultimately commands higher residential and commercial land rents. Yet, the magnitude of the advantage-induced space rent differences between the two centers is trivial (\$59) compared to the magnitude of the resultant wage differences between these centers. This provides considerable numerical support to Proposition 2, suggesting that, under normal conditions, wage differences are likely to capitalize the bulk of the two subcenters' initial advantage difference.

In *Simulation 3*, a maximum advantage of \$2,229 per worker is introduced at Center 1, along the lines suggested by equation (III.13). Consistent with Proposition 3, this maximizes the space rent (\$132) and wage differences (\$2,097) between the two centers, but not their relative magnitude. Once again, wage differences between the two centers are seen to account for most of the capitalization, as Proposition 2 suggests.

Taken together, the three simulations show that in competitive land markets space rent differences between centers *do* reflect differences in residential and commercial land prices, but not the full value of any difference in production cost advantages between these centers. This is simply because there are also wage differences between centers, which under normal conditions capitalize most of the advantage difference to the firm. These conclusions may substantially be altered once Center 1's land market is assumed to be segmented by binding land constraints, regulated with respect to its commercial density, or both be regulated and segmented in a binding fashion. *Simulations 4-12* were developed to illustrate exactly how capitalization outcomes differ in such alternative land markets.

2.2 Model II: A Segmented Land Market

Simulations 4-7, featuring long run equilibria in segmented land markets, clearly suggest that in the presence of binding zoning limits, commercial land and space rent differences between centers *do not* reflect differences in the price of their adjoining residential land. Such a gap between adjoining residential and commercial pricing presents the distinctive feature of segmented land markets.

In *Simulation 4*, Center 1's land area is restricted to about a third of its competitive market size. As a result, its employment size, residential land rents, and labor wages fall, but in order to equalize demand with the constrained supply, its commercial land and space rents rise dramatically above their competitive equilibrium levels. With commercial land rents at Center 1 rising at about three times that center's residential land rents and Center 2's respective land rents, a large rental gap between Center 1's commercial and adjoining residential land emerges, and a pattern of large

positive commercial space and land rent differences between the two subcenters is sustained, as Proposition 4 would imply.

Simulation 5 maintains Center 1's restriction but, in addition, introduces a \$1,000 cost advantage per worker at Center 1. In *Simulation 5*, the \$1,000 advantage difference between the two centers is capitalized into a wage difference of only \$82.44, a trivial amount compared to the \$917.56 space rent difference per worker between the two centers. When compared with *Simulation 2*, *Simulation 5* clearly gives credence to Proposition 5, suggesting that such highly restrictive zoning limits do shift amenity capitalization almost completely away from wage and toward space rent differences between centers. Comparing the effects of the advantage in the cities portrayed in *Simulation 5* and *Simulation 2* also provides support to the assertion that zoning limits help produce stronger (weaker) marginal amenity effects on space rents (labor wages).

Simulation 6 exemplifies the case in which zoning limits are so restraining that about a third of Center 2's workers are forced to cross commute. With a constraint of such a magnitude, the commercial land and space rent differences between centers substantially rise, and the negative residential land and wage differences between these centers dramatically fall. Space rent differences per worker (\$3,102), in particular, rise to more than three times the amount of the initial advantage difference between the two centers, as Proposition 6 would suggest.

2.3 Model III: A Regulated Land Market

In *Simulations 7-9*, portraying a city with a regulated land market, the competitive relationship between residential and commercial land rents is notably restored, but commercial space rents no longer follow movements in

residential or commercial land rents. Such a divergence invariably characterizes regulated land markets.

In *Simulation 7*, for example, as a restriction limits Center 1's capital/land ratio at about a fourth of its competitive level, its land rents fall. Yet, at the same time, forcing firms to consume much more land and much less capital than what the minimum cost combination dictates raises Center 1's production costs so much that its commercial space rents significantly rise, as Proposition 7 would imply. As a result, a pattern of positive space rent, but negative commercial land rent and labor wage differentials emerges in the city.

Simulation 8 maintains this same density limit but, in addition, introduces an advantage difference of \$1,000 between the two centers. Similarly to what happens in the case of segmented land markets, space rent differences capitalize a larger (\$770) and wage differences a smaller (\$230) share of the advantage than that they do in the absence of such a density regulation (*Simulation 2*). As such, the simulation clearly demonstrates Proposition 8, suggesting that, similarly to land constraints, density regulations tend to shift capitalization away from wage and toward space rent differences between centers. Comparing the effects of the advantage in the cities portrayed in *Simulation 8* and *Simulation 2* also supports the assertion that, similarly to zoning limits, density regulations help produce stronger (weaker) marginal amenity effects on space rents (labor wages).

In *Simulation 9*, Center 1's regulatory limit is set at its minimum, along the lines suggested by (III.37). This maximizes the positive space rent and minimizes the negative commercial land rent and wage differences between the two centers. Notably, space rent differences per worker between the two centers (\$3,100) exceed the value of the two subcenters' initial advantage difference, as suggested by Proposition 9. Obviously, the drop in commercial land rents at Center 1 is not sufficient to offset the enormous increase in

the cost of providing floor space at Center 1 dictated by such a rigid density limit.

2.4 Model IV: A Segmented and Regulated Market

Simulations 10-12 portray a land market, which is not only segmented by zoning limits, but also regulated with respect to its commercial density. Hence, the three simulations maintain the zoning limit assumed in the case of the segmented land market but, in addition, introduce a binding density limit at Center 1. In the presence of the binding zoning limit, and irrespectively of the density limit, neighboring commercial and residential land rents must remain unequal.

In *Simulation 10*, the combined effect of two restrictions causes Center 1's employment and labor wages to fall well below their competitive market solutions. Given the rigidity of the land constraint (compared to the relatively mild density regulation), Center 1's commercial land rents rise to about nine times Center 2's respective rents, but still less than they would in the absence of the density limit. The land constraint and density regulation, on the other hand, reinforce each other in producing larger space rent increases at Center 1 than those produced by the land constraint alone. As a result of these adjustments, a pattern of large positive space rent and negative wage differences emerges in the city, supporting thus Proposition 10.

In *Simulation 11*, a production cost advantage difference of \$1,000 between the two centers is again introduced. This is capitalized into large space rent differences (\$2,907), but negative wage differences between the two centers. Again, space rent capitalization is stronger and wage capitalization weaker than they would be in the absence of both, or the presence of just one, of the two development restrictions. Proposition 11, then is well demonstrated by this simulation.

In *Simulation 12*, Center 1's employment is constrained to be about two thirds of its competitive market size. Evidently, Center 1 becomes too small and Center 2 too large, and, as a consequence, 73,261 of Center 2 workers must cross-commute. Under such a cross-hauling pattern, the positive differences in commercial space rents between the two centers are seemingly higher, and their negative wage differences smaller, than they would be under a more normal location pattern. In particular, the two subcenters' space rent differences (\$3,310) do exceed the value of their initial advantage difference, as Proposition 12 would require.

3. Model Simulations: Concluding Remarks

The simulation results, then, have illustrated how capitalization works in competitive land markets; have substantiated the first-order effects that development constraints have on the capitalization process; and have provided numerical support to the assertion that development restrictions may also have nontrivial second-order effects in this process.

Most importantly, perhaps, besides demonstrating the theoretical propositions, the simulation results have shed light to the range of different capitalization outcomes in alternative land markets. Overall, they supported the conclusion that for capitalization outcomes to substantially differ across markets, development restrictions must be quite constraining. Evidently, with mild restrictions, either on a subcenter's total land area or capital/land ratio, the magnitude of space rent and wage capitalization is not likely to dramatically differ in competitive, segmented, or regulated markets.

PART 1:

AN OVERVIEW AND CONCLUSIONS

The capitalization of urban amenities has been a central focus for academic research because of its strong implications for urban land and real estate pricing. The urban economics literature has so far established the mechanism through which transport costs are capitalized by residential land prices within *monocentric* cities, the process through which land rents and wages "dually" capitalize intercenter differences in transport costs within *multicentric* cities, and the process of the "dual" capitalization of productive and nonproductive amenities by land prices and wages within a *system* of cities. This last class of intercity analyses cleared up the misconception that only land prices capitalize locational value and gave credence to the argument that urban locations must best be viewed as tied bundles of rents, wages, and spatial amenities.

What, however, these analyses have seemingly ignored is the active presence of firms in the land market, the way they use space and consume land, and, perhaps most importantly, the role that variations across space in the supply characteristics of land and allowable development densities play in the capitalization process. Against this background, Part 1 of the dissertation proceeded with the exploration of these largely unaddressed issues. This concluding section of Part 1 provides a review of the modeling approach and a summary of the major findings of the theoretical study.

1. The Modeling Approach

Building on the principles of the traditional land market theory, four simplified models of a two-center city have been developed to examine how the capitalization of production amenities works in alternative land markets, and how this eventually helps determine intercenter variations in commercial land rents, floor space rents, and wages.

Following the tradition of the existing multicentric city [i.e., Clapp, 1983] and interarea analyses [i.e., Roback, 1982], the models have explicitly considered the supply of and the demand for labor. In contrast, however, to these analyses, they have accounted fully not only for the demand, but also for the supply of commercial land and floor space. As such, they have allowed for binding zoning limits and/or density regulations to be present in the land market of urban areas.

In particular, Model I was developed to examine capitalization in competitive land markets; Model II, Model III, and Model IV were designed to mirror the effects of zoning limits, density regulations, and growth moratoria on the capitalization process. For the sake of analytical simplicity, the models assumed linear two-center cities, similar residential markets across centers, fixed land consumption by urban households, uniform transport costs per unit distance across markets, and fixed distances between the centers' inner edges. In addition, the models employed fixed Leontief technologies in the output market, utilized neoclassical production functions in the commercial property market, and assumed no agglomeration economies. Any amenity differences between locations were thus assumed to be exogenously determined.

In each of these models the analysis focus was on how rents and wages adjust in response to an exogenous production advantage at one of the city's subcenters. The model solutions evolved around three fundamental premises: that prices in the commercial land, property, and labor markets are the result of a general equilibrium process tending to clear simultaneously these markets; that, as such, commercial pricing is linked in some ways to pricing in the labor and the land market; and, lastly and most importantly, that price differentials across space are largely the result of an amenity capitalization process, which, in turn, may greatly be affected by the presence of binding development controls.

The findings were summarized in a number of propositions, which were then demonstrated through a series of simulated examples. The major theoretical conclusions are highlighted below.

2. Capitalization in Alternative Land Markets

The analysis has clearly shown that, similarly to what happens *between* metropolitan areas, a "dual" capitalization of amenity differences between centers is taking place in the land and labor market *within* metropolitan areas. As a result of this process, not only wages, but also land prices and commercial space rents must vary between centers to allow consumers to enjoy equivalent welfare and firms to produce at equal costs, regardless of location.

Rather than, however, follow the tradition of intercity models that have labor wages share advantage differences with land prices [Roback, 1982; Blomquist et. al. 1988], the models consider capitalization by such direct components of the firm production costs as floor space rents and labor wages. As such, residential land prices indirectly capitalize whatever advantage

difference is shared by labor wages, while commercial land prices, again indirectly, capitalize that portion of the advantage necessary for the land and property markets to jointly clear.

2.1 Capitalization in Competitive Land Markets

In a competitive land market, free bidding between the residential and commercial sectors ensures equal neighboring residential and commercial land rents. Consequently, more advantageous, and hence larger, centers command not only higher residential land prices and higher wages, but also higher commercial land and real estate prices than smaller and less advantageous centers.

All other things being equal and under normal conditions, wage differences (as well as differences in residential and commercial land rents) are likely to capitalize most of the advantage difference to the firm. Alternatively, floor space rents in competitive land markets must only negligibly reflect locational value.

2.2 Capitalization in Segmented Land Markets

In the presence of binding zoning limits in the commercial land market, adjoining commercial and residential land prices need not be equal. Thus variations across centers in commercial land and space rents need not reflect variations in residential land prices.

Capitalization in segmented land markets is still shared by labor wages and space rents, but the relative capitalization magnitudes depend on how restrictive the zoning limits applied to the most advantageous center are. The more restraining these limits, the higher the share of the advantage that is capitalized by floor space rents and the lower the share that is

capitalized by labor wages (and residential land prices). Seemingly, then, zoning limits shift capitalization away from wages and toward commercial space rents.

2.3 Capitalization in Regulated Land Markets

In markets which are regulated with respect to their commercial density, the competitive relationship between residential and commercial land is maintained, but space rents need not move in a parallel fashion with residential land prices. Commercial land is now inefficient, and the additional production costs incurred by this inefficiency must be reflected in higher space rents. Hence, in the presence of regulated markets, it is variations in commercial land prices and *not* space rents that reflect differences in residential land values.

Similarly to what happens in land constrained markets, capitalization in regulated markets depends on how rigid the regulation applied to advantageous centers is. *Ceteris paribus*, the more restrictive density limits are, the higher the share of the advantage that is capitalized by floor space rents and the lower the share that is capitalized by labor wages (and residential and commercial land prices). Again, density limits are seen to shift capitalization away from wages and toward floor space rents.

2.4 Capitalization in Segmented and Regulated Markets

In markets which are restrained with respect to both their commercial land and density or, equivalently, restricted by building moratoria, the competitive relationship between the commercial and residential market is still disturbed. The more restrictive building moratoria are, the higher the space rent and the lower the wage differences between centers, suggesting

thereby that the restrictions again shift capitalization away from wages and toward floor space rents.

3. Concluding Remarks

In summary, then, the analysis has clearly shown that neither space rent nor wage differences alone account fully for any difference in locational advantages that may exist between centers. *Ceteris paribus*, and under normal conditions, wage differences are likely to account for the bulk of this advantage, with floor space rents (per worker) absorbing only a trivial amount. Once, however, binding zoning limits or density regulations are applied to advantageous locations, space rents begin picking up more and wages less locational value.

These conclusions are largely based on the assumption that any endogenous benefits or costs to either firms or households (i.e., agglomeration economies or congestion externalities) are not at work and that residential land markets are similar across centers. A number of alternative assumptions provide fruitful directions for future refinements of the theoretical models. These may include the effect of agglomeration economies at production sites, exogenous advantages to households, differences across centers in residential land markets (i.e., residential land consumption or transport costs) along with variable residential densities, or alternative assumptions on the "location" of development restrictions (i.e., development restrictions are present at both or at the least advantageous location). Such and other extensions of the theoretical model are discussed in the final section of the dissertation.

P A R T 2

**SPACE RENT CAPITALIZATION:
THE CASE OF GREATER LOS ANGELES**

Chapter V.

ANALYZING CAPITALIZATION IN THE COMMERCIAL REAL ESTATE MARKET

The theory developed in Part 1 sets the appropriate stage for empirically analyzing capitalization and pricing issues with contemporary multinodal metropolises. Building on this analysis, Part 2 of the dissertation presents an attempt to test some of the implications of this theory and at the same time provide a consistent explanation for the existence of space rent differences in Greater Los Angeles or, as it is more formally termed, the Los Angeles-Long Beach-Anaheim Standard Consolidated Statistical Area.

In this introductory chapter of Part 2, the main empirical implications of the theory developed in Part 1 are thoroughly discussed, the previous empirical work on capitalization and intrametropolitan commercial pricing is reviewed, and, finally, the empirical study that stemmed out of the theoretical work is outlined.

1. Analyzing Capitalization: Theoretical Implications

The theory advanced in Part 1 of the dissertation has a number of important empirical implications with respect to the existence and magnitude of compensating differences in commercial space rent and wages within metropolitan markets. The following discussion of the main theoretical notions advanced and their implications sets the basis for evaluating existing

studies on intraurban pricing and designing appropriate tests of the capitalization propositions.

[1] Intercenter space rent and wage differentials are the result of a "dual" capitalization process taking place in the labor and the commercial land market of multicentered urban areas. As such, neither space rent nor wage differences can fully capitalize whatever production advantages may exist between centers.^{12/}

Derived out of the analysis of all models, this directly suggests that neither space rent nor wage differences alone may be good indicators of differences in locational value. Consequently, one cannot estimate the full valuation of urban amenities by the firm when only rent or only wage equations are estimated. To estimate the full valuation of productive amenities, both space rent and wage equations must be empirically developed [see Roback, 1982; Blomquist, 1988].

[2] Only in competitive land markets differences in space rents across centers can fully be explained by differences in residential land prices or differences in locational advantages alone. In noncompetitive markets residential values or locational advantages may be poor predictors of intercenter differences in commercial space rents.

Stemming out of the analysis of the competitive model (Model I), the clear implication of all this is that if residential land values or locational amenities cannot fully explain intercenter differences in locational rents within a metropolitan market, binding development restrictions must be present in the commercial land market of this metropolitan area. This seemingly

^{12/} This argument always applies to the case of competitive land markets. In constrained markets, however, there are certain values of zoning limits and density regulations (see Chapter III) at which space rents fully capitalize amenity differences between centers. Nevertheless, these conditions are too restrictive to affect the generality of this argument.

provides for a powerful test of the competitive assumption and an empirically testable hypothesis for verifying the presence of binding zoning limits, density regulations, or growth moratoria in a decentralized metropolitan market.

[3] In the light of government interference which limits commercial development through zoning limits and/or density regulations, space rents capitalize more locational value. In particular, commercial rents absorb more locational value at centers which are more constrained with respect to their commercial land (than those that are less constrained) and at centers which are more restricted with respect to their commercial density (compared to those which are less restricted).

Emanating out of the analysis of the segmented and/or the regulated land market (Models II, III, and IV), this suggests that the share of locational amenities capitalized by space rents is conditional on the level of development restrictions. This points to the strong role that the latter may play in the capitalization process and, at the same time, suggests that the inclusion of land supply variables in hedonic equations is imperative for a well specified model of intrametropolitan rent differences. Seemingly, a failure to fully account for the supply side of land may lead to misspecified empirical models and a misinterpretation of their results.

The most prominent example of such a potential misinterpretation is the role that amenity variables play and the interpretation of their "true" effects. Hedonic regressions controlling just for spatial amenities may potentially lead to the conclusion that, if statistically insignificant, these do not provide benefits to urban firms and thus do not affect location decisions. Yet the "true" positive impact of spatial amenities cannot be identified unless supply variables are controlled for in the hedonic (rent or wage) equation. Only in a competitive market will amenity variables fully explain variations in space rent differences across space. In a

noncompetitive market, amenity variables alone can explain little of observed variations in space rents.

[4] The marginal effects of spatial amenities are conditional on the level of development restrictions. They are higher in constrained communities and weaker at unconstrained ones.

This points to the possible interaction between development constraints and locational amenities, which was contemplated in Chapter III and demonstrated by a number of simulation examples discussed in Chapter IV. To capture such an interplay between development constraints and spatial amenities, hedonic models must assume a multiplicative or a nonlinear functional form. As already suggested in the relevant literature, a failure to account for such an interaction between explanatory variables, in general, may provide for an important source of specification errors in hedonic equations [Bartik and Smith, 1989].

[5] In the presence, then, of development controls, capitalization and the resultant observed variations in space rents and wages across intrametropolitan locations can potentially be explained not only on the basis of spatial differentiations from the demand side, but also from spatial differentiations from the supply side of the commercial land market.

Presenting a synthesis of the above conclusions, this strongly suggests that, overall, urban locations must ultimately be viewed not only as tied bundles of rents, wages, and urban amenities, but as bundles of rents, wages, spatial amenities, and local development restrictions. Alternatively, space rent and wage differences across locations are equalizing differences not only for differences in production amenities across space, but also for differences in land supply characteristics and development densities. A complete

empirical model of price (space rent or wage) differences between centers, therefore, must fully account not only for differences in locational advantages (that may potentially affect the firms' production costs), but also for differences in zoning limits and density regulations.

Accounting for the presence of development controls may be extremely important when significant variations across space in floor space rents exist, in spite of rather narrow differences in production amenities. In fact, the theory tends to suggest that, under such a scenario, much of the variation in space rents may be the result of differences in the rigidity of development constraints rather than differences in locational advantages alone. Notably, in the absence of development constraints, variations in spatial amenities may create big *wage* rather than big *space rent* differences.

2. Past Empirical Studies: A Review and Criticism

The preceding discussion points directly to some of the deficiencies of existing empirical studies on intrametropolitan pricing and sets the basis for properly analyzing capitalization from the empirical perspective. Notably, empirical work on the intraurban level has been confined to very few, scattered pieces of research; in the absence of an explicitly spatial, comprehensive theoretical framework to guide them, these represent simple applications of the Hedonic theory to the labor or the commercial real estate market [i.e., Eberts, 1981; Wheaton, 1984].

2.1 *Wage Capitalization*

Postulating that wage gradients result from the spatial decisions of utility-maximizing workers and the labor requirements of cost-minimizing firms, a number of authors have attempted to investigate the existence of

intraurban wage differentials. None of them, however, directly dealt with office employees, and most of the authors have been criticized because of their approach and their use of unreliable or insufficiently disaggregated data on wages.

Among these authors, Segal [1960], who failed to consistently prove the existence of negative wage gradients in the New York market, has widely been criticized because of the lack of adequate observations, which greatly reduced the vigor of his analysis. Other authors, such as Ehrenberg and Goldstein [1975; 1976] and Wachter [1972], have largely been criticized for not directly dealing with the continuous spatial variation in wages within urban labor markets [Eberts, 1981].

Eberts [1981] made the first successful attempt to empirically ascertain the nature of intraurban wage differentials, using extensive databases on service employee wages and community characteristics. Focusing, in particular, on the Chicago labor market, he tested for the existence of a statistically significant correlation between the accessibility to Chicago's urban core and existing differentials in wages paid to five groups of public employees across the area's communities.

His wage equations accounted for the airline distance from Chicago's urban core and controlled for the socioeconomic structure of the communities, their organization structure, their ability and propensity to pay employees, as well as some selected worker characteristics. With R^2 s ranging from 30% to 31%, the explanatory power of the alternative wage equations he estimated is poor, but the regression results largely substantiate the hypothesis that urban wage gradients *do* exist. The wages of four out of the five labor groups examined by Eberts [1981] were found to exhibit a negative relationship with distance from the urban core, the largest employment concentration in the Chicago area. In particular, administration wages were found to decrease on

average \$24 per mile, clerical wages \$10 per mile, police wages \$12 per mile, and public works wages \$9 per mile. The slope of the wages of fire employees was found to be almost zero, possibly because, Eberts hypothesizes, of their strong labor unions. Yet, he admits that a labor union variable contributed very little to the explanation of wages paid to any labor group. The omission of locational demand and supply variables along the lines suggested so far might have very well been responsible for the relatively poor results of the study.

Most recently, Gyourko and Tracy [forthcoming] have tested for the existence of compensating wage differentials generated by variations in fiscal variables across 125 U.S. cities. They suggested that, with cost of living held constant, variations in such fiscal variables, as state and local taxes or corporate tax rates explain as much of the variance in intrametropolitan wages as do differences in worker characteristics. This study, however, is not exactly intraurban; the units of analysis (cities) are not concentrated in a specific metropolitan area, but are rather dispersed in a number of metropolitan areas in the country.

2.2 Space Rent Capitalization

The studies on intrametropolitan commercial pricing are by and large capitalization studies. They attempt to explain differences in space rents on the basis of such locational attributes, as distance from the CBD, access to white collar labor, other accessibility advantages related to highway systems, or effective tax rates. Yet, similarly to prior theoretical analyses, none of these studies has attempted to incorporate the supply side of land and account for the role that variations in land supply characteristics may play in the capitalization process.

Existing studies on intrametropolitan pricing fall into two broad categories: [1] those attempting to model variations across urban submarkets in commercial space rents and [2] those that attempt to model variations in such rents within more narrowly defined urban areas.

Analyzing Intrametropolitan Variations in Space Rents

Clapp's [1983] and Wheaton's [1984] analyses seek, in general, to model and explain space rent differences across locations within a broader market area. Differences in locational attributes across space become thus increasingly important.

Clapp [1980] hypothesized that market rents on office-commercial space result from the competing bids of office activities and the spatial distribution of supply. He further hypothesized that central locations must be more advantageous than others because of the need for face to face contacts, but also assumed that suburban nodes must exert some decentralizing force as well. The latter is thought to be related to shorter commuting on the part of workers employed at suburban centers. Thus, Clapp suggested, the production costs of firms, in addition to wages and the cost of space, must include the costs of trips to the central business district, as well as the cost of trips to specialized suburban nodes.

Utilizing Coldwell Banker data on annual quoted rents on 105 buildings, Clapp estimated a number of price equations to explain the strong negative rent gradient produced by the centralizing pull of downtown Los Angeles and the decentralizing forces that suburban concentrations exert. In addition to the centralizing force of the CBD and the pull of suburban nodes, he demonstrated the importance of a number of building and neighborhood characteristics in determining floor space rents in the Los Angeles area. His

beta coefficients indicated that access to the CBD was at least twice as important as any of the other locational determinants considered in the study. Together, these variables explained 67% of the observed variation in annual quoted space rents.

Clapp contended that his estimated reduced form provided estimates for implicit market prices for the different locational attributes of office properties. Given, however, the theory so far developed, the full value of these attributes (or amenities) is expressed by the sum of price and wage differences. Proxied by commuting time, the latter were also found by Clapp to be important.

Using average rent data on office buildings in the Boston metropolitan area, Wheaton [1984] also estimated a number of alternative rent equations across jurisdictions. These accounted for the role of such locational advantages, as good access to white collar labor, access to major highways, and low tax rates. He found that access variables were important across a number of alternative model specifications, but that tax payments or tax rates never had a significant impact on gross rents. He attributed this to a price elastic spatial demand for property. In the face of a spatially competitive market, he concluded, land or property owners and *not* tenants must bear the burden of tax differences across jurisdictions.

This conclusion does not contradict the way capitalization works in a competitive land market, where wages (which reflect fully variations across locations in land prices) and not rents absorb amenity/disamenity values. Yet, this could better be illustrated by accounting for the presence of zoning limits, density regulations, and other institutional restrictions in the Boston metropolitan area and demonstrating that their effect on commercial rents was in fact unimportant.

Analyzing Variations in Space Rents within Urban Submarkets

In contrast to the studies just reviewed, Hough's and Kratz's [1983] and Brennan's, Cannaday's, and Colwell's [1984] studies mostly stress the effect of micro-location factors and qualitative characteristics of buildings on space rent determination.

Using standard econometric techniques, Hough and Kratz [1983] examined variations in office rents across 139 buildings in downtown Chicago. They considered a number of extrinsic characteristics of these buildings, such as their distance from the CBD, distance from commuter transportation, or parking facilities, and a number of intrinsic building characteristics, such as the type of construction, rentable area, number of floors, well appointed lobbies, the presence of prestigious tenants, their proximity to complementary firms, the extent of safety features, the number and speed of elevators, and the quality of architecture. They find that radial distances to the nearest commuter stations, the building's total gross floor area, whether a restaurant or a snack shop is present, and whether or not the building has been designated as a Chicago landmark explain the 60% of the variation in average annual rents per square foot.

Brennan, Cannaday, and Colwell [1984] on the other hand, presented a different approach to the analysis of rent differentials within the Chicago CBD. Arguing that the use of the building as the unit of observation precludes considering the effect of lease terms on rental rates, their unit of analysis was the office unit rather than the office building.

Using actual transaction data on 29 office units, their ten-variable regression equations produced an R^2 of more than 80%. Their hedonic equations included such variables as the the amount of "stop", whether the lease included a CPI escalation clause, the size of the unit, its percent of

nonusable area, the size of the building the unit is located, the vertical location of the unit in the building, and, finally, the building's distance from certain streets and the city center.

2.3 Past Empirical Studies: Concluding Remarks

First, by uncovering significant variations across locations in labor wages [Eberts, 1981] and commercial space rents [Clapp, 1983; Wheaton, 1984], existing intraurban studies have provided some evidence on the existence of "dual" capitalization within metropolitan markets. This evidence, however, is indirect and, perhaps, less appealing than that provided by existing interarea studies. In these studies, such as Roback's [1982] or Blomquist's et. al. [1988], both land prices (or proxies of them) and wages are regressed on the same set of amenity variables to show that both factor prices capitalize to some extent amenity variations across regions or urban counties. As such, these interarea studies have definitely provided more compelling tests of the "dual" capitalization hypothesis than the intraurban studies just reviewed.

Second, by implicitly assuming perfectly competitive markets, the hedonic models that these studies have employed may be misspecified. In the case of studies on commercial pricing, the use of individual office leases or office buildings as the unit of their analysis did not help, since land availability, for example, may vary not across sites but rather across broader commercial locations.

Finally, to the extent that they fail to caution for the fact that the hedonic models they employ cannot be used to provide estimates of implicit prices for locational attributes or characteristics, these studies are misleading. In many instances, their underlying assumption is that differences in space rents reflect fully differences in amenity values. Even

in the face of constrained markets this may not be true, because there are also wage differences between locations that may capitalize some of the difference in locational value.

2. The Empirical Analysis: An Overview

In contrast to prior empirical work, the study presents an attempt to test for the presence of and explicitly examine the role that local development constraints play in the capitalization process. Focusing on the capitalization of urban amenities into commercial space rents in the greater Los Angeles area, the analysis builds on the theoretical work to evolve around a number of closely related empirical questions:

[1] Is the commercial land market in Greater Los Angeles competitive? Do differences in housing prices or locational advantages alone explain differences in commercial space rents across centers?

[2] If present, do development constraints play a strong role in the capitalization process as the theory suggests? In other terms, are space rents higher in cities that are more constrained with respect to land than others that are less constrained? Do space rents in nodes with more strict density constraints capitalize more locational value than space rents in nodes with less or no density restrictions? Is amenity capitalization stronger at more--as opposed to less--heavily constrained or regulated centers?

[3] Then, coupled with spatial amenities, do development restrictions help explain well variations across commercial nodes in space rents?

In addressing these questions, the empirical study identifies and models differences in commercial space rents across 33 office-commercial nodes in the Los Angeles area. The methodology employed combines elements from both

categories of commercial pricing studies described above. First, using a set of rental property data from Coldwell Banker, the study draws from the Brennan et. al. [1984] and the Hough and Kratz methodology [1983] to estimate price indices, or "effective" rents across nodes. Then, similarly to Clapp's [1981] and Wheaton's [1984] approaches, it develops a number of hedonic price equations to model these variations as a function of locational attributes or characteristics.

The data utilized to estimate these models included an extensive database on space rents and property characteristics from Coldwell Banker and a set of data on housing rents/prices, locational advantages, and land and density restrictions in a number of commercial nodes in the greater Los Angeles area. These data are not without limitations. Asking rents instead of contract rents were available; building quality variables were insufficient; housing price data represent urban aggregates rather than more localized, "border" data; and data on land availability could be translated into dummy rather than numeric variables.

Yet, despite such data deficiencies, the statistical model specifications and the estimation results provide conclusive answers to the questions posed above in a manner supportive of the theoretical propositions. Because, however, of the data limitations just mentioned, the results presented in this part are merely intended to be only illustrative of the method suggested by the analysis in Part 1 of this dissertation.

Chapter VI proceeds with the description of the study area and its commercial nodes. Chapter VII discusses the estimation of subcenter "effective" rents. Finally, Chapter VIII presents the statistical model specifications and discusses the estimation results.

Chapter VI.

URBAN SUBCENTERS IN THE LOS ANGELES-LONG BEACH-ANAHEIM SCSA

The intensity of commercial activity in Greater Los Angeles, the multicentricity of the area, and the resurgence of development regulations in most of its cities during the recent years make it, perhaps, the most eligible metropolitan area for this analysis. This chapter describes the study area, identifies its most important urban submarkets, and discusses the selection of a number of commercial nodes within their boundaries.

1. The Los Angeles-Long Beach-Anaheim SCSA^{13/}

Greater Los Angeles is formally termed by the U.S Census as the Los Angeles-Long Beach-Anaheim Standard Consolidated Statistical Area (SCSA). It encompasses four Metropolitan Statistical Areas (MSAs)--Los Angeles-Long Beach, Oxnard-Simi Valley-Ventura, Anaheim-Santa Ana-Garden Grove, and Riverside-San Bernandino-Ontario and, as shown in Map VI-1, extends geographically over five urbanized counties--Los Angeles, Ventura, Orange, Riverside, and San Bernandino. Each of these metropolitan areas or counties is characterized by considerable commercial activity, spatially allocated in a number of commercial submarkets. These are listed in Table VI-1.

^{13/} Most of the discussion in this section is based on information obtained from ULI's "Market Profiles" (various issues) and comparable information obtained from various zoning ordinances.

The Los Angeles-Long Beach-Anaheim SCSA



Table VI-1
Commercial Submarkets in Greater Los Angeles

Urban Counties				
Los Angeles ^{a/}	Orange ^{b/}	Ventura ^{c/}	Riverside ^{d/}	San Bernandino ^{d/}
Cerritos	Airport Area	Ventura	Riverside	San Bernandino
Hollywood	Central County			
LA Downtown	Newport Center			
LA Suburban	North County			
Pasadena/Glendale	South County			
San Fernando Valley	West County			
San Gabriel Valley				
South Bay				
West LA				
Wilshire				

Source: Coldwell Banker; Torto-Wheaton

Notes:

^{a/} The Los Angeles county is incorporated into the Los Angeles-Long Beach MSA;

^{b/} Orange county is incorporated into the Anaheim-Santa Ana-Garden Grove MSA;

^{c/} Ventura county is included in the Oxnard-Ventura MSA;

^{d/} Riverside and San Bernandino counties are included in the Riverside-San Bernandino-Ontario MSA.

The Los Angeles metropolitan area (4,000 square miles) is undoubtedly the biggest financial "center" of the West. The majority of multi-tenant space in the area, mostly highrise, is located in eight different urban submarkets: Downtown Los Angeles specialized in finance; the Hollywood market specialized in the entertainment industry; Wilshire District; West Los Angeles; Glendale/Pasadena; South Bay specialized in the aerospace industry; San Fernando Valley specialized in high-tech industries; and the relatively new submarket of San Gabriel Valley.

Most of these areas seem to be confronted by an insufficient supply of commercial land and strict zoning regulations, which have substantially limited the availability of development opportunities in the region. The passage of Proposition U by the city of Los Angeles in 1986 has downzoned allowable FARs to half of their previous maximums, making thus developable sites for highrise office space even more scarce. The central part of the San Fernando Valley is perhaps the area that was hardest hit by the new regulations. As a result, new commercial development is now forced to occur north of Ventura Boulevard toward the Van Nuys Airport area or in the less "crowded" submarket of San Gabriel Valley.

The Oxnard-Ventura metropolitan area (1,843 square miles), which encompasses Ventura county, has emerged as another attractive alternative for businesses wishing to relocate outside the Los Angeles basin. Mostly specialized in the service sector, the area constitutes a single office submarket. This includes the Ventura coastal plain and the county's technology corridor, which straddles the Los Angeles/ Ventura county line and stretches along the Ventura freeway (101). These areas have approximately 4.4 million square feet of prime office space in multi-tenant buildings of over 20,000 square feet each. Approximately, eighty percent of this space was built after 1980. On average, office buildings are lowrise and in business

park settings. Given the fast pace of development during the recent years and fears of uncontrolled growth, a number of zoning regulations are in place in the most of the county's cities to guide new commercial development.

The Anaheim-Santa Ana-Garden Grove metropolitan area (786 square miles), extending over Orange county, is one of California's three largest high-tech and manufacturing centers. The expansion of the industrial sector during recent years has been accompanied by the expansion of the business service sector with law firms, financial institutions, and insurance companies often being relocated from the Los Angeles metropolitan area, or opening regional branches in the county. Major office submarkets include the Airport Area, Central County, Newport Center, and the North, South, and West Orange county. Most of office development, mostly highrise, is located in the Airport/South County submarkets, which host approximately 50% of existing office space. Today, commercial development in the area is confronted with tightening development restrictions, likely to affect both the cost and intensity of future development.

The Riverside-San Bernandino metropolitan area (27,308 square miles), encompassing the San Bernandino and Riverside counties, is one of California's largest metropolitan areas. The area's economy is dependent on its industrial base and its increasingly expanding service sector. Approximately 9 million square feet of office space in buildings over 5,000 square feet are located there. Most of this space is concentrated in the two broader submarkets of San Bernandino and Riverside. Office buildings are primarily lowrise, but a non-negligible number of highrise buildings are located in the two central cities of the area--Riverside and San Bernandino. The pro-growth sentiment that exists and the financial assistance given by the public sector may be some of the reasons behind the location of many new businesses in the area during the last ten years.

2. Urban Subcenters in Greater Los Angeles

For the purpose of this research, commercial nodes or urban subcenters are operationally defined as spatial peaks in office service activity within a metropolitan market. By all accounts, Greater Los Angeles is a multi-nodal area. The Coldwell Banker database on commercial buildings in the various submarkets of the area provided a solid basis for identifying its most important subcenters.

The structure of this database is described in Table VI-2. Available data for each building regularly surveyed include information on its submarket location, its city/area location, the type of rent reported (i.e., gross or net), the low and high range of current asking rents, as well as the height, size, and age of buildings for which asking rent data are available.

The locational information provided by these data, however, left no other choice but that of considering the various cities or towns in Greater Los Angeles as the geographical units of reference in this analysis. The only exception is the city of Los Angeles, where location information allows the identification of a number of important commercial nodes within its boundaries.

Given the floor areas and the city/area location of those buildings which are regularly surveyed and, most likely, offer multi-tenant space, it was possible to identify 23 cities and 10 subcenters within the city of Los Angeles with considerable commercial activity. Shown in Map VI-2, these constituted the subcenter sample of this analysis. Notably, only subcenters with more than 1 million square feet in competitive office space have been selected. The inclusion of smaller subcenters in the sample would undoubtedly

Table VI-2
Commercial Building Data

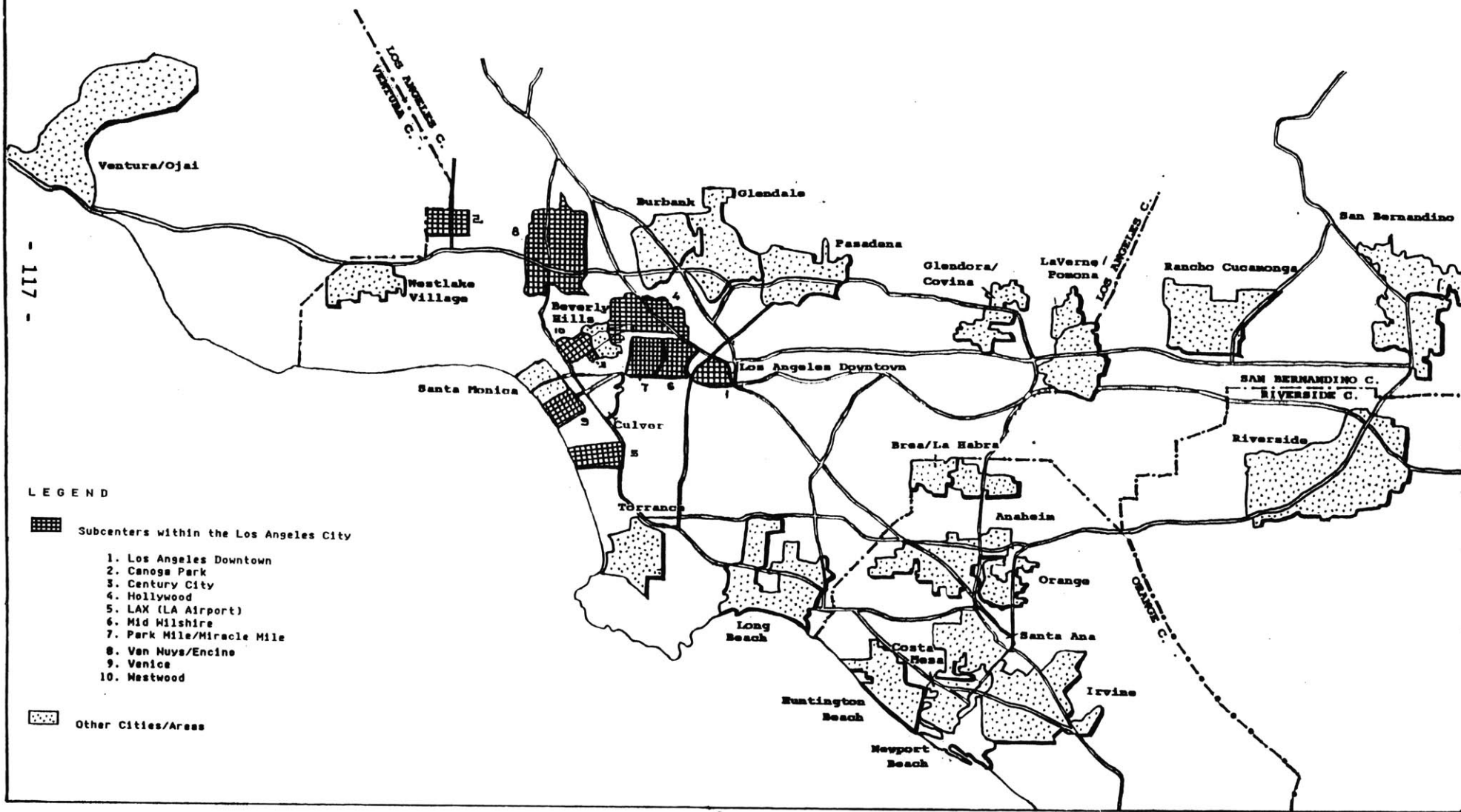
Variable Name	Data Type	Description ^{a/}
DVI	Qualitative	Buildings in central cities that are regularly surveyed ^{b/}
SVI	Qualitative	Buildings in suburban areas that are regularly surveyed ^{b/}
SUBMARKET	Qualitative	Submarket within which the building is located ^{c/}
BANK	Qualitative	City/Area location ^{d/}
LRATE	Numeric	Low Range of asking rents ^{e/}
HRATE	Numeric	High range of asking rents ^{f/}
LTYPE	Qualitative	Type of rent reported ^{g/}
YEAR	Numeric	Year the structure was built
FLOORS	Numeric	# of floors in the structure
AREA	Numeric	Total floor area (in square feet)

Source: Coldwell Banker

Notes:

- ^{a/} Description in the case of DVI and SVI refers to the case the the dummy variable is assigned the value of 1;
- ^{b/} It is most likely that regularly surveyed buildings offer multi-tenant rather than single-tenant office space;
- ^{c/} See Table VI-1;
- ^{d/} In the case of most buildings, city location is given. The only exception are buildings located in the Los Angeles City, for which specific area location within the city is provided;
- ^{e/} For all of the buildings a low range of asking rents is provided;
- ^{f/} A high range of asking rents is reported for some of the buildings (mostly highrise);
- ^{g/} Whether gross rents, rents net of taxes, net of taxes and utilities, or net of taxes, utilities, and maintenance expenses are reported is specified.

Map VI-2
Los Angeles-Long Beach-Anaheim SCSA:
Selected Subcenters



create problems regarding the estimation of "effective" subcenter rents (discussed below).^{14/}

Table VI-3 below lists the selected nodes and their characteristics with respect to total square footage, average space rents, as well as the average age, height, and floor size of their commercial buildings. The Los Angeles downtown (34,267 sq.ft) and Irvine in Orange county (20,000 sq.ft) are the largest commercial nodes in Greater Los Angeles, but not the nodes with the highest average rents. Estimated as the average of the low and the high range of the asking rents reported, these range from \$12.02 in San Bernardino to \$23.81 in Westwood. The average age of buildings in these subcenters ranges from 6.43 years in Brea/La Habra to 35.62 years in the Hollywood area. The average height of commercial buildings ranges from 2.22 floors in Westlake Village (part of Thousand Oaks) to 20.1 floors in Century City within the

^{14/} The intensity of office service activity within these towns (or groups of towns) can be evaluated using one or more of the following measures:

1). Office employment-to-population ratio: This measure is often proposed in the literature as a good indicator of the intensity of a specific activity within a metropolitan market. If higher than the one observed in neighboring municipalities, or as McDonald [1987] suggests, municipalities that are closer to the central business district, it may very well signify the existence of local employment peaks. If high enough, this ratio may also signify large urban subcenters whose workers cross-commute.

2). Office employment-to-total land area: Such or similar measures, utilizing office space instead of office employment, are preferable to simple land use utilization measures (i.e., office employment/office space-to-commercial land area), in that the latter overlook important differences in density variations and, as such, prevent proper comparisons across towns. Office employment(office space)-to-total land area ratios can be used similarly to employment-to-population ratios to evaluate the existence of significant urban subcenters.

3). Alternatively, location quotient-type of measures, utilizing office employment-to-population ratios, or the ratio of office employment (office space) to total developable land area can be used and evaluated against a benchmark value.

However, such considerations as the number of observations (buildings) available in each city and, most importantly, the overall size of the sample suggested that the cities be selected solely on the basis of their size (in terms of square footage). The use of such measures as those discussed above would possibly result in the inclusion of a small number of smaller cities and the exclusion of a larger number of larger cities in the sample. This would considerably limit the size of the sample, and would hinder the proper estimation of hedonic rents in smaller cities.

Table VI-3
Greater Los Angeles:
"Average" Subcenter Characteristics

Cities/ Subcenters	Competitive Square Feet (in 1000s)	Average Rents (\$/sqft)	Average Building Age (years)	Average Building Height (floors)	Average Floor Size (sqft)
1. Los Angeles City					
* Los Angeles Downtown	34,267	\$22.95	29.12	19.25	16,738
* Canoga Park	5,613	17.81	9.00	3.99	23,807
* Century City	8,473	22.68	15.76	20.10	19,050
* Hollywood	3,014	13.28	35.62	8.82	11,198
* LAX (LA Airport)	3,652	14.95	13.75	8.90	20,433
* Mid Wilshire	9,487	14.80	27.54	9.60	15,207
* Park Mile/Miracle Mile	4,462	17.74	19.86	7.28	22,127
* Van Nuys/Encino	7,588	18.14	13.50	5.85	17,560
* Venice	1,247	19.25	12.23	5.23	23,126
* Westwood	5,935	23.81	12.92	10.65	14,554
2. Anaheim	3,122	14.08	11.40	3.69	16,917
3. Beverly Hills	8,515	21.86	19.95	6.81	15,691
4. Burbank	4,897	17.86	9.23	6.65	16,241
5. Costa Mesa	3,057	15.14	7.79	4.63	23,544
6. Covina/Glendora	1,196	16.09	8.47	2.87	19,790
7. Culver City	2,577	16.24	8.61	3.27	17,307
8. Glendale	2,920	17.79	11.96	7.00	13,099
9. Huntington Beach	1,488	14.58	7.50	3.77	14,897
10. Irvine	20,320	16.50	9.42	3.78	18,999
11. Brea/La Habra	1,801	14.88	6.43	2.70	29,898
12. Long Beach	6,193	16.83	12.21	7.22	16,700
13. Newport Beach	3,312	19.16	14.76	3.55	12,878
14. Orange	5,059	15.46	9.83	5.50	25,789
15. Pasadena	5,506	17.21	17.40	5.66	15,753
16. Pomona/LaVerne	1,314	15.61	10.00	3.18	32,508
17. Rancho Cucamonga	1,304	15.31	4.47	2.21	29,675
18. Riverside	4,215	12.12	12.32	2.36	23,687
19. San Bernardino	3,021	12.02	8.68	2.22	19,415
20. Santa Ana	5,692	13.93	13.04	4.20	22,732
21. Santa Monica	5,293	21.81	9.50	4.70	26,533
22. Torrance	4,996	16.26	7.33	3.30	22,245
23. Ventura/Ojai	1,025	12.45	13.14	2.24	12,605
24. Westlake Village	1,252	14.94	7.52	2.22	24,578

Source: Calculated on the basis of data provided by Coldwell Banker
(see Table VI-2).

city of Los Angeles. Lastly, average floor size ranges from 11,198 square feet in Hollywood to 32,508 square feet in Pomona/La Verne.

Evidently, then, there are significant variations across centers not only in size, but also in such characteristics, as the age and height of their office-commercial buildings. Consequently, differences in those subcenters' average rents may reflect not only variations across centers in locational demand and land supply characteristics, but also variations in their mix and characteristics of buildings.

To control for such differentiations and isolate the effect that locational factors have on differences in floor space rents, hedonic price analysis is used here to estimate "effective" subcenter rents. The theoretical basis of the estimation procedure, as well as the estimation results are discussed in Chapter VII, which follows.

Chapter VII.

ESTIMATING "EFFECTIVE" SUBCENTER RENTS

The ultimate objective of the empirical research is to model variations across centers in space rents within the greater Los Angeles area, in order to identify the role that spatial amenities and local development restrictions (if present) play in the capitalization and pricing process.

Given that office space is a highly differentiated or heterogeneous good, both in terms of quality and structural characteristics, average rents cannot be used as a basis for such a modeling. Following Hough's and Kratz's [1983] and Brennan's, Cannaday's, and Colwell's [1984] methodologies, the standard hedonic framework is, therefore, utilized here to estimate hedonic or "effective" subcenter rents, or, as often termed in the relevant literature, "quality-controlled" rental prices.^{15/}

In this chapter the basic methodology of the hedonic framework is briefly discussed, the statistical model specifications adopted and the data utilized to estimate subcenter "effective" rents are presented, and, finally, the hedonic rent estimates are reviewed.

^{15/} Commercial pricing studies have employed hedonic regressions mostly to explain differences in space rents, rather than to estimate quality-controlled prices [Hough and Kratz, 1983; Brennan, Cannaday and Colwell 1984; Clapp, 1981; Wheaton, 1984]. This is in contrast with housing studies, where the technique has quite often been being used as a means for estimating price indices [i.e., Goodman, 1978; Follain and Malpezzi, 1980; Ozanne and Thibodeau, 1983]. Ball [1973] provides a comprehensive review of early housing studies based on the hedonic regression technique, while Quigley [1979] discusses a number of issues associated with the application of the technique to the case of housing markets.

1. Hedonic Price Equations^{16/}

The hedonic framework views the price of a heterogeneous commodity as a vector of the "implicit" or "shadow" prices of its utility-bearing attributes or characteristics. These prices are determined through the interaction of the consumers' value functions and the producers' offer curves. Alternatively, the market price of hedonic goods is determined by the interplay between the demand and supply schedules of its characteristics [Rosen, 1974].^{17/}

Given, the so called identification problem, the relationship between market price and hedonic attributes is econometrically stated as the reduced form:

$$P(z) = P'z, \quad (\text{VII.1})$$

where $P(z)$ is the price of the commodity, z a vector of its utility-bearing attributes, and P' a vector of the implicit, "shadow", or hedonic prices of these attributes, which are thought to contribute toward its price.

Two methodological issues are involved in specifying such a reduced form equation. The first is which hedonic attributes or other explanatory variables to include in the hedonic model. Ideally, a well-specified model

^{16/} Early contributions to the Hedonic technique were first made by Court [1939] and later Griliches [1971], who introduced techniques of hedonic price analysis, in which the valuations of various components can be implicitly determined through standard regression techniques. Despite such early contributions to the hedonic technique, the clear theoretical justification for at least the basic principles underlying the procedure were set out by Rosen [1974] in his analysis of hedonic goods.

^{17/} First made by Rosen, such a statement illustrates the similarities between hedonic analysis and the economics of spatial equilibrium and equalizing differences.

should include all hedonic characteristics of the property and should control for the whole array of other factors that may influence price. The former (hedonic attributes) involve the characteristics and quality of the unit, the quality and characteristics of the building the unit is located, and the characteristics of the lot the space is built on. The physical characteristics of units/buildings are numerous; they include age, architectural style, specific architectural features, quality, size in terms of square footage, and height. Location characteristics include neighborhood composition, neighborhood quality and amenities, access to the central business district, access to other service clusters in the area, access to major highways, public transportation stations, airports, or white collar labor pools. These and similar attributes are quite often considered in existing hedonic studies.

Depending on the exact definition of the model's dependent variable and its time reference, a number of other explanatory variables may need to be included in the hedonic regression. The hedonic modeling of market leases, for example [Brennan et. al. 1984], in addition to property attributes, would require the inclusion of such terms of the lease, as length, time initiated, and the presence of "stops" or "escalation clauses". The modeling of asking rents, on the other hand, would possibly require the inclusion of the time the unit remained in the market unrented, or the landlords' expected returns [Stull, 1978]. However, as it is always the case, the choice of the variables to use in a hedonic model is always constrained by the data available.

The second methodological issue involved in hedonic analysis is what functional form the hedonic model must assume. The Hedonic theory does not provide any basis for the a priori determination of the functional form, simply because hedonic equations reflect both supply and demand factors.

As a result, the functional form of hedonic regressions has been conjectural in treatment. Clapp [1983], for example, used a semilogarithmic form, arguing that such a form is convenient when continuous distance variables are involved. This form allows prices to change exponentially, rather than linearly with distance. Wheaton [1984], on the other hand, used a linear form. Linear functions are often considered as quite convenient. Their coefficients are directly interpreted as "shadow" prices and thought of as quite suitable in the estimation of demand elasticities [Lancaster, 1971]. The implicit assumption, however, embedded in linear hedonic specifications is that the marginal utilities associated with each attribute are constant, an assumption which runs against the "principle" of satiation.

Recently, it has been suggested that the Box-Cox transformation be used to evaluate the fit of alternative model specifications.^{18/} In their hedonic analysis of office space rents, Hough and Kratz [1983] experimented with a linear, a semilogarithmic, a loglinear, and a logarithmic model. Based on Box-Cox tests, they concluded that the linear and semilogarithmic model performed better than the other functional forms. Likewise, Brennan, Cannaday, and Colwell [1984] experimented with linear, logarithmic, semilogarithmic, loglinear, and reciprocal functional forms. Based on a series of Box-Cox/Box-Tidwell transformations and likelihood ratio tests, they concluded that their loglinear and semilogarithmic models were superior to other forms. These findings tend to support contentions by other analysts that the Box-Cox technique tends to reject linear forms in favor of multiplicative ones [Goodman, 1978].

^{18/} For details see Box and Cox [1964]; Box and Tidwell [1962]; Kowalski and Colwell [1986]. Bartik and Smith [1987] provide a good review of the problems associated with the use of the procedure.

2. The Hedonic Model

In specifying, then, the hedonic model in this study, the independent variables to be included in the reduced form were selected, and the functional form of the model was specified.

2.1 The General Model, Variables, and Data

The hedonic models developed here utilize the Coldwell Banker data in Table VII-2 to develop quality-controlled rent estimates for each subcenter included in the sample. As already mentioned, these data include a low and a high range of asking rents, which set the basis for calculating the average asking rent at each location (the dependent variable in the hedonic model), a number of qualifying characteristics of the rent reported (gross, net of taxes, net of taxes and utilities, net of taxes and utilities and other operating costs), and a limited number of building attributes (the year each structure was built, its size, and its height).

Although these data are also segmented by city or area location, the number of observations at certain cities or areas (i.e., Pomona/La Verne, Westlake Village) is too small to warrant the estimation of hedonic equations at each of them. Thus hedonic equations by submarket, including locational dummies for commercial nodes (cities or areas) within each of these submarkets, were finally considered. These were of the general form of:

$$R = f(X_1, X_2, \dots, X_n, SUB_1, SUB_2, \dots, SUB_m, INT_1, INT_2, \dots, INT_n, D_1, D_2, \dots, D_p)$$

(VII.2)

where:

R	: average building gross rents per square foot;
X ₁ , X ₂ , X ₃ ,...	: building attributes;
SUB ₁ , SUB ₂ ,...	: locational dummies denoting subcenter location;
INT ₁ , INT ₂ ,...	: interactive terms between building attributes and locational dummies.
D ₁ , D ₂ , D ₃ , D ₄	: qualifying characteristics of the rent reported.

In particular:

X ₁ =Year	: year the structure was built;
X ₂ =Height	: number of floors;
X ₃ =Areaf1	: total floor area/# of floors;
D ₁ =Gross	: a dummy variable {1,0}; gross=1 denotes buildings for which a gross rent is reported;
D ₂ =Netax	: a dummy variable {1,0}; netax=1 denotes buildings for which the reported rent is net of taxes;
D ₃ =Unknown	: a dummy variable {1,0}; Unknown=1 denotes buildings for which the type of rent was not reported; ^{19/}
D ₄ =Range	: a dummy variable {1,0}; range=1 denotes buildings for which a "low" as well as a "high" rent is reported. ^{20/}

Variable Effects

The Year variable may capture at least two effects: the effect of newer and possibly more energy efficient buildings on asking rents and the effect of older, historic buildings. With the former effect likely to prevail, a significantly different from zero, positive Year coefficient is expected.

The Height variable is included to capture the rent premium that higher buildings may command. Naturally, then, a significantly different from zero, positive coefficient is expected.

^{19/} There are a number of buildings for which it is not specified whether the reported rent is gross, net of taxes, or net of taxes, utilities, and operating expenses. Instead of arbitrarily classifying the reported rents as gross, or net, or excluding them altogether from the sample, it was thought of as more suitable to represent them by this dummy variable.

^{20/} Whenever appropriate, an interaction term between Range and Height was also included in the hedonic model.

The Areafl (floor area per floor) variable was used in place of total floor area, simply because the latter is to some extent collinear with Height. Along with Year, Areafl is considered as a measure of the building's responsiveness to the tenant's needs. As such, the Areafl variable reflects the effect of contiguous space, which may be thought of as an advantage to those firms that may want to expand at some point in the future. A significantly different from zero, positive coefficient for Areafl is thus expected.

The Gross, Netax, and Range dummies reflect identity effects. These were included to capture the difference that the type of rent reported makes. With the effect of reporting asking rents net of taxes, utilities, and operating expenses reflected in the intercept of the regression equation, Gross and Netax are both expected to have a significantly different from zero, positive coefficient. When included alone, Range is expected to produce a positive effect. When interacted with Height, however, its effect is expected to be larger. In other terms, the higher the number of floors in the building, the greater the divergence between the low rent and the average rent estimates.

Data Deficiencies

The regression model above is not without problems. First and foremost, asking rents are not the result of actual market transactions. As such, these may not represent market equilibrium rents, but just the landlords' perception of what their space is worth on the current market. It would, therefore, be much preferable to use contract rent data (controlled for the time the lease was signed, the lease concessions made, escalation clauses, workletters, etc.) in place of asking rents, but Coldwell Banker's contract

rent database for Greater Los Angeles is less extensive, more noisy, and less detailed than the one used in this study.^{21/}

Second, factors that may affect variations across buildings in average asking rents have not been incorporated into the model. Asking rents may vary considerably with such factors, as the time the commercial space has been in the market unrented, as well as the landlord's expected returns. Notably, factors that affect asking rents have not yet thoroughly been investigated by the empirical literature. Stull [1978] poses a number of interesting questions the answers to which would suggest a set of appropriate independent variables to be included in such a hedonic model. Do landlords have a fallback strategy? Do they customarily begin their search for a tenant by asking a high rent, which they gradually lower over time? Do they consider the trade off between expected return and expected "waiting" time?

Third, the quality of the structure and its immediate surroundings is missing from the data. Variables such as the architectural quality of the structure [Hough and Kratz, 1983], internal amenities, such as lobbies and elevators, external amenities, such as parking, the "character" of surrounding buildings or, in general, the quality of their neighborhood, simply, were not available [Brennan et. al., 1984].

Fourth, the hedonic regressions above ignore differences in asking gross rents attributable to differences in micro-location factors. The latter may include distance to freeways, distance to public transport stations, distance to other public amenities, proximity to retailing establishments, or access by higher income clients.

^{21/} In Schmenner's [1981] study on intrametropolitan industrial rents, for example, the omission of data on lease terms might have been responsible for the poor results obtained.

Finally, the hedonic regression does not control for differences in tenant characteristics. As such, the estimated price function is an average market price function, which, by definition, does not especially refer to a specific consumer group.

2.2 Functional Form(s)

The hedonic regressions estimated here are presented in (VII.3). These were of a linear (linear in the dependent variable and the characteristics) and a semilogarithmic (linear in the dependent variable and log in the characteristics) form. Box-Cox transformations were not done, but the R^2 and standard errors of the linear and semilogarithmic equations can directly be compared in this case to indicate the model with the best fit.

$$R = a_1 + b_1 X_1 + b_2 X_2 + \dots b_n X_n + c_1 SUB_1 + c_2 SUB_2 + \dots c_m SUB_m + d_1 D_1 + d_2 D_2 + \dots d_n D_n$$

$$e^R = a_1 + b_1 X_1 + b_2 X_2 + \dots b_n X_n + c_1 SUB_1 + c_2 SUB_2 + \dots c_m SUB_m + d_1 D_1 + d_2 D_2 + \dots d_n D_n$$

(VII.3)

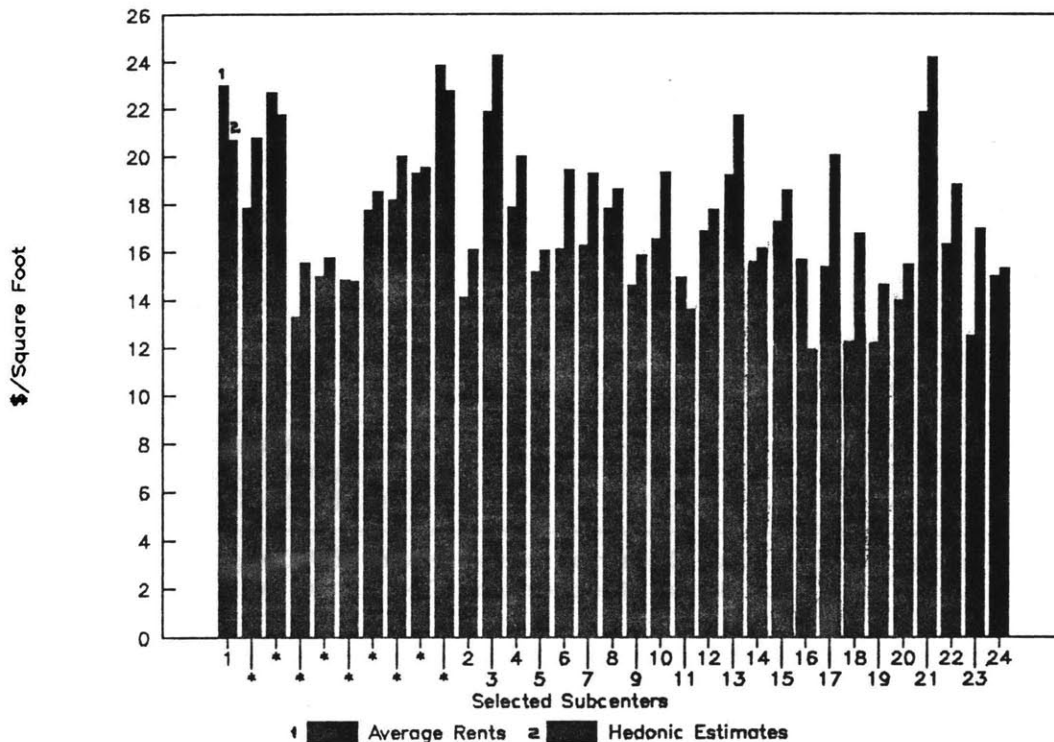
2.3 Estimation Results

Given the data deficiencies, the estimation results of the semilogarithmic equation (see Appendix III) are quite satisfactory and marginally better than those of the linear equation. The explanatory variables have by and large the expected sign, and in most submarkets variations in such factors as those considered helped explain well over 50% of the variation in average gross rents. In some of these submarkets (i.e., Hollywood, San Gabriel Valley, West Los Angeles, North and Central Orange County) the unexplained variance is relatively small, but in a few other (i.e., Wilshire District, Riverside, Ventura) this is quite significant. Although definitely not a

rule, it seems that the hedonic model works better in smaller and possibly more homogeneous markets, where differences in location and quality may be less discernible.

Given the estimated coefficients of the semilogarithmic equations, the "effective" average gross rents for a 7-story, 10-year old building, of 19,602 square feet per floor, with both a low and a high rental rate reported have been computed. Figure VII-1 and Table VII-1 present the estimated "effective" subcenter rents and provide for their comparison with the average existing rents in these centers.

Figure VII-1^{22/}
Greater Los Angeles:
Effective Vs "Average" Subcenter Rents



^{22/} The asterisks in Figure VII-1 signify subcenters within the city of Los Angeles. These are presented in the same order they appear on Table VI-3 and Table VII-1.

Table VII-1
Greater Los Angeles:
Commercial Space Rent Estimates

Cities/ Subcenters	Average Rents (\$/sqft)	Hedonic Rents (\$/sqft)*'
1. Los Angeles City		
* Los Angeles Downtown	\$22.95	\$20.67
* Canoga Park	17.81	20.77
* Century City	22.68	21.74
* Hollywood	13.28	15.53
* LAX (LA Airport)	14.95	15.74
* Mid Wilshire	14.80	14.74
* Park Mile/Miracle Mile	17.74	18.51
* Van Nuys/Encino	18.14	19.99
* Venice	19.25	19.52
* Westwood	23.81	22.73
2. Anaheim	14.08	16.08
3. Beverly Hills	21.86	24.24
4. Burbank	17.86	19.99
5. Costa Mesa	15.14	16.04
6. Covina/Glendora	16.09	19.41
7. Culver City	16.24	19.25
8. Glendale	17.79	18.61
9. Huntington Beach	14.58	15.83
10. Irvine	16.50	19.28
11. La Brea/La Habra	14.88	13.54
12. Long Beach	16.83	17.73
13. Newport Beach	19.16	21.67
14. Orange	15.46	16.05
15. Pasadena	17.21	18.53
16. Pomona/La Verne	15.61	11.70
17. Rancho Cucamonga	15.31	20.01
18. Riverside	12.12	16.72
19. San Bernardino	12.02	14.61
20. Santa Ana	13.93	15.44
21. Santa Monica	21.81	24.14
22. Torrance	16.26	18.76
23. Ventura/Ojai	12.45	16.94
24. Westlake Village	14.94	15.30

*' Average 1989 gross rents for a 10 year old, seven-story building of 19,602 square feet per floor.

Notably, "effective" rents give a somewhat different picture than that the average subcenter rents reflect. As already mentioned, the diversity between average and effective rents is solely attributable to the different "mix" of commercial buildings in the various centers considered in the empirical study.

As Figure VII-1 and Table VII-1 also show, there are wide differences in the "effective" rental price of office space across centers in the greater Los Angeles area. These range from a low of \$11.70 in Pomona/La Verne to a high of \$24.24 per square foot in Beverly Hills. Buildings in the Los Angeles downtown command an effective rent of \$20.67, which is notably lower than other subcenters in the Los Angeles city, such as Westwood (\$22.73) or Century City (\$21.74), and other cities included in the sample, such as Santa Monica (\$24.14).

Since differences in building characteristics across centers are presumably controlled for by the hedonic estimates, any differences in effective rents must be accounted for by differences in those centers' locational attributes. This notion is further explored in Chapter VIII, which follows.

Chapter VIII.

ANALYZING THE PATTERN OF "EFFECTIVE" RENTS

In this chapter, the hedonic estimates presented in Table VII-1 are utilized to test some of the implications of the theory developed in the first part of this dissertation and, at the same time, provide an explanation for the observed differences in these rents across centers.

Given the subcenters' "effective" rent estimates, data on housing rents and/or housing prices, as well as data on locational advantages and development restrictions across the 33 selected centers in the Los Angeles-Long Beach-Anaheim SCSA, two empirical tests are made possible:

[1]. A simple, preliminary test for the presence of binding development constraints in the greater Los Angeles area. This examines the extent to which locational advantages and/or housing prices (rents) alone explain differences in space rents across centers.

[2]. A direct test of the role that local development restrictions play in the amenity capitalization process. This involves the testing of those theoretical propositions suggesting that in the presence of binding development controls space rents begin capturing more locational value; the examination of the sign and magnitude of marginal amenity effects; and the exploration of the extent to which, together, locational advantages and development constraints can better explain intercenter differences in floor space rents.

1. Testing for the Presence of Development Constraints

Building on Model I's analysis of the competitive land market, the first test requires the testing of the null hypothesis that the commercial land

market in Greater Los Angeles is competitive. In such a market, intercenter variations in commercial space rents must be explained by intercenter variations in residential land prices. Alternatively, variations across centers in commercial space rents must be explained by variations across centers in locational advantages. At the same time, however, differences in residential land markets between centers must be accounted for. This suggests a role for both residential land prices and locational advantages in the statistical model, despite the risk of running into multicollinearity problems. The test of the competitive market assumption, then, requires the estimation of the alternative, general models in (VIII.1) below:

$$\begin{array}{ll} [1] & R = f(RPrice) \\ [2] & R = f(C_A) \\ [3] & R = f(C_A, RPrice) \end{array} \quad (VIII.1)$$

where:

RPrice: residential land prices (or proxies for land values)
 C_A : a vector of spatial amenities

The specific null hypothesis underlying the reduced form [1] is that intercenter differences in space rents are *solely* attributable to differences in residential land prices between centers. The null hypothesis underlying statistical equation [2] is that intercenter differences in commercial space rents can *solely* be explained by differences in locational advantages between centers. Statistical equation [3] combines features from both equation [1] and equation [2]; the inclusion of residential values, in addition to spatial amenities, is exactly intended to control for differences in residential land markets between centers. In particular, differences in residential land values are considered to be a summary measure for any advantage differences that may exist between residential markets (i.e., differences in the quality

of public services or differences in the level of property tax rates). In addition, this variable controls for additional firm benefits associated with higher residential values, such as better environment or access to higher income clientele, from the consumption side of the commercial real estate market.^{23/}

1.1 The Variables and Data

The data required for and the variable proxies used in the estimation of these models are discussed below. The final variables selected for inclusion in the econometric models are listed in Table VIII-1.

1]. *Residential Land Values.* Directly suggested by the theoretical analysis of the competitive city in Part 1, this variable is crucial to the testing of the competitive market assumption. Yet, consistent and reliable information by city on the price of residential land bordering commercial development does not exist.

In the absence, then, of such information, it must necessarily be assumed that residential land prices can reasonably be proxied by median housing values or median contract apartment rents, which are more readily available. Variations in binding residential densities may make this assumption less appealing, but, on the other hand, the nature of the median estimates may alleviate to some extent this problem.^{24/}

^{23/} Residential land values may also, to some extent, be a proxy for the areas' redevelopment potential. Higher residential land prices may minimize the potential for redevelopment, often taking place in central and older residential sections of central cities. However, such an interpretation is more relevant in the case noncompetitive markets are assumed. Different redevelopment potential in these markets may affect the degree to which zoning limits bind.

^{24/} A hedonic representation of housing values would be much more preferable. Census data, however, are insufficient, and reliable data on an array of housing attributes could not readily be made available from other sources.

Table VIII-1
Empirical Data: Definition of Variables

Variable Name	Variable Type	Source	Description
R	Numeric	Estimates based on Coldwell Banker Data	"Effective" subcenter rents, 1989
RRent	Numeric	1980 Census	Median contract rents
RValue	Numeric	1980 Census	Median housing values
Educ1	Numeric	1980 Census	% of persons 16 years old or older that attended 12 years of schooling or more
Capital	Numeric	County and City Databook 1988	Capital expenditure of local governments per capita 1984-1985
Access	Numeric	Maps	# of hwys passing through the community & # of airports

The only source of readily available data on housing values or apartment rents by city is the 1980 Census of Population and Housing [Chambers of Commerce, 1980]. This provides direct information for each of the 23 cities and indirect information by census tract for the remaining areas included in the sample. Given Coldwell Banker's geographic definition of the 10 subcenters within the city of Los Angeles, their corresponding census tracts were identified and median subcenter housing values and apartment rents were computed for each.

There are relative advantages and disadvantages in using housing values or apartment rents as proxies for residential land prices. The advantage of using housing values rather than apartment rents is that the former may be a better proxy for the value of residential land than the latter, which may also reflect the effect of rent controls, which are prevalent in some of the cities included in the sample. The advantage, however, of using the latter lies in the fact that apartment units more directly compete for urban land with the commercial sector than single family units. Usually, more intensive uses, such as multifamily housing, are found in central parts of the city, where commercial development is located, while less intensive uses, such as single family housing, are located in more remote suburban areas.

Often made in cross-sectional studies, the implicit assumption in using 1980 in place of 1989 prices is that relative housing prices and apartment rents across centers have not significantly changed since 1980. The assumption may not be unreasonable, provided that the relative demographics and locational attributes across cities have not significantly changed over this time period.

2]. *Locational Advantages.* As far as the advantage variables are concerned, the theory does not explicitly specify which are the variables that affect the firms' production costs and therefore the firm advantages that

different urban locations offer. Consequently, the identification of these variables involves considerable experimentation with the data and a review of the findings of past empirical studies.

Effective tax rates is, perhaps, the most widely discussed--and, at the same time, the most controversial--variable examined in past empirical studies of nonresidential location and pricing [Erickson and Wasylenko, 1980; Wheaton, 1984]. Unfortunately, however, it is unlikely that nontrivial tax rate variations across the 33 communities included in the sample exist.

Proposition 13 in California has specified a maximum statutory rate of 0.5% of assessed value, which most of communities in the state use. In the absence, then, of interjurisdictional variations in tax rates, it seems unwarranted to consider this variable.

Within this context, a number of other advantage variables, which are expected to have a positive effect on commercial space rents, were considered and tested in preliminary regressions. The ones that were finally utilized in the statistical models are discussed below.^{25/}

^{25/} Besides the variables discussed here, a number of additional variables were initially considered, but finally excluded from the equations because of their poor performance across all alternative model specifications discussed in this and the following section. These were the following:

Educ2: # of persons 16 years old or older, who attended 16 or more years of schooling [Census of Population, 1980]. It was used as a proxy for the concentration of white collar labor. Because of its strong correlation with Educ1, it was used in place, and not in addition to this variable. In the case of subcenters within the city of Los Angeles, the city average was used.

Distancel: Distance from the Los Angeles downtown. This was measured along major highways connecting the various subcenters with the Los Angeles downtown. The assumption underlying its use is that the concentration of banking and finance establishments in the Los Angeles downtown must provide for cost advantages and, hence, exert a major centralizing pull on office-commercial activities in the greater Los Angeles area. This is consistent with the contact hypothesis discussed by Clapp [1980] and Tauchen and White [1980].

Distance2: Distance from nearest urban concentrations. For subcenters in Los Angeles and Ventura county, Los Angeles downtown was considered to be the center of attraction. For subcenters in Orange county, distances were measured from Anaheim. For subcenters in Riverside and San Bernardino county, distances from Riverside were considered. Again, this variable was intended to be used in place of, rather than in addition to, Distancel.

Educl: # of persons 16 years old or older, who attended 12 years of schooling or more [Census of Population 1980]. The variable is a proxy for the concentration of white collar labor, which a number of past empirical studies have found to play a crucial role in the location of business and nonresidential pricing patterns [i.e., Archer, 1983; Wheaton, 1984].

In the case of subcenters within the city of Los Angeles, the city average was used. The use of city averages instead of localized data within the city of Los Angeles seems more reasonable, because of the large size of these subcenters, their spatial proximity, and, consequently, the small likelihood that localized labor markets within the city itself exist.

Access: the # of highways passing through the communities plus the number of existing airports in these communities, both taken from area transportation maps. The availability of a diverse highway network and airports facilitates the movements of employees and, as such, provides significant advantages to urban firms. Notably, the availability of airports, a factor which has not often been considered in empirical studies, may be critically important for many businesses--especially those related to the entertainment industry and those involving activities that are often being conducted outside the subcenters. This composite variable is the basic accessibility measure examined in this study.

Capital: the local government capital expenses per capita, 1984-1985 [County and City Databook, 1988]. This variable may reflect the scale and, to a certain extent, the quality of urban infrastructure. As such, it may capture the effect of differences in the efficiency of transport network across the area's various centers.

1.2 Statistical Models

Given the data just described, the following simple linear regressions were estimated:

$$\begin{aligned} [1.1] \quad R &= b_0 + b_1 \text{RRent} \\ [1.2] \quad R &= b_0 + b_1 \text{RValue} \end{aligned}$$

$$[2.1] \quad R = b_0 + b_1 \text{Educ1} + b_2 \text{Access} + b_3 \text{Capital}$$

$$\begin{aligned} [3.1] \quad R &= b_0 + b_1 \text{RRent} + b_2 \text{Educ1} + b_3 \text{Access} + b_4 \text{Capital} \\ [3.2] \quad R &= b_0 + b_1 \text{RValue} + b_2 \text{Educ1} + b_3 \text{Access} + b_4 \text{Capital} \end{aligned}$$

(VIII.2)

1.3 Estimation Results

The results of the statistical estimation of the simple regression models in (VIII.2) are displayed in Table VIII-2. Notably, the five models perform very poorly. In Models [1.1] and [1.2], the coefficients of the housing value (RValue) and housing rent (RRent) variables have the correct sign and are statistically significant, but the unexplained variance in both models is quite large. Evidently, RValue performs better than RRent, possibly because of external constraints, in the form of rent controls, imposed on the latter.

Model [2.1], regressing space rents solely on the set of advantage variables, exhibited a very poor fit. In Model [3.1], which, in addition to the advantage variables, includes housing rents, the effects of neither the housing rent nor the advantage variables (with the exception of capital) are statistically different from zero at the 95% level of confidence. This may, to a certain extent, be due to a collinearity problem between the model's independent variables. The explanatory power of Model [3.2] is stronger than

Table VIII-2
Regression Results: Testing for the Presence of Development Constraints
Dependent Variable: 1988 Annual Average Asking Rent per square foot

	Statistical Models				
	1.1	1.2	2.1	3.1	3.2
Independent Variables: ^{a/}					
Constant	13.15*** (+5.64)	13.50*** (+10.15)	12.60*** (+2.85)	12.74*** (+2.91)	11.37*** (+3.10)
RRent	0.016** (+2.20)	-	-	1.39E-2 (+1.29)	-
RValue	-	4.94E-5*** (+3.71)	-	-	4.91E-5*** (+3.82)
Educl	-	-	5.62E-2 (+0.97)	-4.29E-2 (-5.81E-2)	-1.86E-2 (-0.36)
Access	-	-	0.11 (+0.35)	0.30 (+0.85)	0.76** (+2.40)
Capital	-	-	7.56E-3** (+2.34)	6.33E-3* (+1.89)	4.64E-3 (+1.67)
N	33	33	33	33	33
R ²	0.14	0.31	0.21	0.25	0.48
R ² -adjusted	0.10	0.29	0.13	0.15	0.41
Standard Error of Regression	2.83	2.53	18.17	2.76	2.30

^{a/} The numbers in parentheses below the coefficients are t-statistics. One, two, and three asterisks next to the regression coefficients denote statistical significance at the 90%, 95%, and 99% level of confidence, respectively.

the explanatory power of other models, but it again seems that Educ1 and RValue are to some extent collinear. By looking across rows in Table VIII-2 it also becomes evident that the sign and the magnitude of the Educ1 coefficient is quite sensitive to the specification of the model. In the absence of RRvalue and RRent, the variable has the correct sign; on the contrary, in the presence of these variables, Educ1 has the wrong sign.

The estimated statistics and the poor fit of these simple regression models suggest that neither housing prices nor locational advantages (at least those considered here), together or alone, can explain to a satisfactory degree differences in commercial rents across centers. The null hypothesis that the commercial land market in Greater Los Angeles is competitive must then be rejected in favor of the alternative one, which invalidates this competitive market assumption. In the face, then, of a noncompetitive market, and in the absence of variables to control for the supply side of this market, the hedonic models above may be misspecified and their estimation results misleading. Consequently, it would be premature to conclude that spatial amenities such as those considered are not capitalized to some extent by floor space rents. It remains, therefore, to be seen whether the inclusion of spatial variations in land supply characteristics and development densities significantly improves the explanatory power of the hedonic model.

2. Testing the Capitalization Hypothesis

Suggesting that binding development controls may be present in Greater Los Angeles, the simple tests just discussed have set the stage for the second test of this study. Presenting a direct test of the capitalization propositions developed in the theoretical part, this attempts to test the general null hypothesis that development restrictions do not play a role in

influencing the capitalization process and, eventually, in determining the magnitude of spatial variations in commercial pricing. Building on the analysis of the noncompetitive cities (Models II, III, and IV), the simple regression models in [1]-[3] above have thus been expanded to include measures of local development controls:

$$[4] \quad R = f(C_A, \text{Cons})$$

$$[5] \quad R = f(C_A, \text{RRent}, \text{Cons})$$

$$[6] \quad R = f(C_A, \text{RValue}, \text{Cons})$$

(VIII.3)

where:

C_A : a vector of spatial amenities
 RRent : median contract rents, 1980
 RValue : median housing values, 1980
 Cons : a vector of land supply characteristics

The data used for the estimation of these models, as well as the alternative functional forms that these models assume are discussed below.

2.1 The Variables and Data

The advantage, as well as the housing value and apartment rent variables have already been described when discussing the first test of this study. The data collected on three types of development controls--zoning restrictions, density regulations, and growth moratoria--are described in Table VIII-3 and briefly discussed below.^{26/}

1]. *Zoning restrictions.* These refer to measures of land availability. Such measures were collected from the commercial sections of the various

^{26/} Only the variables that have been used in the final regression equations are described here. Additional data collected, but not finally used, included FAR limits.

Table VIII-3
Development Restrictions: Definition of Variables

Variable Name	Variable Type	Source ^{a/}	Description
Land1	Dummy	Planning, Redevelopment, Departments, CB	Land1=1 denotes communities that are severely constrained with respect to their commercial land
Land2	Dummy	Planning, Redevelopment, Departments, CB	Land2=1 denotes communities that are moderately constrained with respect to their commercial land
Height	Numeric	Zoning Ordinances, Zoning Maps	Average height limits imposed on office-commercial developments
HRestr	Dummy	Zoning Ordinances, Zoning Maps	HRestr=1 denotes communities that impose height restrictions on commercial development
Growth	Dummy	Planning, Redevelopment, Departments, CB	Growth=1 denotes communities that are land constrained and at the same time impose growth moratoria on commercial development

^{a/} CB: Coldwell Banker

planning and redevelopment departments of the cities included in the sample and from the local offices of Coldwell Banker's commercial division. Mostly, the data obtained were in the form of vacant land zoned commercial as a percentage of the total commercial land in the area or in the form of precise acreage figures. The former were often given in terms of a range, while the latter were available for only half of the communities included in the sample.

For this reason, the percentage estimates obtained were subsequently used to construct dummy variables in place of a single continuous variable for the availability of vacant land zoned commercial. The two dummies--Land1 and Land2--denote the areas which are considered to be severely and moderately constrained with respect to their commercial land, respectively. The default dummy denotes the remaining communities, that is, those which are not being confronted with land scarcity problems. Anecdotal evidence presented in various Urban Land Institute publications [ULI, 1986-1989] tends to support this classification.

2]. *Density regulations.* These refer to the height limits that local governments impose on commercial development. They were taken from the zoning ordinances of the communities included in the sample. Often, the average or most prevalent limit was considered as the most representative of each community or subcenter included in the sample. Only those limits applied to business districts or to areas designated as office-commercial were considered.

3]. *Growth moratoria.* These refer to regulatory actions enacted by communities desiring to limit the amount of commercial space to be built per year. They were taken from zoning ordinances. Temporary or short-term growth controls, which are slated to last less than a year, or conditional moratoria, which have not yet been enacted, were not considered. Notably, the few

communities with persistent growth control measures are, at the same time, confronted with severe land scarcity problems.

2.2 Statistical Models

Given the amenity data and the restriction variables just described, three sets of alternative statistical model specifications have been developed. As already mentioned, the models in (VIII.4) explore the null hypothesis that land constraints do not play a strong role in the capitalization process. If this is the case, the inclusion of supply variables must not significantly improve the explanatory power of the model, and the regression coefficients of these variables must be statistically insignificant.

$$\begin{aligned}
 [4] \quad & R = a_0 + b_1 C_{A1} + \dots + b_m C_{Am} + c_1 \text{Cons}_1 + \dots + c_n \text{Cons}_n \\
 & R = a_0 + a_1 \text{RRent} + b_1 C_{A1} + \dots + b_m C_{Am} + c_1 \text{Cons}_1 + \dots + c_n \text{Cons}_n \\
 & R = a_0 + a_1 \text{RValue} + b_1 C_{A1} + \dots + b_m C_{Am} + c_1 \text{Cons}_1 + \dots + c_n \text{Cons}_n
 \end{aligned}$$

$$\begin{aligned}
 [5] \quad & R = a_0 + \text{WAdv}(b_0 + b_1 \text{Cons}_1 + \dots + b_n \text{Cons}_n) \\
 & R = a_0 + a_1 \text{RRent} + \text{WAdv}(b_0 + b_1 \text{Cons}_1 + \dots + b_n \text{Cons}_n) \\
 & R = a_0 + a_1 \text{RValue} + \text{WAdv}(b_0 + b_1 \text{Cons}_1 + \dots + b_n \text{Cons}_n)
 \end{aligned}$$

$$\begin{aligned}
 [6] \quad & R = (b_0 + C_{A1} + b_2 C_{A2} + \dots + b_m C_{Am}) * (c_0 + c_1 \text{Cons}_1 + \dots + c_n \text{Cons}_n) \\
 & R = a_1 \text{RRent} + (b_0 + b_1 C_{A1} + b_2 C_{A2} + \dots + b_m C_{Am}) * (c_0 + c_1 \text{Cons}_1 + \dots + c_n \text{Cons}_n) \\
 & R = a_1 \text{RValue} + (b_0 + b_1 C_{A1} + b_2 C_{A2} + \dots + b_m C_{Am}) * (c_0 + c_1 \text{Cons}_1 + \dots + c_n \text{Cons}_n)
 \end{aligned}$$

(VIII.4)

where:

C_{A1}, \dots, C_{Am} : a set of advantage variables
 $\text{Cons}_1, \dots, \text{Cons}_n$: a set of variables representing development constraints

In particular:

CA_1 : Educ1
 CA_2 : Access
 CA_3 : Capital
WAdv : Weighted Advantage Index, calculated on the basis of the linear models in [4] above.
 $Cons_1$: Land1: A dummy variable {1,0}; Land1=1 denotes communities which are severely constrained with respect to their commercial land;
 $Cons_2$: Land2: A dummy variable {1,0}; Land1=1 denotes communities which are very/moderately constrained with respect to their commercial land;
 $Cons_3$: Restr: A dummy variable {1,0}; Restr=1 denotes communities that impose height limits on commercial buildings;
 $Cons_4$: HRestr: H*Restr; where H: Height limits (in feet)
 $Cons_5$: Gro: A dummy variable {1,0}; Gro=1 denotes communities that restrict the amount of office-commercial space to be built per year.

The first set of alternative models in [4] simply build on the reduced forms in [1]-[3] to explore the specific null hypothesis that in the light of development restrictions, rents do not absorb more locational value. While, then, maintaining the housing value/rent and advantage variables, the models enter, also linearly, a number of land supply characteristics--Land1, Land2, Hrestr, Restr, Gro--, which are expected to be statistically significant and, as such, notably improve the explanatory power of the hedonic model. If this is the case, the null hypothesis can be invalidated, and it can be concluded that, in the face of institutional restrictions on the operation of the commercial land market, space rents do in fact absorb more locational value.

By definition, the linear forms in [4] discard any interaction that may take place between spatial amenities and development restrictions. As such, they cannot be used to analyze the strength of the marginal amenity effects on space rents. To detect such effects, the regression model has to be expanded to include interaction terms between each advantage and each constraint variable. This would, however, add an excessive number of independent variables to the model, which would, in turn, significantly limit the

equation's degrees of freedom and, ultimately, the reliability of the estimation results. To circumvent this problem, the statistical results in [4] were utilized to develop weighted advantage indices (WAdv). Interacting these with all constraint variables in [5] can help reject the specific null hypothesis that, in the presence of development restrictions, spatial amenities do not have a stronger marginal impact on space rents. However, the estimation of weighted indices from the linear equations in [4] (which exclude interaction effects) and the exclusion of the five individual constraint variables from [5] (due to the limited number of observations) present two notable weaknesses of these models.

By employing a multiplicative, nonlinear functional form, the statistical models in [6] circumvent the problems associated with the use of advantage indices and the problems associated with the exclusion of the "individual" effect of development restrictions. Yet, the biggest, perhaps, advantage of this nonlinear specification is that it allows for the interaction of each advantage variable with each constraint variable, without adding an excessive number of parameters to be estimated. Given the limited number of observations in the sample, this presents, perhaps, the most critical advantage of the model. Notably, given the overidentified nature of the equation, for the algorithm to properly converge to a solution, the coefficient of one of the model's independent variables must be set exogenously.

2.3 Estimation Results

The estimation results are displayed in Table VIII-4, Table VIII-5, and Table VIII-6. Evidently, the coefficients of all variables representing spatial amenities and development restrictions are statistically significant,

and the goodness of fit of these regression models presents a significant improvement over the fit of the simple regression models already displayed in Table VIII-2.^{27/}

Looking at Table VIII-4, in particular, it becomes clear that in the presence of variables representing development constraints, spatial amenities acquire their expected sign and are of a statistically significant magnitude at high levels of confidence. This contrasts sharply with the models in Table VIII-2, where, in the absence of supply restriction variables, spatial amenities--Educl, Access, Capital--hardly displayed statistically significant coefficients. RRent, however, still behaves erratically, and although the RValue coefficient has the correct sign, this is only significant at the 80% level of confidence.

The effect of development constraints, on the other hand, appears to be quite strong, indicating that these must be binding. Evidently, the magnitude of the land restriction dummies is consistent with the definition of the variables (see Table VIII-3). All else being equal, space rents in severely constrained communities (Land1=1) are by \$4.18 higher than space rents in nonrestricted communities. Similarly, space rents in communities which are moderately constrained with respect to their commercial land (Land2=1) are higher by only \$2.17 than space rents in nonconstrained communities.

^{27/} The effect of FAR limits was also tested in preliminary regressions. Apparently, these are less widespread than height limits, as only 11 communities (which also have height limits) have such regulations in place. The effect, however, of FAR limits appeared to only be negligible and, hence, this variable was excluded from all regression models. A number of possible explanations can be advanced with respect to the weak effect of these limits on floor space rents. First, this may be due to the various variances and FAR bonuses that cities (i.e., West Hollywood) offer in exchange for the development of residential units in commercial complexes. Second, FAR limits may be less binding than height limits. Third, FAR limits may be less enforceable than height limits. Finally, FAR and height limits may be correlated to some extent; the only possible way that the two density measures should differ is through setback provisions. Yet, a simple correlation coefficient between the two variables in the 11 communities could not unequivocally substantiate this explanation.

Table VIII-4
Linear Regression Results¹: Testing the Capitalization Hypothesis
Dependent Variable: 1988 Annual Average Asking Rent per square foot

	Statistical Models		
	4.1	4.2	4.3
Independent Variables: ^{a/}			
Constant	10.29*** (+6.32)	10.29*** (+6.18)	10.39*** (+6.59)
RRent	-	-3.26E-4 (-7.92E-2)	-
RValue	-	-	9.82E-6 (+1.62)
Educ1	7.56E-2*** (+3.94)	7.71E-2*** (+2.81)	5.74E-2** (+2.65)
Capital	5.40E-3*** (+5.08)	5.44E-3*** (+4.67)	4.86E-3*** (+4.49)
Access	0.42*** (+3.86)	0.42*** (+3.45)	0.52*** (+4.27)
Land1	4.18*** (+10.17)	4.18*** (+9.80)	4.06*** (+10.03)
Land2	2.71*** (+6.04)	2.70*** (+5.65)	2.76*** (+6.34)
Hrestr	-5.27E-2*** (-5.84)	-5.28E-2*** (-5.67)	-5.11E-2*** (-5.80)
Restr	+1.35** (+2.77)	+1.36** (+2.70)	+1.33*** (+2.81)
Gro	4.47*** (+9.02)	4.49*** (+8.74)	3.92*** (+6.70)
N	33	33	33
R ²	0.93	0.93	0.94
R ² -adjusted	0.91	0.91	0.92
Standard Error	0.88	0.90	0.86

^{a/} See Table VIII-2.

Furthermore, communities without height restrictions ($\text{Restr}=0$) have lower rents than communities with such restrictions in place. As evident in the sign and magnitude of Restr and HRestr , the less binding these restrictions are (i.e., the lower the limits imposed), the smaller their positive effect on floor space rents.

Persistent growth control measures also appear to strongly affect commercial space rents. All else being equal, communities with such controls ($\text{Gro}=1$) appear to have significantly higher space rents than communities without such controls. Apparently, the effect of growth controls on space rents is somewhat stronger than the effect that land constraints have on these rents. This may be attributable to the fact that communities with growth moratoria also face severe shortages in their commercial land.

The statistical models in Table VIII-5, which test for interaction effects between development constraints and spatial amenities, also display promising results. Interestingly enough, both the RRent and RValue coefficients have the correct sign. Yet, in contrast to what was observed in the previous models, only the RRent coefficient is statistically significant at the commonly accepted confidence level of 95%. Notably, the weighted advantage index in these models has a strong positive effect, which, as hypothesized, also depends on how severe land constraints are, whether or not communities have height restrictions in place, and whether or not these communities have enacted growth control moratoria.

In particular, the effect of locational advantages on space rents is seemingly higher in communities which are severely constrained with respect to their commercial land than in those which are less constrained, stronger in communities which impose more stringent height limits than in those imposing less relaxed height limits, and stronger in communities which attempt to

Table VIII-5
Linear Regression Results2: Testing the Capitalization Hypothesis
Dependent Variable: 1988 Annual Average Asking Rent per square foot
t-statistics in ()

	Statistical Models		
	5.1	5.2	5.3
Independent Variables:*/			
Constant	10.72*** (+9.76)	10.65*** (+8.83)	10.91*** (+10.01)
RRent	-	6.18E-5* (+2.00)	-
RValue	-	-	7.53 (+1.51)
WAdv	0.99*** (+6.86)	0.98*** (+6.05)	1.02*** (+6.77)
WAdv*Land	10.54*** (+9.68)	0.53*** (+9.44)	0.64*** (+8.89)
WAdv*Land2	0.38*** (+5.89)	0.38*** (+5.67)	0.46*** (+5.97)
WAdv*HRestr	-8.30E-3*** (-6.00)	-8.16E-3*** (-5.84)	-9.94E-3*** (-5.90)
WAdv*Restr	0.22*** (+3.06)	0.22*** (+3.00)	0.27*** (+3.07)
WAdv*Gro	0.67*** (+8.89)	8.67*** (+8.15)	0.74*** (+7.28)
N	33	33	33
R ²	0.92	0.92	0.92
R ² -adjusted	0.90	0.90	0.90
Standard Error	0.94	0.96	0.94

*/ See Table VIII-2.

control commercial development within their boundaries through the enactment of growth control and building moratoria than in those they do not.

Lastly, the results of the nonlinear models displayed in Table VIII-6, which allow for interaction between each individual spatial amenity and development restrictions, lead to quite similar conclusions. All equation parameters, but those of R_{Rent} or R_{Value} , are statistically significant at commonly accepted levels of confidence. This simply suggests that the effect of all locational amenities are strongly dependent not only on the presence, but also the rigidity of development constraints.

The strong statistical significance of the interaction variables in these models provides credence to the assertion that in the presence of development controls the marginal effects of spatial amenities on space rents are stronger. This ultimately supports the conclusion that an interplay between a location's amenities and development restrictions *does* take place to ultimately determine its locational rent. The relative magnitude of effects is similar to those discussed above. Space rents in severely constrained communities, communities that have strict height limits, and communities that have growth moratoria in place absorb more locational value.

In comparing the R^2 s and standard errors of the three sets of models, it becomes apparent that the simple linear models in Table VIII-4 perform marginally better than the models with the interaction forms and those with a nonlinear specification. This does not have, however, to lead to the conclusion that spatial amenities do not closely interact with development restrictions. If this were true, the relevant parameters of the nonlinear model would not appear to be statistically significant, and the fit of the nonlinear regression models would not be as strong as it now appears to be.

Table VIII-6
Nonlinear Regression Results: Testing the Capitalization Hypothesis
Dependent Variable: 1988 Annual Average Asking Rent per square foot

	Statistical Models		
	6.1	6.2	6.3
Estimated Parameters: ^{a/} b/			
a ₁	-	0.11E-2 ^{c/} (+0.41)	0.94E-5 ^{d/} (+1.52)
b ₀	24.73*** (+3.75)	24.23*** (+2.99)	20.56*** (+3.37)
b ₁	0.16** (+2.60)	0.15** (+2.49)	0.10* (+1.86)
b ₃	0.01E-1*** (+3.14)	0.11E-1*** (+2.89)	0.87E-2*** (+2.91)
c ₀	0.44*** (+3.82)	0.44** (+3.77)	0.53*** (+4.17)
c ₁	0.10*** (+3.35)	0.11*** (+3.15)	0.13*** (+3.49)
c ₂	0.68E-1*** (+3.26)	0.71E-1*** (+3.04)	0.89E-1*** (+3.24)
c ₃	-0.14E-2*** (-3.40)	-0.14E-2*** (-3.21)	-0.17E-2*** (-3.47)
c ₄	0.36E-1** (+2.65)	0.38E-1** (+2.50)	0.46E-1** (+2.63)
c ₅	0.11*** (+3.17)	0.11*** (+3.11)	0.13*** (+3.52)
N	33	33	33
R ²	0.93	0.93	0.94
R ² -adjusted	0.91	0.91	0.91
Standard Error	0.90	0.92	0.88

^{a/} See Table VIII-2;

^{b/} The access coefficient, b₂, was exogenously set to 1;

^{c/} Coefficient of RRent;

^{d/} Coefficient of RValue.

Overall, then, the statistical results lead to the rejection of the general null hypothesis that development constraints do not play a strong role in amenity capitalization; dismiss the more specific null hypothesis that in the presence of development controls space rents absorb more locational value; and give some credence to the assertion that the marginal amenity effects are stronger in more restrained as opposed to less restrained communities. Taken together, the results provide a well-supported explanation for the observed differences in space rents across commercial nodes in Greater Los Angeles.

It is important to note that the estimated hedonic price models cannot be used to estimate the full valuation of urban amenities by commercial firms. As already mentioned and documented in the theoretical analysis, part of amenity values is also capitalized by wage differences between locations. The full value of urban amenities can only be given by the sum of space rent and wage differences (per worker). Again, wage equations could not be estimated here, simply because of the absence of reliable data on wages at the subcenter level.

Part 2's concluding section, which follows, provides a brief review of the empirical study, gathers together its major findings, and draws its overall conclusion.

PART 2:

SPACE RENT CAPITALIZATION IN GREATER LOS ANGELES

Suggesting that simple applications of the Hedonic theory to the commercial real estate market may be quite misleading, the theoretical study pointed directly to the deficiencies of existing empirical studies on intrametropolitan commercial pricing [i.e., Clapp, 1983; Wheaton, 1984]. Presenting simple hedonic representations of commercial space rents within urban markets, these studies have altogether ignored the supply side of the commercial land and real estate market and the way it influences amenity capitalization. Building, then, on the theoretical study and the deficiencies of prior empirical work, the present empirical study has tested for the presence of development restrictions and has thoroughly explored the role they play in the capitalization process.

1. The Methodological Approach

The principal hypothesis the study sought to empirically address is that development restrictions, if present, do in fact play a strong role in the capitalization process and, as such, help explain to a large extent intercenter differences in commercial space rents within metropolitan markets.

In the absence of wage data at the subcenter level, the empirical research was confined to the econometric analysis of space rent capitalization across 33 commercial subcenters in the greater Los Angeles area, 10 of them located within the city of Los Angeles. Selected solely on the basis of

square footage information provided by Coldwell Banker, these centers may represent the largest commercial centers in the five-county statistical consolidated area.

Utilizing a Coldwell Banker database on average building rents and a number of such building characteristics as age, height, and floor area, "effective" subcenter rents were first estimated and their pattern analyzed through standard econometric techniques.

In particular, a number of alternative statistical model specifications have been developed to analyze this pattern: a simple linear model, where space rents were assumed to solely reflect differences in residential house values and/or locational advantages; an extended linear model, accounting in addition for local development controls; a linear model with interactive terms between spatial amenities and development restrictions; and, lastly, a nonlinear, multiplicative model. Their statistical estimation has produced very promising results.

2. Empirical Findings

In particular, the empirical results gave rise to the following set of conclusions:

1]. The commercial land market within the greater Los Angeles area is not competitive. Evidently, government interference has created binding development constraints, which are strongly intervening with the capitalization of spatial amenities into commercial space rents. This was apparent in the inability of residential house values and/or locational advantages alone to explain these differences and the strong statistical significance of the supply variables, once included in the hedonic equations.

2]. Development constraints do in fact play a strong role in the capitalization process. In the presence of development controls, space rents do reflect more locational value, and the marginal effect of locational amenities on space rents does appear to be conditional on the presence or absence of development restrictions. These marginal effects appear to be stronger in those communities that are severely constrained with respect to their commercial land than in those that are less constrained, stronger in those communities imposing more restraining as opposed to more relaxed height limits, and stronger in those communities that persistently attempt to control commercial development within their boundaries through growth moratoria than in those they do not.

3]. In the face, then, of a noncompetitive market, variations in floor space rent differences across commercial subcenters in Greater Los Angeles can to a large extent be explained by differences across centers in both spatial demand and land supply characteristics. Such locational advantages, as access to white collar labor and the extent and quality of transport network, and such supply restrictions, as zoning limits, density regulations, and growth moratoria have ultimately explained more than 90% of the observed variation in "effective" subcenter rents.

Taken together, these conclusions give credence to the theoretical argument that in the light of government interference with the operation of the commercial land market, the modeling of capitalization must fully account for the supply side of this market. Evidently, in the absence of variables controlling for this interference in the hedonic model, the effect of spatial amenities had either appeared to be insignificant or ran contrary to what the underlying theory suggests.

As such, the empirical study has provided a sound example of the failure of simple hedonic models as means to explain urban pricing. Most importantly, however, it has shown that such hedonic models can easily be extended to successfully explore capitalization and commercial pricing issues within contemporary multicentric metropolises.

AN OVERVIEW AND EXTENSIONS

Overall, the dissertation presented an attempt to extend the capitalization debate to the case of the commercial land and real estate market. It asked whether and to what extent variations across commercial centers in land rents, floor space rents, and wages reflect differences in locational value, and thoroughly examined the role that local development restrictions play in affecting the magnitude of these variations.

The study has thus aimed at improving the understanding of an important aspect of real estate pricing. Given this objective, it has provided a simplified, explicitly spatial theoretical framework within which to analyze capitalization outcomes in nonmonocentric city settings, and it has suggested and--to the extent permitted by the available data--implemented a methodology for empirically analyzing commercial pricing and capitalization issues.

Yet, there are a number of important directions toward which both the theoretical and empirical analyses can first be refined and then be extended to better reflect some of the complexities characterizing the operation of urban land markets.

1. The Theoretical Analysis

Theoretical modeling can be refined in a number of directions. These include basic modeling refinements, as well as significant model reformulations. All emanate out of the simplified assumptions underlying the theoretical work.

1.1 Modeling Refinements

Modeling refinements, for example, are needed to account for development constraints at the least advantageous or at all centers within a metropolitan market, to incorporate agglomeration economies or co-location benefits at production sites, and to examine the effects of differences across centers in residential benefits or nonproductive amenities to households, differences in land consumption, congestion externalities, and other irregularities operating in the land market of urban areas. The following discussion presents an attempt to speculate on the impact that the presence of such complexities in the urban land market may have on the amenity capitalization process.

The "Location" of Development Constraints

The location of development constraints may greatly affect the relative space rent and wage capitalization shares. What happens if development constraints exist--although unlikely--at the least advantageous center? Or, how would capitalization outcomes differ, if similar institutional rigidities are assumed to exist at all centers in a metropolitan area?

If development constraints exist at the least advantageous center, then, given the equilibrium impacts of these constraints, the constrained center's disadvantage will likely be shifted toward higher space rents and lower wages at this center. If, on the other hand, all centers in the metropolitan market are constrained to the same degree, then it is possible that wage differences between centers will still reflect the major portion of locational value to the firm.

Agglomeration Economies

As already mentioned, the results of the theoretical models are largely dependent on the assumption that no agglomeration benefits exist in the commercial land market. Agglomeration economies are often omitted in theoretical studies because of the analytical complexities they introduce, but they are also often cited as one of the primary reasons for the existence of cities and the primary driving force for the spatial concentration of economic activity within their boundaries.^{28/}

The likely impact that the introduction of agglomeration effects may have can formally be addressed by a more refined version of the model. Agglomeration or external scale economies in aggregate form can easily be built into the model by introducing appropriate cost functions in the service market [Sullivan, 1986]. In this case, external scale economies can be assumed to be dependent on the city's total export output, total square footage, or total number of workers. In the presence of agglomerative effects and in the face of a competitive land market, the relative size of a city's subcenters will jointly be determined by differences in both their exogenous advantages and agglomeration benefits. As a center grows because of an exogenous advantage, the center's endogenous benefits will grow as well; hence, the center's endogenous and exogenous advantages will ultimately work together to produce large space rent and wage differences over a less advantageous center. Capitalization, then, may still continue favoring labor wages rather than space rents.

^{28/} Alonso's [1964], Mill's [1969], and White's [1976] pioneering work, for example, does not consider external economic effects at all. A major exception to this observation includes spatial nonmonocentric models, such as Ogawa's and Fujita's [1980], where the number and location of centers are determined endogenously. The explicit consideration of agglomeration effects was necessary in these analyses to indicate the process through which city centers are formed.

In a segmented or a regulated market, however, as an advantageous center shrinks in size, some of its agglomeration benefits are lost, and this, in turn, may exert a downward pressure on its space rents and labor wages. As a result, some of the positive effect of a zoning limit or a density regulation on a center's space rents may be offset due to its decreasing scale of production. On the contrary, however, the loss in agglomeration benefits will reinforce the constraint's negative effect on that center's labor wages. Given the small likelihood that the effect of agglomeration economies will prevail over the effect of the constraints, the marginal effect of the latter on space rents will likely remain positive, but definitely be smaller than it would be in the absence of agglomeration effects.

Co-location Benefits

Agglomeration benefits, on the other hand, may more explicitly be thought of as emanating out of the interaction between firms. It is often argued that in the broader context of urban economic activity, the interdependence of production with such services as banking, insurance, or marketing becomes increasingly important.

Often termed co-location benefits, benefits from such interactions can be incorporated into the model by modifying the cost function in the output market to include the cost incurred to the firm [Clapp, 1983; Tauchen and Witte, 1984; Sullivan, 1986; Ogawa and Fujita, 1980]. In this case, different firm types linked through production relationships have to be assumed to be present at the city's centers. The effects of co-location benefits may be quite similar to the effects of agglomeration economies discussed above.

Nonproductive Amenities

Just how the existence of nonproductive amenities to workers interferes with the capitalization of production amenities by space rents and wages needs to also formally be addressed. Advantages to workers may derive either out of the characteristics of the center itself, or the characteristics of its supporting residential area. The existence of retailing outlets in employment centers or better transportation facilities, which may be associated with savings in commuting costs, fall in the first category. Differences in property tax rates fall in the second category.

In the light of differences in residential benefits across centers, workers at the most amenable center may be willing to accept lower wages in exchange for the savings associated with that center's amenities. This would, in turn, allow firms to spend more on locational rents. An advantage to workers, therefore, may intervene with the capitalization of firm amenities so that in the presence of residential benefits, rents may reflect a higher share of production amenities than that they would in their absence. Simply, then, both in competitive and constrained or regulated land markets, the higher the advantage to households at the advantageous center, the higher the share of that center's production amenity that will be capitalized by space rents and the lower the amenity share that will be capitalized by labor wages.

Differences in Land Consumption

The role that variations across centers in land consumption play in the capitalization process provides another debatable issue. Differences in exogenous residential land consumption may very well lead to different pricing patterns than those discussed, but again not disqualify the

conclusions regarding the role that zoning limits or density regulations play in the capitalization process.

Suppose that the exogenously determined residential land consumption at a central city center is lower than the exogenous residential land consumption at a suburban center. In the absence of any advantage difference between these centers, the central city center would have higher space rents and lower wages than the suburban center.

If now a production cost advantage is introduced at the more dense, central city center, both its wages and space rents will rise. As a result, the space rent differences between the two centers will clearly be reinforced, while their wage differences will be certainly weakened. The production amenity in this case may thus be capitalized mostly by space rents rather than labor wages. It can easily be inferred that if the less dense center is the more advantageous of the two, labor wages would still capitalize a higher share of the production amenity than space rents.

Variable Residential Densities

The above discussion sets the stage for elaborating on the effects that variable instead of fixed residential densities might have on the theoretical conclusions. Most likely, their effect on the relative capitalization shares will be most pronounced if advantageous centers are also assumed to present other amenities, which are positively valued by and thus provide utility to urban households. In such a case, the households' density and price gradients will be steeper, favoring thus capitalization shifts away from wages and toward floor space rents. Yet, in the light of variable residential densities, the sign of the marginal impact of any zoning limits or density regulations imposed on the commercial land market is not likely to be affected.

Congestion Externalities

Congestion is a pervasive problem at many advantageous urban centers. Introduced by Mohring [1972], congestion depends on the capacity of highway facilities and the magnitude of their usage. In the presence of congestion in the transport market, the cost of commuting is no longer a simple function of distance from the city center, but both a function of distance and traffic volumes, which are themselves a function of residential densities. Models assuming that the latter are endogenous involve a simultaneous determination of densities and commuting costs. Household equilibrium, then, should reflect the interdependency between congestion and transport costs and, therefore, the interplay among congestion, residential densities, and locational rents.

Such an endogeneity complicates theoretical models to the extent that analytic solutions may become virtually impossible and numerical or simulation solutions the only viable alternative. The effects that congestion externalities may have on the operation of urban land markets within monocentric city settings have first been addressed by Mills [1972] and Solow [1972, 1973]. Both concluded that the introduction of congestion makes the rent profile more convex; the rent falls sharply as one leaves the congested center and less sharply near the limits of the residential area, where congestion is much less pronounced, if not entirely absent. If this does ultimately lead to higher rents at the congested center's edges, then, in a competitive land market, capitalization will favor space rents more than it does in the absence of congestion.^{29/}

^{29/} If, however, the addition of roads limits congestion and hence transport costs, the households' rent gradient will be flatter, and capitalization may favor labor wages more than it does in the absence of congestion.

As a constraint, however, either on a center's total land or commercial density, is introduced, commercial activity is restricted, and congestion externalities may be less prevalent. The effects of the restricted supply on space rents will, therefore, be weakened, but still remain positive. In the presence of local development restrictions and congestion externalities, capitalization will, then, continue favoring space rents, but less than it would in the absence of the effects of these constraints on congestion.

Other Complexities

The models have also assumed one-worker households, identical households and firms, and ignored multiple trips within urban areas. Yet, the growing tendency for two-worker households, the large amount of travel for purposes other than commuting to work, and the variety of firm and household types within metropolitan areas display realities that have to somehow be taken into account. It seems, however, unlikely that the analytic solution mode is appropriate to be adopted in all of these cases; simulation techniques may provide a more feasible alternative for analyzing the impact that some of these complexities may have on the commercial capitalization process.

1.2 Theoretical Reformulations

The adjustments discussed above basically retain the long run equilibrium assumption, suggesting thereby the formulation of some variant of the basic model. Thus, even with such improvements as those just discussed, the models will not cease representing a static theory of economic equilibrium.

Suggesting that this in fact may never be achieved, a number of authors attempted to develop more dynamic models, which recognize the durability,

locational fixity, and nonmalleability of the built capital [Harrison and Kain, 1976; Anas, 1978; Wheaton, 1982; Capozza, 1989]. The ability of these models to explain numerous irregularities observed in real world cities demonstrates by and large their superiority over their long run equilibrium counterparts.

Against this background, the theoretical models developed in this dissertation need to be reformulated to explicitly address the inherently "disequilibrium" nature of urban growth. A more dynamic approach to capitalization must account for adjustment or decision lags, transaction costs or indivisibilities, recognize the durability of capital and its replaceability for economic reasons, and account for suppliers with foresight.

Short Vs Long Run Adjustments

Given the adjustment lags in the real estate property market and the inflexibility of wages in the labor market, one would hypothesize that short-run capitalization outcomes would not differ from the likely capitalization outcomes in the face of constrained land markets.

Take, for example, the case where a production cost advantage, representing an investment in a better transport network, is exogenously introduced at a particular center. In the presence of such an advantage over other centers, the advantageous center's wages cannot immediately respond. Given the increased demand for space at the center, existing landlords can very well raise their rents, once leases are expired. At maximum, rent changes may reflect the full amount of the exogenously introduced cost savings at the center.

Construction will then begin responding to the increased demand and prices with a lag, and the increased supply may begin exerting a downward pressure on prices. This, in turn, will facilitate absorption of commercial space, and the center will be expanding, exerting thus an upward pressure on wages. Thus space rents will be falling and wages increasing, and capitalization will gradually be shifted away from space rents and toward wages, as long run equilibrium in the market would require.

Thus, at least in the short run, even in a competitive land market, space rents may potentially capitalize a high share of a center's cost advantage than wages. Only after a period of time, when supply adjusts and absorption responds, wages may begin capturing the bulk of the locational value to the center's firms.

A more dynamic approach, therefore, to capitalization would account for the path of capitalization outcomes, which may be diametrically different at different stages of the adjustment process.

Accounting for Redevelopment

What role development restrictions play in the face of durable but replaceable capital is another question that needs to be addressed in the context of a more dynamic model. This issue becomes increasingly important as land scarcities at advantageous locations in many metropolitan markets force growth to mostly occur through the replacement of existing capital, rather than through the development of vacant land.

If this is the case, zoning limits at centers that are more susceptible to redevelopment, i.e., older centers, may play less an important role than that they play in centers that are for economic reasons less susceptible, i.e., have more built capital, are newer, and more dense.

Developers with Foresight

Lastly, how the incorporation of foresight on the part of the suppliers of commercial space affects capitalization is another debatable issue. In anticipation of future improvements at certain locations, land and property values at these locations may capitalize the value of such advantages before they are realized. Thus, once in effect, the improvements may appear to have no effect on prices, or even have less of the expected positive effect if overbuilding occurs.

Similar arguments may be advanced in the case of zoning restrictions, density regulations, or growth control moratoria which can easily be anticipated. In such cases, an increased supply of space may occur, vacancies may increase, and rents may fall below their equilibrium level. Once in effect, the restrictions may again appear to have no or less impact on prices, depending on the degree of oversupply that occurred before they were enacted.

2. The Empirical Research

The empirical part, on the other hand, can be refined with respect to the quality and precision of required data, extended to address some of the theoretical propositions (or the assumptions which underlie them) that could not empirically be addressed because of data constraints, or even extended to explore such unresolved theoretical questions such as those just discussed.

The Data

First, more precise empirical work requires contract rent data, more refined quality characteristics of office-commercial properties and floor area

ratios at the property level, as well as more accurate housing value/rent data and land availability measures. Housing value/rent indices in place of average values/rents and a continuous land availability variable in place of the dummy variables could be used. The 1990 Census along with the more detailed locational variables likely to be surveyed and the completion of an inventory of zoned vacant land by the Southern California Association of Governors may provide a good opportunity to repeat the analysis with more precise measures.

Subcenter Size

Then, a number of additional hypotheses reflected in the propositions advanced in the theoretical part of the dissertation could be empirically addressed: Is the size of commercial centers explained by residential land prices, locational advantages, or both development restrictions and spatial amenities? In analyzing size differences, instead of, or in addition to, using a linear or multiplicative model, a probability or a discrete choice model could be estimated.

Moreover, given the likelihood that large commercial centers present substantial endogenous benefits, the predictive ability of a model which accounts for the simultaneous determination of employment size and rents must be examined.

Land Price Capitalization

There are a number of additional theoretical questions that could also empirically be addressed, if consistent and reliable data on both residential and commercial land prices can be made available.

The first question draws from the assumptions made in constructing the empirical models: Is the price of housing a good proxy for residential land prices? The other directly draw from the propositions advanced in the theoretical part: Is the price of commercial land explained by residential land prices? If not, then, does the inclusion of land and/or density constraints increase the explanatory power of the statistical model? Is the gap between commercial and residential prices explained by zoning limits, as the theory suggests?

Wage Capitalization

The empirical study can also be extended to include the examination of "effective" wage differences across urban centers. To empirically verify the hypothesized effects that zoning limits, density regulations, or growth moratoria have on wage differences and make possible the estimation of the full difference in locational value between centers, wage data at the subcenter level are needed.

Moreover, the statistical analysis of both wage and space rent differences in a metropolitan area where tax rates vary may shed more light to the so far controversial effect of property taxes. In addition, the estimation of both space rent and wage equations may provide further support to the "dual" capitalization propositions advanced in this dissertation.

The Industrial Market

The theoretical analysis may also be applied to the case of industrial land and real estate markets. Given the rather intense competition for land in the Los Angeles and other metropolitan areas between industrial and

office-commercial uses, it would be interesting to see the extent to which the prices of office land or commercial space affect the price of industrial space.

Markets in a Disequilibrium

Finally, the issue of how departures from equilibrium are likely to affect the results and interpretation of empirical findings needs to be addressed. Perhaps, capitalization is weaker in softer than in more tight markets, or, similarly, weaker in periods during which the market is soft as opposed to periods during which the market is tight. The testing of such a hypothesis would require the estimation of hedonic models during such different periods and the comparison of their estimated coefficients. For a proper analysis of these coefficients, however, data on housing prices and locational advantages must refer to the specific years hedonic rents are to be estimated.

2. Final Remarks

The utility of the four models developed in this dissertation does not lie in their ability to produce results for policy analysis, but rather in their ability to deductively illustrate how urban nonresidential land markets work under a variety of supply conditions. Despite their overly unrealistic assumptions, the clarity of their modeling structure has pointed to the important effects that government intervention may have on the operation of land markets and its repercussions on space rent and wage capitalization. This, in turn, has stimulated meaningful empirical research on commercial rent capitalization.

Notably, the model adjustments and empirical refinements or extensions just outlined provide a number of fruitful directions for further research. Agglomeration economies and other nonlinearities, such as congestion, may greatly complicate the modeling of capitalization, but their effect can be analyzed using more complex variants of the models analyzed in this dissertation. Yet, as postulated, at least in a long run framework, the fundamental principles and the essence of capitalization may not substantially differ under such alternative assumptions.

How exactly, however, capitalization works under a more dynamic growth model is an issue which calls for an explicit model of short-run, gradual adjustments in the market. This should simulate the evolutionary process of urban development and emphasize the importance of history and change to patterns of urban pricing. Such an approach can, perhaps, better justify long run capitalization outcomes as the end result of an adjustment process and give directions on how to empirically address capitalization in markets that are in disequilibrium.

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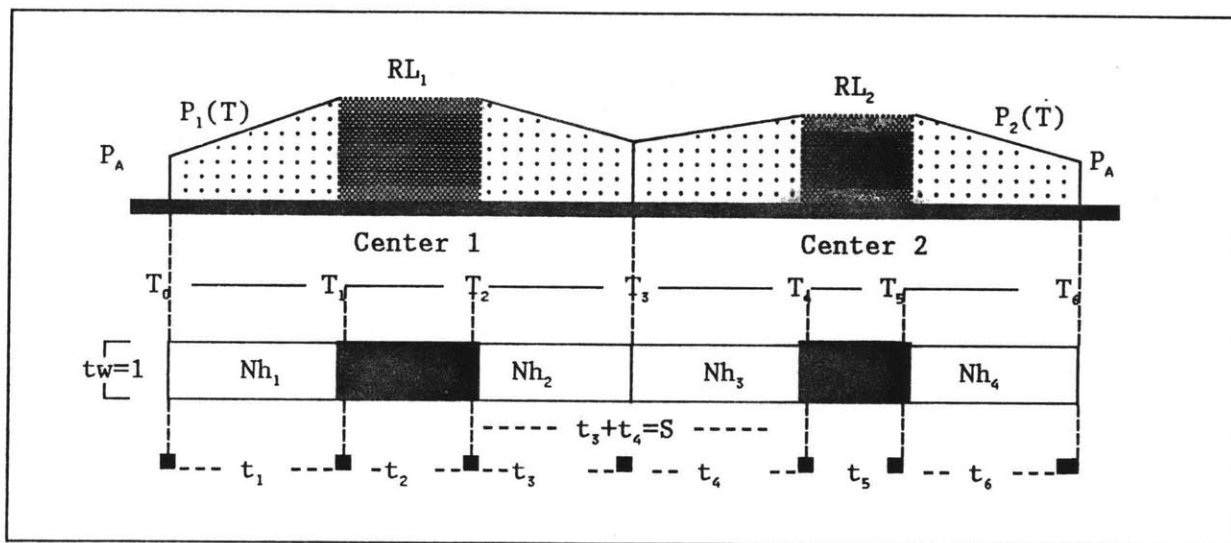
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APPENDIX I.

The Model Specification

The Appendix describes the general model of the city presented in Part 1 of this dissertation (Figure A-1). It gathers together the demand functions and the equilibrium conditions in the city's various markets, and presents the modifications that led to the development of the alternative models in Chapter III.

FIGURE A-1
A SIMPLIFIED TWO-CENTER CITY



1. THE MODEL'S

EXOGENOUS VARIABLES

ENDOGENOUS VARIABLES

a	: Utility parameter	U^o	: Household utility
q	: Fixed land consumption	X	: Fixed, nonland consumption
k	: Annual transport cost/unit distance		
S	: Distance between centers	t_1, \dots, t_6	: Area borders
tw	: Fixed width of the city		
N_h	: Total number of households	$N_{1,2}$: Labor supply at Center 1,2
a_n	: Labor coefficient	Q_o	: Fixed firm output
a_s	: Floor space coefficient	$Q_{s,1,2}$: Size of Center 1,2 (sq.ft)
r	: Rental price of capital	$cl_{1,2}$: Optimal capital/land ratio at Center 1,2
b	: Production function parameter		
P_A	: Annual agricultural land rent/unit land rents/acre at Center 1,2	$P_i(T)$: Residential land rents
		$RL_{1,2}$: Commercial land
		$R_{1,2}$: Floor space rents/sqft at Center 1,2
W_2	: Exogenous wage at Center 2	W_1	: Relative wage at Center 1

2. DEMAND FUNCTIONS AND EQUILIBRIUM CONDITIONS

a. The Residential Market

The Objective Function

$$\text{subject to:} \quad \max U(\bar{X}, q) = \bar{X}^a q^{1-a}$$

$$\begin{aligned} W_1 &= X + R(T) + k^*(T_1 - T) & \text{for } T_0 < T < T_1 \\ &= X + R(T) + k^*(T - T_2) & \text{for } T_2 < T < T_3 \\ W_2 &= X + R(T) + k^*(T_4 - T) & \text{for } T_3 < T < T_4 \\ &= X + R(T) + k^*(T - T_5) & \text{for } T_5 < T < T_6 \end{aligned}$$

The Demand Functions

$$\begin{aligned} X &= W_1 - R(T) - k^*(T - T_2) & \text{for } T_2 < T < T_3 \\ X &= W_2 - R(T) - k^*(T_4 - T) & \text{for } T_3 < T < T_4 \\ X &= W_2 - R(T) - k^*(T - T_5) & \text{for } T_5 < T < T_6 \\ q(T) &= \bar{q} \end{aligned}$$

Equilibrium Conditions

$$U^o = U \frac{T_0}{C_1} = U \frac{T_1}{C_1} = U \frac{T_2}{C_1} = U \frac{T_3}{C_1} = U \frac{T_3}{C_2} = U \frac{T_4}{C_2} = U \frac{T_5}{C_2} = U \frac{T_6}{C_2} = X^a$$

Derived conditions:

$$\begin{aligned} \blacksquare W_2 &= W_1 - k^*(t_1 - t_6) \\ \blacksquare t_3 - t_4 &= t_1 - t_6 \\ \blacksquare W_1 - P_1(T_1) &= W_2 - P_2(T_4) = U^{1/a} \\ \blacksquare P_1(T_1) &= P_1(T_2) = P_a + k^*t_1 \\ &= P_1(T_3) + k^*t_3 \\ \blacksquare P_2(T_4) &= P_2(T_5) = R_a + k^*t_6 \\ &= P_2(T_3) + k^*t_4 \end{aligned}$$

b. The Commercial Market

Objective Functions

The Market for Service Output

subject to:

$$\min C_1 = W_1 * N_1 + R_1 * Q_{S_1} + CE_1$$

$$Q_0 = \min \{N_1/a_n, Q_{S_1}/a_s\}$$

The Market for Commercial Space

$$\max \pi = R_1 * Q_{S_1} - rK - L_1 * RL_1$$

subject to:

$$Q_{S_1} = K_1^b L_1^{(1-b)}; \quad 0 < b < 1$$

Demand Functions

All Models

$$Q_{S_1} = a_s Q_0; \quad N_1 = a_n Q_0$$

Models I and II

$$K_1 = \frac{a_s}{a_n} N_1 \left[\frac{bRL_1}{(1-b)r} \right]^{1-b}$$

$$L_1 = \frac{a_s}{a_n} N_1 \left[\frac{(1-b)r}{bRL_1} \right]^b$$

Models III and IV

$$K_1 = c1_1^{1-b} * Q_{S_1}$$

$$L_1 = c1_1^{-b} * Q_{S_1}$$

Equilibrium Conditions

The Output Market

$$W_1 + R_1 \frac{Qs_1}{N_1} + CE_1 = W_2 + R_2 \frac{Qs_2}{N_2} + CE_2$$

The Labor Market

$$\begin{aligned} N_1 &= Nh_1 + Nh_2 = (t_1 + t_3)/q \\ N_2 &= Nh_3 + Nh_4 = (t_4 + t_6)/q \\ N_1 + N_2 &= Nh = (t_1 + S + t_6)/q \end{aligned}$$

The Commercial Property Market

$$\pi = R_1 Qs_1 - RL_1 L_1 - rK_1 = 0$$

or:

$$R_1 = \left[RL_1 L_1 + rK_1 \right] / Qs_1$$

The Commercial Land Market

$$\begin{aligned} L_1 &= t_2 \\ L_2 &= t_5 \end{aligned}$$

c. Border Conditions

All Models

$$\begin{aligned} P_1(T_3) &= P_2(T_3) \\ P_1(T_0) &= P_2(T_6) = P_A \end{aligned}$$

$$t_3 + t_4 = S$$

Models I and III

$$\begin{aligned} RL_1 &= P_1(T_1) = P_1(T_2) \\ RL_2 &= P_2(T_4) = P_2(T_5) \end{aligned}$$

APPENDIX II.

Simulation Solutions

The Appendix discusses the model solutions and presents the complete simulation results. Simulations 1, 2, 3, 4, 5, 7, 8 and 9 were relied on the solution of nonlinear equations (i.e., III.5) for t_1 or N_1 through the Newton-Ramphson iterative method. This is briefly explained below.

1. The Newton-Ramphson Method

The equations to be solved are of the general form of:

$$F(x) = 0,$$

If x_0 denotes the approximation to the root, r , the latter can be written as $r = x_0 + h$. Applying Taylor's theorem, then:

$$F(r) = F(x_0 + h) = F(x_0) + hF'(x_0) + \frac{1}{2}h^2F''(x_0) + \dots$$

Assuming that h is small, higher powers of h can be neglected. Therefore:

$$h = h_0 = -F(x_0)/F'(x_0)$$

The sum $x_0 + h$ is not the exact root, but it can be taken as a new approximation, x_1 , which can likewise be expressed as:

$$x_1 = x_0 - F(x_0)/F'(x_0)$$

Using x_1 to replace x_0 , this approximation process can be repeated, until a required precision is obtained. Starting then with x_0 , a sequence of x_n is calculated according to the formula:

$$x_n = x_{n-1} - F(x_{n-1})/F'(x_{n-1}) \text{ for } n \geq 1$$

Noting that $F(x_{n-1})/F'(x_{n-1}) = f$ has no repeated roots, the Newton-Ramphson process for f can be written as:

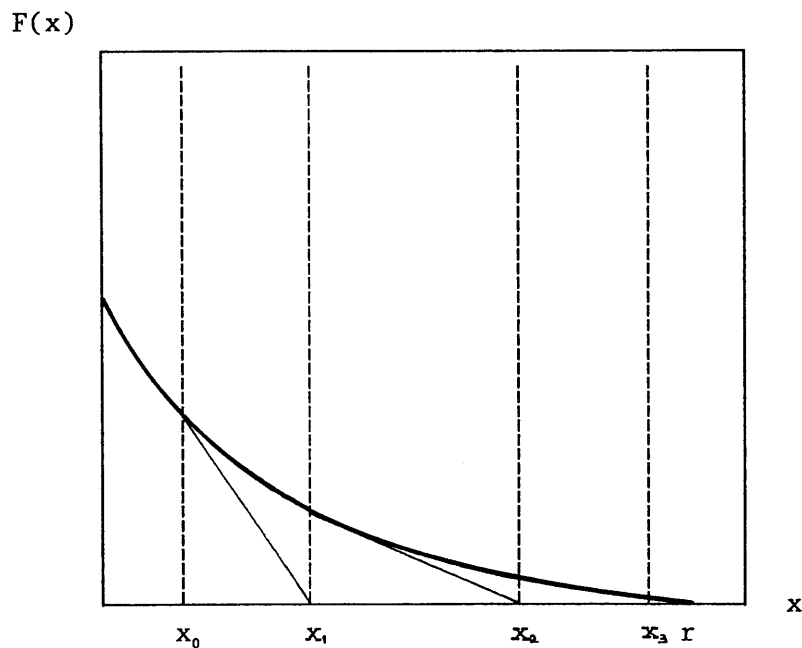
$$x_n = x_{n-1} - f(x_{n-1})/f'(x_{n-1})$$

As a result, the quadratic convergence for all roots is:

$$x_n = x_{n-1} - \frac{w}{1 - wF''(x_{n-1})/F'(x_{n-1})}, \quad w = F(x_{n-1})/F'(x_{n-1})$$

Figure A-2 portrays this process. For each new iteration the intersection of the x axis with the tangent line for the current iteration is used.

FIGURE A-2
The Newton-Ramphson Method:
Graphic Illustration



The method employed here for obtaining the simulation output is just one of the variations of the process that can effectively be used in BASIC for the solution of nonlinear equations. Dvorak and Musset [1984] discuss a number of other variants of the method.

2. Computer Simulation Results

The actual computer simulation outputs are appended. Simulations 1-3 portray the competitive land market (Model I); Simulations 4-6 feature the segmented land market (Model II); Simulations 7-9 the regulated land market (Model III); and Simulations 10-12 the segmented and regulated land market (Model IV).

S I M U L A T I O N 1

MODEL I: The Base Case

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, Nh	:	1,000,000.00
City Width, tw, in miles	:	2.00
Distance between the Subcenters' Inner Edges, S, in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q, in acres	:	0.07
Annual Agricultural Land Rent, P _A , per acre	:	7,500.00
Annual Transport Cost per mile, k, \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C _A , \$/worker	:	0.00
Commercial Space per worker, a _s /a _n , sq.ft/worker	:	250.00
Rental Price of capital, r, \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation:

$$C_0 C_3 (C_1 + X)^{1-b} - C_0 C_3 (C_1 + C_2 - X)^{1-b} + 2X - (C_2 + C_A) = 0$$

where:

$$X = kt_1; C_0 = r^b((1-b)/b)^b + b/(1-b)^{1-b}); C_1 = P_A q; C_2 = k((0.0015644Nhq)/tw - S); C_3 = a_s/a_n$$

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N ₁ , N ₂	: 500,000.00	500,000.00
Center 1's Annual Equilibrium Wage, W ₁	: 20,000.00	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R ₁ , R ₂	: 9.85	9.85
Annual Commercial Land Rents/acre, RL ₁ , RL ₂	: 129,385.00	129,385.00
Annual Residential Land Rents/acre at T ₂ , T ₄	: 129,385.00	129,385.00
3. Center Development Characteristics		
Optimum Commercial Land Area, L ₁ tw, L ₂ tw	: 3.42	3.42
Optimum Capital/Land Ratio, cl ₁ , cl ₂	: 1.42	1.42
4. Other		
Area Borders in Miles	t ₁ , t ₆ : 24.38	24.38
	t ₃ , t ₄ : 3.00	3.00

S I M U L A T I O N 2

MODEL I: Center 1 Is More Advantageous Than Center 2

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, Nh	:	1,000,000.00
City Width, tw, in miles	:	2.00
Distance between the Subcenters' Inner Edges, S, in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q, in acres	:	0.07
Annual Agricultural Land Rent, P _a , per acre	:	7,500.00
Annual Transport Cost per mile, k, \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C _A , \$/worker	:	1,000.00
Commercial Space per worker, a _s /a _n , sq.ft/worker	:	250.00
Rental Price of capital, r, \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation:

$$C_0 C_3 (C_1 + X)^{1-b} - C_0 C_3 (C_1 + C_2 - X)^{1-b} + 2X - (C_2 + C_A) = 0$$

where:

$$X = kt_1; C_0 = r^b((1-b)/b)^b + b/(1-b)^{1-b}); C_1 = P_A q; C_2 = k((0.0015644Nhq)/tw - S); C_3 = a_s/a_n$$

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N ₁ , N ₂	: 549,108.00	549,108.00
Center 1's Annual Equilibrium Wage, W ₁	: 20,941.09	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R ₁ , R ₂	: 9.97	9.73
Annual Commercial Land Rents/acre, RL ₁ , RL ₂	: 136,107.09	122,692.92
Annual Residential Land Rents/acre at T ₂ , T ₄	:	
3. Center Development Characteristics		
Optimum Commercial Land Area, L ₁ tw, L ₂ tw	: 3.62	3.22
Optimum Capital/Land Ratio, cl ₁ , cl ₂	: 1.49	1.35
4. Border Solutions		
Area Borders	t ₁ , t ₆	25.72
in Miles	t ₃ , t ₄	4.34
		23.03
		1.66

S I M U L A T I O N 3

MODEL I: Center 1 Presents A Maximum Advantage Over Center 2

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, Nh	:	1,000,000.00
City Width, tw, in miles	:	2.00
Distance between the Subcenters' Inner Edges, S, in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q, in acres	:	0.07
Annual Agricultural Land Rent, P _A , per acre	:	7,500.00
Annual Transport Cost per mile, k, \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, CA, \$/worker	:	2,229.00
Commercial Space per worker, a _s /a _n , sq.ft/worker	:	250.00
Rental Price of capital, r, \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation:

$$C_0 C_3 (C_1 + X)^{1-b} - C_0 C_3 (C_1 + C_2 - X)^{1-b} + 2X - (C_2 + C_A) = 0$$

where:

$$X = kt_1; C_0 = r^b((1-b)/b)^b + b/(1-b)^{1-b}); C_1 = P_A q; C_2 = k((0.0015644Nhq)/(tw-S)); C_3 = a_s/a_n$$

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N ₁ , N ₂	: 609,445.00	390.555.00
Center 1's Annual Equilibrium Wage, W ₁	: 22,097.39	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R ₁ , R ₂	: 10.11	9.58
Annual Commercial Land Rents/acre, RL ₁ , RL ₂	: 144,366.36	114,403.65
Annual Residential Land Rents/acre at T ₂ , T ₄	: 144,366.36	114,403.65
3. Center Development Characteristics		
Optimum Commercial Land Area, L ₁ tw, L ₂ tw	: 3.84	3.94
Optimum Capital/Land Ratio, cl ₁ , cl ₂	: 1.58	1.26
4. Border Solutions		
Area Borders		
in Miles	t ₁ , t ₆ t ₃ , t ₄	: 27.37 6.00
		21.38 0.00

S I M U L A T I O N 4

MODEL II: Center 1 Has No Production Cost Advantage Over Center 2 Binding Zoning Limits Are Imposed On Center 1

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, N_h	:	1,000,000.00
City Width, tw , in miles	:	2.00
Distance between the Subcenters' Inner Edges, S , in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q , in acres	:	0.07
Annual Agricultural Land Rent, P_A , per acre	:	7,500.00
Annual Transport Cost per mile, k , \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C_A , \$/worker	:	0.00
Center 1's zoning limit, $rl*tw$, in square miles	:	1.20
Commercial Space per worker, a_s/a_n , sq.ft/worker	:	250.00
Rental Price of capital, r , \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation:

$$C_0C_4C_6(C_8X-C_3)^{1-b/b}-C_0C_5C_6(C_1+C_2-X)^{1-b}+2X-(C_7+C_A)=0$$

where:

$$X=kt_1; C_0=r^b(((1-b)/b)^b+(b/(1-b))^{1-b}); C_1=P_Aq; C_2=k((0.0015644Nhq)/tw-S)$$

$$C_3=(0.0015644Nhq)/2tw-S; C_4=((((1-b)/b^b a_s r^b)/0.0015644*27866482))a_n r^{(1-b)/b}$$

$$C_5=(1/(43593.836qr))^{1-b}; C_6=a_s/a_n; C_7=C_A+C_2; C_8=2/k$$

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N_1, N_2	:	458,478.00
Center 1's Annual Equilibrium Wage, W_1	:	19,204.28
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R_1, R_2	:	13.13
Annual Commercial Land Rents/acre, RL_1, RL_2	:	451,397.19
Annual Residential Land Rents/acre at T_2, T_4	:	123,701.27
3. Center Development Characteristics		
Optimum Commercial Land Area, L_1tw, L_2tw	:	3.68
Optimum Capital/Land Ratio, cl_1, cl_2	:	4.95
4. Border Solutions		
Area Borders	t_1, t_6	23.24
in Miles	t_3, t_4	1.86
		25.51
		4.14

S I M U L A T I O N 5

MODEL II: Center 1 Has A Production Cost Advantage Over Center 2 Binding Zoning Limits Are Imposed On Center 1

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, Nh	:	1,000,000.00
City Width, tw, in miles	:	2.00
Distance between the Subcenters' Inner Edges, S, in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q, in acres	:	0.07
Annual Agricultural Land Rent, P _a , per acre	:	7,500.00
Annual Transport Cost per mile, k, \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C _A , \$/worker	:	1,000.00
Center 1's zoning limit, rl*tw, in square miles	:	1.20
Commercial Space per worker, a _s /a _n , sq.ft/worker	:	250.00
Rental Price of capital, r, \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation

$$C_0 C_4 C_6 (C_8 X - C_3)^{1-b/b} - C_0 C_5 C_6 (C_1 + C_2 - X)^{1-b} + 2X - (C_7 + C_A) = 0$$

where:

$$X = kt_1; C_0 = r^b((1-b)/b)^b + (b/(1-b))^{1-b}); C_1 = P_a q; C_2 = k((0.0015644Nhq)/tw - S)$$

$$C_3 = (0.0015644Nhq)/2tw - S; C_4 = (((((1-b)/b^b a_s r^b)/0.0015644*27866482))a_n r^{1-b})^{1/b}$$

$$C_5 = (1/(43593.836qr))^{1-b}; C_6 = a_s/a_n; C_7 = C_A + C_2; C_8 = 2/k$$

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N ₁ , N ₂	: 504,302.00	495,698.00
Center 1's Annual Equilibrium Wage, W ₁	: 20,082.44	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R ₁ , R ₂	: 13.51	9.84
Annual Commercial Land Rents/acre, RL ₁ , RL ₂	: 510,844.35	128,796.15
Annual Residential Land Rents/acre at T ₂ , T ₄	: 129,973.86	128,796.15
3. Center Development Characteristics		
Optimum Commercial Land Area, L ₁ tw, L ₂ tw	: 5.60	3.40
Optimum Capital/Land Ratio, cl ₁ , cl ₂	: 5.60	1.41
4. Border Solutions		
Area Borders	t ₁ , t ₆	24.49
in Miles	t ₃ , t ₄	2.88

S I M U L A T I O N 6

MODEL II: Center 1 Has A Production Cost Advantage Over Center 2
Binding Zoning Limits Are Imposed On Center 1; Center 2 Workers Cross-Commute

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, N_h	:	1,000,000.00
City Width, tw , in miles	:	2.00
Distance between the Subcenters' Inner Edges, S , in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q , in acres	:	0.07
Annual Agricultural Land Rent, P_a , per acre	:	7,500.00
Annual Transport Cost per mile, k , \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C_A , \$/worker	:	0.00
Center 1's zoning limit, $rltw$, in square miles	:	0.04
Commercial Space per worker, a_s/a_n , sq.ft/worker	:	250.00
Rental Price of capital, r , \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N_1, N_2	: 93,118.00	906,882.00
Cross Commuters	: 0.00	297,112.00
Center 1's Annual Equilibrium Wage, W_1	: 17,893.00	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R_1, R_2	: 22.53	10.11
Annual Commercial Land Rents/acre, RL_1, RL_2	: 4,718,718.25	144,435.00
Annual Residential Land Rents/acre at T_2, T_4	: 114,335.00	144,435.00
3. Center Development Characteristics		
Optimum Commercial Land Area, L_1tw, L_2tw	:	5.70
Optimum Capital/Land Ratio, cl_1, cl_2	: 51.77	1.58
4. Border Solutions		
Area Borders t_1, t_6	: 21.37	27.39
in Miles t_3, t_4	: 0.00	6.00

S I M U L A T I O N 7

MODEL III: Center 1 Has No Production Cost Advantage Over Center 2 Binding Density Limits Are Imposed On Center 1

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, Nh	:	1,000,000.00
City Width, tw, in miles	:	2.00
Distance between the Subcenters' Inner Edges, S, in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q, in acres	:	0.07
Annual Agricultural Land Rent, P _A , per acre	:	7,500.00
Annual Transport Cost per mile, k, \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C _A , \$/worker	:	0.00
Limit on Center 1's Capital/Land Ratio	:	0.30
Commercial Space per worker, a _s /a _n , sq.ft/worker	:	250.00
Rental Price of capital, r, \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation:

$$C_0 C_3 (C_1 + X)^{1-b} - 0.5 C_0 C_3 (C_1 + C_2 - X)^{1-b} + 2X - (C_2 + C_A) = 0$$

where:

$$X = kt_1; C_0 = r^b((1-b)/b)^b + b/(1-b)^{1-b}); C_1 = P_A q; C_2 = k((0.0015644Nhq)/(tw-S)); C_3 = a_s/a_n$$

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables		Center 1	Center 2
1. Center Employment and Wages			
Center Employment, N ₁ , N ₂	:	466,035.00	533,965.00
Center 1's Annual Equilibrium Wage, W ₁	:	19,349.10	
2. Land and Space Rents			
Annual Commercial Space Rents/sq.ft, R ₁ , R ₂	:	12.54	9.93
Annual Commercial Land Rents/acre, RL ₁ , RL ₂	:	124,735.68	134,034.32
Annual Residential Land Rents/acre at T ₂ , T ₄	:	124,735.68	134,034.32
3. Center Development Characteristics			
Optimum Commercial Land Area, L ₁ tw, L ₂ tw	:	10.56	3.56
Optimum Capital/Land Ratio, cl ₁ , cl ₂	:		1.47
4. Border Solutions			
Area Borders	t ₁ , t ₆	23.45	25.31
in Miles	t ₃ , t ₄	2.07	3.93

S I M U L A T I O N 8

MODEL III: Center 1 Has A Production Cost Advantage Over Center 2 Binding Density Limits Are Imposed On Center 1

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, Nh	:	1,000,000.00
City Width, tw, in miles	:	2.00
Distance between the Subcenters' Inner Edges, S, in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q, in acres	:	0.07
Annual Agricultural Land Rent, P _A , per acre	:	7,500.00
Annual Transport Cost per mile, k, \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C _A , \$/worker	:	1,000.00
Limit on Center 1's Capital/Land Ratio	:	0.30
Commercial Space per worker, a _s /a _n , sq.ft/worker	:	250.00
Rental Price of capital, r, \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation:

$$C_0 C_3 (C_1 + X)^{1-b} - 0.5 C_0 C_3 (C_1 + C_2 - X)^{1-b} + 2X - (C_2 + C_A) = 0$$

where:

$$X = kt_1; C_0 = r^b((1-b)/b)^b + b/(1-b)^{1-b}); C_1 = P_A q; \\ C_2 = k((0.0015644Nhq)/(tw-S)); C_3 = a_s/a_n$$

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N ₁ , N ₂	: 512,029.00	487,971.00
Center 1's Annual Equilibrium Wage, W ₁	: 20,230.52	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R ₁ , R ₂	: 12.90	9.82
Annual Commercial Land Rents/acre, RL ₁ , RL ₂	: 131,031.60	127,738.41
Annual Residential Land Rents/acre at T ₂ , T ₄	: 131,031.60	127,738.41
3. Center Development Characteristics		
Optimum Commercial Land Area, L ₁ tw, L ₂ tw	: 11.60	3.38
Optimum Capital/Land Ratio, cl ₁ , cl ₂	:	1.40
4. Border Solutions		
Area Borders t ₁ , t ₆	: 24.71	24.05
in Miles t ₃ , t ₄	: 3.33	2.67

S I M U L A T I O N 9

MODEL III: Center 1 Has A Production Cost Advantage Over Center 2 Maximum Density Regulation Is Imposed On Center 1

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, Nh	:	1,000,000.00
City Width, tw, in miles	:	2.00
Distance between the Subcenters' Inner Edges, S, in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q, in acres	:	0.07
Annual Agricultural Land Rent, P _A , per acre	:	7,500.00
Annual Transport Cost per mile, k, \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C _A , \$/worker	:	1,000.00
Limit on Center 1's Capital/Land Ratio	:	0.08
Commercial Space per worker, a _s /a _n , sq.ft/worker	:	250.00
Rental Price of capital, r, \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

SOLVING THE SYSTEM THROUGH THE NEWTON-RAMPHSON ITERATIVE METHOD

The Basic Nonlinear Equation:

$$C_0 C_3 (C_1 + X)^{1-b} - 0.5 C_0 C_3 (C_1 + C_2 - X)^{1-b} + 2X - (C_2 + C_A) = 0$$

where:

$$X = kt_1; C_0 = r^b((1-b)/b)^b + b/(1-b)^{1-b}); C_1 = P_A q; \\ C_2 = k((0.0015644Nhq)/tw - S); C_3 = a_s/a_n$$

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N ₁ , N ₂	: 390,493.00	609,507.00
Center 1's Annual Equilibrium Wage, W ₁	: 17,901.41	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R ₁ , R ₂	: 22.50	10.11
Annual Commercial Land Rents/acre, RL ₁ , RL ₂	: 114,395.09	144,374.92
Annual Residential Land Rents/acre at T ₂ , T ₄	: 114,395.09	144,374.92
3. Center Development Characteristics		
Optimum Commercial Land Area, L ₁ tw, L ₂ tw	: 24.84	3.84
Optimum Capital/Land Ratio, cl ₁ , cl ₂	:	1.58
4. Border Solutions		
Area Borders	t ₁ , t ₆	27.37
in Miles	t ₃ , t ₄	6.00
	:	21.38
	:	0.00

S I M U L A T I O N 10

MODEL IV: Center 1 Has No Production Cost Advantage Over Center 2 Binding Zoning Limits And Density Regulations Are Imposed On Center 1

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, N_h	:	1,000,000.00
City Width, tw , in miles	:	2.00
Distance between the Subcenters' Inner Edges, S , in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q , in acres	:	0.07
Annual Agricultural Land Rent, P_a , per acre	:	7,500.00
Annual Transport Cost per mile, k , \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C_a , \$/worker	:	0.00
Center 1's zoning limit, $rltw$, in square miles	:	1.20
Limit on Center 1's Capital/Land Ratio	:	4.20
Commercial Space per worker, a_s/a_n , sq.ft/worker	:	250.00
Rental Price of capital, r , \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N_1, N_2	: 403,855.00	596,045.00
Center 1's Annual Equilibrium Wage, W_1	: 18,157.48	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R_1, R_2	: 17.45	10.08
Annual Commercial Land Rents/acre, RL_1, RL_2	: 1,014,569.45	142,545.83
Annual Residential Land Rents/acre at T_2, T_4	: 116,224.17	142,545.83
3. Center Development Characteristics		
Optimum Commercial Land Area, L_{1tw}, L_{2tw}	:	3.80
Optimum Capital/Land Ratio, cl_1, cl_2	:	1.56
4. Border Solutions		
Area Borders	t_1, t_6 :	21.74
in Miles	t_3, t_4 :	0.37
		27.01
		5.63

S I M U L A T I O N 11

MODEL IV: Center 1 Has A Production Cost Advantage Over Center 2 Binding Zoning Limits And Density Regulations Are Imposed On Center 1

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, N_h	:	1,000,000.00
City Width, t_w , in miles	:	2.00
Distance between the Subcenters' Inner Edges, S , in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q , in acres	:	0.07
Annual Agricultural Land Rent, P_A , per acre	:	7,500.00
Annual Transport Cost per mile, k , \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C_A , \$/worker	:	1,000.00
Center 1's zoning limit, $rltw$, in square miles	:	1.20
Limit on Center 1's Capital/Land Ratio	:	4.20
Commercial Space per worker, a_s/a_n , sq.ft/worker	:	250.00
Rental Price of capital, r , \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N_1, N_2	: 403,855.00	596,145.00
Center 1's Annual Equilibrium Wage, W_1	: 18,157.48	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R_1, R_2	: 21.45	10.08
Annual Commercial Land Rents/acre, RL_1, RL_2	: 1,451,055.64	142,545.83
Annual Residential Land Rents/acre at T_2, T_4	: 116,224.17	142,545.83
3. Center Development Characteristics		
Optimum Commercial Land Area, L_1tw, L_2tw	:	3.80
Optimum Capital/Land Ratio, cl_1, cl_2	:	1.56
4. Border Solutions		
Area Borders t_1, t_6	: 21.74	27.01
in Miles t_3, t_4	: 0.37	5.63

S I M U L A T I O N 12

MODEL IV: Center 1 Has A Production Cost Advantage Over Center 2 Binding Zoning Limits And Density Regulations Are Imposed On Center 1 Center 2 Workers Cross-Commute

VALUES OF EXOGENOUS VARIABLES

1. General Characteristics of the City		
Number of Households, N_h	:	1,000,000.00
City Width, t_w , in miles	:	2.00
Distance between the Subcenters' Inner Edges, S , in miles	:	6.00
2. Household Equilibrium		
Household Utility Parameter, a	:	0.50
Household Land Consumption, q , in acres	:	0.07
Annual Agricultural Land Rent, P_A , per acre	:	7,500.00
Annual Transport Cost per mile, k , \$:	350.00
Exogenous Wage at Center 2	:	20,000.00
3. Firm equilibrium		
Production Cost Advantage at Center 1, C_A , \$/worker	:	1,000.00
Center 1's zoning limit, $rl \cdot t_w$, in square miles	:	1.20
Limit on Center 1's Capital/Land Ratio	:	3.00
Commercial Space per worker, a_s/a_n , sq.ft/worker	:	250.00
Rental Price of capital, r , \$/sq.ft	:	7.00
Production Function Parameter, b	:	0.77

DERIVED VALUES OF ENDOGENOUS VARIABLES

Endogenous Variables	Center 1	Center 2
1. Center Employment and Wages		
Center Employment, N_1, N_2	: 311,678.00	688,322.00
Cross Commuters	:	73,261.00
Center 1's Annual Equilibrium Wage, W_1	: 17,690.00	
2. Land and Space Rents		
Annual Commercial Space Rents/sq.ft, R_1, R_2	: 23.37	10.13
Annual Commercial Land Rents/acre, RL_1, RL_2	: 1,458,396.82	145,885.00
Annual Residential Land Rents/acre at T_2, T_4	: 112,885.00	145,885.00
3. Center Development Characteristics		
Optimum Commercial Land Area, $L_1 t_w, L_2 t_w$:	4.30
Optimum Capital/Land Ratio, cl_1, cl_2	:	1.60
4. Border Solutions		
Area Borders t_1, t_6	: 21.08	27.68
in Miles t_3, t_4	:	6.00

Estimating "Effective" Subcenter Rents: Semilogarithmic Equations

I. Los Angeles County

Independent

N	R^2	\bar{R}^2
72	0.75	0.72

N	R^2	\bar{R}^2
61	0.93	0.92

- 200 -

3. Glendale/Pasadena

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Glendale	-657.24 (-2.07)	87.99 (+2.09)	1.06 (1.46)	2.42 (2.58)	2.14 (+0.99)	-1.29 (-1.21)	-1238.08 (-2.21)	1.41 (+1.43)	162.83 (+2.20)	-0.30 (-0.23)	-	-0.26 (-0.19)
Pasadena	-657.24 (-2.07)	87.99 (+2.09)	1.06 (1.46)	2.42 (2.58)	2.14 (+0.99)	-1.29 (-1.21)	-	-	-	-0.30 (-0.23)	-	-0.26 (-0.19)
											N	R ²
											58	0.57
												\bar{R}^2 0.48

4. San Fernando Valley

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Burbank	251.97 (0.80)	-32.70 (-0.79)	1.15 (+3.58)	2.90 (5.28)	0.30 (+0.44)	-0.81 (-1.96)	-	-	-	7.02 (+6.55)	4.79 (+4.05)	6.85 (+5.99)
Van Nuys	251.97 (0.80)	-32.70 (-0.79)	1.15 (3.58)	2.90 (5.28)	0.30 (+0.44)	-0.81 (-1.96)	-1692.78 (-3.20)	-0.12 (-0.19)	223.13 (+3.20)	7.02 (+6.55)	4.79 (+4.05)	6.85 (+5.99)
Canoga Park	251.97 (0.80)	-32.70 (-0.79)	1.15 (3.58)	2.90 (5.28)	0.30 (+0.44)	-0.81 (-1.96)	-467.28 (-0.66)	0.12 (+0.21)	61.68 (+0.66)	7.02 (+6.55)	4.79 (+4.05)	6.85 (+5.99)
Westlake Village	251.97 (0.80)	-32.70 (-0.79)	1.15 (3.58)	2.90 (5.28)	0.30 (+0.44)	-0.81 (-1.96)	1199.98 (+0.77)	0.75 (+0.29)	-158.23 (-0.77)	7.02 (+6.55)	4.79 (+4.05)	6.85 (+5.99)
											N	R ²
											169	0.69
												\bar{R}^2 0.65

5. San Gabriel Valley

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Covina/ Glendora	-4816.56 (-5.15)	636.25 (+5.17)	-1.12 (-2.59)	3.75 (+3.48)	-2.13 (-3.63)	-	-	-	-	4.12 (+3.68)	2.15 (+1.78)	2.72 (+2.32)
Pomona/ La Verne	-4816.56 (-5.15)	636.25 (+5.17)	-1.12 (-2.59)	3.75 (+3.48)	-2.13 (-3.63)	-	4185.01 (+4.24)	-10.34 (-6.52)	-549.88 (-4.24)	4.12 (+3.68)	2.15 (+1.78)	2.72 (+2.32)
Rancho Cucamonga	-4816.56 (-5.15)	636.25 (+5.17)	-1.12 (-2.59)	3.75 (+3.48)	-2.13 (-3.63)	-	9398.05 (+2.23)	0.68 (+0.44)	-1237.79 (-2.23)	4.12 (+3.68)	2.15 (+1.78)	2.72 (+2.32)
											N	R ²
											45	0.80
												\bar{R}^2 0.71

6. South Bay Area

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Lax	-2722.45 (-4.29)	360.63 (+4.32)	-0.08 (-0.22)	-1.89 (-2.74)	-1.56 (-1.96)	0.63 (+1.33)	- -	- -	- -	5.13 (+4.29)	2.24 (+1.81)	3.89 (+2.41)
Torrance	-2722.45 (-4.29)	360.63 (+4.32)	-0.08 (-0.22)	-1.89 (-2.74)	-1.56 (-1.96)	0.63 (+1.33)	1543.35 (+1.66)	3.52 (+4.34)	-203.88 (-1.66)	5.13 (+4.29)	2.24 (+1.81)	3.89 (+2.41)
Long Beach	-2722.45 (-4.29)	360.63 (+4.32)	-0.08 (-0.22)	-1.89 (-2.74)	-1.56 (-1.96)	0.63 (+1.33)	-100.58 (-0.14)	4.07 (+5.23)	12.48 (+0.14)	5.13 (+4.29)	2.24 (+1.81)	3.89 (+2.41)
										N	R ²	\bar{R}^2
										140	0.68	0.64

7. West Los Angeles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Beverly Hills	-1094.10 (-1.07)	145.78 (+1.08)	1.46 (+5.19)	2.59 (+4.90)	-1.70 (-2.04)	0.65 (+1.40)	-1488.81 (-1.39)	-2.80 (-4.12)	196.99 (+1.39)	1.94 (+1.56)	1.73 (+1.37)	1.08 (+0.79)
Century City	-1094.10 (-1.07)	145.78 (+1.08)	1.46 (+5.19)	2.59 (+4.90)	-1.70 (-2.04)	0.65 (+1.40)	-1150.47 (-0.80)	-1.87 (-2.41)	152.02 (+0.81)	1.94 (+1.56)	1.73 (+1.37)	1.08 (+0.79)
Culver	-1094.10 (-1.07)	145.78 (+1.08)	1.46 (+5.19)	2.59 (+4.90)	-1.70 (-2.04)	0.65 (+1.40)	-2892.59 (-1.42)	0.24 (+0.23)	380.51 (+1.42)	1.94 (+1.56)	1.73 (+1.37)	1.08 (+0.79)
Santa Monica	-1094.10 (-1.07)	145.78 (+1.08)	1.46 (+5.19)	2.59 (+4.90)	-1.70 (-2.04)	0.65 (+1.40)	-2316.49 (-1.83)	30.00 (+2.51)	304.79 (+1.83)	1.94 (+1.56)	1.73 (+1.37)	1.08 (+0.79)
Venice	-1094.10 (-1.07)	145.78 (+1.08)	1.46 (+5.19)	2.59 (+4.90)	-1.70 (-2.04)	0.65 (+1.40)	2466.72 (1.39)	-1.16 (-1.01)	-325.11 (-1.39)	1.94 (+1.56)	1.73 (+1.37)	1.08 (+0.79)
										N	R ²	\bar{R}^2
										220	0.78	0.75

8. Wilshire District

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mid Wilshire	-2031.84 (-4.86)	269.63 (+4.89)	1.42 (+2.90)	0.85 (+0.97)	-0.10 (-0.07)	0.25 (+0.36)	1931.63 (+3.79)	0.23 (+0.30)	-255.14 (-3.80)	-1.32 (-1.38)	- -	-2.02 (-1.68)
Park/Miracle Mile	-2031.84 (-4.86)	269.63 (+4.89)	1.42 (+2.90)	0.85 (+0.97)	-0.10 (-0.07)	0.25 (+0.36)	- -	- -	- -	-1.32 (-1.38)	- -	-2.02 (-1.68)
										N	R ²	\bar{R}^2
										83	0.63	0.58

II. Orange County

1. North County

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Brea/	-6722.36	885.96	1.76	2.73	0.96	-	-	-	-	1.69	-	1.08
La Habra	(-5.05)	(+5.05)	(+3.65)	(+2.30)	(+0.83)	-	-	-	-	(+1.54)	-	(+0.84)
										N	R ²	\bar{R}^2
										18	0.85	0.77

2. Central County Area

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Orange	-3954.13	522.38	-0.12	1.43	-0.52	-0.10	-	-	-	3.36	2.02	1.41
	(-7.66)	(+7.68)	(-0.52)	(+4.39)	(-0.92)	(-0.31)	-	-	-	(+4.62)	(+2.38)	(+1.75)
Anaheim	-3954.13	522.38	-0.12	1.43	-0.52	-0.10	2022.95	1.27	-266.79	3.36	2.02	1.41
	(-7.66)	(+7.68)	(-0.52)	(+4.39)	(-0.92)	(-0.31)	(+3.54)	(+2.86)	(-3.55)	(+4.62)	(+2.38)	(+1.75)
Santa Ana	-3954.13	522.38	-0.12	1.43	-0.52	-0.10	1528.04	-0.86	-201.19	3.36	2.02	1.41
	(-7.66)	(+7.68)	(-0.52)	(+4.39)	(-0.92)	(-0.31)	(+2.61)	(-2.44)	(-2.60)	(+4.62)	(+2.38)	(+1.75)
										N	R ²	\bar{R}^2
										140	0.79	0.76

3. Airport Area

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Irvine	-1336.43	177.68	-0.22	2.11	-0.30	-0.52	-	-	-	3.25	0.48	1.36
	(-4.30)	(+4.34)	(-1.05)	(+7.12)	(-0.51)	(-1.37)	-	-	-	(+6.28)	(+0.69)	(+2.18)
Costa Mesa	-1336.43	177.68	-0.22	2.11	-0.30	-0.52	-4589.99	-0.97	604.62	3.25	0.48	1.36
	(-4.30)	(+4.34)	(-1.05)	(+7.12)	(-0.51)	(-1.37)	(-3.24)	(-1.74)	(+3.24)	(+6.28)	(+0.69)	(+2.18)
										N	R ²	\bar{R}^2
										228	0.64	0.63

4. West County

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Huntington Beach	-2902.18	383.22	1.09	2.99	-1.87	-	-	-	-	2.46	-	-
	(-1.57)	(+1.57)	(+1.17)	(+3.05)	(-1.74)	-	-	-	-	(+1.56)	-	-
										N	R ²	\bar{R}^2
										25	0.74	0.67

5. Newport Beach

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Newport	-2447.34	324.44	0.37	2.31	-0.08	-	-	-	-	0.93	-	1.17
Beach	(-3.15)	(+3.16)	(+0.53)	(+5.28)	(-0.14)	-	-	-	-	(+1.06)	-	(+0.73)
												-
										N	R ²	R ²
										39	0.70	0.65

III. Riverside County

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Riverside	-532.61	71.38	-0.06	3.74	0.05	-	-	-	-	1.27	-	0.67
	(-2.66)	(+2.71)	(-0.23)	(+9.78)	(+0.09)	-	-	-	-	(+1.25)	-	(+0.84)
										N	R ²	\bar{R}^2
										74	0.62	0.59

IV. San Bernardino County

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
San	-677.14	89.80	1.51	2.14	1.07	-2.02	-	-	-	1.90	-1.40	2.91
Bernardino	(-2.62)	(+2.64)	(+5.74)	(+4.32)	(+1.74)	(-3.12)	-	-	-	(+2.03)	(-1.37)	(+3.25)
										N	R ²	\bar{R}^2
										59	0.74	0.70

V. Ventura County

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Ventura	-1577.26	209.02	0.79	2.80	-0.66	-	-	-	-	-	-	-
	(-2.66)	(+2.67)	(+2.92)	(+4.66)	(-1.08)	-	-	-	-	-	-	-
										N	R ²	\bar{R}^2
										26	0.65	0.59
