LAND SCARCITY AND RESIDENTIAL LOCATION BY INCOME

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LOCATION BY INCOME

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

LIST OF SYMBOLS

s	consumption of land
R	market rent per unit of land or housing
x	distance from the CBD in miles
$T(x)$	commuting cost at x
T'	marginal commuting cost
λ	Lagrange multiplier in Chapter II transformation parameter in the Box-Cox specification in Chapter VI-X
r	bid rent per unit of land or housing
R_A	agricultural land rent per unit of land
L	supply of land
City H	a city with land scarcity, high-rent city
City L	a city with land abundance, low-rent city
x_f	urban fringe, distance from the CBD to the urban boundary
q	consumption of housing in square feet
S	structural density, capital per acre of land
D	population density ($= h(S)/q$) in Chapter III demolition cost in Chapter V
T^a	daily commuting cost of a car
f^a	per day fixed cost of the car.
c^a	variable monetary cost of the car per round-trip mile
w	wage rate

t^a	line-haul time per round-trip mile
MC^a or T_x^a	marginal commuting cost of the car
AC^a	the average commuting cost of the car
T^b	daily commuting cost of mass transit
c^b	monetary cost of transit per two miles
t_L^b	line-haul time per round-trip mile
t_C^b	collection and distribution time of the whole trip
m	density of mass transit service at given distance
l	land abundance
MC^b or T_x^b	marginal commuting cost of mass transit
x^*	break-even distance
AC^b	the average commuting cost of mass transit
F	$T^a - T^b$ in Chapter IV present value of the foregone rental income net of maintenance cost in Chapter V
η_h	income elasticity of housing consumption
$\eta_{T'}$	income elasticity of marginal commuting cost
r^a	bid-rent conditional on car commuting
r^b	bid-rent conditional on transit commuting
subscript r	represents the rich
subscript p	represents the poor
x'	distance where the bid rents of the two income groups intersect
V	land value
C	conversion cost, $D + F$
V_A	agricultural land value

UA	urbanized area
MA	metropolitan area
CMSA	consolidated metropolitan statistical area
PMSA	primary metropolitan statistical area
MSA	metropolitan statistical area
TCT	modal choice variable, ratio of transit users to car commuters in a UA
POP	city size variable, population of a UA
LV	land value variable, estimated agricultural land value at the fringe of a UA
AGE	city age variable, 1990 minus a decennial census year the urban population of the State containing the urban area at hand began to exceed half of the urban population in 1990
PYSC	income disparity variable, ratio of per capita income in the suburbs to that in the central city
POVCS	income disparity variable, ratio of the percentage of persons with income below poverty level in the central city to that in the suburbs
HU70	filtering variable, percentage of housing built before 1970
HUYR	filtering variable, median year housing units were built in the central city minus that in the suburbs
NWHCS	race variable, percentage of nonwhite population in the central city divided by that in the suburbs
OCOSTCS	tax variable, 'selected monthly owner cost of units not mortgaged' per dollar of housing value in the central city divided by that in the suburbs
CRIMECS	crime variable, crime index of a central city divided by that in suburbs

Sources of the Variables in the Empirical Study

LV: 1992 Census of Agriculture (Geographic Area Series Disc 1B)

CRIMECS: Uniform Crime Reports 1990

All the other variables:
1990 Census of Population and Housing Summary Tape File 3C (CD90 3C1 and 3C2)

CHAPTER I

INTRODUCTION

Statement of the Problem

Suburbanization has been an international trend (Mieszkowski and Mills, 1993). Mills and Tan (1980), however, state that suburbanization has proceeded farther and faster in the United States than it has worldwide. Urban population density gradients for most other developed countries are much steeper than for the United States. For example, the average population density gradient for a sample of Japanese cities declined by 64 percent per mile – 3.2 times as steep as for a sample of American cities (Mills and Ohta, 1976). To a lesser degree, density gradients for European cities are steeper than those of the United States (Mills and Hamilton, 1989).

The differences, however, are not limited to urban population density and the speed of suburbanization. Other important differences are urban poverty concentration and a positive income-distance relationship in U.S. cities. In American urban areas wealthier households tend to live farther from the city center. In 241 out of total 396 urbanized areas, according to 1990 U.S. census reports, median household income in the suburbs was higher than that in the central city. The poorest in American cities live very close to the CBD. Alonso (1964) states that in European and Latin American cities the poor usually inhabit the peripheral areas while the rich live in the central city. Fujita (1989) points out "the general tendency in most large Japanese cities for wealthy households to live closer to the CBD than less affluent households." Downs (1997) states "This American concentration of poor households within older, centrally located neighborhoods… is not found in most other nations. It is a peculiarly American condition."

Table 1.1. Central cities vs. Suburban Incomes in France and the U.S.**

	Household Income*	
Case	Central City	Suburbs
ILE DE FRANCE (Paris metro area)	124,000 Fr.	106,000 Fr.
PROVINCE (other metro area)	76,000 Fr.	84,000 Fr.
FRANCE (all metro area)	84,000 Fr.	82,000 Fr.
DETROIT (metro area)	$20,207	$40,084
U.S. (all metro area)	$26,727	$36,314

Source: Brueckner et al (1997), Table 1
* Fr: the 1990 average value, $: the 1989 median value.

Brueckner, Thisse, and Zenou (1997) state that the positive income-distance pattern found in America is often reversed outside the United States, and they present evidence, shown in Table 1.1, comparing French and American cities. They also cite studies (Hohenberg and Lees (1985) and Ingram and Carroll (1981)) reporting negative income-distance patterns in other countries. Hohenberg and Lees (1985) write "incomes rose with distance to the city center in America, whereas they typically fell in Europe." Looking into the concentration of high status groups in the central cities, Ingram and

Carroll (1981) show that a negative income-distance pattern also exists in many Latin American cities. It is an overstatement, however, to say that all non-American cities have the negative income-distance pattern. Ingram and Carroll (1981), for instance, show that the concentration of high status groups in Latin American cities is declining. However, the positive income-distance relationship is stronger in American cities.

Table 1.2 Commuting Modes in Ten Largest Urbanized Areas

	Percent of workers 16 years and over who...	
Mode	Live in Central City	Live in Suburbs
Drive alone	49.2	75.2
Carpool	13.0	12.0
Bus	11.9	2.8
Subway	12.7	1.4
Walk	7.3	2.6

Source: 1990 Census of Summary Tape File 3C-2

Another difference between U.S. and other countries' cities is found in urban transportation systems. Public transport dominates in the former European socialist countries and developing countries. However, most commuters in the United States rely on the automobile. As shown in Table 1.2, in 1990 about 87% of suburbanites and 62% of central city residents in the ten largest urbanized areas in the United States commuted by car. Ingram and Carroll (1981) state that intra-city travel in Latin American cities also is primarily by transit, especially bus. The majority of urban workers in Japan and Korea commute by transit, too. Western European countries lie between two extremes.

Table 1.3 Comparison of modal split in urban passenger transportation

	Percentage of total passenger trips			
Country	Auto	Transit	Pedestrian and bicyclist	Ratio of auto to transit
Hungary	11	58	31	0.19
Soviet Union	12	88	N.A.	0.14
Czechoslovakia	13	52	35	0.25
Poland	15	85	N.A.	0.18
East Germany	24	27	48	0.89
Italy	31	26	N.A.	1.20
Sweden	36	11	49	3.30
Switzerland	38	20	39	1.90
Austria	39	13	40	3.00
Denmark	42	14	41	3.00
United Kingdom	45	19	33	2.40
Netherlands	45	5	48	9.00
France	47	11	35	4.30
West Germany	48	11	40	4.40
Canada	74	15	11	4.90
United States	82	3	10	27.30

Source: Pucher (1990), Table 4
Note: The years for the figures range from 1978 to 1987.

Pucher (1990) shows that the ratio of automobile to public transportation in terms of passenger trips in urban areas is 27.3 for the United States, 4.9 for Canada, 2.4 for the United Kingdom, 0.89 for East Germany, and 0.14 for the former Soviet Union. The detailed information is shown in Table 1.3. The table shows that the role of cars in urban transportation is exceptionally large in the United States. According to 1990 U.S. census data, 80.7 % of commuting workers who live in central cities of urbanized areas commuted by car, and only 14.9% by mass transit. In the suburbs, 92.2 % commuted by car, and 4.1% used transit. Despite the dominance of the car as a commuting mode in U.S. cities, many central city residents, especially in the northeast and the north-central regions, commute by transit. In large cities in other countries, transit service is available even in suburbs. However, it is difficult to use public transit in U.S. suburbs, even in those of large cities.

The concentration in central cities of older housing units that receive little maintenance is another characteristic of U.S. cities. The demand for housing rises with income, and housing units deteriorate with the passage of time unless renovated or maintained with considerable care. Thus, old housing units successively filter down to next lower income groups, and a series of concentric zones or income-stratified neighborhoods are formed. This process is called filtering. Since urban areas are built from the middle out, older housing units tend to be nearer to the center of a city.

Filtering is a ubiquitous process. However, concentration of low quality housing units in central cities can be overcome by redevelopment, renovation, and maintenance. In U.S. central cities old housing units are frequently not redeveloped or renovated. Thus, in almost all American central cities, there are many old and some abandoned housing units and buildings. Mills and Hamilton (1989) report that abandoned dwelling units represent about 3 to 5 percent of the housing stock in cities such as Baltimore, Philadelphia and New York. In central cities of other countries, deteriorated or abandoned housing is not prevalent as in the United States. For instance, it is almost impossible to find abandoned buildings in the central cities of Seoul and Tokyo.

Table 1.4 Ratio of Old Housing Units to Total Housing Units in the United States and Korea

	the United States		Republic of Korea	
Built before	Nation	Urbanized Areas	Nation	Urbanized Areas*
1960**	41.4%	43.7%	9.6%	3.7%
1970**	57.5%	52.1%	15.9%	10%

Source: 1990 Census of Population and Housing, Bureau of the Census, U.S.A.
1995 Population and Housing Census Report, National Statistical Office, Rep. of Korea
* Areas that consists of *Tongs*, low level components of a city in Korea
** Note the implication of different census years.

In 1990, 52.1% of housing units in the central cities of U.S urbanized areas was 30 years old or older. The comparable number for their suburbs was 34.8 %. That is, a substantial portion of American suburban housing units is old, too, although outer rings of the suburbs consist of newer housing units. Table 1.4 compares ratios of old housing units to total housing units in the United States and Korea. Only 10 % of the housing units in Korean cities were 25 years old and older, while 43.7 % of the housing units in U.S. urbanized areas were 30 years old and older. Since the National Statistical Office of Korea does not present separate data for central city and suburbs, it is difficult to know the extend to which older housing units are concentrated in the central cities. Although filtering is ubiquitous, in many countries it does not result in concentration of old housing units in the central city, a substantial number of old housing units in the entire urban area, and a series of concentric zones as in the United States. In that sense, filtering is different in U.S. urban areas.

In short, a positive income-distance relationship, heavy reliance on the automobile, and old and abandoned housing units in central cities are characteristics of American cities. These patterns ask for theoretical explanations. Many conventional urban economic theories throw some light on these patterns. Most of them have theoretical and empirical merits. However, they fail to explain why those patterns are especially stronger in the United States or not found in other countries, perhaps, with the exception of heavy reliance on the automobile. To quote, Brueckner *et al* (1997),

"*Despite substantial progress in urban economic theory since the 1960's, the absence of a convincing and robust explanation of location by income represents a significant failure of the standard model.*"

We attempt to aid in solving this problem.

The Objectives of the Study

Our main objective is to find out what causes the positive income-distance relationship or urban poverty concentration in the United States. There must be some variable(s) or parameter(s) that are unique and have made suburbanization in the United States different from many other developed countries. In our view, the key difference is relative land scarcity. The United States has ample land supply and very low population density, quite different from those of other developed countries except Canada and Australia. We will explore how land abundance in the United States has affected urban structures and residential location patterns.

Our first objective is to examine how land scarcity promotes urban poverty concentration via the urban transportation structure. Land scarcity affects urban population density and the efficacy of mass transit through its effect on demand density. We incorporate the two facts to help explain urban transportation structures. In particular, we attempt to determine if lower population density and insufficient mass transit service in U.S. suburbs have promoted urban poverty concentration. Mass transit is costly in suburbs when the population density gradient of an urban area is relatively low. Consequently, there is less provision of mass transit service in the suburbs. This results in a concentration of the poor in the central city if they have no access to a car or if they find commuting by car too costly.

The next objective is to study how land abundance promotes U.S style filtering, which affects suburbanization and causes positive income-distance patterns. Abundant land supply and low population density make the density gradients of urban population and land rent flatter and lower. The lower urban and agricultural land rents in turn promote filtering and urban poverty concentration in the United States, because low land rent in a city hinders redevelopment and conversion.

The first two objectives of our study, therefore, are to seek theoretical explanation of the effects of land scarcity on urban structure and, eventually, residential location patterns. Theories alone would not provide complete understanding of the real world. It is desirable to test or complement theoretical analysis with empirical work. Our third objective is to test empirically the two theoretical models on income-distance relationships. We will test the effects of land value on modal choice and filtering. Finally, the relationship between income disparity and modal choice and filtering will be estimated.

Organization of the Study

The study is organized as follows. Chapter II presents a review of conventional theories on suburbanization and urban poverty concentration. Those theories fall into two categories: the natural evolution theory and the flight from blight theory. Pros and cons of the two theories are discussed. Chapter III presents the effects of land scarcity on urban structure. The implications of land value to the monocentric model and modal choice are presented. In Chapter IV and V, we extend the two core theories of the natural evolution theory. Chapter IV presents our modal choice theory with land scarcity as an explanatory variable. Chapter V inspects how low land value promotes filtering and positive income distance patterns. In Chapter VI, the scope of the empirical analysis and the estimation techniques are discussed. Chapter VII presents the empirical work of our modal choice theory. First, the effects of urban size and land value on modal choice are tested. Then, the relationship between modal choice and income disparity in urban areas is tested. Chapter VIII presents an empirical analysis of the filtering model with land value and city age as explanatory variables. In Chapter IX, the combined effects of modal choice and filtering on income disparity are empirically analyzed. Chapter X presents the empirical results of the extended models that include both natural evolution and blight variables.

CHAPTER II

REVIEW OF THE CONVENTIONAL THEORIES

Introduction

Many theories offer explanations for suburbanization and urban poverty concentration. Most belong to one of two categories: the natural evolution theory and the flight from blight theory. The former focuses on income changes and technology, and the latter emphasizes fiscal and social problems in central cities. Natural evolution theory states that suburbanization and the formation of income-stratified neighborhoods take place as a result of an orderly market process determined by natural economic forces such as income increases, transport cost reductions and innovations, and the heterogeneity of the housing stock. This theory views suburbanization and urban sprawl as a natural and efficient process.

Alternately, the flight from blight theory or, in short, the blight theory argues that high and middle income households flee to the suburbs to avoid fiscal and social central city problems such as tax burdens, low quality public schools, pollution, crime, congestion, and racial tensions. This rather pessimistic view lends itself to the conclusion that "*American metropolitan growth process inevitably drains resources out of central cities and inner-ring suburbs, thereby contributing to both urban decline and general social inequalities within metropolitan areas* (Downs, 1997)."

In this chapter, we review the two theories. First, the blight theory is reviewed, and its limitations are discussed. Second, an implication of the traditional monocentric model is presented, since the premise of many natural evolution theories is a monocentric city. A limitation of the traditional approach on income-distance patterns is also discussed. Finally, two well known natural evolution theories, filtering theory and LeRoy and Sonstelie's (1983) transport innovation or modal choice theory, are reviewed. Those theories provide plausible accounts for suburbanization in the United States, but they lack generality due to inability to explain other income-distance patterns.

Although, theoretically and empirically, suburbanization does not necessarily mean a stronger positive income-distance relationship, it has in the Unites States. Thus, some suburbanization theories have also been used to explain urban poverty concentration or income-distance pattern theories.

The Flight from Blight Theory

The blight theory maintains that affluent households move to suburbs to avoid problems in the central cities. Let us describe the flight from blight process. Pollution and crime level are high in central cities, and the middle-class and wealthy persons are more responsive to those problems than the poor. Thus, wealthy households flee to suburbs. This flight imposes fiscal burdens on central cities because of the reduced tax base. The central city government must either decrease the provision of government services such as public education, safety, and utilities or increase tax rates, particularly property tax rates. High-income households can avoid these problems by moving to the suburbs, and forming homogenous high-income neighborhoods. On the other hand, the flight of affluent residents further worsens the central city problems. The wealthy households remaining in the central city face worse situations, and their flight continues. In other words, the positive income-distance relationship and suburbanization are self-reinforcing. The process is exacerbated by fragmentary local jurisdictions with their fiscal autonomy. Suburban local governments use zoning to exclude poor households that would impose fiscal burdens. As suggested by the Tiebout hypothesis, blight theory expects households to form homogenous communities so as to avoid negative neighborhood externalities and to seek positive ones.

There have been many empirical studies on the effects of central city problems on suburbanization and urban poverty concentration. One of the well-known studies is Bradford and Kelejian (1973). They used 1960 census data and supported the blight model, even though they claimed to have found that the racial composition of the central city did not appear to affect the residential-location decision. On the other hand, Mills and Price (1984), using 1960-70 data, estimated a large set of density functions and found that measures of central city social problems such as crime, taxes and educational attainment add almost nothing to the understanding of suburbanization in the United States. They found that only racial minorities have an effect on suburbanization. Mills and Price also estimated the Bradford-Kelejian model with their data, and found that blight variables were unimportant. Later, Mills (1992) introduced another measure of suburbanization and tested it with the 1980 census data. He again found that central city problems have little effect on suburbanization of population and housing.

Bradbury, Downs, and Small (1982) did the most extensive empirical study on urban decline. They tested various theories of urban decline against data gathered from 1960 to 1975 on 153 American cities, and reported that rapid suburbanization results from local disparities in attributes such as relatively high taxes and a relatively large black population in central cities. They also found that employment and population loss are closely intertwined; Jobs followed people, and people followed jobs. Bruekner and

Fansler (1983) tested a traditional monocentric model with 1970 census data and concluded that urban sprawl is related to basic economic forces. They argued this result should deflate criticism of urban sprawl.

Thus, the empirical results are mixed. However, the seemingly conflicting findings do not raise a serious problem because the blight and natural evolution theories are not mutually exclusive. Mieszkowski and Mills (1993) assert that "the two theories have a number of interactions and interrelations, and consequently, it is difficult to distinguish between them empirically." It is safe to state that that suburbanization and urban poverty concentration result from many variables and that both of the conventional theories provide some explanation. Follain and Malpezzi (1981) support this view. Using the hedonic regression method, they estimate the effects of many natural evolution and blight variables and cautiously concluded that two conventional theories work together.

The blight theory, arguably, has some empirical evidence. It may have stronger empirical evidence regarding urban poverty concentration, an important aspect of suburbanization in the United States, because it is reasonable to believe that many social and fiscal disparities between central city and suburbs are related to income disparity. However, the causality between blight variables and suburbanization or urban poverty concentration should be examined with care. The causality may run in both directions. It appears that the blight variables cause income segregation. In our view, however, the logic behind the blight theory is unable to explain 1) what triggers the self-feeding process in the first place and 2) why the income segregation of the poor central city vs. affluent suburbs pattern should be the only result of the process.

As for the first question about the triggering forces, there have been a few accounts. Some cite pollution and crime as problems inherent in central cities. Pollution and crime can result from high-density development. However, central cities in the United States have relatively low densities compared to central cities in other countries. Extremely high density central city areas such as Seoul and Tokyo have very low crime rates. It is true that crime rates per given number of persons are higher in the central city than in the suburbs, but empirical evidence suggests that there is no significant link between crime and suburbanization. Mills and Price (1984) even found their crime variable had the wrong sign. Bradbury, Downs, and Small (1982) stated that avoidance of high crime rates appeared to play no role in either inter or intra metropolitan location decisions. They "never found any significant effects" of violent crime rates on suburbanization or relative city-suburbs income growth. Considering their favorable view of the blight theory, their finding of little empirical evidence of the effects of crime is striking.

Baumol (1967) argues that progressive and cumulative increases in costs of municipal services create financial problems in central cities. He sees the city governments as a sector without productivity gains because the essence of municipal services is labor, which has little potential of productivity gain. However, these problems exist in central cities around the world, but urban poverty concentration is peculiar to America. In our view, Baumol's contention that the municipal service sector has little productivity gains is plausible. However, suburban municipalities face the same problem. To argue that central cities have the disadvantage, one should prove increasing average costs of central city services relative to suburban services. We believe the case was not made. Baumol cites the flight of the rich as a force imposing progressive pressure on central city governments. However, this argument is incomplete unless the costs of suburban government services are considered. It is more costly to provide public utilities in lower density suburban areas. The Baumol hypothesis, therefore, does not explain the trigger mechanism.

It should be also noted that central cities have not only problems but also opportunities. Otherwise, cities would not exist. The question is which income group is more sensitive to which problems and opportunities. It is true the rich tend to be more responsive to central city problems or negative externalities, but they are also more sensitive to many benefits central cities offer. For instance, Brueckner *et al* (1997) argue that the rich households in Paris live at central locations because 1) valuation of central city amenities rises rapidly with income and 2) the center in Paris has advantages over the suburbs in amenities. Since there is no fixed theoretical premise that central city problems should dominate opportunities the central city offers, the blight theory cannot explain what triggers the self-reinforcing process.

There is another problem with the blight theory. The rationale behind the blight theory, the Tiebout hypothesis, can be applied to various income-location patterns, although the existing theory intends to describe only one pattern, the positive income-distance pattern. Suppose, for some reason, the rich live in the central city. Then, concentration of the rich in the center would result in less fiscal pressure, better municipal services, public education, etc. This would in turn reinforce the negative income-distance relationship. Besides, the income location pattern does not necessarily depend on the distance from the center. Suppose the rich live in the northern part of a city. Now the rich in the north vs. the poor in the south pattern would be reinforced.

Hamnett (1976) reported an interesting trend that happened in London by stating "Inner London is becoming a city of the very rich and the very poor, the middle income groups and skilled manual workers migrating or being forced out." As this example shows, application of the Tiebout hypothesis to urban location decisions does not necessarily result in a positive income-distance pattern.

In short, the blight theory works only something has triggered suburbanization.. This does not deny the effects of blight variables but to indicate incompleteness of the theory. As far as our task in this study is concerned, the most important shortcoming of the blight theory is that it does not explain why urban poverty concentration is peculiar to the United States. Despite the problems, the blight theory helps explain suburbanization in the U.S., especially its self-feeding nature. We now consider natural evolution theories.

Monocentric Models

A typical natural evolution theory is based on the monocentric model developed by Alonso, Muth, and Mills. A typical monocentric model has the following assumptions. A pre-existing CBD exists on a featureless plain. Everyone commutes to the CBD. A transport system is dense and radial. Thus, commuters choose a residential location considering land rent and commuting cost. A household's utility function is specified as $v(z, s)$, where z denotes the amount of non-land composite consumer good and s represents the consumption of land or the lot size of the house. The price of z is one because it is assumed to be the numeraire. The household earns a fixed income y per unit time. Suppose x is the distance from the CBD. The consumer pays the rent, $R(x)$, per unit of land at x. $T(x)$ is the transport cost at x.

Then the utility maximization problem of the household is given as

$$\max v(z(x), s(x)), \text{ subject to } z + R(x)s(x) = y - T(x) \tag{2.1}$$

where $x \geq 0, z > 0, s > 0$.

Rewrite this as

$$\pounds\,(z, s, x) = U(z, s) + \lambda[z + R(x)s - y + T(x)] \tag{2.2}$$

From one of the first order condition of (2.2), we get

$$\frac{dR(x)}{dx} = -\frac{T'(x)}{s} \tag{2.3}$$

This is the well-known location equilibrium condition. The left-hand side is the slope of the land price function. Since land consumption, s, and marginal transport cost, $T'(x)$, are positive, the slope is negative. This tells us that land price falls as distance from the CBD increases. Rewrite the equation as

$$\frac{dR(x)}{dx}s = -T'(x) \tag{2.4}$$

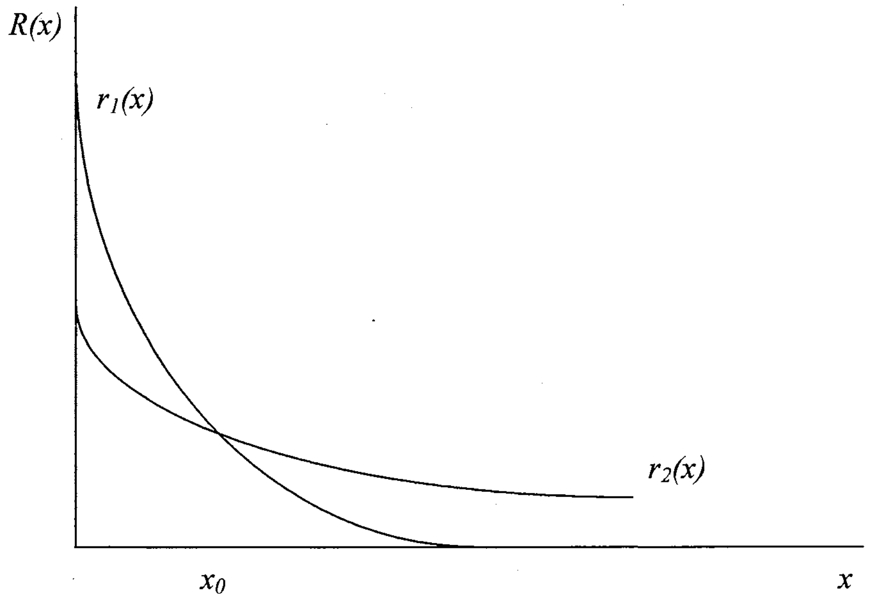
Equation (2.4) shows that only when the transportation cost increase with a move away from the center is exactly balanced by a land cost decrease will the household be in location equilibrium.

The location equilibrium condition along with income changes was once used to explain the positive income-distance relationship. To see this point, rewrite Equation (2.3) as

$$\frac{dr(x)}{dx} = -\frac{T'(x)}{s} \tag{2.5}$$

where r is bid (land) rent of the household. We have replaced R with r since they could differ and market rent is decided by the highest bid rent. The dual problem of (2.1) yields (2.5). One's bid rent declines as one resides farther from the CBD. At each x, the rent actually paid, the market rent, is the highest bid rent. Thus, the steeper this slope, the more strongly the resident is attracted to the CBD. When marginal commuting cost declines or land consumption increases, the slope gets flatter, making a resident more likely to reside in the suburbs.

Figure 2.1 Bid Rent Functions for Different Households.



$r_1(x)$: bid rent for Group 1
$r_2(x)$: bid rent for Group 2

Suppose two groups have different bid rent functions as shown in Figure 2.1. Because Group 1 members with a steeper gradient outbid Group 2 members between 0 and x_0, Group 1 will occupy the central city area. Similarly, Group 2 will live outside x_0 because its members have a flatter bid rent function and outbid the other group in that region.

Land consumption, s, rises with income. As Equation (2.5) shows, an increase in land consumption makes the bid rent gradient flatter. Therefore, Muth (1969) and Mills (1972) argued that richer households, which Group 2 consists of, would live relatively far out where land rents per unit are lower. Poor households would have steeper bid rent gradients and live near the CBD. To Muth and Mills, a rise in income meant flatter bid rent gradients and a positive income-distance pattern.

Their contention, however, faced criticism. Commuting cost consists of monetary cost and time cost. The opportunity cost of commuting time also rises when income increases. In Equation (2.5), both the numerator and the denominator increase with income. Thus, the theory can not predict location patterns unless income elasticities of land and commuting cost are known. If the income elasticity of land consumption is greater than that of marginal commuting cost, a positive income-distance pattern emerges as a result of income growth, and vice versa. To avoid confusion, it should be noted that replacing, land consumption in the above discussion with h, housing consumption does not change the result. While Alonso and Wheaton analyzed frameworks where land is directly consumed and capital on land is considered part of the composite good, Muth, Mills, and Brueckner explored a model where housing is the final consumer good and land is an intermediate input to housing production. As far as the above discussion is concerned, both models yield the same results.

Estimates of the income elasticity of housing consumption vary substantially. In the 1960s, it was believed to exceed one. However, Ellwood and Polinsky (1979) reported that the income elasticity of housing demand is about 0.75. Mills (1989) asserts that their estimate is the best current evidence. Muth (1969 and 1984) estimated that time cost is only one-half of the marginal cost of commuting. Thus, he argued that the income elasticity of demand for housing service is greater than that of marginal commuting cost. Wheaton (1977), however, found that the bid rent curves of different income groups to be almost identical. His study suggests that the two elasticities are very similar. Thus, he argued that the Alonso, Muth, and Mills model contributes little to the explanations of the typical American location-income pattern. Some even believed that the income elasticity of demand for housing service is likely to be smaller than that of marginal commuting cost. If so, the rich would live closer to the CBD. As Mills and Hamilton (1989) said, the empirical evidence for these elasticities is mixed and uncertain. Thus, it is probable that income growth does not flatten bid rent gradients and, hence, fails to explain the positive income-distance pattern.

Due to the aforementioned problem with the traditional monocentric model approach, variants of the theory have tried to explain a positive income-distance pattern. LeRoy and Sonstelie's (1983) modal choice or transportation innovation theory introduces a transportation innovation model with multiple transport modes to explain the pattern. Their theory will be reviewed in detail in the subsequent section. Time extended models of Fujita (1989) and DeSalvo (1985) explain the income-location pattern, too. Their time extended models differentiate nonwage income and wage income and conclude that households with higher nonwage income locate farther from the CBD than households with lower nonwage income. They derive this conclusion because they assume transport cost is independent of nonwage income. When nonwage income rises, housing consumption increases while transport cost remains the same. Thus, the bid-rent gradient becomes flatter. This theory is essentially the same as the traditional approach of Alonso and Muth and provides few new implications.

In our view, the assumption that transport cost is independent of nonwage income level is problematic. It assumes that the opportunity cost of leisure and commuting time depends only on foregone wage income. That is, nonwage income does not affect the value of leisure time. However, it will be realistic to assume that opportunity cost of time is also a function of nonwage income. Even if you are rich largely because of nonwage income, you will put more value on time. Your leisure time is more valuable, and you are likely to be more sensitive to the inconvenience of commuting time. Even if their assumption on nonwage income sheds some light on the positive income-distance pattern in the United States, it does not explain various income-location patterns across the world.

Thus, Fujita[1] (1989) introduces a pure-wage earner case and explains the location pattern in terms of the income elasticity of land consumption and the cross-elasticity of land consumption to the price of leisure time. According to his analysis, when the sum of the income elasticity of land consumption and the cross-elasticity of land consumption to the price of leisure time is less than one, both the high and low wage earners reside near the city center and middle wage earners gravitate toward the suburbs. He argues that this is consistent with observations in large cities in America, but he does not provide systematic empirical evidence.

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[1] For details, see Fujita (1989 pp.31-38).

Moreover, this theory does not produce satisfactory results as to the different income-location patterns in different countries. There is no evidence or reason that the wage elasticity[2] of lot size is greater than unity in other developed[3] countries. Do consumers in those countries have different tastes? Maybe, yes. However, explaining different results in terms of different tastes is ad hoc theory.

In short, the traditional monocentric approach focusing on income growth was empirically refuted. The time extended models have not received much attention as far as the income-distance pattern is concerned. Two other natural evolution theories have received more attention. They are filtering theory and the transportation innovation theory.

The Filtering Theory

Filtering theory focuses on preferences, income, and durability, heterogeneity, and deterioration of dwelling units. Filtering is "the process by which older homes gradually depreciate in quality and in price and thus become available to poorer families" (Ohls, 1974). One premise of the filter-down theory is the monocentric nature of the city. In a monocentric city, central areas are developed first. As an urban area grows, new housing is built at the periphery when the central areas are filled. The original residential areas close to the CBD tend to have old deteriorating housing stock as time passes. When income increases, people demand newer and more spacious housing. Thus, they move to the suburbs because land is cheap there, and the central areas are already filled with old

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[2] Fujita's expression for the sum of the two elasticities at hand.

[3] The word 'developed' is used to assume away the effects of differences in income and transport technology.

housing stock. The older dwelling units the rich leave behind subsequently filter down to a lower income group. This process continues as income rises and housing stock deteriorates. As a result, income stratified neighborhoods are formed. It should be noted that income growth is not a necessary condition of filtering, although it promotes the filtering process. The presence of multiple income groups and depreciation of housing units are the key premises of the filtering theory.

The filtering theory addresses not only suburbanization but also implications of filtering regarding housing markets. Because of heterogeneity of housing units, the urban housing market is composed of multiple sub-markets. What occurs in one sub-housing market affects other sub-markets. Since filtering is an essential feature in used housing markets, filtering models are often used to analyze housing markets and the efficiency of filtering. The efficiency of filtering as a vehicle to provide housing to low-income groups is controversial, but there is little controversy about the effects of filtering on suburbanization.

The nucleus of the theory is a description of what has happened in U.S. urban areas. Many empirical studies on suburbanization have confirmed the effects of filtering on income-distance patterns. Cook and Hamilton (1982 and 1984) constructed a model introducing the durability of housing units to a conventional monocentric model, and simulated it with data on Baltimore and Houston, an old and a new city. They claimed that the tendency of old housing to be located in central cities fully accounts for income segregation between the central cities and their suburbs. Bradford and Kelejian (1973) and Bradbury *et al* (1982) also found that high percentages of old housing stock in central cities are related to suburbanization and urban decline. Interregional comparisons present similar results. Old cities in the Northeast tend to have more older housing, and the income disparities between the central cities and their suburbs in those areas are also higher. This associates filtering with a positive income-distance pattern.

Despite merits of the filtering theory on the positive income-distance pattern, this theory raises a few questions. Income growth, depreciation of capital on housing, and the presence of multiple income groups are not confined to the United States. Thus, filtering occurs in other countries, too. However, the typical American income-location pattern is often reversed in other countries. Thus, we suspect that 1) the filtering process is relatively weak in other countries or 2) filtering does not necessarily result in the positive income-distance pattern. That is, the conventional filtering theory is not sufficient to justify the American income-location pattern. To overcome this limitation, in Chapter 8 we will explore how, in the presence of land abundance, filtering promotes the positive income-distance pattern.

The Transportation Innovation Theory of LeRoy and Sonstelie

LeRoy and Sonstelie's modal choice model has been widely cited as an alternative theory, in the context of the trade off theory of the income-location pattern. Transportation innovations accelerate suburbanization by reducing commuting costs. In the monocentric city, the advantage of the central city lies in lower transport cost resulting from the shorter distance to the CBD. However, this advantage is eroded by commuting cost reduction. Suburbs become more attractive, and the central locations less appealing. Density gradients become flatter. Another look at Equation(2.5)shows this relationship.

$$\frac{dr(x)}{dx} = -\frac{T'(x)}{s} \tag{2.5}$$

A smaller marginal commuting cost, $T'(x)$, implies a flatter bid rent gradient. In short, reduction in commuting cost promotes suburbanization by making the CBD more easily accessible from suburbs. No one argues against this point. However, a decrease in commuting cost does not provide an explanation for location-income patterns. People will move to suburbs. But who are they? Why could the poor not move to the suburbs?

LeRoy and Sonstelie (1983) argued that the introduction of new transport modes caused both suburbanization and income segregation. They introduced transportation innovations into the monocentric model to explain the income-distance relationship. They argued that when cars first became practical for commuting it gave the rich access to cheaper suburban land, since cars were available only to them. Accordingly, the rich lived in the suburbs and the poor in the centers.

Assuming the income elasticity of the demand for housing is less than that of the marginal cost of commuting[4], they envisaged four eras for the central city:

- Paradise: The faster mode is so expensive that all commuters use the slower mode, thus the rich live downtown.
- Paradise lost: The cost of the faster mode falls enough so that the rich, but only the rich, can afford to adopt it. Then the rich live in the suburbs.

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[4] Then, other things being equal, the rich will have a steeper bid rent curve and live in the central city. This assumption is not strongly supported by empirical evidence, but it has no theoretical problems as long as the emergence of the positive income-distance pattern is concerned.

- Regentrification: The material cost of the faster mode continues to decline so that some poor households now use it and can move to the suburbs while some of the rich move downtown.
- Paradise regained: A further decline in the material cost of the faster mode enables all the poor to move to the suburbs. The wealthy live in the center again.

Their theory overcomes one of the limitations of the monocentric model. Although a number of subsequent studies on U.S. suburbanization cite their work., it has some problems. First of all, successive transport innovations have occurred all around the world, but the positive income-distance relationship is peculiar to the United States. Their theory suggests a limited view in that sense. This problem has been noticed by others, too. Brueckner et al (1997) state "it is not clear that the theory [LeRoy and Sonstelie (1983)] is capable of explaining the worldwide variation in location patterns."

Second, they just assumed a faster and expensive mode and a slower but inexpensive mode. Switching from transit, slower but inexpensive, to the car, faster and expensive, is the core of their theory. However, the railway system, whose private cost is low, is not technically slower than the car. It is faster than the car, more often than not. The bus, another transit mode, shares the basically same technology with the car as far as the mechanical speed is concerned. Cars might be faster than buses. However, the speed difference is minor in urban areas, where traffic congestion and relatively strict speed regulations are present. Their model is too simple to capture major differences between the car and mass transit. Major advantages and disadvantage of mass transit hinge on demand density, which is positively related to population density, at a given location. An essential feature of urban areas, which they neglected, is that population density declines with distance from the CBD.

Third, gentrification would have occurred by now according to their theory. When they wrote their paper, they observed some signs of central city renovations and gentrification. Frieden and Sagalyn (1991) found that the number of renovations was very small, however. Gin and Sonstelie (1992) stated that regentrification has occurred since the 1970s, but they acknowledged that it has not been substantial.[5] Hill and Wolman (1997) tested causes of the changes in income disparities between U.S. central cities and their suburbs from 1980 to 1990. One of their findings, which is not consistent with paradise regained, is that the gap in per capita income of central city and suburban residents is large and grew from 1980 to 1990.

The best empirical evidence is that there is no significant difference between the elasticity of marginal commuting cost and the income elasticity of housing demand. However, it is difficult to assume this pattern in a theoretical model with multiple commuting modes. Obviously, the elasticity of housing demand is independent of commuting modes, but the elasticity of marginal commuting cost is not. Different modes are more likely to imply different income elasticities of marginal commuting cost. This poses theoretical complications, because we cannot simply assume that the (two) elasticities of marginal commuting costs and the income elasticity of housing demand are always equal.

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[5] Note one of the authors, Sonstelie (1983) anticipated stronger regentrification when he and LeRoy first presented their theory on transportation mode choices and residential patterns presented their theory on transportation modal choices and residential patterns.

If we assume, as LeRoy and Sonstelie did, that the income elasticity of the demand for housing is smaller that of the marginal cost of commuting in any case, this problem disappears. If a force could change the paradise phase (the rich in downtown) to the paradise lost phase (the rich in suburbs), it would change more easily the no income-segregation phase to the paradise lost phase.

A number of theories offer explanations on suburbanization and urban poverty concentration. They are not necessarily conflicting and may complement each other. The flight from blight theory has some variables prominent in the United States. It is doubtful, however, that racial tensions and fragmentary local jurisdictions alone can explain why urban poverty concentration is severe in the United States. The conventional monocentric model failed to predict the income-distance relationship. The filtering theory and the transportation innovation theory account for urban poverty concentration, but do not explain why the positive income-distance relationship is prevalent in the United States and not in other developed countries.

CHAPTER III

LAND SCARCITY AND URBAN STRUCTURE

Introduction

There must be some variables or parameters that are unique or especially strong and have made suburbanization in the United States distinctive from that of many other countries. In our view, the key difference is relative land scarcity. In this chapter, we examine the effects of land scarcity on basic urban structure. Its eventual effects on the income-distance pattern are studied in the two subsequent chapters. Land scarcity depends on population density and economic growth. The demand for land increases with the increases in population and income. Population densities of various countries are compared. Data on the ratios of the total land value to GNP are also presented, since they imply relative land costs of a given country. These two sets of data show the land abundance of the United States.

After relative land costs of a number of countries are compared, we formally discuss why land scarcity results in high agricultural land rent. There are many fine mathematical monocentric models, all of which yield the same comparative static results. Thus, a typical mathematical approach to the monocentric model is introduced to show the effects of agricultural land rent. The model's conclusion of interest is that high agricultural land rent causes higher urban density gradients. Higher equilibrium structural density, capital intensity of housing, and its changes over time have an important implication with respect to filtering. This is discussed later in Chapter 6.

In this chapter, the effects of population density on urban transportation structure are also examined. High population density is a necessary condition for mass transit efficiency, while low population density make commuting by car advantageous providing that the income level is relatively high. These effects are the premise of our modal choice theory, discussed in the next chapter. Finally, in this chapter, another important implication of the effects of land scarcity on urban transportation structure is discussed. Many big U.S. city governments struggle financially to maintain their transit. We contend that rapid suburbanization caused by land abundance is responsible for this problem.

International Comparison of Land Scarcity

Other things being equal, the more people residing in a given area, the more valuable the land is. Thus, we need to compare average population densities of many countries to see how scarce or abundant land is in the United States. Land scarcity depends on land supply, population, and income. Demand for land and land value rise as an economy grows, since land is a normal good. Heterogeneity and immobility of land are also important aspect of land scarcity. Desert or rainforest a thousand miles away from a highly populated area does not mean much in terms of land scarcity. The United States has ample land supply and very low population density, quite different from other developed countries except Canada and Australia. In these last two countries, however, most of land is hardly inhabitable or arable. Table 3.1 shows a few countries with lower population densities than America. They are Australia, Bolivia, Brazil, Canada, Congo, Iceland, Libya, Mongolia, and Russia. However, they either are low-income countries or have large portions of uninhabitable or inarable land. To quote Mills and Hamilton

(1989, p.378): "The only nations with lower population densities than the United States are those with large tracts of virtually uninhabitable land."

Table 3. 1 Average Population Densities (In persons Per Square Mile), 1994

Country	Population Density	Urban Population	Country	Population Density	Urban Population
Australia	6.1	85%	Austria	245	54%
Bangladesh	2,184	14%	Belgium	853	97%
Bolivia	18	58%	Brazil	48	76%
Bulgaria	205	67%	Canada	7	77%
China	322	28%	Congo	18	41%
Czech Republic	342	73%	France	275	74%
Germany	588	85%	Greece	207	58%
Iceland	7	91%	India	752	26%
Indonesia	270	31%	Italy	499	68%
Japan	857	77%	Libya	7	76%
Mexico	122	71%	Mongolia	4	57%
Russia	22	73%	Rep. of Korea	1,176	74%
Singapore	10,574	100%	Spain	201	78%
Switzerland	441	68%	Taiwan	1,524	75%
United Kingdom	616	92%	United States	69	75%

Source: The World Almanac and Book of Facts 1995.

One characteristic of countries with lower population densities than the United States is that their population is concentrated in the small portions of whole national territory. Few people live in deserts of Australia, tundra in Siberia, or the rain forest in Brazil. The rain forest in Brazil and Congo can be converted to arable or inhabitable land. However, the conversion takes capital and many of those areas are remote from the cities. In the United States, population and urban areas are rather evenly distributed compared with those countries. Thus, land abundance is a variable that may differentiate U.S. urban structures and urban poverty concentration, relative to other countries. The population densities of European countries are five to ten times as high as that of the United States. In Japan, the density almost doubles those of many European countries.

As we noted earlier, some developing countries in Africa and Latin America have lower population densities than the United States. They, however, do not appear to have the American income-location pattern. For the isolation of the effects of land scarcity, it will be wise to compare countries with similar conditions, except land scarcity. It is not just how much land is available but how expensive usable land is that counts. Or, even more precisely, the opportunity cost of urban land is the key in our discussion. Comparing ratios of land value to GNP to population density is more helpful in understanding land scarcity in a given country.

Table 3.2 compares values of some European countries and the United States. Note that those countries have similar per capita income. Although the ratio of land value to GNP of the United States is similar to those of European countries, it is clear that the land prices in the United States are quite low, when land availability per person is taken into account. In short, empirical evidence shows that land is more costly in Western Europe and Japan, where land is relatively scarce, than in the United States.

Table 3.2 Ratios of Land Value[6] to GNP and Population Density

Year	Ratio of Land Value to GNP (1977)	Population Density (per square mile,1994)	Area per person* (in square mile,1994)
Denmark	0.60	311	3.22
France	0.93	275	3.64
Germany	1.08	588	1.70
Switzerland	0.88	441	2.27
U.K.	0.88	616	1.62
USA	0.98	69	14.49
Japan	3.32**	857	1.17

Source: Boone (1989) for ratios of land value to GNP; *The World Almanac and Book of Facts 1995* for population density; Mills and Ohta (1976) for Japan

* reciprocal of population density

** 1972

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[6] The land value data is old, but it is generally believed that the ratio of land value to GNP is relatively stable. Notable exceptions were Korea and Japan due to very rapid land price increases that occurred during the 1950-80s. However, the trend in Korea and Japan was reversed in the 1990s.

Land Scarcity, Agricultural Land Rent, and the Monocentric Model

Land scarcity of a country determines agricultural land value, which in turn, increases urban land value. To look at the effects of land scarcity on urban areas, suppose H and L represent two identical countries, except the former has little land, and the latter has much land. Assume two cities, City H and City L, which have the same population size. Then, City H would have a spatially smaller urban area, higher population density, and higher land rent[7]. City L would have a larger urban area, lower population density, and lower land rent. This conclusion can be reached by a casual observation around the world. To see this, however, it is helpful to note that the agricultural land rent will be higher outside City H. Holding population constant, a reduction in national land supply implies that agricultural land will be intensively used with more capital and labor. Then, the marginal productivity of agricultural land and, accordingly, its rent will be higher. Higher marginal productivity implies higher rent. In addition, in the country where land is scarce, rural areas will be more densely inhabited. This also raises rural land rent.

Suppose a country's agricultural production function is given as

$$Q = f(I, L) \tag{3.1}$$

where Q = the output level of agricultural product, I = composite non-land inputs, and L = the supply of arable land. Assume that input and output markets are perfectly competitive. Although L is mostly fixed, individual farmers face a perfectly elastic supply curve for land. Thus, the assumption of competitive land market is not unrealistic.

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[7] Land rent per unit is the precise term. However, for simplicity, we will refer to it as land rent or rent unless otherwise noted.

Further, assume that constant returns to scale apply to the production function. Under constant returns to scale, by Euler's theorem, we get:

$$f_I I + f_L L = Q \tag{3.2}$$

where subscripts are used to denote partial derivative of each variable. Multiplying both sides of (3.2) by the price of agricultural product, P, yields:

$$VMP_I I + VMP_L L = PQ \tag{3.3}$$

If the marginal product of land falls as land supply increases, we can state that land scarcity results in higher marginal productivity and high agricultural land lent. To make this point rigorous, let us take a few more steps.

Differentiate (3.2) with respect to I and L respectively, to get

$$f_{II} = -f_{IL}\frac{L}{I} \tag{3.4}$$

$$f_{LL} = -f_{IL}\frac{I}{L} \tag{3.5}$$

By totally differentiating (3.1) along an isoquant, we get

$$\frac{dI}{dL} = -\frac{f_L}{f_I} \tag{3.6}$$

Differentiate (3.6) with respect to L, and after some algebraic manipulations[8], we can see that

$$\frac{d^2I}{dL^2} = \frac{f^2 f_{IL}}{LIf_I^3} \tag{3.7}$$

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[8] For details, see Binger and Hoffman's Micro Economics with Calculus (1986, p.247).

Diminishing marginal rate of technical substitution implies that (3.7) is positive, which, in turn, means that $f_{IL} > 0$. Then, (3.4) and (3.5) are negative, which implies diminishing marginal products. In the above discussion, constant returns to scale have been assumed. However, the result does not depend on that assumption. When a conventional U-shaped long-run average cost curve is present, the only possible long run equilibrium occurs where the output price equals long-run average and marginal costs. That is, competitively priced payments to inputs exhaust revenues, which means (3.3) holds.

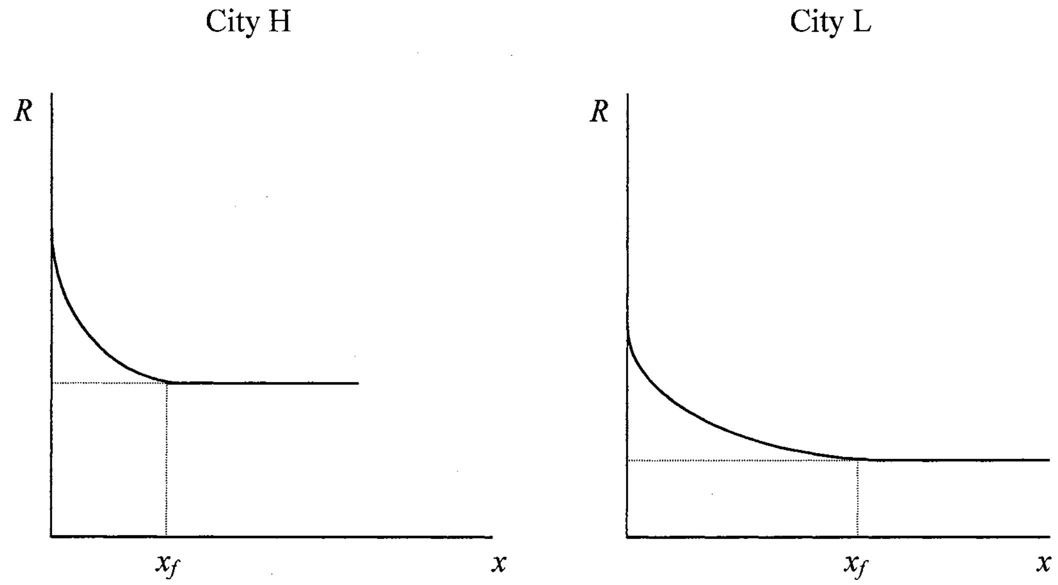
Diminishing marginal returns to land input means that land rent will be lower when the supply of arable land is ample. That is, land scarcity implies higher agricultural land rent, other things being equal. Since the alternative use of urban land is agricultural production, the common assumption in basic urban economic analysis, land scarcity would also mean higher rent at the urban boundary. Thus, we get:

$$\frac{dR_A}{dL} < 0 \tag{3.8}$$

where R_A = agricultural land rent or land rent at the urban boundary and L = national land supply or land abundance. (3.8) implies that a country with land abundance will have low agricultural land value.

Now we will discuss the effects of agricultural land value on urban land value and other urban economic variables. Scarcity of land makes land rent gradients higher. Imagine an urban area on a plain where agricultural land rent is zero. Then, modify the assumption that agricultural land rent is zero. Because of the positive agricultural land rent, the distance between the center and the city boundary becomes shorter. Thus the urban area shrinks; its population density increases. Then, thanks to a new higher density, land rent gradients would become higher. Figure 3.1 represents this relationship between land supply and land rent gradient.

Figure 3.1 Land Supply and Land Rent Gradients



x_f: urban fringe

These effects of an increase in agricultural land rent were proven by both theory and empirical evidence. Wheaton (1974) did a comparative static analysis of the Alonso model, as did Brueckner (1987) of the Muth-Mills model. Fujita (1989) also offered an elegant analysis of that matter. Considering both a housing or land demand function and a corresponding production function, they derived equilibrium solutions and provided comparative static results. Brueckner's model appears to be in more depth than Wheaton's because land is treated as an intermediate good for housing production. Thus, it gives additional information on housing and structural density.

In Brueckner's model, all consumers are identical with the same income y per period and identical preferences. They commute to the CBD along a dense radial road network. Commuting cost is T per round trip mile. The strictly quasi-concave utility function is $v(z, q)$, where z is a composite non-housing good and q is consumption of housing measured in square feet of floor space. The price of z is the same everywhere and assumed to be one. Housing rental price per square foot, p, varies with distance x to the center. Since consumers are identical, they must achieve the same utility level u regardless of location. Their budget constraint is given as $z + pq = y - Tx$. Housing is produced with capital and land under constant returns to scale. Producers maximize profit per acre of land, which is $ph(S) - iS - R$, where h is housing per acre of land, i is the rental price of capital, S is structural density (capital per acre of land), R is land rent. Population density in the model is $h(S)/q = D$ (floor space per acre divided by floor space per dwelling).

The equilibrium conditions for the city are

$$R(x_f, t, y, u) = R_A \tag{3.9}$$

$$\int_0^{\bar{x}} 2\pi x D(x,t,y,u)dx = N \tag{3.10}$$

where N is the urban population. Equation (3.9) implies that the equilibrium land rent at the urban fringe x_f must equal agricultural land rent R_A, while Equation (3.10) says that the urban area contains all the urban population.

Monocentric models are divided into closed-city models and open-city models. In the closed-city model, the urban population N is exogenous. That is, migration is ruled out.

Thus, the utility level of the residents is endogenous. In the open-city model, however, migration is assumed to be costless. Hence, the urban utility level is exogenous such that it equals that of the rest of the country. Costless migration also implies that the population of the city is endogenous. Brueckner (1987) analyzes both models, but our focus in this study is on the closed-city model. It is because that the closed-city model is theoretically more fundamental and that it is more appropriate to explain the American location-income pattern. To quote Fujita (1989, p.54), ".... it [the closed-city model] is more fundamental from a theoretical point of view,.... The closed-city model is a useful conceptual device for analyzing urban land uses in large cities or "average cities" of developed countries. The open-city model, however, better describes urban conditions in developing countries that have surplus labor in rural areas. In the latter case, rural life often establishes the base utility level of the economy."

The comparative static analysis of the closed-city case provides the following results[9]. The signs are the same in the models where land is directly consumed.[10] The effects of an increase in N, urban population of the urban area, are

$$\frac{\partial x_f}{\partial N} > 0, \quad \frac{\partial u}{\partial N} < 0, \quad \frac{dq}{dN} < 0, \quad \frac{dR}{dN} > 0, \quad \frac{dS}{dN} > 0 \tag{3.11}$$

The effects of an increase in R_A, agricultural land rent, are

$$\frac{\partial x_f}{\partial R_A} < 0, \quad \frac{\partial u}{\partial R_A} < 0, \quad \frac{dp}{dR_A} > 0, \quad \frac{dq}{dR_A} < 0, \quad \frac{dR}{dR_A} > 0, \quad \frac{dS}{dR_A} > 0 \tag{3.12}$$

(3.12) shows that when agricultural land rent is high,

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[9] For derivation, see *Handbook of Regional and Urban Economics*, V II, pp.840-844.

[10] See Wheaton (1974).

- the spatial size of the urban area is small.
- the urban utility level is low.
- the housing price of given quantity is high.
- the consumption of housing (or land) is small.
- the urban land rent is high.
- the housing is more capital intensive.

The results describe the status in Japanese cities, and the exact opposite phenomena are observed in U.S urban areas. The most important cause behind these differences is land scarcity. Brueckner and Fansler's (1983) test Brueckner's model, and they conclude that urban sprawl (a greater value of x_f) is related to population, income, and agricultural land rent in the way indicated by the comparative static results. Their empirical work, however, does not test the residential location pattern.

Agricultural land rent in the model is exogenous. In reality, it depends on a number of factors such as land scarcity, fertility, amounts of capital and labor, technology in the agricultural production function. Suppose agricultural land rent is a function of land supply L. That is, $R_A = R_A(L)$. In the above model, the supply of land does not affect any other variable than the agricultural land rent. R_A remains exogenous. The mathematical structure of the model does not change at all. Thus, (3.12) can be rewritten as

$$\frac{\partial x_f}{\partial L} > 0, \quad \frac{\partial u}{\partial L} > 0, \quad \frac{dp}{dL} < 0, \quad \frac{dq}{dL} > 0, \quad \frac{dR}{dL} < 0, \quad \frac{dS}{dL} < 0 \tag{3.13}$$

(3.13) explains that land abundance in the United States causes low-density development and low urban land value.

Land Scarcity and Urban Transport Systems

Mass transit and cars are the two most important commuting modes in urban areas. According to 1990 U.S. census reports, 95.8 % of workers in urbanized areas used either a car or transit. The car is suitable for low-density areas, while mass transit is suitable for high-density areas. Land scarcity affects urban population density, which falls with the distance from the CBD. Thus, land scarcity is bound to influence urban transportation systems and modal choice. In this section, those relationships are analyzed. Let us see how higher land value induces cities to depend more on mass transport system than on automobiles. First, the relationship between land value and traffic congestion sheds light on that point. Generic monocentric models assume away traffic congestion. Our discussion has so far ignored congestion, too. Now consider the possibility of congestion. Land is an important part of road construction. When land value is high, road construction cost will be high. Then it is efficient to economize on land and roads. Traffic congestion can be a solution, since congestion is the substitution of commuting time for land or road capacity. In other words, greater congestion is efficient when land value is higher.

Congestion should be worse in central cities or cities facing land scarcity. This point has already been made by urban transportation economists. However, it is not well appreciated that high land value, which implies higher levels of optimum congestion, leads to relatively heavy use of mass transit. A bus takes more space on a road than a car does. That is, its cost on congestion is greater than that of a car. However, the cost difference is minor considering the accommodation capacity of the bus. A bus can carry more passengers by far than a car. Thus, buses have lower congestion cost per rider than cars. In other words, the efficacy of buses relative to cars increases with land scarcity. The advantage of mass transit in the face of congestion is more evident for the subway. Construction of a subway system involves heavy capital cost. However, the land use of subway systems is extremely low. As far as congestion is concerned, subway systems impose the least cost. In short, mass transit alleviates congestion and uses scarce land more effectively than the car. Thus, the closer to the CBD or the more scarce land is, the worse congestion is and the more efficient mass transit becomes.

Second, by raising demand density for commuting, land scarcity increases the efficacy of mass transit relative to cars. This point is valid even under the assumption of no traffic congestion. To understand this point, we examine the components of commuting cost. Commuting modes have three sets of costs related to each part of a work trip. Line-haul cost is the cost of moving passengers by the main vehicle from the collection point to the downtown distribution point. Collection cost involves travel cost from the home to the main travel vehicle. Distribution cost involves travel from the end of the vehicular trip to the workplace. It also includes parking cost, if necessary, in the CBD. All three costs mentioned here involve time, convenience, and money, although out of pocket expenses of collection and distribution costs are much lower than those of line haul cost. However, it should be noted that the money cost of distribution could be higher than that of line-haul cost if parking cost is very high due to higher land value.

Another way of looking at commuting cost is dividing the cost into time cost and monetary cost. Monetary cost is out-of pocket expenses spent on the whole trip while time cost is the subjective value of time spent on the trip. The phrase "subjective" has an important implication. The value of time depends not only on the physical time but also on income and comfort. As income rises, the value of time also increases. Hensher (1977a) reports that commuters value line-haul time cost at between one-third and one-half their wage rates. Convenience or comfort is important, too. For instance, according to Hensher (1977b, p90), a value of walk time per person hour is $US 5.46, whereas a value of in-vehicle time per person hour is $US 0.95.

Let us compare commuting costs of mass transit and cars for each phase of a work trip.

- Collection cost: The auto mode has no collection cost because the driver uses his own vehicle right from home. The mass transit mode has significant collection cost because the rider must walk from his home to the transit stop. He also has to wait for the vehicle to arrive at the stop. Inclement weather can also be a problem. Unanticipated delays might add additional cost. However, monetary costs of both modes are zero or minimal at this portion of trip.
- Line-haul cost: LeRoy and Sonstelie (1983) implicitly assume that the physical speed of the car is faster than that of mass transit. However, the speed of the bus is comparable to that of the car. Subways, which are mass transit, are faster than the bus and the car. However, the overall speed can be another story. Mass transit makes frequent stops to pick up passengers on the way to the CBD and it could require transfers. Nevertheless, it is fair to say that subways are the fastest, while cars are faster than buses. When it comes to monetary cost, cars are more expensive than mass transit. It should be also noted that cars provide more privacy and comfort. Thus, it is difficult to generalize each mode's relative advantage in terms of line-haul costs.

- Distribution cost: The time cost is higher for mass transit because of the headway, time between scheduled transit services, and the distance between the stop and the workplace. The headway increases with distance because transit service is less available to distant low-density suburbs. The car has little distribution time cost because of its easy accessibility to a single point. When it comes to money, cars have higher cost because car commuting requires parking at the CBD, where land cost, hence parking cost, is high. The higher the density of the CBD, the higher the distribution cost of cars. On the other hand, mass transit incurs no monetary cost at this part of the trip. If we assume, for simplicity, that the CBD is a single point where workplaces and transit stops are concentrated, it can be said that overall distribution cost is higher for the car.

Now let us compare commuting cost in terms of time and monetary costs.

- Monetary cost: As a whole, it is higher for the car because the car has higher parking and operation costs while the mass transit fare is low, given adequate demand. Besides, the car involves substantial fixed costs such as the payments for the car ownership and insurance costs. Note that insurance premium is higher in larger cities. The cost of mass transit is low in larger cities due to their high density in central areas.
- Time cost: Roughly speaking, it is higher for mass transit because its collection and distribution time costs are higher. Since the subway network is usually less dense than the road network, collection and distribution time costs of the subway are higher than those of the bus. The fast speed of subways can be offset by their high collection and transfer costs. Line-haul time cost of transit is not much

different from that of a car, although the key assumption of LeRoy and Sonstelie's model is that it is higher for mass transit. A very important feature of mass transit commuting cost is that its collection and distribution costs increase with distance from the CBD.

Table 3.3 Commuting Costs with Three Phases of a Trip

Mode	Components	Total cost	Collection*	Line-haul	Distribution
Transit	Time	high	high	similar	moderate
	Monetary	low	0	low	0
Car	Time	low	0	similar	0
	Monetary	high	0	high	high

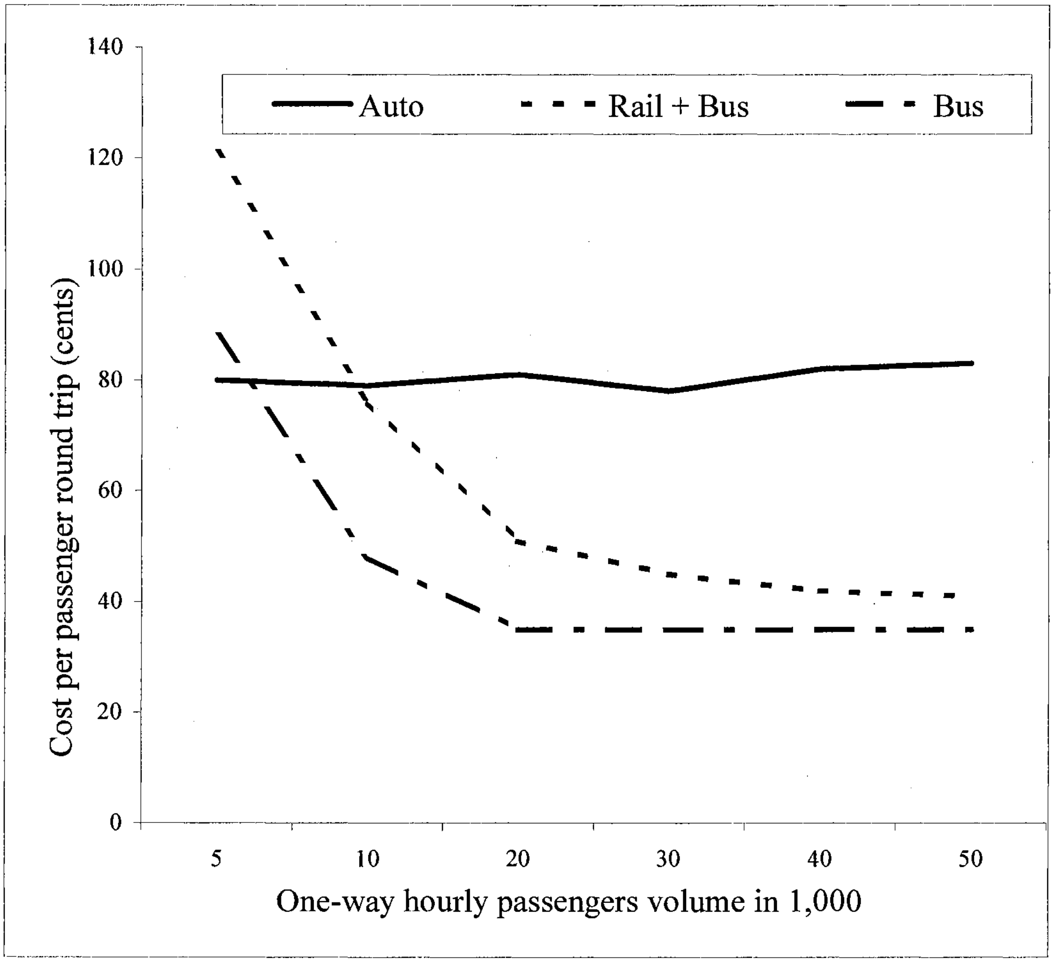
* Collection cost of transit increases with distance.

To sum up the discussion, Table 3.3 is introduced. Note that fixed costs such as the payments for the car ownership and insurance costs are not included to make the tables simpler. The tables are based on the assumption that 1) the city is monocentric, and the person commutes to the CBD, 2) only one line-haul vehicle is used, and 3) the person walks during the collection and distribution phases. Mass transit has advantages in monetary cost, but its time cost is higher. In short, the car has an advantage in collection cost. However, the true costs borne by a commuter are more complicated than the table suggests, since time cost is subjective and depends on the commuter's income.

As income rises, time becomes more valuable and the car becomes more affordable. This implies that commuters are more likely to adopt a car as their income rises. Thus, the fact that the United States and Western European countries are more auto-oriented than Eastern European and developing countries can be explained by differences in per capita income. However, income differences between the United States and Western European countries are minor, while the United States is significantly more auto-oriented than Western European countries. Why? Pucher (1990) states that much of the variation is due to public policy. He says that, in European countries, governments have set the costs of auto ownership high and offered extensive public transport services at extremely low fares, while in the United States large subsidies to highway construction, automobile use, and low density suburban housing have made the automobile very appealing. His contention may have some points, but it misses the mark. What caused the different public policies? Is there any natural economic force, other than income level, that has affected the public policy and modal choices of individuals? In our view the variation in urban transport systems can be attributed to, technology, income, and land scarcity, which public policy reflects. When income and technology levels are similar, land scarcity would explain the differences among urban transport systems.

Demand density for mass transit is no less important to the modal choice than income. It is well known that an essential feature of mass transit is that there are great economies of scale. Meyer, Kain, Wohl (1965) did a pioneering study on this subject. Figure 3.2 comes from their study. All results are for a ten-mile line-haul facility and a two-mile downtown distribution route. Integrated service means that all three phases of the trip are done by a single vehicle. The cost for the car is relatively constant, while costs for mass transit modes decline, due to the inherent returns to scale, as passenger volume along the corridor increases. Only at very low volumes is the cost per passenger lowest for the car.

Figure 3.2 Comparative Modal Costs



Studies subsequent to the work of Meyer *et al* (1965) yield similar results. Keeler *et al* (1975) report that the automobile is the cheapest mode at demand densities of less than 2,000 passengers per hour and a subway becomes more economical than the car only when density exceeds a bit over 20, 000. Both studies show that an integrated bus system is the cheapest over a modest level of density. Meyer *et al* (1965) contended that railway systems can be cheaper than bus systems above 30,000 passenger per hour, although their claim is refuted by Keeler *et al*(1975) and Boyd *et al* (1978).

Public transport systems require a very large capital investment to operate and high fixed costs. Railway systems have the greatest economies of scale, while bus systems also have significant economies of scale. In car-based systems, on the other hand, there are no economies of scale beyond very modest densities of travel. The cost of running a train or a bus is largely independent of the number of passengers carried. Time-wise, collection and distribution costs of mass transit are high but they can be reduced if demand densities are high. Thus, mass transit is most economical when a large number of passengers commute. The relative disadvantage of mass transit in suburbs can be explained by the spatial nature of cities, not just by high fixed capital costs of mass transit. Urban areas are not lines but spaces. Suppose, x is the distance from the city center and x_f denotes the distance from the center to the urban boundary. Given x, the size of the area is πx^2. Thus when x increases, space expands more than proportionally to the distance. Therefore, if x_f becomes greater, the transit system has to cover an area that increases more than proportionally. This is true for both modes, but it causes more problems for transit. Cars can run on narrow streets and roads, and its driver can go to most points in an urban area. On the other hand, buses run only on certain routes, and railroad service is available only along limited and much denser lines. Thus, the cost of a given level of mass transit increases with distance from the city center.

As seen in Figure 3.2, most empirical work on intermodal cost comparisons show results of varying demand density at a given distance. Land value is positively related to population density. Population density decreases with distance from the CBD, and it is higher in a large city. High population density implies high demand density. Then, by combining these facts, we can derive important implications:

- The average cost of car commuting is roughly constant as distance from the CBD increases.
- The average cost of mass transit rises as distance increases.
- The cost of mass transit is lower in a larger city.

A large city with concentrated workplaces at a single center and higher residential densities is one in which mass transit oriented systems work well. Countries with land scarcity and higher land value tend to rely relatively more on mass transit because they have higher urban densities. Since population density is low in suburbs, economies of scale inherent to mass transit account for the fact that suburban commuters find the car more appealing than mass transit. However, it is also true that mass transit can be less costly than the car, if suburban densities are very high. Table 3.4 shows that Tokyo is an example. It can be inferred that fewer commuters in Tokyo use cars even in the suburbs than in a large but low-density city such as Los Angeles. Mills and Ohta (1976) report that only 31 percent of families in the twelve largest cities in Japan owned cars in 1972 while the proportion rose with decreasing city size, reaching 42 percent in small towns and villages. Thus, it is fair to say that the heavy reliance on mass transit in Tokyo suburbs is partially due to high density. Table 3.4 shows that larger cities rely more on mass transit than smaller cities. Table 3.5 provides data on commuting modes of Japan and the United States. As expected the United States relies far more on cars.

Table 3.4 Modes of Commuting, Large Japanese Cities, 1970

City	Number of commuters (thousands)	Percentage commuting by					
		Foot	Railway	Bus	Car	Bicycle or Motor cycle	Other
Tokyo CBD	1,847	3.1	85.8	4.2	5.3	0.4	1.1
Tokyo ward area	5,599	15.1	66.5	7.2	7.2	3.1	0.9
Osaka	2,137	16.0	60.2	8.5	9.7	4.9	0.8
Nagoya	1,136	16.5	29.6	24.6	20.9	6.9	1.5

Source: Mills and Ohta (1976, p.719)

Table 3.5 Modes of Commuting in Japanese Cities and U.S. SMSAs, 1970

Mode	Japan	United States
Automobile	14.5	78.3
Railway	46.0	12.1
Foot	23.4	6.4
Other	16.1	3.2

Source: Mills and Ohta (1976, p.718)

Table 3.6 Advantages of Transportation Systems

Land scarcity	City Size	Central City	Suburbs
Scarce	Large	Mass transit	Mass transit
	Small*	Mass transit	Car
Abundant	Large**	Mass transit	Car
	Small	Car	Car

*: could be ambiguous. Transit-transit pattern is also possible.
**: Transit/car-car pattern is possible, too. This is the case with most large U.S. cities.

Relative advantages of urban transportation systems or modal choices are represented by the stylized facts in Table 3.6. Because the definitions of large or small cities are arbitrary, ambiguity exists. Some large cities in the United States, there are exceptions, however, may not have sufficient demand density to support mass transit even in the central cities. Los Angeles is somewhat different from an abstract monocentric city. Despite its huge size, its CBD has a lower development density, and it has many edge cities. Furthermore, Los Angeles has a less extensive mass transit system than other large cities in the United States. Besides, our discussion implicitly assumed a relatively high-income level. When the income level is so low that only a few can afford a car, cities will turn to mass transit regardless of land scarcity. However, it seems that the car is more likely the preferred mode in the suburbs or a country with land abundance and higher income compared with the central city or a country with land scarcity and lower income. These implications provide explanations for the positive income-distance pattern in the United States.

CHAPTER IV

MODAL CHOICE THEORY AND LAND VALUE

Introduction

In the previous chapter, we discussed how land scarcity and demand density influence the urban transportation structure and commuting modal choice. This point can provide explanations for the positive income-distance pattern by extending LeRoy and Sonstelie's model (1983). In this chapter, we explore how land scarcity affects income-distance patterns through its effects on modal choice. First, an intuitive exposition of our model is presented. It is argued that the car has an advantage in the suburbs because transit becomes more costly there due to low demand density, not slower line-haul speed. We also discuss the implication of urban history with respect to our modal choice theory.

In the following two sections, a formal model is presented. After the implication of the condition on the income elasticity of housing/land and those of marginal commuting costs with the presence of multiple modes is discussed, our transit and car commuting cost functions are presented. We analyze these two functions to examine the effects of parameter values on break-even distance. Then, our modal choice theory, which uses a bid-rent approach, is presented. It shows how positive income-distance patterns emerge under certain conditions.

The last section is devoted to discussion complementary to the modal choice theory. First, the condition on the convexity of the model is discussed. Then, the effects of congestion and the exhaustion of scale economies are presented. Finally, we discuss the implications of unequal income elasticities of marginal commuting costs conditional on different modes.

The Modal Choice Theory at a Glance

LeRoy and Sonstelie(1983) noticed that suburbanization and the flight of the middle class occurred at a fast rate in the 1950s and 1960s. They devised a transportation innovation theory to account for that trend and to predict its reversal. The gist of their theory follows.

If the rich and the poor use the same commuting mode, the rich will reside in the central city, because the income elasticity of housing demand is less that that of marginal commuting cost. During the 1950s and 1960s, the middle class could afford cars, which previously were available only to wealthy households, and whose adoption was limited by the Great Depression an World War II. People, the wealthy, with cars moved to the suburbs because the cars had the advantage there due to its faster (line-haul) speed. Now that most people can afford a car, they predict that the wealthy and middle class households will return to the central cities.

The weakness of their theory lies with the generality of the model. The positive income-distance pattern is not often observed outside of the United States despite similar technological innovations and income growth. We argue that they erred in their treatment of the advantage of each mode. The advantage of the car/transit in suburbs/central cities depends on demand density, determined in great part by land value and land scarcity, not physical speed. We generalize their model by introducing the effects of demand density on each mode. Thus, we provide a model that accounts for different income-distance patterns.

The best empirical evidence available so far suggests that the income elasticity of housing demand is not much different from that of marginal commuting cost, so that increased housing consumption with income is not believed to be the reason for the positive income-distance pattern. Keeping that in mind, assume a monocentric city that depends on mass transit only. This city will not show a positive income-distance pattern. Residential density declines with distance from the center. Since everyone is assumed to commute by mass transit, declining residential density means decreasing demand density for mass transit. Then, the average cost per mile of mass transit commuting will increase with distance from the center because the cost of mass transit increases, as demand density falls.

Mass transit requires heavy fixed cost in the form of capital investment and operation cost. From the commuters' point of view, however, that fixed cost is not relevant as far as commuting distance is concerned. The fixed cost has an effect on the level of fare, but it does not impose fixed cost on commuters. Commuters make their decision by considering the money and time costs. The mass transit fare per mile usually falls with commuting distance. This means that average monetary cost per mile will decline as commuters live farther from the center. However, time cost per mile increases with distance. Commuters have to walk longer to reach a mass transit stop, and waiting time increases. This increase in time cost more than offsets the decrease in average monetary cost. Thus, it is fair to say that average commuting cost of mass transit increases with the distance.

Suppose cars are introduced in this city. The car has substantial costs fixed with respect to distance, such as insurance and parking. Its variable cost, however, is roughly proportional to the length of a trip, and does not depend on demand density.[11] Thus, the average cost per mile of automobile transportation declines as distance increases. The car has an advantage over transit only beyond a certain distance. The break-even distance is the distance from the center where the preferred mode switches from transit to car. Different income groups face different break-even distances. Since we assumed the car is not available to the poor, the break-even distance applies only to the rich in this discussion, unless otherwise noted.

If the break-even distance is located beyond the urban fringe, everyone commutes by transit. If the break-even distance is inside the urban fringe, the wealthy households will move to the suburbs or a range between the break-even distance and the urban fringe. The poor will be concentrated in the central city. Thus, a positive income-distance pattern emerges. It should be noted that the flight of the rich households could extend the urban fringe, because rich households could reside in areas too costly to commute from by mass transit. When the wealthy households move to suburbs, residential density in the central city would decline. Then, the efficiency of mass transit could decline. This could further promote the flight of the middle class. In other words, the flight of the rich can be a self-reinforcing process because the flight lowers the efficacy of mass transit in the central city. This self-reinforcing nature is ignored in LeRoy and Sonstelie's model.

However, if the break-even distance is beyond the urban fringe, both income groups will use the same mode, mass transit. Then, the positive income-distance pattern will not emerge. Land scarcity can lead to this result, because it causes a city to have higher

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[11] As is the case with most generic monocentric models, we have assumed away congestion. When congestion is considered, the cost of the car indirectly depends on residential density.

residential density. If the city is dense enough for mass transit to have the advantage, even in the suburbs, the positive income-distance pattern will not occur. As we saw in Table 3.4, commuters in Tokyo rely on mass transit even in the suburbs. Tokyo is notorious for its higher land price and residential density and, as Fujita (1989) states, the positive income-distance relationship is not observed there. On the other hand, the United States has an abundant supply of land. Thus, U.S. cities tend to have low density. This suggests a stronger possibility that mass transit has the advantage in the central city while the car has it in suburbs; if so, the poor live in the central city and the rich reside in suburbs.

In short, our modal choice model is capable of explaining various income-location patterns. However, it should be noted that the positive income-distance pattern might disappear when even the poorest income group finds car commuting less costly in suburbs. Therefore, modal choice may not be a factor that actually promotes a positive income-distance pattern in the United States, because cars have become available to virtually all income groups. The car is virtually the only mode in small U.S. urban areas because the densities even in their central cities are too low to support the use of mass transit. Thus, it is fair to state that modal choice is not responsible for income disparities in small areas. The positive income-distance pattern in large US cities can be, at least partly, explained by the modal choice model. This is because:

- The urban structure of today is, to some degree, determined by its history. The effects of modal choice on income distance patterns are likely to remain even now. Current urban transportation systems also reflect the system of the past.

- The flight of the middle class caused by modal choice split is a self-reinforcing process, which creates and worsens central city problems. That is, modal choice creates a condition in which blight variables cause the positive income distance pattern.
- The fact that every income group can afford a car does not mean that all would find car commuting a better choice than transit commuting. Some poor persons would still find car commuting costly in very large U.S. cities due to higher operation, insurance, and parking costs. In the central areas of large cities, mass transit can be a less expensive choice than alternative transport for the poor.

Commuting Costs and Break-Even Distance

Now let us examine commuting costs of a car and mass transit to find the break-even distance. The implications from this break-even distance analysis shed light on the relative advantage of each mode in central cities and suburbs and the effects of cost variables on modal choice. The model rests on a set of assumptions as follows.

1. Two commuting modes, car and mass transit, are available.
2. The city is monocentric. All jobs are located in the CBD, which is a single point.
3. Commuting to work is the only travel. Travel is free of congestion. There is a dense, radial road network, but transit service density declines with distance from the center.
4. The land is a featureless plain.

The second assumption implies that distribution time cost of car commuting is zero. If the CBD is a single point, commuters do not need to walk from the distribution point to work. However, transit users face waiting time on their return trip due to the headway.

The headway is likely to be longer for a longer trip because transit service will be more infrequently available to lower density suburbs

Now let us specify the commuting cost functions of a car and of mass transit

Daily commuting cost of a car: T^a

$$T^a(x) = f^a + c^a x + wt^a x \tag{4.1}$$

f^a : per day fixed cost of the car.

c^a : variable monetary cost of the car per two miles

w : wage rate

t^a : line-haul time per two miles

x : miles from the CBD

Assumptions 4.1:

- f^a, c^a, and t^a are constant and positive
- w is nonnegative.

T^a is identical to LeRoy and Sonstelie's (1983) definition of daily travel cost of car commuting. $f^a + c^a x$ represents out-of-pocket costs for a commuter residing x miles away from the center, while $wt^a x$ denotes time cost in terms of money, the opportunity cost of time spent in commuting. MC^a, the marginal commuting cost of the car, $\frac{dT^a}{dx} = T_x^a = c^a + wt^a > 0$, a constant. Since $T_{xx}^a = 0$, marginal commuting cost of the car is constant at any given distance. AC^a, the average commuting cost of the car, is $(f^a + c^a x + wt^a x)/x$. Since $\frac{dAC^a}{dx} = -\frac{f^a}{x^2} < 0$, we can see that AC^a is decreasing at all x.

Daily commuting cost of mass transit

$$T^b(x) = c^b x + wt_L^b x + wt_C^b[m(x,l)] \tag{4.2}$$

c^b : monetary cost of transit per two miles

t_L^b : line-haul time per two miles

t_C^b : collection and distribution time of the whole trip

m : density of mass transit service at given distance

l : land abundance

Assumptions 4.2:

- $T^b(x)$ is continuous and differentiable.
- c^b, t_L^b, and l are constant and positive.
- $t_L^b = t^a$
- m is nonnegative.
- Density of mass transit service declines as distance increases; $\frac{dm}{dx} < 0$.
- When commuting distance is zero, commuting cost is zero; $T^b(0) = 0$ and $wt_C^b[m(0, l)] = 0$.
- Mass transit service declines when land is less scarce; $\frac{dm}{d\ell} < 0$.

- Collection and distribution time cost increase when mass transit service declines;

  $\frac{dt_C^b}{dm} < 0.$

- Collection and distribution time cost increase more than proportionally with distance;

  $\frac{dt_C^b}{dx} > 0$ and $\frac{d^2 t_C^b}{dx^2} > 0.$

$c^b x$ is the money cost, while $wt_L^b x + wt_C^b[m(x,l)]$ is the time cost, the opportunity cost of time spent in transit commuting. $wt_L^b x$ is the line-haul time cost, and $wt_C^b[m(x,l)]$ is the collection and distribution time cost. As commuting distance increases, the line-haul time cost increases proportionally. Since demand density is high at the CBD, the distribution time cost is a minor portion of $wt_C^b[m(x,l)]$. Density of mass transit service, *m*, at given distance is a policy variable that reflects demand density and the legacy of the past policy. Recall that provision of mass transit requires substantial initial fixed cost. The government provides mass transit service according to demand density, which in turn is positively related to residential density. If everyone uses mass transit, demand density will be equal to residential density. Demand and residential density decline with x. Thus, $\frac{dm}{dx} < 0.$

Land abundance is negatively related to residential density and transit demand density, which in turn are positively related to density of mass transit service: $\frac{dm}{dl} < 0$. The fact that collection and time cost increase when mass transit service declines, $\frac{dt_C^b}{dm} < 0$, is the most important assumption in our model. It is obvious that commuting cost will be zero if a commuter live at the CBD, which is assumed to be a single point. To ensure this property, we assume $w t_C^b\ [m(0, l)] = 0$. Land abundance can be defined as the single level of land abundance a city faces: agricultural land rent. Since the effect of land value at given distance on transit service density is captured by $\frac{dm}{dx}$, we assume l as the single value of land abundance for a city.

The transit commuting cost function of LeRoy and Sonstelie (1983) is given as

$$T^b = f^b + c^b x + w t^b x$$

which has the same form as T^a. They assume $f^a > f^b$, $c^a > c^b$, and $t^a < t^b$. Note that their t^b is comparable to our t_L^b. We assume $t^a = t_L^b$, which implies that the line-haul speeds of both modes are the same. We have assumed f^b is zero, since f^b is negligible. Even if f^b is positive, it does not cause a problem in our analysis as long as AC^b, the average cost of mass transit, exceeds AC^a commuting at certain distance. The variable monetary cost of the car is likely to be higher than that of mass transit. Thus, we assume $c^a > c^b$. It is not an essential assumption in our analysis, but it is in LeRoy and Sonstelie's (1983) model.

The largest difference lies with the time costs. LeRoy and Sonstelie's assumption that $t^a < t^b$ is too simple to capture the key difference between two modes. In their model, time costs vary proportionally with distance. This may be true for the car but not so for mass transit, which is subject to scale economies and has collection and distribution costs increasing with distance. Collection cost of the car is zero at all distance. Mass transit becomes inefficient at longer distance not because its line-haul vehicle speed is lower but because its collection cost rises. Thus, we have adopted a mass transit commuting cost function different from theirs.

The whole effect of x on mass transit commuting cost is represented as:

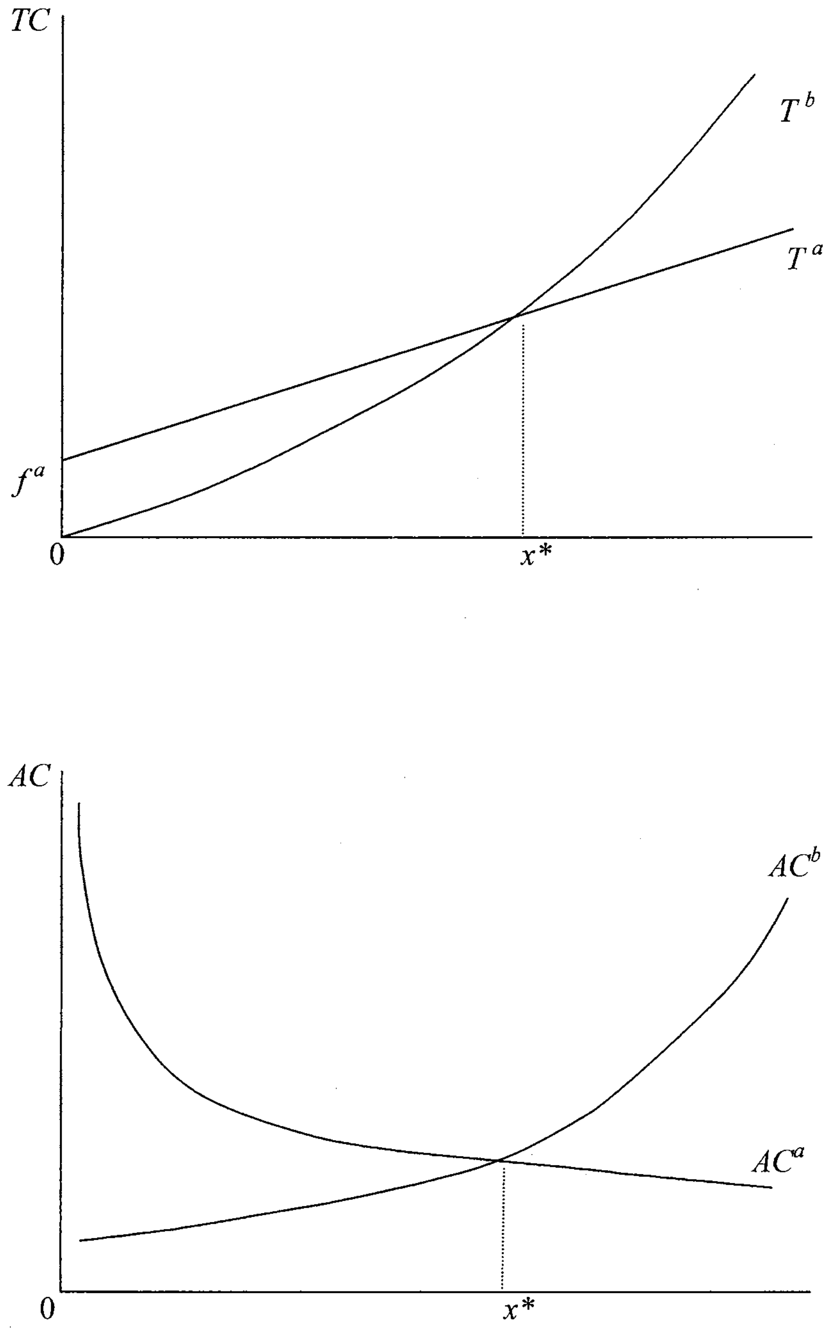
$$\frac{dT^b}{dx} = c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx} > 0 \tag{4.3}$$

$$(+)\ (+)\ \ (+)(-)(-)$$

Equation (4.3) is the marginal commuting cost of mass transit, MC^b or T_x^b. Since MC^b rises with distance due to increasing collection and distribution cost, we assumed that t_C^b increases more than proportionally with distance; $\frac{dt_C^b}{dx} > 0$ and $\frac{d^2 t_C^b}{dx^2} > 0$. However, relaxing this assumption does not change the implications of the model as long as T^b exceeds T^a at certain distance. This point is discussed later. The increasing marginal cost and zero fixed cost imply that the average cost increases with distance.

Figure 4.1 shows the total and average commuting costs of the two modes. When $x = 0$, $T^a = f^a > 0$ and $T^b = 0$. Thus, T^a is greater than T^b. This implies that commuters, rich or poor, will use mass transit very near the CBD. By assumption, MC^a is constant but MC^b increases as x increases. Thus, T^b will eventually exceed T^a. Then, there will be a break-even distance, x^*, where $T^a = T^b$, and the AC curve of the car intersects that of mass transit. This may seem odd since consumers' behaviors are usually based on the marginal principle. The fixed cost of the car f^a consists of parking fee and installment and insurance payments. Installment and insurance payments, costs associated with car ownership, are fixed sunk costs on a given day; car owners have to bear them even if they do not drive to work. Thus, the break-even distance for car commuters on a day is not

Figure 4.1 Commuting Costs Comparison



based on the condition that $T^a = T^b$. However, residential choice is not a daily decision. Besides, car owners can remove installment and insurance payments by selling their car if they want to switch to mass transit commuting. That is, costs associated with car ownership are not sunk costs as far as commuting patterns are concerned. Therefore, break-even distance is the distance where the total or average costs of the two modes are equal. It should be noted that the break-even distance could be located beyond the exiting urban fringe. If $0 < x < x^*$, mass transit costs less; conversely if $x^* < x$, the car costs less.

To find the break-even distance, x^*, let $T^a = T^b$,

$$f^a + c^a x + wt^a x = c^b x + wt_L^b x + wt_C^b [m(x,l)] \tag{4.3}$$

Solving this for x yields:

$$x^* = X[f^a, c^a, t^a, w, t_L^b, m(l)] \tag{4.4}$$

Since the specific form of $wt_C^b[m(x,l)]$ is unknown, we cannot specify the right side of Equation (4.4). However, the implicit function theorem can be used to obtain the derivatives of the break-even distance. Given the nature of the two commuting costs function, we cannot expect there will be more than one break even distance for variables, f^a, c^a, t^a, w, t_L^b, and $m(l)$. Thus, we can consider Equation (4.4) the implicit function of the equation, $F = T^a - T^b = 0$:

$$F = f^a + c^a x + wt^a x - c^b x - wt_L^b x - wt_C^b [m(x,l)] = 0 \tag{4.5}$$

Partial derivatives of an implicit function $y = f(x_1, \ldots, x_n)$ are

$$\frac{\partial y}{\partial x_i} = -\frac{F_i}{F_y} \quad (i = 1, 2, \ldots, n)$$

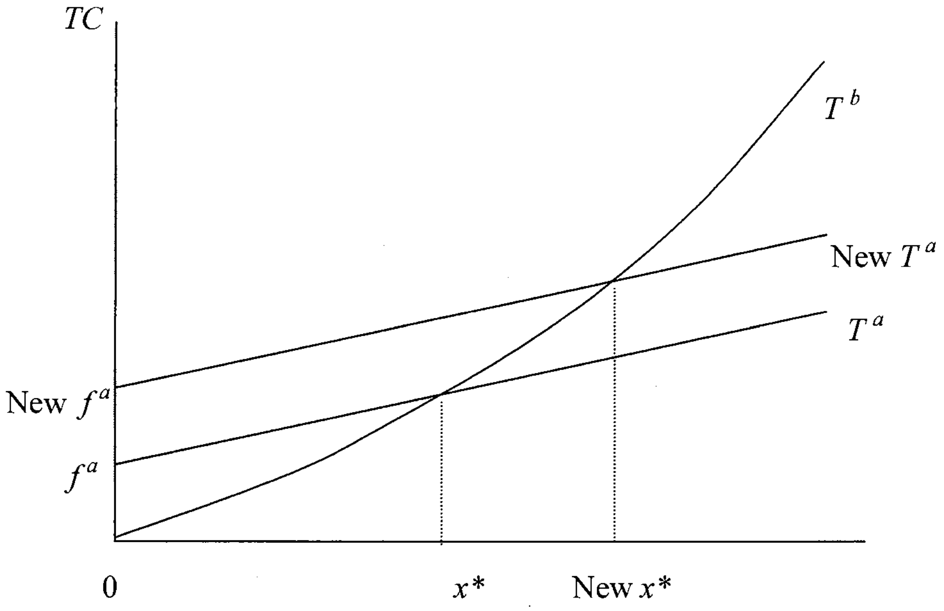
Using this rule, we can obtain the following derivatives of (4.4).

(4.5.1) $\frac{dx^*}{df^a} > 0$: An increase in the fixed cost of the car leads to greater break-even distance.

$$\frac{dx^*}{df^a} = -\frac{F_{f^a}}{F_x} = -1/[c^a + wt^a - (c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})]$$

A look at the denominator, F_x, indicates that F_x is $(MC^a - MC^b)$. We know MC^b is greater than MC^a at the break-even distance, since, as seen in Figure 4.1, the slope of T^b is steeper than T^a when they are equal. Thus, F_x, is negative. Accordingly, we get $\frac{dx^*}{df^a} > 0$. Figure 4.2 shows this effect. An increase in fixed cost of the car shifts up the *AC* and the total cost *TC* of the car, and break-even distance increases.

Figure 4.2 The Effect of an Increase in f^a on x^*

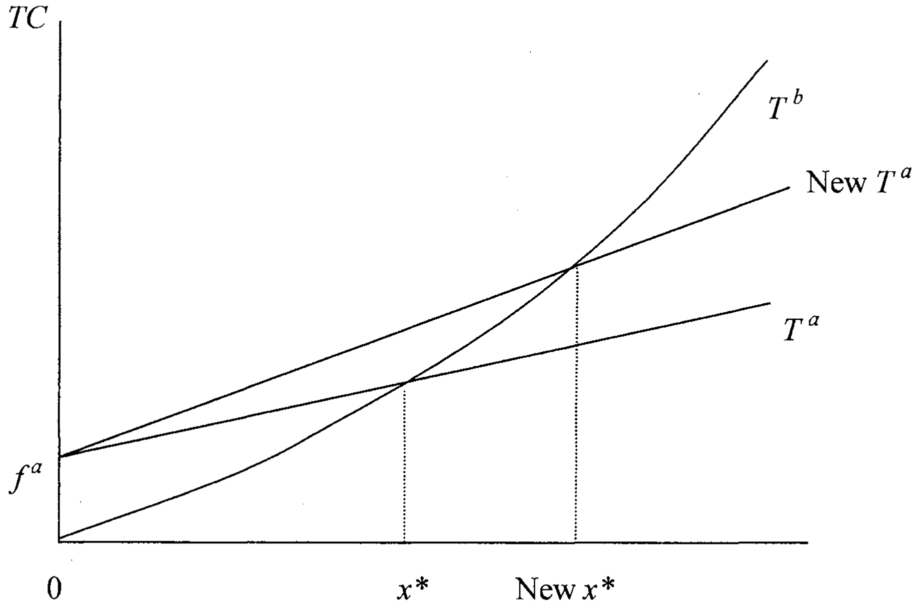


(4.5.2) $\frac{dx^*}{dc^a} > 0$: When the variable money cost per 2 miles of the car rises, break-even distance increases.

$$\frac{dx^*}{dc^a} = -\frac{F_{c^a}}{F_x} = -\frac{x}{F_x} = -x/[c^a + wt^a - (c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})]$$

When c^a rises, the T^a curve gets steeper while its vertical axis intercept remains the same, which is shown by the counter-clockwise movement in Figure 4.3. Then break-even distance becomes greater.

Figure 4.3 The Effect of an Increase in c^a on x^*



(4.5.3) $\frac{dx^*}{dt^a} > 0$: When the line-haul time cost per 2 miles the car increases, break-even distance become greater.

$$\frac{dx^*}{dt^a} = -\frac{F_{t^a}}{F_x} = -\frac{wx}{F_x} = -wx/[c^a + wt^a - (c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})]$$

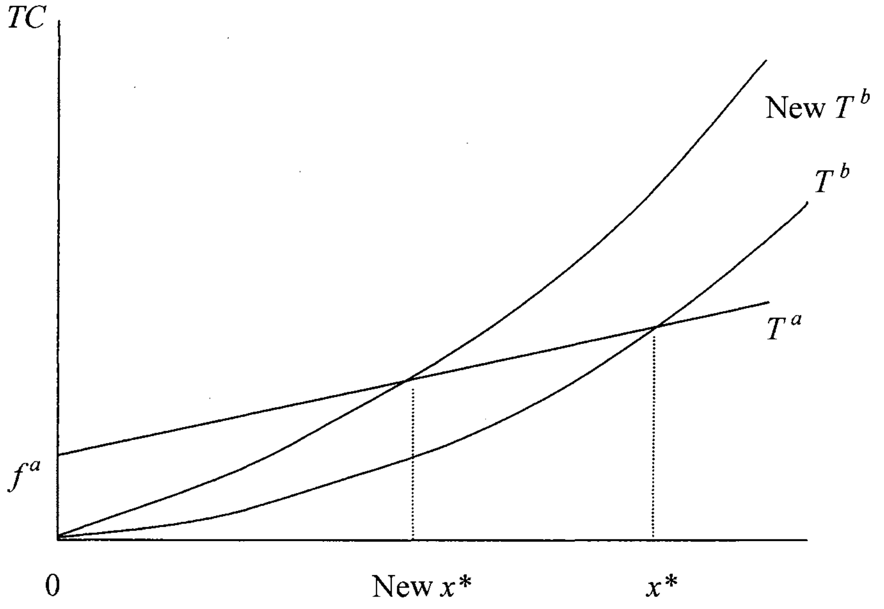
An increase in t^a implies a reduction in the speed of the car. When the car runs slower, its TC curve will get flatter and the break-even distance increases. Any change increasing the cost of the car will increase x^*. Similarly, the break-even distance will decrease when mass transit cost increases. The graphical representation of this effect is similar to that seen in Figure 4.3.

(4.5.4) $\frac{dx^*}{dc^b} < 0$: If the variable monetary cost of mass transit per round trip mile rises, break-even distance decreases.

$$\frac{dx^*}{dc^b} = -\frac{F_{c^b}}{F_x} = \frac{x}{F_x} = x \Big/ [c^a + wt^a - (c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})]$$

When transit fare per mile increases, mass transit becomes less attractive. Thus, break-even distance, at which the car catches up with mass transit, decreases.

Figure 4.4 The Effect of an Increase in c^b on x^*

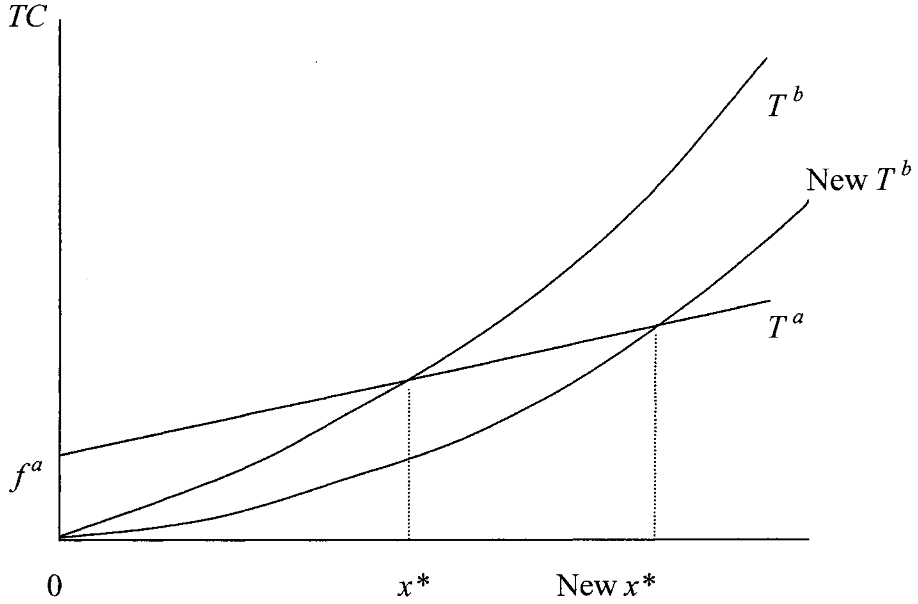


(4.5.5) $\frac{dx^*}{dm} > 0$: When mass transit service density increases, break-even distance becomes greater.

$$\frac{dx^*}{dm} = -\frac{F_m}{F_x} = w\frac{dt_C^b}{dm}\Big/F_x = w\frac{dt_C^b}{dm}\Big/[c^a + wt^a - (c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})]$$

Since $\frac{dt_C^b}{dm} < 0$ and $F_x < 0$, we get $\frac{dx^*}{dm} > 0$. An increase in density of mass transit service will make mass transit relatively more attractive. As a result, the break-even distance increases. That is, there is a greater chance that commuters will use transit even in suburbs. Figure 4.5 shows this effect. When m increases, the T^b curve becomes flatter. Then, the new break-even distance is greater than before.

Figure 4.5 The Effect of an Increase in *m* on *x**



(4.5.6) $\frac{dx^*}{dl} < 0$: Land abundance results in smaller break-even distance.

$$\frac{dx^*}{dl} = -\frac{F_l}{F_x} = w\frac{dt_C^b}{dm}\frac{dm}{dl}\Big/F_x = w\frac{dt_C^b}{dm}\frac{dm}{dl}/[c^a + wt^a - (c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})]$$

Since $\frac{dt_C^b}{dm} < 0$, $\frac{dm}{d\ell} < 0$, and $F_x < 0$, we get $\frac{dx^*}{dl} < 0$. Because it leads to lower urban population density, abundant land supply decreases transit service density. A decrease in transit service increases transit commuting cost. As a result, abundant land supply decreases the break-even distance. The graphical representation of this effect is similar to that in Figure 4.4.

(4.5.7) $\frac{dx^*}{dR_A} > 0$: Higher agricultural land rent causes break-even distance to become greater.

Since R_A, agricultural land rent, represents land scarcity, the opposite of land abundance, $\frac{dx^*}{dl} < 0$ also implies $\frac{dx^*}{dR_A} > 0$. That is, more people use mass transit in suburbs when land value at the urban fringe is high. The graphical representation of this effect is similar to that in Figure 4.4.

(4.5.8) $\frac{dx^*}{dw} < 0$: When income rises, the break-even distance become shorter.

$$\frac{dx^*}{dw} = -\frac{F_w}{F_x} = -\frac{(t^a - t_L^b - t_C^b)}{F_x} = -(t^a - t_L^b - t_C^b)/[c^a + wt^a - (c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})]$$

Now let us look at the effect of a wage rate increase on the break-even distance. Since an increase in wage income raises both T^a and T^b, the effect of wage income on the break-even distance may appear ambiguous. The above derivative shows that $\frac{dx^*}{dw} < 0$ if $[t^a - (t_L^b + t_C^b)] < 0$. That is, if the time cost of mass transit exceeds that of the car, $\frac{dx^*}{dw} < 0$. We have assumed that $t^a = t_L^b$, which implies that both modes have the same line-haul speed; smaller values of t^a or t_L^b represent higher line-haul speed. Since the collection cost of mass transit is positive, we know $[t^a - (t_L^b + t_C^b)] < 0$ by the assumption. Cars may be faster than buses. However, considering the speed regulations in urban areas, both modes run at similar speed. Frequent stops of buses give speed advantage to cars. Thus, cars appear to be faster on the line-haul. However, railroads and subways are faster than cars, although stops and transfers reduce their overall line-haul speed. In short, it is difficult to declare with certainty which one of the two modes, cars and mass transit, has higher line-haul speed. That is why we have assumed that $t^a = t_L^b$.

Suppose $t^a > t_L^b$. $[t^a - (t_L^b + t_C^b)]$ is negative because of t_C^b if the difference between t^a and t_L^b is negligible. At or near the CBD, it is possible that $[t^a - (t_L^b + t_C^b)] > 0$, because t_C^b, collection and distribution cost of mass transit, will be small because of the relatively high density. At or near the CBD, T^b is smaller than T^a, due to higher fixed cost of the car. As distance from the center increases, T^b exceeds T^a because of increasing t_C^b. That is, t_C^b is substantial at break-even distance. Therefore, it is likely that $[t^a - (t_L^b + t_C^b)] < 0$ at x^* even if $t^a > t_L^b$. Thus, the condition for $\frac{dx^*}{dw} < 0$ is easily met even if $t^a > t_L^b$. The only condition for $\frac{dx^*}{dw} \geq 0$ is that 1) cars are slower by far than mass transit and 2) t_C^b is negligible and very mildly increasing in x with distance so that $[t^a - (t_L^b + t_C^b)] > 0$ at x*. The probability that this condition is met is very small. In short, break-even distance becomes smaller with an increase in income. This means that more people would commute by car even in central cities when income rises, which is a trend found in most cities around the world.

Figure 4.6 The Effect of an Increase in w on x*

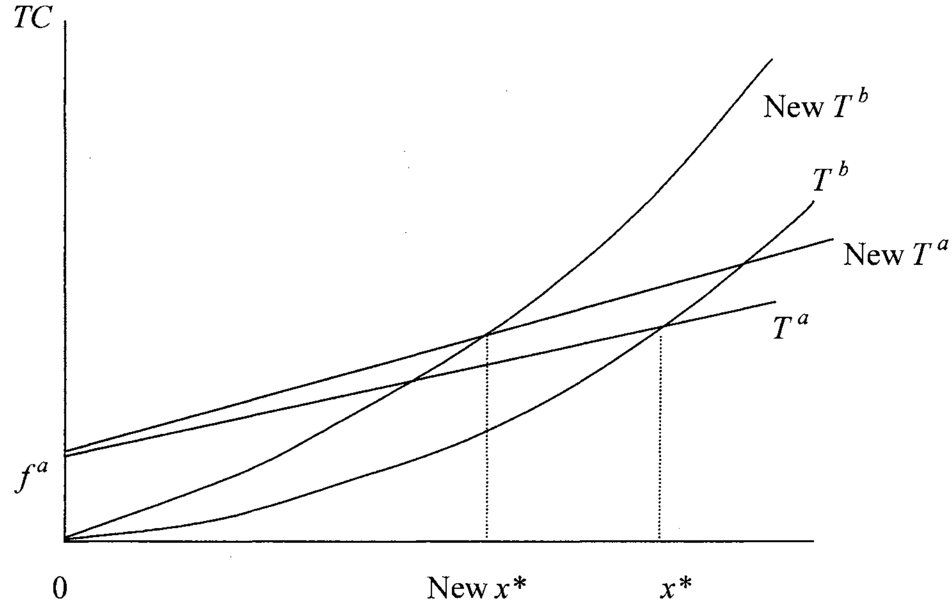


Figure 4.6 shows the effect of an increase in wage rates on break-even distance. As income rises, both T^a and T^b increase. Roughly speaking, the car has advantage in time cost, and mass transit in money cost. The disadvantage of mass transit is its high collection and time costs. Time becomes more valuable as income rises. Thus, the mass transit cost function reacts more to an increase in wage rates, which is shown in larger movement of T^b curve in Figure 4.6.

Now look an extreme case where a commuter's wage income is close to zero, the time cost in terms of foregone wage income will be close to zero, too. This implies that the commuter finds mass transit appealing at all distance ($x^* = \infty$). In other words, the commuting cost of the car is greater than that of mass transit at all distance when $w = 0$. If $w = 0$, $T^a = f^a + c^a x$, and $T^b = c^b x$. Thus, $T^a > T^b$ by the reasonable assumption that $c^a > c^b$. However, when the value of time spent on commuting increases because of an increase in income, higher time cost of mass transit becomes a burden and commuters will adopt a car beyond a certain distance.

The simple rule regarding break-even distance is that anything that makes car commuting (mass transit commuting) relatively inexpensive shortens (lengthens) break-even distance. Land scarcity and higher population density result in greater break-even distance. This accounts for the fact that in large European and Japanese cities many people still use mass transit even in suburbs. However, more people would switch to a car as income rises, because an increase in income makes mass transit relatively more expensive. High income and land abundance are responsible for the dominance of the automobile in the United States. Thanks to steadily rising income, low urban density, and cheap land at the urban fringe, residents in U.S urban areas have moved to distant suburbs and commute by car. Thus, we contend that the rapid and extensive suburbanization in the United States is a result of two economic forces, high income and land abundance. We know income affects break-even distance. Since income varies, the break-even distance of different income groups will differ. The break-even distance for the rich will be closer to the CBD. This provides a tool for an analysis of income-distance patterns. This issue is discussed in the next section.

The Modal Choice Theory with a Bid-Rent Function Approach

Now let us formalize the effects of modal choice on location patterns by adopting a bid-rent function approach. The assumptions are as follows.

1. Two commuting modes, car and mass transit, are available.
2. The city is monocentric. All jobs are located in the CBD, which is a single point.
3. Commuting to work is the only travel. Travel is free of congestion. There is a dense, radial road network, but transit service density declines with distance from the center.
4. The land is a featureless plain.
5. Only two income groups, the rich and the poor, exist.
6. $\eta_h < \eta_{T'}$; the income elasticity of housing consumption is smaller than that of marginal commuting cost of both modes.

Only the fifth and the six assumptions are new ones. The sixth assumption implies that the rich group has a flatter bid-rent function as long as both the poor and the rich use the same mode. This assumption on the elasticities requires some explanations, although a brief discussion was made in Chapter 2. As we mentioned earlier, the empirical evaluation of the income elasticity of housing demand and that of marginal commuting cost has been controversial over the years.

Although the contention that the two elasticities are similar appears relatively more widely accepted, we choose to adopt the fifth assumption. The reason is as follows. In our model, two modes are assumed to exist. However, most estimates of the income elasticity of marginal commuting cost do not report separate results according to modal choice. The income elasticities of marginal commuting cost for the two modes could differ. Thus, it is difficult to maintain the assumption that $\eta_h = \eta_{T'}$. Besides, there is no theoretical reason that $\eta_{T'}$ will remain constant when income changes. This difficulty applies to housing consumption, too. That is, η_h and $\eta_{T'}$ could vary with income. Assuming that either $\eta_h < \eta_{T'}$ or $\eta_h > \eta_{T'}$ has algebraic merits. If we could show the possibility of a positive income-distance pattern even under the assumption that $\eta_h < \eta_{T'}$, that location pattern would be possible under the other assumptions; the positive income-distance relationship would become stronger if $\eta_h > \eta_{T'}$.

Bid-rent functions are now defined conditional on the commuting mode. When the number of hours available for working and commuting is normalized at one, the budget constraint of a household given as

$$w = z + pq + T \tag{4.6}$$

z: composite of non-housing goods

p: rent per unit of housing consumption

q: housing consumption

T: commuting cost

The household's utility function is specified as $v[z(x), q(x)]$. The household's residential choice is given as

$$\max v(z, q), \text{ subject to } w = z + pq + T \tag{4.7}$$

Bid-rent, r, is the maximum rent per unit of land that the household pays for living at x with a given utility level u. r is expressed as

$$r(x\,; u) = \max_{z,q}\left\{\frac{w - z - T}{q} \middle| v(z,q) = u\right\} \tag{4.8}$$

When the household consumes (z, q), (w - z - T) is the money available for rent. Thus, $(w-z-T)/q$ is the rent per unit of housing consumption.

The bid-rent function for car commuters is defined by

$$r^a(x\,;u) = \max\ [(w - z - f^a - c^a x - wt^a x)/q] \ \text{ s.t. } v(z, q) = u \tag{4.9}$$

Solving Equation (4.7) yields

$$\frac{\partial r(x)}{\partial x} = -\frac{T'(x,w)}{q} \tag{4.10}$$

Equation (4.10) is the gradient of the bid-rent function or the well-known location equilibrium condition. Hence, the gradient of the bid-rent function (4.9) is

$$\frac{\partial r^a}{\partial x} = -\frac{c^a + wt^a}{q} \tag{4.11}$$

The bid-rent function for mass transit commuters is

$$r^b(x\,;u) = \max\ [(w - z - c^b x - wt_L^b x - wt_C^b[m(x,l)]/q] \ \text{ s.t. } v(z, q) = u \tag{4.12}$$

The gradient of the bid-rent function for mass transit is

$$\frac{\partial r^b}{\partial x} = -(c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})/q \tag{4.13}$$

(4.11) and (4.13) are bid-rent gradients conditional on one commuting mode.

The unconditional bid-rent function is the maximum of (4.11) and (4.13). The household commutes by transit inside the break-even distance and by car outside the break-even distance. Thus, the unconditional bid-rent function is

$$r(x\,;z,w) = r^b(x\,;z,w) \qquad \text{if } x \le x^*$$

$$= r^a(x\,; z, w) \qquad \text{if } x \geq x^* \qquad (4.14)$$

The unconditional bid-rent gradient is

$$\frac{\partial r(x;z,w)}{\partial x} = -(c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})/q \qquad \text{if } x \leq x^* \qquad .$$

$$= -\frac{c^a + wt^a}{q} \qquad \text{if } x \geq x^* \qquad (4.15)$$

Note that Equation (4.14) and (4.15) imply that r^b, the bid-rent gradient for transit is steeper than r^a, the bid-rent gradient for the car by the definition of the unconditional bid-rent function. If $x \leq x^*$, transit is less expensive. More money becomes available for rent when transit is used. Hence, $r^b > r^a$. Similarly, if $x \geq x^*$, $r^b < r^a$.

Now using graphical analysis, we will describe equilibrium residential patterns of different income groups. Let subscript r denote the rich and subscript p denote the poor.

- The negative income distance pattern

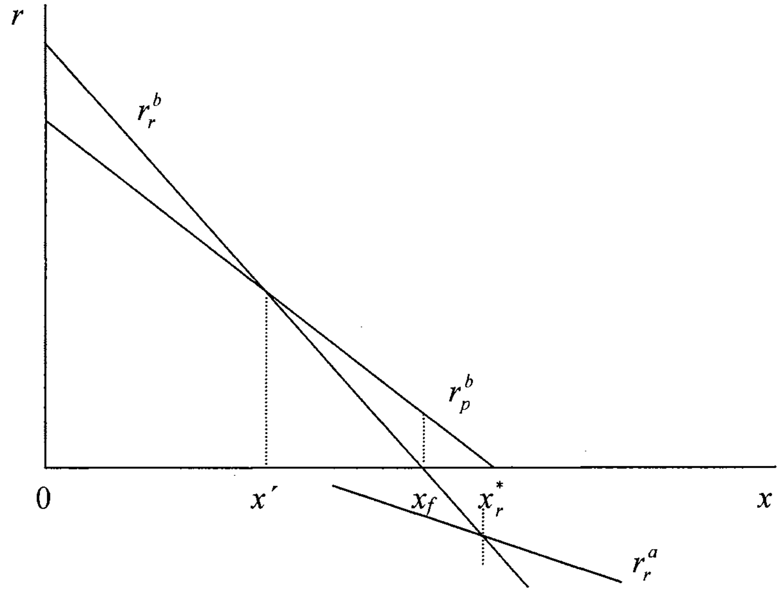
Suppose wage rates are so low that the break-even distances for both groups are well beyond the urban boundary x_f. That is, even the rich find that the money cost of car commuting is so high that it is not sufficiently offset by its saving in collection cost. Then, both groups commute by transit. Their bid-rent gradients are

$$\frac{\partial r_p}{\partial x} = -(c^b + w_p t_L^b + w_p \frac{dt_C^b}{dm}\frac{dm}{dx})/q_p \qquad (r \geq.\ 0 \text{ and } x_p^* > x_f) \qquad (4.16)$$

$$\frac{\partial r_r}{\partial x} = -(c^b + w_r t_L^b + w_r \frac{dt_C^b}{dm}\frac{dm}{dx})/q_r \qquad (r \geq.\ 0 \text{ and } x_r^* > x_f) \qquad (4.17)$$

The rich have a steeper bid-rent gradient because of the assumption that the income elasticity of housing demand is smaller than that of marginal commuting cost. As it is shown in Figure 4.7, the rich will live closer to the CBD, (0 - x'), and the poor will live near the urban fringe (x' - x_f). Note that bid rent gradients below the x-axis means that the commuter must be compensated to commute from there by those modes. In Figure 4.7, r_r^a and r_r^b are negative at x_r^*. However, the bid-rent at x_r^* does not have to be negative for a negative-income distance pattern to exist. A negative-income distance pattern will exist as long as both x_r^* and x_p^* are beyond x_f.

Figure 4.7 Negative Income-Distance Pattern ($x_f < x_r^* < x_p^*$)



Now suppose the wage rate of the rich is high enough to make their break-even distance, x_r^*, inside the urban boundary. The rich have a bid-rent gradient with a kink inside the fringe, whereas the bid-rent gradient of the poor has no kink. The bid-rent gradients are

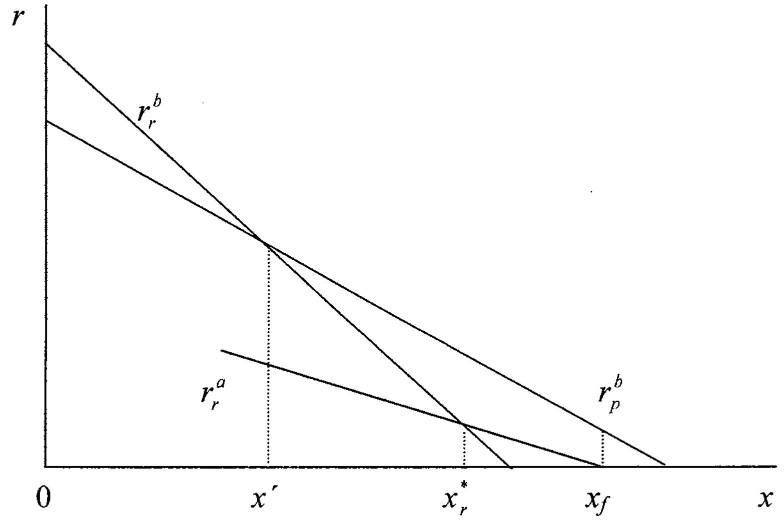
$$\frac{\partial r_p}{\partial x} = -(c^b + w_p t_L^b + w_p \frac{dt_C^b}{dm}\frac{dm}{dx})/q_p \qquad (r \geq .\ 0 \text{ and } x_p^* > x_f) \qquad (4.16)$$

$$\frac{\partial r_r}{\partial x} = -(c^b + w_r t_L^b + w_r \frac{dt_C^b}{dm}\frac{dm}{dx})/q_r \qquad (r \geq .\ 0 \text{ and if } x < x_r^* < x_f)$$

$$= \ -\frac{c^a + w_r t^a}{q_r} \qquad (r \geq .\ 0 \text{ and if } x_r^* < x < x_f) \qquad (4.18)$$

The rich find car commuting preferable in the suburbs. However, the advantage of the car is not strong enough to overcome the market rent set by the poor. That is, the rich are outbid by the poor in the suburbs as seen in Figure 4.8. Both groups commute by mass transit. The rich live on the side of the CBD,(0 - x'), and the poor live on the side near the urban fringe (x' - x_f). Figure 4.8 shows that the rich do not necessarily live in the suburbs and commute by car, although their break-even distance is inside the urban fringe.

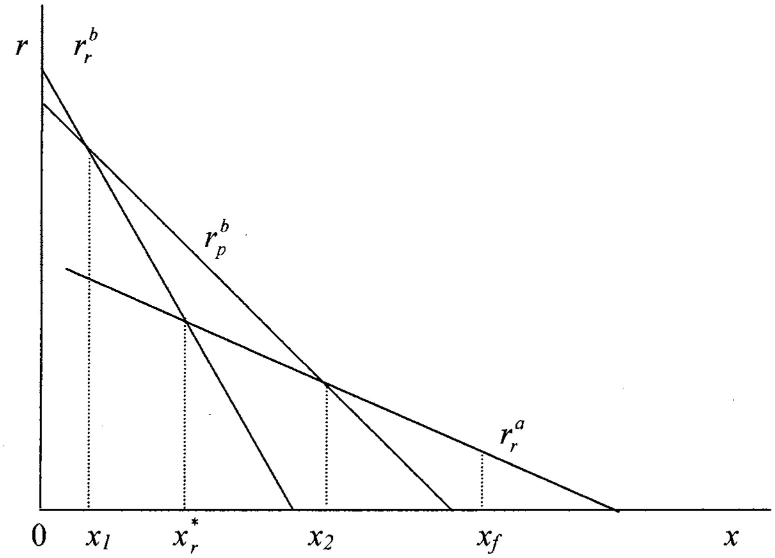
Figure 4.8 Negative Income-Distance Pattern ($x_r^* < x_f < x_p^*$)



Land scarcity leads to high population density. High population density implies high transit demand density. Transit service density will be high with the high transit demand density. High transit demand density reduces transit costs. Consequently, the break-even distances will be smaller. We also know the spatial size if an urban area is smaller when land is scarcer. Higher value of x^* and smaller value x_f imply that x^* is more likely to be greater than x_f. Thus, the situations described in Figure 4.7 and 4.8 are more likely to occur in countries with land scarcity.

- The sandwich pattern

Figure 4.9 Sandwich Pattern



Now consider the situations in which the rich move to the suburbs and commute by car due to further increases in wage rates. The mathematical expressions of the bid-rent gradients remain the same as the ones for the pattern illustrated in Figure 4.8. As wages rise, commuting costs of both modes at all distance increase. However, the commuting cost of mass transit rises relatively more sharply, because of the high time cost. The relatively sharper increase in mass transit cost is felt more seriously by the rich, because the rich are more sensitive to time costs. In other words, the rich find car commuting in the suburbs more attractive than before, and their break-even distance is inside the urban fringe and closer to the CBD. Suppose that the break-even distance of the poor also become smaller but that it is still outside the urban fringe. If the wage increases so much that the bid-rent of the rich conditional on car commuting exceeds that of the poor conditional on transit commuting, the rich will move to the suburbs and commute by car. However, two equilibria exist under this condition. The first pattern is what we call 'the sandwich pattern,' where some of the rich remain near the CBD and commute by car, and the other rich move to the suburbs and commute by car. The poor are spatially sandwiched by the rich, and use mass transit.

This situation is illustrated in Figure 4.9.[12] The rich will live near the CBD, (0 - x_1), and the far- suburbs (x_2 - x_f), and the poor reside in between, (x_1 - x_2). If business firms outbid residential demands in the CBD, which is the case in the real world, the rich will not reside near the CBD, which is not a single point as in an abstract model but an area. In other words, the sandwich pattern may not appear in reality even if parameter values imply this equilibrium. It is also noteworthy that the sandwich pattern assumes a pre-existing negative-income distance pattern. Suppose the income elasticity of marginal transit commuting cost is equal to that of housing demand. Then, the sandwich pattern may not emerge despite increases in wage rates.

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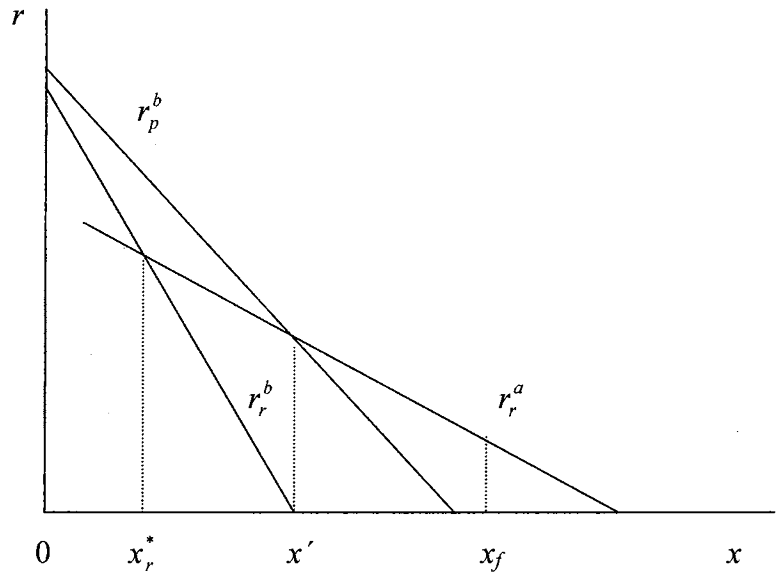
[12] Figure 4.9-10 have the same shapes as Figure 3a and 3b in LeRoy and Sonstelie (1983).

The second pattern, the positive income-distance pattern, emerges when all the rich eventually move to the suburbs. This situation is illustrated in Figure 4.10. The poor reside in the central areas, $(0 - x')$, and use transit, and the rich live in the suburbs, $(x' - x_f)$ and commute by car. In our view, the positive income-distance pattern is more likely to occur than the sandwich pattern. First, the positive-income distance pattern prevails even when business firms outbid residential bid-rents at or near the CBD. Second, this pattern can occur regardless of the assumptions on the income elasticity of marginal commuting cost and that of housing demand.

- The positive income distance pattern

Figure 4.10 Positive Income-Distance Pattern



So far both our model and LeRoy and Sonstelie's have shown the same result that the positive income-distance pattern can occur in the context of a monocentric model even if the income elasticity of housing (or land) demand is smaller than that of marginal commuting cost. What are the differences, then? The most important distinction is that LeRoy and Sonstelie argue that the paradise lost phase, the positive income-distance pattern in our case, is bound to occur as the material cost of car commuting declines, whereas the positive income-distance pattern may or may not occur in our model, depending on the city size and land scarcity.

First, LeRoy and Sonstelie pay no attention to either the impact of the urban fringe or the effects of land scarcity on commuting costs. If the break-even distances of both income groups are beyond the urban fringe, the movement of the rich to the suburbs would not occur. Suppose that land is relatively scarce in an urban area: smaller l or higher R_A. Other things being equal, the spatial size of an urban area is smaller. From (3.12), we know $\frac{dS}{dR_A} > 0$. Since population density D is $h(S)/q$[13], it is evident that $\frac{dD}{dR_A} > 0$. By assumption, high population density implies high transit service density. Accordingly, transit commuting cost is less; $\frac{dt_C^b}{dm} < 0$. That is, smaller x_f and greater x^* result from land scarcity; $\frac{\partial x_f}{\partial R_A} < 0$ from (3.12) and $\frac{dx^*}{dR_A} > 0$ from (4.5.7). In consequence, the break-even distance is more likely to be outside the urban fringe. In other words, the positive income-distance pattern is less likely to occur.

Second, the size of a city matters in our model, but it is not considered in LeRoy and Sonstelie's (1983). In a small and sparsely populated urban area with a relatively high

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[13] Recall that h = square feet of housing per acre of land, S = structural density, capital per acre of land, and q = housing in square feet of floor space.

income level, transit commuting cost may exceed car commuting cost at all distances. If transit demand density is extremely low even in the central city, the city government would not provide transit service. Commuters cannot use transit if it is unavailable. Negative or non-positive income-distance patterns are probable in this case. In a large and dense urban area where transit service density is high even in the suburbs, the break-even distances are likely to be greater than the urban fringe. Then, the positive income-distance pattern is less likely to occur. The positive income-distance pattern is most likely to occur in a large but sparsely populated city, because it is probable that transit is cost efficient in the central city but not in the suburbs. Then, there is a greater chance that x_r^* is inside x_f and that r_r^a exceeds r_r^b in the suburbs as shown in Figure 4.10. Land is very scarce in Japan, but it is abundant in the United States. Thus, given the same population size, U.S. urban areas are less densely populated. The analysis of the impact of the city size and land scarcity presents the following implications: 1) in the United States, the positive income-distance relationship will be strong in larger cities but weak in smaller cities and 2) in large Japanese cities, the positive income-distance pattern is not likely to occur.

Third, increases in income are responsible for residential pattern changes in our model, but decreases in the material, that is, monetary, cost of car commuting change residential patterns in LeRoy and Sonstelie's (1983). Our analysis is more realistic. LeRoy and Sonstelie's (1983) own data[14] show that the money costs of both bus and car increased from 1950 to 1977. Theoretically, there is no guarantee that the paradise lost

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[14] See Table 4 in LeRoy and Sonstelie's (1983).

era would occur when money costs of both modes decline or rise. The algebraic expression of their break even distance d^* is

$$d^* = \frac{f^a - f^b}{c^b + wt^b - c^a - wt^a} \tag{4.19}$$

Suppose f^a, f^b, c^b, and c^a rise at the same time. It is unclear whether d^* will increase or not. In our model, $\frac{dx^*}{dw} < 0$. Since our analysis of residential pattern changes focuses on w, there is no ambiguity regarding the impact of income on break-even distance in our model. In fact, they use variable time costs to calculate break-even distances, stating "The change in these costs relative to the value of time is the key to our explanation." In other words, theoretically they focus on money costs but empirically they rely on overall costs and income. Collection and distribution time cost of transit commuting decreases with transit service density, but that is not the case with car commuting. This difference becomes more important as income rises, since the value of time depends on income. We believe that a modal choice theory on residential patterns must reflect these attributes.

Another point, which is ignored in LeRoy and Sonstelie (1983) model, is that the flight of the rich to the suburbs could eventually make mass transit more costly in the central city. When residential density in the central city declines, demand density for mass transit declines. If the city government maintains m, it would incur mass transit deficit. If the city chooses to let m fall(this adjustment will take time because of heavy fixed cost of mass transit), mass transit cost will increase. Then, the break-even distance will become close to the CBD and more commuters will switch to cars. In other words, the flight of the rich to the suburbs is self-reinforcing even in the context of the modal choice theory.

In conclusion, as far as modal choice is concerned, residential patterns depend on income, land value, and city size. In LeRoy and Sonstelie's model (1983), residential patterns change only as a result of a change in income. Thus, they fail to explain various income-location patterns across the world and between small and large cities. On the other hand, our model accounts for various residential patterns, given the same income level.

Supplements to the Modal Choice Theory

Convexity of Bid-Rent Curves

Most urban consumer theories assume that the marginal transport cost is non-increasing in distance; $\frac{d^2T(x)}{dx^2}$ or $\frac{dT'(x)}{dx} \leq 0$. This assumption is employed to make bid-rent curves convex. Market rent curves observed in the real world are usually convex. That is, rent rises faster than linearly as distance to the CBD decreases. This property is important, because it implies that the capital/land ratio also would rise as distance decreases. Substitution of capital for land in areas with high land rent is characteristic of urban areas. Market rent is not the same as bid rent, since the former is the maximum of the latter at each distance. Thus, multiple non-convex bid-rent curves can result in a convex market rent curve. However, it will be appropriate for individual bid-rents to be convex, since even individual urban residents have an incentive to substitute capital for land. Besides, most basic urban consumer theories assume the presence of identical consumers. Then, a non-convex bid-rent curve results in a non-convex market-rent curve, which is unrealistic. In short, it would be nice for bid-rent curves to be convex.

Let us describe the convexity condition. Bid-rent functions have the form

$$\frac{dr}{dx} = -\frac{T'(x)}{q(x)} < 0$$

Strict convexity of the bid-rent implies

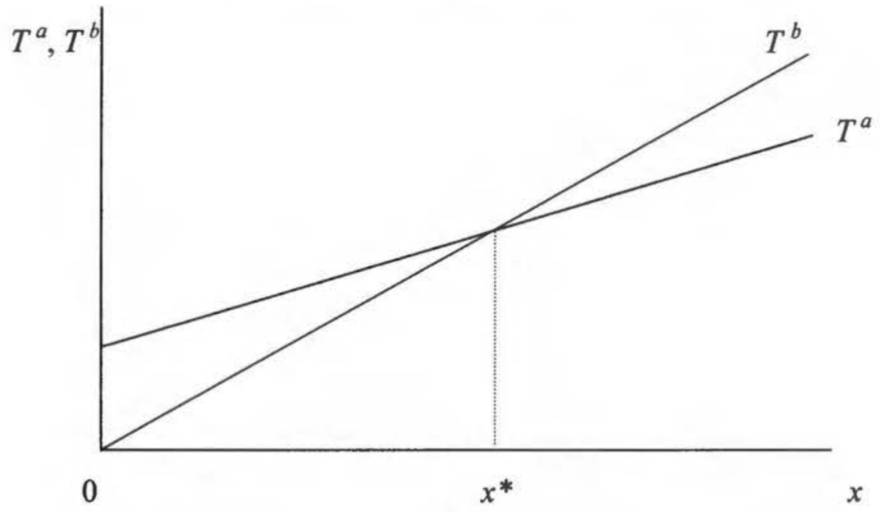
$$\frac{d^2r}{dx^2} = -\frac{T''(x)}{q(x)} + \frac{T'(x)q'(x)}{q(x)^2} > 0 \tag{4.20}$$

We know $T'(x) > 0$ and $q'(x) > 0$. Therefore, (4.20) will be positive if $T''(x) \leq 0$. That is, bid-rent curves are strictly convex if the marginal commuting cost is non-increasing in distance.

In our modal choice theory, we have assumed $\frac{d^2T^a}{dx^2} = 0$ but $\frac{d^2T^b}{dx^2} > 0$. The assumption that the marginal transit commuting cost increases in distance may appear problematic. However, that is not the case. First, the condition that $T''(x) \leq 0$ is not a necessary condition but a sufficient condition for the strict convexity of bid-rent curves. It is possible for bid-rent curves to be strictly convex even if $T''(x) > 0$ if the second term on the right hand side of (4.20) more than offset the first term. Second, our model does not necessarily require that $\frac{d^2T^b}{dx^2} > 0$. Even if $\frac{d^2T^b}{dx^2} \leq 0$, the implications of the model do not change as long as T^b begins to exceed T^a at a certain distance. Suppose collection and distribution time cost of transit commuting increases proportionally with distance; $\frac{d^2t_C^b}{dx^2} = 0$. Then, $\frac{d^2T^b}{dx^2} = w\frac{d^2t_C^b}{dx^2} = 0$. Thus, both MC^a and MC^b would be constant. Because of the positive fixed cost of car commuting, T^b is still lower than T^a near the

CBD. If $MC^b > MC^a$, T^b will eventually exceed T^a at certain distance. This point is illustrated in Figure 4.11.

Figure 4.11 Constant Marginal Transit Commuting Costs



MC^b and MC^a are constant in x, but $MC^b > MC^a$

To sum up, the implications of our modal choice model regarding the positive income-distance pattern hold even if $\frac{d^2T^b}{dx^2} \leq 0$, when the following conditions are met.:

(1) $T^b(0) < T^a(0)$

(2) $MC^b > MC^a$ because collection and distribution transit time costs are increasing in x.

In reality, condition (1) is usually met because of the higher fixed cost of car commuting. When 1) the transit demand density is very low even near the CBD and 2) even the poorest resident's income is very high, it is possible that $T^b(0) > T^a(0)$. You cannot afford your own bus or subway. This possibility just suggests that modal choice has little impact on residential patterns in small urban areas with high income. In fact, income-disparities between central cities and suburbs of small U.S. urbanized areas are small. Condition (2) has been proved by urban transportation economists, as seen in Figure 3.2.

Congestion

Most generic monocentric models assume away traffic congestion. However, congestion exists in the real world when population density and land prices are high. High land prices are positively related to high population density. Land is an important part of road construction. When land price is high, road construction cost is high. However, higher population density requires a wider and denser road network, because of a greater demand for travel. Thus, the level of congestion increases as the CBD is approached. This may cause ambiguity with respect to the cost of mass transit, since we have contended that higher population density promotes the efficacy of mass transit commuting. The existence of congestion seems to suggest the other possibility. Thus, it may look unclear whether high population density can be translated into lower travel cost of mass transit.

However, this ambiguity does not affect the conclusions of our modal choice theory. That is because congestion raises the travel cost of the car as well. Congestion is the substitution of travel time for land. Mass transit is an efficient tool achieving this substitution. In other words, the existence of congestion implies that mass transit is the more efficient mode of the two because mass transit alleviates congestion cost. It is also noteworthy that railroad or and subway systems are free of congestion. In short, whether high density creates congestion or not, it is true that mass transit cost is relatively low in high-density areas.

Exhaustion of Scale Economies of Mass Transit

In our modal choice model, we have assumed:

1) Average transit commuting cost decreases with transit service density.

2) Transit service density is positively related to transit demand density.

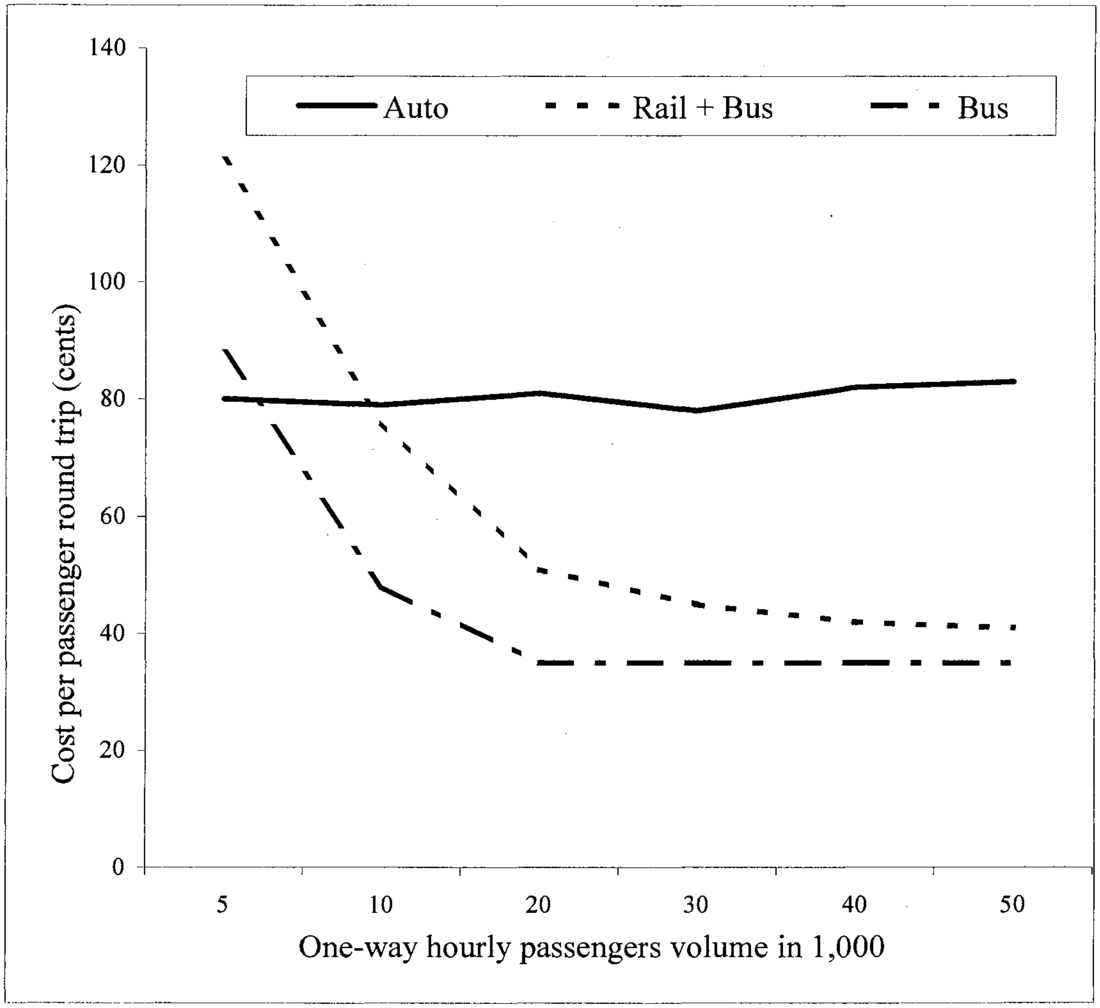
3) Transit demand density rises with residential density.

Since residential density increases as the CBD is approached, it is evident that average transit commuting cost falls as distance decreases, provided that the fixed cost of transit commuting is negligible. Residential density increases more than proportionally as the CBD is approached. Does this imply that average transit commuting cost declines more than proportionally as well? The answer to this question would provide a more realistic transit cost function than the one we have employed before.

Mass transit is subject to economies of scale. Higher transit demand density reduces the travel cost of transit, whereas the car commuting cost does not depend on its demand density. This point is well illustrated in Figure 3.2, which is reintroduced here. The round trip cost of car travel is relatively constant at about 80 cents regardless of demand density. At first, the costs of the two transit modes decline sharply as demand density rises, which implies inherent returns to scale. However, the economies of scale are exhausted after demand density reaches certain volumes. Bus travel cost remains at about 35 cents at volumes higher than 20,000. Since the economy of scale is larger with rail systems, the travel cost of the integrated system of rail and bus ceases to decline at much higher volumes.

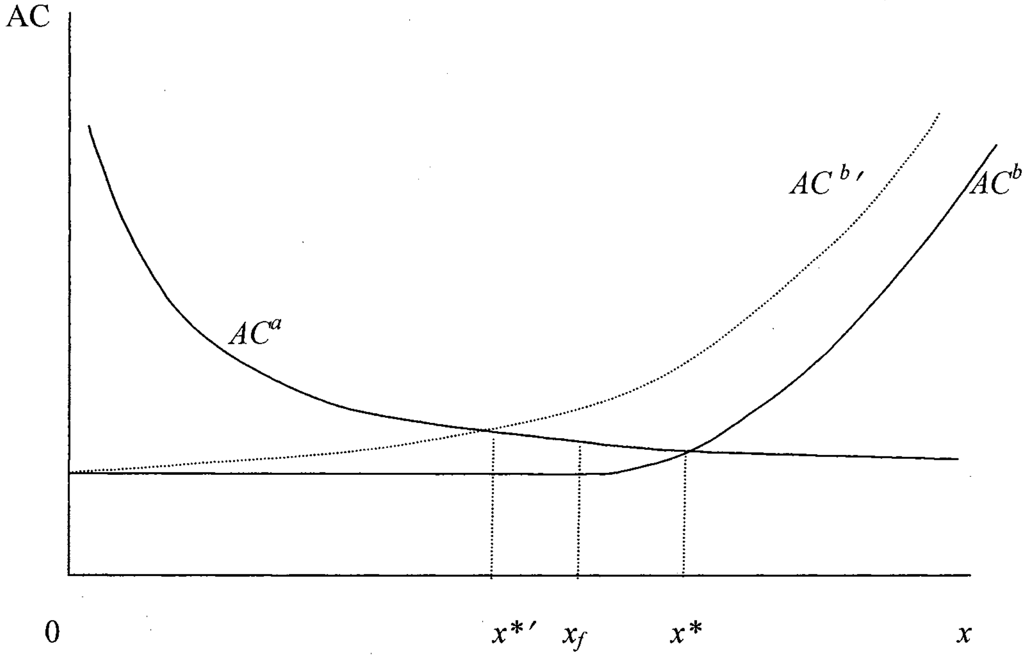
There is strong evidence that, in all but very highly dense cities such as New York and Chicago, travel density is not high enough to support subway systems. Meyer *et al* (1965) concluded that an optimum bus system is the most economical way to deliver workers to the CBD in about top twenty U.S. urban areas. That number is believed to be smaller now, considering the rapid decentralization that has occurred the past decades. Note that exhaustion of scale economies means full utilization of increasing returns to scale.

Figure 3.2 Comparative Modal Costs



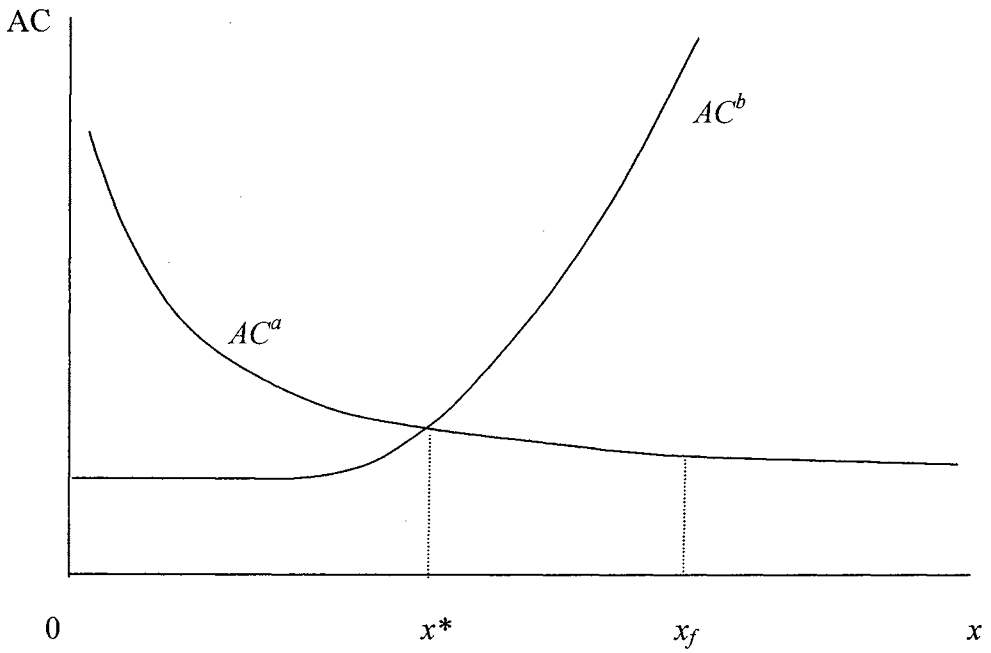
Exhaustion of scale economies and empirical studies on intermodal cost comparisons suggest that 1) average transit commuting cost may cease to decline at some very high density central locations and 2) average transit commuting cost continues to fall as the CBD is approached if the density is low even in central locations. Application of this property yields various shapes of average transit commuting cost. Let us consider a few possibilities.

Figure 4.12 Commuting Costs in a Large City with Land Scarcity



First, we can think of a case in which the economies of scale are fully achieved even in the suburbs. This is illustrated by the average cost curve in solid line in Figure 4.12. A large urban area with land abundance can show this pattern. Because the density in the suburbs is high enough to exhaust the scale economies of transit service, the break-even distance x^* is outside of the urban fringe x_f. $AC^{b\prime}$ in dotted line represents the average cost in the absence of exhaustion of scale economies. In this case, the break-even distance $x^{*\prime}$ is inside x_f. Depending on parameter values, x^* and $x^{*\prime}$ could be either inside or outside x_f. However, it is evident that $x^* > x^{*\prime}$. In short, exhaustion of scale economies implies that the positive income distance-pattern is less likely to occur in a large city with land scarcity. That is, it reinforces the conclusions of our modal choice theory.

Figure 4.13 Commuting Costs in a Large City with Land Abundance



Second, there may be the case in which the scale economies are exhausted in the central city but not in the suburbs. This case is probable in a large city with land abundance. Figure 4.13 shows this situation. Note that Figure 4.12 and 4.13 are drawn with the same scale for the purpose of comparison. The AC^a curves are the same[15] in both figures, since AC^a is not subject to the economies of scale. In Figure 4.13, x_f is greater (larger spatial size with land abundance), and x^* is smaller (the economies of scale are not exhausted in the suburbs). Therefore, the transit in the central city vs. car in the suburbs pattern and, accordingly, the positive income-distance pattern are more likely to happen in a large city with land abundance.

In conclusion, introduction of more realistic transit travel cost functions reflecting exhaustion of scale economies may algebraically complicate the model, but it does not change the implications of our modal choice model. In fact, it reinforces the implications.

Revisiting the Income Elasticities

In our modal choice theory, we have assumed than the income elasticities of marginal commuting costs of both modes ($\eta_{T'}$)are greater than that of housing demand (η_h). LeRoy and Sonstelie (1983) adopted the same assumption, the opposite of the traditional approach by Muth. We have assumed this to show that a negative income-distance pattern can change to a positive one, due to modal choice split caused by an increase in income. As said before, empirical evidence on the magnitudes of those elasticities has been mixed and controversial. Using the controversial assumption, LeRoy and Sonstelie (1983) predicted that regentrification would continue to occur. Empirical evidence did not confirm their prediction.[16] Now few authors rely on the relative magnitudes of the

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[15] In reality, AC^a near the CBD will be higher in a situation described in Figure 4.12, because of higher congestion and parking costs. Introduction of this property reinforces our theory, since the difference of x^* in Figure 4.12 and 4.13 will be wider.

[16] See "Transportation Innovation Theory of LeRoy and Sonstelie" in Chapter II.

elasticities to account for residential patterns in the United States. As Wheaton stated, it may be the case that $\eta_{T'} = \eta_h$. One reason we did not assume that $\eta_{T'} = \eta_h$ was for the sake of algebraic convenience. It is unlikely that the income elasticities of marginal commuting costs conditional on different modes are equal. Obviously, two different values cannot be equal to another value. We will consider the implications of different income elasticities of marginal commuting costs.

Let $\eta_{MC}{}^{a}$ denote the income elasticities of marginal car commuting cost and $\eta_{MC}{}^{b}$ that of marginal transit commuting cost. We have

$$T^a(x) = f^a + c^a x + wt^a x \tag{4.1}$$

$$T^b(x) = c^b x + wt_L^b x + wt_C^b[m(x,l)] \tag{4.2}$$

Then,

$$\eta_{MC}{}^{a} = \frac{dMC^a}{dw}\frac{w}{MC^a} = \frac{wt^a}{c^a + wt^a} < 1 \tag{4.21}$$

Since c^a, w, and t^a are positive, $\eta_{MC}{}^{a} < 1$. Recall $MC^b = c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx} > 0$.

Then,

$$\eta_{MC}{}^{b} = \frac{dMC^b}{dw}\frac{w}{MC^b} = = \frac{wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx}}{c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx}} < 1 \tag{4.22}$$

Since all terms in (4.22) are positive, $\eta_{MC}{}^{b} < 1$. As w approaches infinity both $\eta_{MC}{}^{a}$ and $\eta_{MC}{}^{b}$ become greater, approaching unity. If you are extremely rich, monetary commuting cost would not be much of a concern. As far as our model is concerned, the income elasticities of marginal commuting costs cannot be a single value. Ellwood and Polinsky (1979) estimated that η_h is about 0.75. If η_h is 0.75 regardless of the level of income, we can conclude that very high wage earners' bid-rent gradients would get steeper as their wage rates rise. Given the circumstance, this implication appears reasonable. However, it may or may not be the case in the real world.

Now turn to the issue of the relative magnitudes of $\eta_{MC}{}^a$ and $\eta_{MC}{}^b$. By assumption, $\eta_{MC}{}^a$ is constant in x. If we assume $\frac{d^2T^b}{dx^2} > 0$ (i.e., $\frac{d^2t_C^b}{dx^2} > 0$) as we did before, $\eta_{MC}{}^b$ is increasing in x since $\frac{d\eta_{MC^b}}{dx} = (c^b w \frac{d^2t_C^b}{dx^2}) \Big/ (MC^b)^2 > 0$. If $\frac{d^2T^b}{dx^2} = 0$, $\eta_{MC}{}^b$ is constant in x. Thus, if we assume $\frac{d^2T^b}{dx^2} > 0$, it is likely that $\eta_{MC}{}^b$ exceeds $\eta_{MC}{}^b$ in low-density areas. It appears unclear which elasticity is greater in high-density areas. It also looks uncertain which is greater when $\frac{d^2T^b}{dx^2} = 0$. Let us compare those two elasticities to see which is greater. For convenience, let M denote $w\frac{dt_C^b}{dm}\frac{dm}{dx}$, which is positive regardless of the sign of $\frac{d^2T^b}{dx^2}$. Multiply (4.21) by $(c^b + wt_L^b + M)/(c^b + wt_L^b + M)$. We have

$$\eta_{MC}{}^a = \frac{wt^a(c^b + wt_L^b + M)}{(c^a + wt^a)(c^b + wt_L^b + M)} = \frac{wt^a c^b + w^2 t^a t_L^b + wt^a M}{(c^a + wt^a)(c^b + wt_L^b + M)}$$

Now multiply (4.22) by $(c^a + wt^a)/(c^a + wt^a)$. We get

$$\eta_{MC}{}^b = \frac{(wt_L^b + M)(c^a + wt^a)}{(c^b + wt_L^b + M)(c^a + wt^a)} = \frac{wt_L^b c^a + w^2 t_L^b t^a + c^a M + wt^a M}{(c^b + wt_L^b + M)(c^a + wt^a)}$$

Considering the heavy reliance on automobile, it is likely that his estimates were derived from car commuting. Assume $\eta_{MC}{}^{a} = \eta_h$. Then, by (4.23), we have

$$\eta_{MC}{}^{b} > \eta_{MC}{}^{a} = \eta_h \tag{4.24}$$

Note that split modal choice still leads to the movement of the rich to the suburbs if (4.23) holds. In other words, the negative income-distance pattern can change to positive income-distance patterns under the assumption that $\eta_{MC}{}^{b} > \eta_{MC}{}^{a} = \eta_h$. Since $\eta_{MC}{}^{b} > \eta_h$, the rich live on the CBD side when the wage rates are so low that both income groups use transit. When income rises, the rich begin to move to the suburbs in the same fashion described in the previous section. There is no theoretical reason that the introduction of the new assumption changes the nature of our break-even distance analysis. The only difference is that the paradise regained era does not occur even when both income groups commute by car. If we abide by the assumption that $\eta_{MC} > \eta_h$ for both modes and ignore other factors such as the legacy of the past, filtering, and some blight variables, the paradise regained era would occur in our original modal choice model, too, when the wage rates are *very* high. However, if $\eta_{MC}{}^{b} > \eta_{MC}{}^{a} = \eta_h$, our modal choice theory can exclude the possibility the paradise regained era. Recall also that, as explained before, the positive income-distance pattern is unlikely to occur in large cities with land scarcity.

If (4.24) is true, we can derive the following implications

1) When transit is the single mode in urban travel, the rich will reside in the central city.

2) When the car is the single mode, modal choice will not affect residential patterns.

The first implication indicates that urban areas heavily depending on mass transit would have negative-income distance patterns. This accounts for the residential patterns in large cities in Europe, Latin America, and Japan. The second implication suggests that the paradise regained era does not occur even when both income groups commute by car. This explains why regentrification movement has been minimal in U.S. urban areas, most of which now rely almost exclusively on car commuting. In fact, income disparities increased during the 1980s, according to Hill and Wolman (1997).

The United States, Western European counties, and Japan have similar levels of per capita income. If one attempts to explain the positive income-distance pattern in the United States by arguing that $\eta_{MC} < \eta_h$, he has to explain why η_{MC} is not smaller than η_h in Paris and Japan. This approach may be justified by differences in preferences among consumer in different countries. However, theory based on this approach is *ad hoc* and cannot be accepted as a serious economic theory. Our modal choice theory under the assumption that $\eta_{MC}^a < \eta_{MC}^b = \eta_h$ explains various residential location patterns across the world without resorting to *ad hoc* assumptions

The denominators are the same. Recall that we have assumed that $c^a > c^b$ (higher line-haul money cost for car commuting) and that $t^a = t_L^b$ (the same line-haul speed). Then,

$$\eta_{MC}{}^{a} < \eta_{MC}{}^{b}$$

Since $wt^a c^b < w t_L^b c^a + c^a M$. In fact, unless $c^a < c^b$, the condition that $t^a \leq t_L^b$ is a sufficient condition for the inequality, $\eta_{MC}{}^{a} < \eta_{MC}{}^{b}$.

The definition of the income elasticity of marginal commuting cost implies

η_{MC} = (marginal time cost)/[marginal cost (= marginal money cost + marginal time cost)]

$= MTC\ /\ [MC\ (= MMC + MTC)]$

Roughly speaking, transit is cheaper in terms of money but expensive in terms of time. Given the nature of the two commuting modes, it is probable that a larger portion of the total transit commuting is time cost, while much of the total car commuting cost is money cost. This is likely to be true for marginal commuting costs as well. That is, we have

$$\eta_{MC}{}^{a} < \eta_{MC}{}^{b} \equiv \frac{MTC^a}{MMC^a + MTC^a} < \frac{MTC^b}{MMC^b + MTC^b} \qquad (4.23)$$

We can reasonably assume that MMC^a, MTC^a, and MMC^b are constant in x, as we did before. Unless MTC^b is decreasing in x, (4.23) will hold at all distance. In short, it is probable that $\eta_{MC}{}^{a} < \eta_{MC}{}^{b}$. What implications would follow, then?

Although controversy still exits, Wheaton's (1977) contention that there is no significant difference between $\eta_{MC}{}^{a}$ and $\eta_{MC}{}^{b}$ has been accepted without much refutation. He did not specify on which commuting mode his estimates were based.

CHAPTER V

FILTERING THEORY AND LAND VALUE

Introduction

The conventional monocentric theory was not successful in explaining the income-location pattern in the United States because it cannot explain the pattern in the United States and the opposite in other countries. Filtering theory is another that has been used to explain residential location patterns. The monocentric theory emphasizes the demand side and neglects the historical side of development. Capital in housing goods is durable. Thus, the past pattern of development affects the present residential location. The filter-down theory captures this effect.

In our opinion, the largest problem with the filtering explanation is that it does not explain various income-distance patterns across the world. This problem arises because the filtering explanation downplays the effects of land value. The filtering theory focuses on durability and depreciation of housing stock and demand for better housing resulting from income increases. These features exist throughout the world.

Why has the U.S. style filtering not occurred in other countries? Filtering takes place in other countries;. for instance, in Korea, old and smaller apartment units are occupied by low-income groups. In Korea, however, very old apartments in central cities are often demolished, and new and better ones are built there. The new apartment complexes are built with higher density than before. Although filtering might explain the positive income-distance pattern in the United States, it does not necessarily lead to the U.S.

pattern in other countries. Thus, we need to clarify on what conditions the filtering process leads to that pattern.

Poor urban residents have two choices regarding housing consumption. They can live in an old and deteriorated dwelling unit or a newly constructed one with less quality. High frequency of filtering implies the former is the choice of many low-income urban residents. A larger supply of old housing units makes filtering more attractive, since the prices would be lower. What then causes the supply of old housing units to increase? The fact that less frequent redevelopment is responsible for a larger supply of old housing stock indicates that low land value is the answer to this question. First, low land value hinders redevelopment, because of relatively high ratios of demolition cost to redevelopment cost. Second, changes in land value gradients play an important role in redevelopment and filtering. When central city land prices decline over time, the redevelopment of the inner city becomes more difficult. Third, the age of a city combined with low land value leads to a larger supply of old housing units, since the effect of filtering is cumulative. Old cities with high land prices, however, experience redevelopment and less fewer cases of filtering. That is, when it comes to the effect of filtering on the positive income-distance pattern, the age of a city matters only in the presence of low land value, which enables the U.S. style filtering to occur.

In this chapter, the implications of the above three factors are discussed. Our exposition in this chapter shows why filtering leads to a positive income-distance pattern in a country with land abundance.

Redevelopment and Land Value

We believe land supply and land value are the keys to the U.S. style filtering process. It is our contention that the relationship between demolition cost and land value determines how actively the filtering process occurs and what residential pattern it leads to. In this section, we discuss the relationships among demolition cost, redevelopment, land value, and filtering.

One drawback of the conventional monocentric model is that it neglects the effects of the past development. By contrast, the filtering theory was based on historical observations, and has merit in recognizing the nonmalleablity of the housing stock. Thus, some authors (e.g., Harrison and Kain (1974), Anas (1978), Brueckner (1980 and 1981), Wheaton (1982), and Cook and Hamilton (1982 and 1984)) have incorporated these two theories. By introducing the durability and the nonmalleablity of the housing stock into a monocentric model, they have attempted to build a dynamic model of the urban residential market that reflects the history of the city. Most of those dynamic models have paid little attention to the role of redevelopment. Those models assume complete durability of capital, which implies no possibility of redevelopment. Only abandonment is considered.

Cook and Hamilton (1982 and 1984) have not modeled demolition or abandonment in their studies. One exception is Wheaton (1982). He notices that the opportunity use of old inner housing is not agricultural use of land, but rather the net land rent that redevelopment would bring. He states that redevelopment is desirable only if the net rent from the new use exceeds the gross[17] rent from the old use. Incorporating the possibility of redevelopment with the Anas model, he reaches a conclusion that redevelopment acts as a compromise between the two models; the traditional model without capital durability and the model with complete durability.

Wheaton's definition of '*the capital expenses associated with replacement*' does not differentiate new construction cost from demolition cost. However, the algebraic expression[18] of the net rent defined by him implies that he ignores demolition cost. Suppose there are two new identical houses at a virtually identical location. Assume that one was built on vacant land, whereas the other was built after the demolition of the pre-existing one. Both houses would command the same gross rent, but the net rent from the house with demolition cost would be lower. Wheaton's model does not reflect the role of demolition cost. Hence, little attention is paid to the effect of low land value on filtering.

In short, most filtering theories ignore the role of demolition cost associated with land value. This is odd considering that the occurrence of the filtering hinges on demolition cost of existing housing stock. Their lack of attention to demolition cost may be due to the difficulty of mathematical modeling. Or it may be because other factors rather than demolition cost are sufficient for a dynamic model.

Filtering is caused by deterioration of housing units, income growth, and population growth. Even population and income growth alone, without considering depreciation, could explain filtering and cumulative urban growth. Anas (1978) states that his short

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[17] He compares the net rent (gross rent – capital cost associated with replacement) from the new use with the gross rent from the old use, because the capital cost of existing housing is sunk cost.

[18] See Equation (1) in Wheaton (1982).

run dynamic model without conversions ought to be an adequate tool for prediction. His justification is that demolition has had a limited impact on long term urban development. Harrison and Kain (1974) report that only 3.8% of the 1950 SMSA housing inventory was reported as demolished in 1959. Thus, they maintain that:

"*It appears that the stocks of residential and nonresidential structures are so durable that it is too costly to alter them in this* way [i.e. conversion or demolition of existing units]. *As a result urban densities been modified principally thorough new constriction* [on vacant land]."

Therefore, their lack of attention to demolition is understandable. However, the limited impact of demolition on U.S. urban areas begs the question: why has demolition had a limited impact on U.S. cities? The question can be rephrased as 1) why has demolition occurred with less frequency in the United States? or 2) why is demolition too costly in the United States? This question is important because the answer to it explains why the filtering has led to the positive income-distance pattern in the United States and has not in some other countries.

Let us examine the relationship between filtering and demolition cost. Housing units deteriorate, but are also durable. Proper maintenance and renovation, a mild form of conversion, would keep them in good shape. Demand for high-quality housing can be met by upgrading existing structures without demolishing them. Sometimes conversion would require the demolition and the construction of a new building, which can be considered the extreme case of conversion. We will refer to conversion requiring demolition as redevelopment from now on. Some define demolition cost as the sum of wrecking cost and rental income the building would have generated if it had not been demolished. To avoid confusion, we define demolition cost as wrecking cost only. Demolition is worthwhile only if the vacant land value minus the wrecking cost is greater than the present value of foregone rent. Even if the existing building is worthless so that the potential foregone rent is zero, redevelopment can be deterred by wrecking cost.

Table 5.1 Demolition Cost Per Acre as a Function of Building Height.

Building Height (Stories)	Wrecking Cost per Acre	Critical Distance (Miles)			
		20%, $2000	20%, $3,000	30%, $2,000	30%, $3,000
2	$ 91,476	19	17.1	12.7	11.4
3	$137,214	21	19.1	14.1	12.7
4	$365,964	26	24.0	17.4	16.0
5	$457,380	27	25.1	18.1	16.8

Source: Mills and Hamilton (1989, p.138). Column 4,5, and 6 were added by us.
(%, $) denotes the steepness of the land price gradient and rural land value.

Mills and Hamilton (1989) explain the effects of demolition cost. Table 5.1, an example in their discussion, reports wrecking costs as a function of building height. Column 2 represents wrecking costs per acre, as supplied by a demolition contractor. To see the effects of the steepness of land gradients and agricultural land value, column 3, 4, and 5 are added to their original table. The table shows that demolition cost can be a serious impediment to redevelopment, as Mills and Hamilton (1989) said. They define the "critical distance" as the distance from the edge of the urban area at which land value is just sufficient to justify the demolition of unwanted buildings. Suppose that rural land value is worth $2000 per acre and that urban land value rises 20 percent per mile from the urban edge. When the demolition cost per acre for two story buildings is $91,746, the buildings must be 19 miles away from the edge to cover the demolition cost. They state "For an urban area whose radius is smaller than this critical distance, demolition is not justified even at the CBD."

When agricultural land value is higher or land value increases more sharply as the center is approached, the critical distance is smaller. An extension of this implication can elucidate the effects of land scarcity on filtering and various income-distance patterns. That is, lower (higher) land value makes it difficult (easy) to demolish buildings. Suppose the value of a current building is zero because rental income does not exceed the maintenance cost. Redevelopment cost is the sum of new construction cost, vacant land cost, and wrecking cost. The wrecking cost will occupy a relatively insignificant portion to the whole redevelopment cost when land value is high. Then, demolition and redevelopment are more likely to happen. Since cities are built from the middle out and low quality housing tends to be old, old housing units tend to be in central cities. If land values near the center are high enough to justify redevelopment, those old housing units are replaced relatively easily by new ones. Filtering would occur but housing units at the bottom of the chain will be redeveloped, rather than abandoned. New housing units can be occupied by high-income households. Consequently, poverty concentration in central parts of the city will be limited.

By contrast, when land is abundant, land value is low. Even near the CBD, land values can be too low for redevelopment to occur. New housing units are more likely to be built on vacant land at the periphery, and low-income households will be concentrated in the central city, occupying old units. Some of the old residential units will be abandoned if the rental income does not cover the maintenance cost, which includes property taxes. Abandonment, in turn, creates a negative externality and causes further declines in land and property values. The decline in land value would make redevelopment less feasible. In short, low land value resulting from land scarcity promotes filtering and abandonment and, consequently, leads to poverty concentration in the central city.

For simplicity, let us introduce algebraic expressions regarding redevelopment. V is the current land value. D represents demolition cost. F denotes the present value of foregone rental income net of maintenance cost, which includes property taxes. Let us define conversion cost C as the sum of demolition cost and foregone income. That is, $C = D + F$. Obviously, all variables are defined as a value per unit of land. Demolition is worthwhile only when the vacant land value, the present value of expected land rent stream, is greater than the conversion cost.

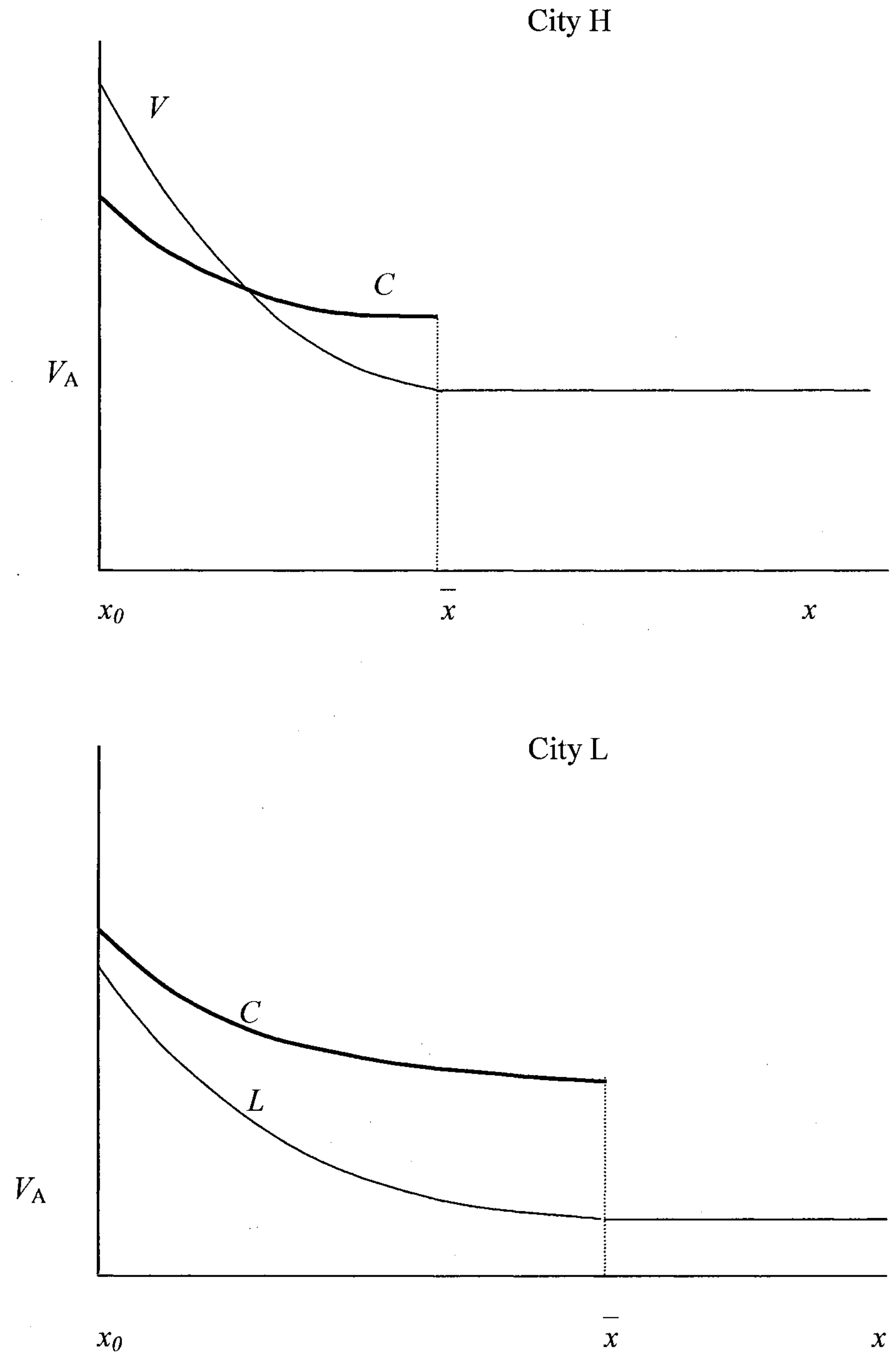
$$V > D + F \tag{5.1}$$

That is, (5.1) is the condition for demolition and redevelopment. It is evident that redevelopment is less likely to occur when land value is low. However, this analysis is rather simple in that the relationship between conversion cost and land value is ignored. Demolition cost depends on structural density, which is, in turn, positively related to land value of the past. The past land value would differ from the current value. For simplicity, assume that they are the same. Both V and D increase as you move closer to the center. When V is high, D is high as well. Therefore, it is possible that demolition is not profitable even if land value is high as the center is approached. However, as long as the slope of demolition cost gradient is flatter than that of land value gradient, there could be some distance from the center at which demolition is profitable. The assumption that the ratio of demolition cost to land value decreases as the CBD is approached can be justified if 1) structural density increases less than proportionally to land value or 2) demolition cost rises less than proportionally to structural density.

What about *F*? *F* could either rise or fall as the center is approached. Higher structural density near the center implies higher *F* if old housing units in the urban areas have been well maintained or renovated. However, if older housing units are substantially deteriorated, *F* could decline due to higher maintenance cost as the center is approached. In fact, many cases of abandonment in U.S. inner cities indicate that *F* is negative in those areas.

Suppose there are two otherwise identical cities facing different land scarcity or agricultural land rent. City H, the high-rent city, would have a spatially smaller urban area and higher population density. City L, the low-rent city, would have a larger urban area and lower population density. Assume both cities grew from the middle out with complete durability for a few decades, which implies housing units are older at a smaller value of distance x. Relax this assumption by introducing the possibility of redevelopment. Figure 5.1 represents some plausible situations. In City H, conversion cost is lower than land value in the central city. New housing units will be built, and the poor will not be concentrated in the inner city. In the suburbs, housing units are relatively new and yield high *F*. Thus, conversion cost is higher than land value.

Figure 5.1. Plausibility of Filtering and Land Scarcity



V_A: agricultural land value

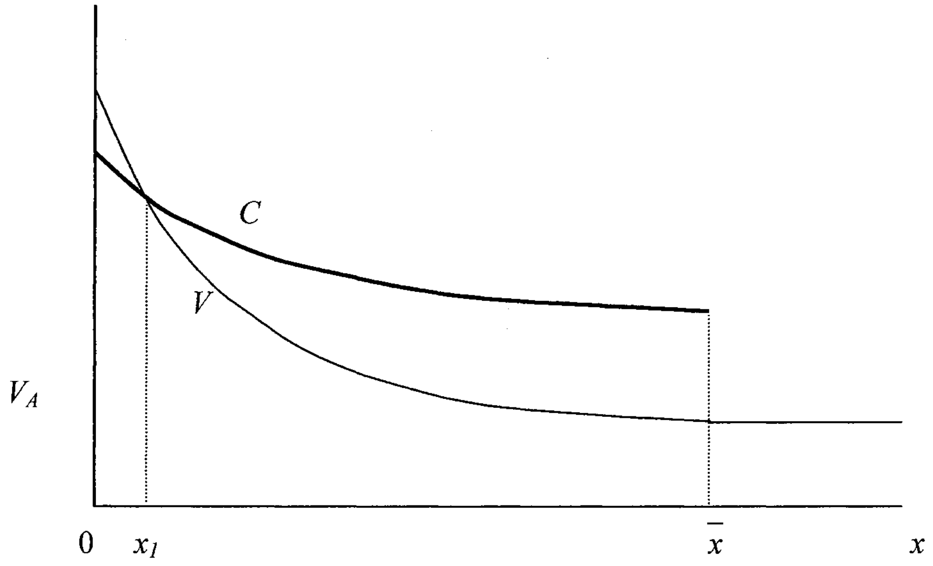
V: land value

C: conversion cost

Otherwise, new housing units would not have been built in the first place. However, in City L, conversion cost exceeds land value even in the center. Old housing units in the inner city will be filtered down to the low-income households. Lack of vacant land inside the urban area would further push the boundary outward.

Figure 5.2 suggests another possibility the low-rent city faces. Land value exceeds conversion cost between 0 and x_1. High land value very near the center makes redevelopment plausible. That area is likely to be the CBD occupied by commercial buildings. Thus, new residential units are not likely to be built inside $\bar{x}$. In most large U.S cities, we observe properly maintained or new buildings in the CBD. Just outside of the CBD areas, old deteriorated and housing units and abandoned commercial or residential buildings exist. Newer housing units are seen in the suburbs. Figure 5.2 illustrates this U.S. urban form..

Figure 5.2. Plausibility of Redevelopment at the Center in the Low-Rent City



We know that redevelopment is more likely to happen when land value is higher. Land scarcity or higher agricultural land value makes land rent gradient higher. Does it make urban gradients steeper? What will happen when land value gradient is steeper? Competitive equilibrium models of the urban residential market, one of which is introduced in Chapter 2, show that higher agricultural land rent makes density or rent gradient higher but not necessarily steeper. Those mathematical models do not predict the effect of higher agricultural land rent on the slope of the gradients. However, it does not imply that land scarcity or higher agricultural land has no impact on the steepness of the gradients. Real world observations tell us that urban gradients are steeper when land is scarce. Density gradients are steep in the order of Japan, European countries, and the United States.

Those equilibrium models do not predict the effect of higher agricultural land rent on the slopes of the gradients because the transport cost functions are not specified to reflect the effect of land value or land scarcity. In fact, however, land value or land scarcity affects transport cost. That is why land scarcity makes gradients steeper as well as higher. When land is scarce, land value is high. High land value implies high cost of road construction. Limited road capacity resulting from high road construction cost causes congestion, which is the substitution of commuting cost for land and implies high transport cost.

When the commuting cost increases, the land rent gradient rotates in a clockwise direction, with land rent rising inside some distance and falling beyond that distance[19]. That is, the gradient becomes steeper. Thus, we can conclude that land scarcity or high land value leads to steeper urban gradients. To quote Mills and Hamilton (1989):

> *For a sample of Japanese cities, where transport cost is much higher (largely due to congestion), the average population density gradient was 3.2 times as steep as for the sample of American cities. .... The steeper density gradients for Japanese cities are what would be predicted based on higher commuting cost in Japan.*

Although they do not mention land scarcity in the quote, it is obvious that the steeper density of Japan is due to land scarcity or high land value since higher commuting cost in Japan is the result of high land cost. Most mathematical residential market models ignore this relationship because a dense radial road network and no congestion are assumed even though the construction of a dense radial road network and the level of congestion, in reality, depend on land value. This lapse is understandable. Recall that the land value gradient is an endogenous variable or a solution of the models. Specifying transport cost as a function of land scarcity or land value would make the models complicated.

In the previous chapters, we argued that mass transit is appropriate for the city of high density and cars for the city of low density. A bid-rent gradient conditional on mass transit commuting is steeper than one conditional on car commuting because being near the high density CBD reduces the average cost of mass transit commuting while average

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[19] See Bruekner (1987).

fixed cost of car commuting falls at long distance. The bid-rent approach in Chapter 4 proves this point. Let us reintroduce (4.14) and (4.15).

The unconditional bid-rent function is

$$\begin{aligned} r(x\,;z,w) &= r^b(x\,;z,w) && \text{if } x \le x^* \\ &= r^a(x\,;z,w) && \text{if } x \ge x^* \end{aligned} \tag{4.14}$$

The unconditional bid-rent gradient is

$$\begin{aligned} \frac{\partial r(x;z,w)}{\partial x} &= -(c^b + wt_L^b + w\frac{dt_C^b}{dm}\frac{dm}{dx})/q && \text{if } x \le x^* \\ &= -\frac{c^a + wt^a}{q} && \text{if } x \ge x^* \end{aligned} \tag{4.15}$$

If $x \le x^*$, transit is less expensive. More money becomes available for rent when transit is used. Hence, $r^b > r^a$. Similarly, if $x \ge x^*$, $r^b < r^a$. Thus, Equation (4.14) and (4.15) imply that the bid-rent gradient for transit is steeper than the bid-rent gradient for the car. It may be that case that an unconditional bid-rent gradient depends on only one mode, because the break-even distance is either beyond the urban fringe or 0. However, the bid-rent gradient conditional on transit commuting would still be steeper, given the nature of the mass transit cost function.

The reason we have discussed the effect of land scarcity on the slope of gradients is that the steeper land value gradient is, the more easily redevelopment could occur. Recall that steeper rent gradient also implies steeper density gradient. That is, both V and C rise as the center is approached. Thus, assuming that C/V, the ratio of conversion cost to land value, decreases with land value, in City L, whose rent gradient is not only lower but flatter, demolition and redevelopment are less likely to happen. Another way to look at this effect is that the critical distance for redevelopment is greater when density gradient is flatter. Table 5.1 suggests this effect. Even when land value gradient is relatively flat, land value increases as the CBD is approached. Given the same agricultural land value, steeper land value gradient implies even higher land value near the center. Old buildings tend to be located near the center, because cities are built from middle out. The higher land value near the center would make replacement of old units even easier. In other words, relative steepness of land value gradient hinders the poverty concentration near the city centers. In sum, the higher and steeper land value gradient resulting from high land value or land scarcity hinders the emergence of the positive income-distance pattern caused by the filter-down process.

Changes in Equilibrium Densities and Filtering

So far, only the effect of a high and steep land value gradient on filtering and redevelopment has been discussed. However, changes in equilibrium urban densities are very important, too. Besides, it must be pointed out that land scarcity can have an impact on changes in equilibrium densities. The former is well known, and the latter is not well appreciated.

(5.1) can be rewritten as

$$V_t > D_t\,[S_0\,(V_0)] + F_t \qquad (5.2)$$

S is structural density. Subscript t represents the current time period, whereas Subscript 0 denotes the time period for the initial construction. Assuming myopic foresight, (5.2) reflects the fact that demolition cost depends on the equilibrium structural density of the past, which in turn is related to the past land value. Obviously, $\frac{\partial D_t}{\partial S_0}$ >0 and $\frac{\partial S_0}{\partial V_0}$ >0. F_t depends on many factors, but, for simplicity, assume that F declines over time, mainly due to deterioration; $\frac{dF_t}{dt} < 0$. To add perspective, consider the following relationship

$$S_t = S_t\ (V_t) \tag{5.3}$$

and $\frac{\partial S_t}{\partial V_t} > 0$.

Let K and r denote capital and its rental rate respectively. At the time of the initial development, $V < F$ since $F = rK + V$ and $rK > 0$. That is, rental income from housing, the sum of land and capital, is greater than rent from the vacant land. Then, the condition for redevelopment cannot be met in the first place since demolition cost D is positive. From this, we can see that $V > F$ is a necessary but not sufficient condition for redevelopment. In addition to the condition that $V > F$, the difference between V and F should be large enough so that $V - F > D$ and redevelopment occurs.

Land value and equilibrium structural density gradients change with the passage of time. However, the adjustment to the changes takes a long time because of the nonmalleablity and durability of housing stock. Suppose land value has increased over time; $V_t > V_0$. Since D is constant, V_t could exceed $D + F$. Then, redevelopment would occur, and the actual structural density would reflect the equilibrium structural density, which is higher than before. In other words, $S_t > S_0$ since $V_t > V_0$ and $\frac{\partial S_t}{\partial V_t}$ >0.

Suppose land value has fallen; $V_t < V_0$. We know

$$V_0 < D_0\,[S_0\,(V_0)] + F_0 \tag{5.4}$$

at the time of initial development. Otherwise, construction would not have occurred in the first place. Recall that the condition for redevelopment is $V_t - F_t > D_t$. (5.4) can be rewritten as $V_0 - F_0 < D_0\,[S_0\,(V_0)]$, which implies redevelopment is unprofitable at the time of initial development, when $t = 0$. Assume that D is constant over time, since the structural density of a building remains the same over time. Other things being equal, reduction in V keeps redevelopment unprofitable. What would happen if V and F fall simultaneously? A slight decrease in V and a very large decrease in F may make $V - F$ smaller, which increases the chance of redevelopment. Suppose that F falls to the level of zero, while V decreases only slightly. Then, the redevelopment condition can be met more easily. However, in the real world, a decrease in F is associated with a substantial decline in land value. That is, it is unlikely that a slight decrease in V and a very large decrease in F occur simultaneously. Cities in a country with land abundance are more likely to experience a decline in the central city land value, because those cities can take advantage of inexpensive agricultural land more easily when income increases and transportation technology advances. Thus, redevelopment is less likely in the central cities of those cities. In sum, an increase in land value makes redevelopment easier, whereas a decrease in land value makes redevelopment improbable.

Redevelopment will almost always result in higher structural density[20]. Mills and Hamilton (1989) provide a similar explanation. They (1987, p.137) state:

> *It is economically more difficult to convert from high to low density than the other way around for two reasons. First, demolition of low-density structures is cheaper than demolition of high-density structures. Second, the reason people would want to convert from high to low density in the first place is that raw land value has fallen. However, if the cleared land is not worth very much any way, the pay off to demolition is low.*

For simplicity, we have assumed that *F* or the net rental income from the old use decreases over time. *F* depends on many factors such as the structural density, the current land value, and the level of deterioration. Without deterioration, *F* would increase when land value rises. Even in that case, redevelopment would be profitable if land value increases sharply, which implies a large difference between the new equilibrium structural density and the old structural density. If an increase in land value is not high enough to justify demolition and redevelopment, renovation is likely to be profitable. In reality, however, deterioration is unavoidable unless renovation is done. An increase in land value would enhance the possibility of renovation. Renovated housing units would not (easily) filter down to the lower income group. In sum, a rise in land value, implying a new higher equilibrium structural density, increases chances of redevelopment or renovation, which decreases the supply of old and cheap housing units. In other words, urban poverty concentration is deterred when land value increases.

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[20] In Wheaton's model (1982), the density under redevelopment is always "substantially" greater that that of the replaced use.

Empirical evidence indicates that some countries with high land scarcity have experienced rapid increases in land prices. The land prices for Korea's twelve largest cities increased 37 times[21] in real term from 1962 to 1993. According to Stone and Ziemba (1993), the land prices in the six largest cities in Japan increased 100-175 times between 1955 and 1971 and three to four times from 1971 to 1989. Those numbers for Japanese cities are not adjusted for inflation. However, it is certain that the land prices increased very sharply. It is no wonder that old and poorly maintained buildings are rarely seen in central cities in Korea and Japan. Fast economic growth and a speculative bubble appear to be responsible for the rapid land prices. It would be, however, reasonable to believe that very high land scarcity in Korea and Japan played a major role in those land price hikes. When an economy grows, demand for land and, accordingly, land prices increase. A shortage of land would lead to an even higher land price increase. In short, land scarcity is responsible for high land values and their rapid increase, which hinders urban poverty concentration and the U.S. style filtering by increasing chances of redevelopment and renovation.

The U.S. provides a contrasting example. Stone and Ziemba (1993) state that in 1985 Japanese land prices were in the range of 80-120 times U.S. land prices and that in 1990 the average lot for a U.S. house would have cost as much as about $ 9 million in Japan. That is, land prices in U.S. are very low compared to Japan. Although few data are available on the changes of U.S. urban land prices, it is clear that equilibrium structural density has declined in U.S. central cities, especially old large Northeastern cities. When equilibrium densities or land prices decline, redevelopment has high costs and a low payoff. Thus, old high-density housing units in central cities are allowed to deteriorate or to be abandoned. A positive income-distance pattern would emerge as a result of

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[21] See Lee (1997).

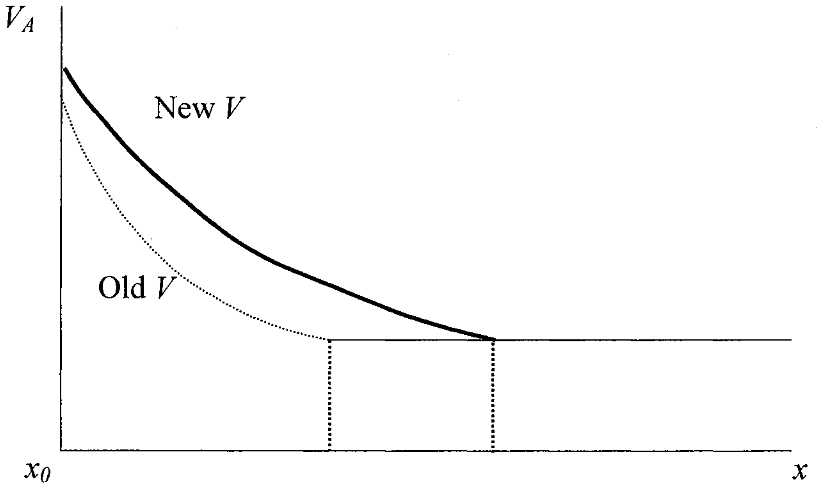
extensive filtering and abandonment that, in turn, are caused by lower equilibrium densities or land prices.

American cities, especially large ones, went through this process. Mills and Hamilton (1989) state that the steepness of equilibrium densities density gradients for American cities has declined for the past several decades. Theoretically, flattened density gradients do not always imply lower densities in central cities. However, Mills and Hamilton (1989) implicitly equate flattened density gradients with lower equilibrium structural density. Thus, they argue that the difficulty of converting to lower central-city density results in concentration of old housing in the central city. In fact, depopulation in U.S. central cities suggests that equilibrium densities in many U.S. central cities have declined so that the actual structural densities are below the equilibrium structural densities.

Mills and Hamilton (1989) discuss this process in terms of the flattening equilibrium densities, caused by transport cost reduction, in the United States. However, it is the change in land value or the level of equilibrium density gradients not the change in the steepness that counts. Suburbanization has been an international trend. Density gradients have become flatter not only in America but also in other developed countries. Even if density gradients have become flatter, structural densities and land prices in central cities could be higher than before.

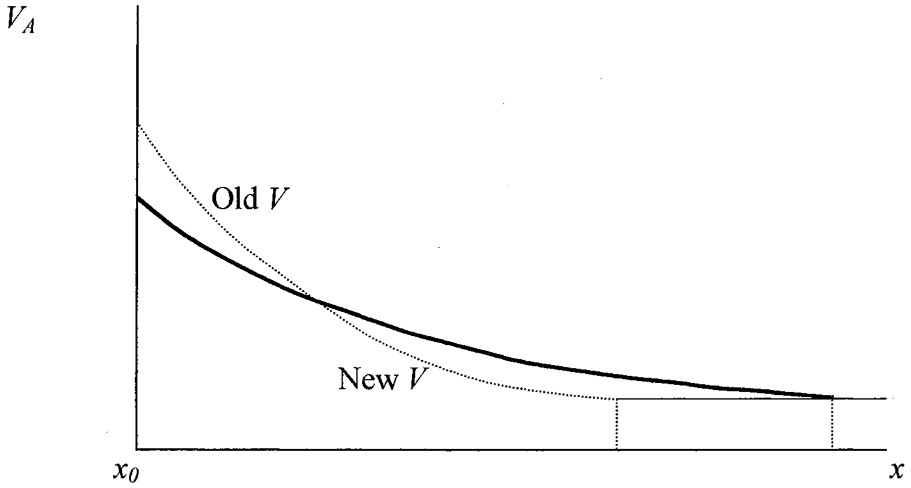
This is illustrated in Figures 5.3.and 5.4, in both of which land value gradients have become became flatter. In the high-rent city, the new land value gradient is flatter but higher at all distance inside the urban fringe. Redevelopment will be easier due to the even higher land value in the central city. On the other hand, land value declined in the central city but rose in the suburbs in the low-rent city. It is evident that old housing will be concentrated in the central city, due to difficulty of redevelopment.

Figure 5.3 Changes in Land Value Gradient with Land Scarcity



City H

Figure 5.4 Changes in Land Value Gradient with Land Abundance



City L

What would cause the different movements in density gradients? The flattening of gradients is often attributed to transport cost reduction and increases in income. However, as we noted before, empirical evidence suggest that increases in income have little to do with the steepness of density gradients as far as the traditional trade off theory is concerned. However, a rise in income flattens density gradients through its effect on modal choice. It is certain that transport cost reduction make density gradients flatter, but we need to recall that transport costs differ, conditional on the mode of commuting. A rapid shift from mass transit to cars has occurred in American cities. We have already indicated that the bid rent gradient conditional on car commuting is flatter than that on mass transit commuting and that the dominance of car commuting in the United States is due to increases in income and low urban densities caused by land abundance. Recall that a rise in income makes car commuting more attractive.

In short, income increases combined with land abundance result in the pattern of the change illustrated in Figure 5.4, because a switch to extensive car commuting makes equilibrium densities decline in central cities and rise in suburbs that used to be rural areas. This situation is applicable to U.S. cities, especially large old cities, which had high structural density in the central cities.

Empirical evidence indicates that population density gradients also became flatter in countries with land scarcity such as Japan and Korea. As mentioned before, land prices rose sharply both in the central cities and in the suburbs of those countries in past decades except the 1990s. Thus, it can be said that land value and structural density gradients not only flattened but also shifted up in those countries, as illustrated by Figure 5.3. A theoretical implication of our modal choice theory explains this phenomenon. Land scarcity shifts up land rent gradients when the economy grows. Besides, when land is scarce, an urban transport system is likely to be mass transit-oriented. The transit-oriented system supported by high density is more resistant to a switch to a car-oriented system. If the switch occur easily, the advantage of central cities is eroded.

Let us summarize the conclusions of this section. First, a reduction in land value and equilibrium presents redevelopment with low payoff and high cost. Second, equilibrium structural density in the central city of an urban area with land abundance is more likely to decline, due to a rapid and extensive switch to a car-oriented urban transportation system. Third, the car-oriented system makes suburban and adjacent rural land more attractive, because it is more easily accessible by car than by transit. As a result, redevelopment becomes more difficult in the central cities of a country with land abundance. Difficulty of redevelopment means higher concentration of old housing in the central city and more filtering, which results in urban poverty concentration.

Age of Urban Areas and Filtering

In the previous two sections, it was shown that low land value and declining central city density hinder redevelopment and promote filtering. The age of an urban area is another factor associated with filtering. Urban areas have history due to durability of capital, a main implication of which is filtering. Filtering theory attempts to explain effects of the past. Filtering itself is a process that occurs over a long time, and the effects of filtering are cumulative. For instance, old housing filters down on multiple occasions, as it continues to deteriorate. In the context of filtering theory, housing units in the central city become older with the passage of time, and new housing is built at the urban fringe. Since old housing attracts low-income households, old urban areas would experience stronger urban poverty concentration than new urban areas.

Another reason that urban poverty concentration is more severe in older urban areas is found in its self-reinforcing effect on urban flight. Many other forces as well as filtering affect income-distance patterns. Although they are not triggering factors, a number of blight variables are self-reinforcing. They increase the disparities between the central city and the suburbs.

The self-reinforcing effect is also found in our modal choice theory. As discussed before, mass transit has externalities in the sense that one's long-term transit cost rises when his neighbors use it less frequently. For any given day, from the perspective of an individual transit user, it could be better if there are fewer transit commuters, since the vehicle will be less crowded. If the decrease in demand density persists, however, the transit service provider has to either decrease the service density or increase the fare. As the richest people move to the suburbs and switch to car commuting, mass transit cost in the central city will rise, unless the transit density in the central city is high enough to exhaust the scale economies. Then, the next high-income group would find it preferable to move to the suburbs as well.

In short, filtering and the self-reinforcing nature of the urban disparities imply that positive income–distance patterns will be stronger in older cities. However, a great caution is required for this implication. Suppose that land is very scarce. Filtering could still occur, but it would be less pervasive due to frequent redevelopment. At least, filtering would not result in concentric rings of housing stocks, with inner rings successively older. Hence, urban poverty concentration would not occur even if the urban area is old. The same is true for the effects of the self-reinforcing nature. If an urban area does not have conditions for urban poverty concentration to occur in the first place, old age of the urban area does not imply cumulative effects of filtering or stronger poverty concentration.

That is why positive income–distance patterns are not observed in old cities such as Paris and Tokyo, whereas relatively new U.S. cities have urban poverty concentration. By contrast, if all urban areas at hand have conditions for urban poverty concentration, urban poverty concentration will be stronger in older cities. Empirical evidence on U.S. cities supports this, as seen in Table 5.2. The table shows fractions of persons with income below poverty level, as defined in the 1990 U.S. Census Reports, fractions of old housing stock built before 1970, and the first Decennial Census year when the urban population of each Region or Division reached more than half of the urban population as of 1990. An older census year in the table implies the region or division is older. As we already knew, Northeast and Midwest Regions are older. Urbanized areas in those regions show larger income disparity between the central cities and their suburbs than urbanized areas cities in the South and West. As expected, housing units in the Northeast and Midwestern cities tend to be older.

Turn to the reasons. First, cities in the Northeast and Midwest have longer cumulated effects from filtering because of their age. Second, those cities have experienced a sharper decline in equilibrium densities in the center. Densities in old large central cities were higher because of a lack of car commuting and of high transport cost in the past. That is, the cities had to be compact in the distant past even with land abundance, due to lack of income and well-developed transport systems. Due to spatial nature of land, land

Table 5.2 Income Disparities by Region and Division

	Poverty Rate*			Old Housing Stock***	Year****
	Central City	Suburbs	Ratio**		
United States	0.179	0.073	2.454	0.610	1950
Region & Division					
Northeast	0.185	0.054	3.454	0.780	1910
New England	0.144	0.050	2.900	0.737	1910
Middle Atlantic	0.198	0.055	3.611	0.793	1920
Midwest	0.190	0.057	3.312	0.692	1920
East North Central	0.203	0.059	3.444	0.713	1930
West North Central	0.153	0.052	2.941	0.628	1920
South	0.191	0.087	2.205	0.490	1960
South Atlantic	0.171	0.080	2.143	0.476	1960
East South Central	0.198	0.097	2.040	0.579	1950
West South Central	0.207	0.104	1.999	0.479	1960
West	0.150	0.090	1.658	0.534	1960
Mountain	0.146	0.089	1.642	0.410	1960
Pacific	0.151	0.091	1.666	0.572	1960

* Fraction of persons with income below poverty level

** Central city/suburbs ratio

*** Fraction of old housing stock built before 1970

**** Decennial Census year when urban population first exceeded half of that in 1990

Source: calculated from urbanized area data in *1990 Census of Population and Housing Summary Tape File 3C.*

supply ample in physical quantity does not always mean the lack of land scarcity. . Large urban areas face land scarcity when rural land outside the urban fringe is difficult to access. Thus, older cities in the Northeast and Midwest had higher density when they were young. On the other hand, newer cities in the South and West did not need to have high density when they were young. As a result, cities in the Northeast and Midwest had to experience shaper decline in densities in the central cities.

Another factor associated with these regional differences is the overall land abundance of the United States. Land is a spatial good, which implies that not all land is used with the same intensity, even if all land is identical, except for its location. The location of land cannot be the same by nature, and, consequently, land is bound to be heterogeneous in this sense. When transportation costs were high, as in the distant past, the difference of land use intensity would have been greater in a country with small population and extensive land supply. The northeastern part of the United States was populated first. Other things being equal, urban land prices rise at all distance when urban population increases. In Japan and Europe, existing old cities, which were relatively evenly distributed across the country, had to accommodate new urban population. In America, newly emerging cities in the South and West, where land is cheap, could absorb increasing urban population, as seen in Table 5.3. From 1890 to 1990, urban population in the South and West rose about 18 and 40 times, whereas it increased only about eight and four times in the Northeast and Midwest.

This relative land scarcity explains the differences in the changes in urban land price and equilibrium density gradients: up in Japan and Europe, a shaper decline in the inner-cities in the Northeast and Midwest, and a milder decline in the South and West.

Obviously, this difference is related to the different income-distance patterns. In other words, land abundance of the United States is associated with regional differences in U.S. urban structures.

Table 5.3 Change in Urban Population: 1890 to 1990

	Urban Population 1990	Urban Population 1890	Percentage Growth
United States	187,053,487	22,106,265	846%
Northeast	40,091,737	10,266,078	391%
Midwest	42,774,196	7,418,101	577%
South	58,656,267	3,261,326	1799%
West	45,531,287	1,160,760	3923%

Source:, 1990 Census of Population and Housing United States Summary

Let us summarize this chapter. The contention that filtering causes urban poverty concentration has rarely been refuted. However, the conventional filtering theory does not explain why urban poverty concentration is peculiar to the United States, because it has neglected the effects of land scarcity, while focusing on the durability of capital. The factors affecting filtering are land value, age of city, and changes in density and land value gradients. First, low land value, resulting from land abundance, makes redevelopment a less viable option. Second, old age of urban areas implies more urban poverty concentration, since filtering is a cumulative process. If land is scarce, however, cumulative effects of filtering on urban poverty concentration would not occur in the first place. Third, declines in equilibrium density and land value in the central city make redevelopment unprofitable. Land scarcity or abundance influences changes in equilibrium density and land value in the long run. Land scarcity combined with economic growth would increase central city land prices, although land prices in the suburbs is likely to rise at higher rates. The availability of a vast amount of unused or cheap land in substantial parts of a country make equilibrium density in central cities of old urban areas decline more sharply, as the mobility across the country increases. In conclusion, all the three factors promoting filtering in the United States are strongly related to land abundance. This explains why the effect of filtering on urban poverty concentration is peculiar to the United States.

CHAPTER VI

THE SCOPE OF THE EMPIRICAL ANALYSIS

Introduction

This chapter is a guide and an introduction to the subsequent chapters that present the empirical results. Two approaches can be considered regarding empirical tests of our residential location theory. One option is to compare income-distance patterns or central city-suburbs income disparities across the world and analyze what variables contributed to various patterns. This approach could directly shed light on the peculiarity of the U.S. urban residential pattern. However, it is difficult to obtain accurate and consistent data on a substantial number of international cities. The other choice, which we adopted, is to work with data on U.S. cities. With this approach, we cannot directly test the peculiarity of the U.S. income-distance pattern. However, rather extensive data on U.S. urban areas make the empirical tests more comprehensive. If the test results support our theory, we can draw relevant implications regarding the peculiar U.S. pattern as well. Pros and cons of these two approaches are discussed in this chapter.

Since *urbanized areas* more aptly corresponds to the economist's concept of urban areas than *metropolitan areas*,[22]data on urbanized areas were used in our tests. Sources of the data and relevant definitions are discussed. The chapter concludes with a discussion of the estimator. The Box-Cox and Box-Tidwell specifications were used in our study, because they are superior when the specific functional forms are unknown.

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[22] A metropolitan area could mean two similar but different objects. First, it may mean a metropolitan area in generic sense. Second, it can also mean the definition of a metropolitan area used by the U.S. Census Bureau. The latter refers to an MSA (metropolitan statistical area), PMSA, or CMSA. To avoid ambiguity, we will italicize the word or use the abbreviation, MA, to refer to the statistical concept.

Empirical Analysis of International Cities vs. U.S. cities

Our foremost question at hand is 'Why is the positive income-distance relationship stronger in the United States than in other countries? Therefore, we had hoped to do an empirical analysis by comparing major cities across the world. The city is a complicated economic system influenced by many factors interacting with each other. They are, to name a few, income, land supply, population, technology, history, and government policy. Regressing those variables on the income disparities between central cities and their suburbs for various countries would have been the choice for our empirical analysis. It is difficult, however, to obtain reliable and extensive data on urban areas in less developed countries. Thus, analyzing only industrialized countries looked appealing because of data availability.

This process may appear to pose problems that could arise when samples with only certain features are arbitrarily selected in an empirical analysis. Although the role of land scarcity is the core of our analysis, its effects on urban structures and residential patterns cannot be explained without other variables such as income and technology. For instance, without sufficient levels of income and transportation technology, modal choices promoting the income disparity between the central city and suburbs would not occur. Hence, similar levels of land scarcity could result in different income-distance patterns, depending on the levels of income and transportation technology. If a country's income level is so low that most income groups cannot afford private passenger cars as a means of commuting, the modal choice model could not shed much light on the income segregation within the city. It does not mean that our theory becomes irrelevant or inconsistent, but it implies that the effects of land scarcity on income disparity is negligible when only one commuting mode is available as far as the modal choice theory is concerned.

The same argument can be made with respect to filtering. Filtering depends not only on land prices but also increases in income. The effect of land abundance on filtering would be weak if the national income level is very low or stagnant. Suppose the income level of urban residents in a country has been low and stagnant for a long time. Since filtering occurs partly due to income growth, the U.S.-type filtering process will be deterred, although it could still occur depending on other factors such as depreciation of housing stock. In short, limiting samples to industrialized free market economies would rid our empirical analysis of some complications, since we could reasonably presume that transportation technology availability and the level of income are not significantly different. Thus we can control other variables and focus on the effects of land scarcity.

Despite these merits, however, we were unable to do our empirical analysis on cities of the various industrialized nations because of difficulties with finding relevant and consistent data. Unlike macroeconomic data, urban data on foreign countries are difficult to obtain. Data on individual cities in many countries, not just the countries, are required, but it is difficult to collect urban data on large samples of cities across many nations. Collecting the data is not impossible, but it is beyond the scope of this study. Besides, we need data not only on urban areas as a whole but on central cities and their suburbs. Different values of such variables as income level, population, proportion of old housing stocks, and modal choice between the central city and suburbs are necessary to analyze our model.

In short, we need data on components of a city not just a city as a unity. Even in the United States, census data were not available in easily computable formats before 1990. Printed versions of the census reported extensive data on *metropolitan areas* and their components but not on urbanized areas, which correspond to the economist's notion of urban areas or cities. That is, fewer data have been available on urbanized areas than on metropolitan areas. Tracking numerous census tracts was necessary to compile urbanized area data not available in printed reports.

Using data, if available, on cities of many countries poses another problem. Different countries use different criteria in defining the central city and the suburbs, and some countries do not employ such a distinction at all. For instance, the census bureau of Korea does not make any statistical distinctions regarding the central city and its suburbs, although a researcher may make an arbitrary distinction. This is somewhat understandable since 1) a large city government's jurisdiction in Korea usually covers the whole metropolitan area and 2) outside of the CBD, there are no sharp distinctions, as in the United States, between the central city and the suburbs. Thus, this inconsistency with definitions of the city and its components would cause trouble in empirical analyses. This problem might be avoided if estimated gradients of variables, instead of data on the central city and the suburbs, were used. However, that task is even more difficult to accomplish, considering the procedures and data required for estimation. With the gradient approach, it would be possible to compare cities of different countries. It is, however, very challenging to obtain a sufficient number of observations necessary for rigorous statistical analysis. With a small number of observations, comparison of data and interpretation with insight may be the only feasible options.

The aforementioned problems with the empirical analysis with international data made us focus on U.S. cities for our empirical analysis. We relied mainly on the *1990 Census of Population and Housing* data, which is the most recent decennial census data. These 1990 census reports are available both in print and on CD-ROMs. The CD-ROM data were used for our analysis because they are more extensive and pose fewer computational challenges. The fact that the CD-ROM data were used should be noted because different definitions are used in some cases although both media use the same raw data. Data were also obtained from other sources such as *1992 Census of Agriculture* and *Uniform Crime Reports 1990.*

The biggest advantage with using U.S. census data lies with the computability and accessibility to them. It is obvious that this contrasts with the most serious obstacle we faced exploring the option of empirically analyzing cities across the world. The 1990 U.S. census data are very extensive and readily available. Besides, the CD-ROM data are more extensive and provide easy computability. Most U.S. census data before 1990 are available only on printed reports and magnetic tapes, which poses computational challenges. As we can see from subsequent chapters, most of our variables were not directly obtained from the sources. The computability of the CD data enabled us to estimate or calculate them from the original data. Besides, the large size of the U.S. economy and the detailed census data guarantee a sample size.

As of 1990 there were 396 urbanized areas (UAs) and 355 *metropolitan areas* (MAs). Since all 20 consolidated metropolitan statistical areas (CMSAs) are composed of 71 primary metropolitan statistical areas (PMSAs), there are fewer than 355 independent *metropolitan areas*. These numbers are more than sufficient for statistical analysis.

Relatively consistent criteria for definitions of data or categories, especially the central city and suburbs, yield fewer measurement errors, although they cannot be avoided altogether. Using the U.S. census data or only one country's data provides some consistency within data sets. The Census Bureau has specific criteria for UA, MA, MSA, PMSA, and CMSA, although all these definitions do not fully correspond to the concepts of urban economists. This consistency could not have been found in international data.

The dentition of 'central city' employed by the U.S. Census Bureau is 'the largest city in each MSA/CMSA and additional cities that may qualify as such if specified requirements are met concerning population size and commuting patterns.' '*Metropolitan areas* not in central city' correspond to suburbs. Although many urban economists use MA data to analyze differences between central cities and suburbs, that procedure has a problem. MAs are delineated by jurisdictions. Thus, they consist of central cities and counties. Parts of the counties are rural. Therefore, '*metropolitan areas* not in central city' does not exactly describe the generic definition of suburbs.

On the other hand, urbanized areas fit the economist's concept of urban areas more closely than *metropolitan areas*. Urbanized areas consist of 'central places' and the 'urban fringe'. The definition of 'central place' is similar to 'central city' in MA. The *urban fringe*[23] generally consists of contiguous territory with a density of at least 1,000 persons square mile. That is, the urban fringe excludes rural areas. It is evident that data on urbanized areas are conceptually superior to data on *metropolitan areas* as far as our

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[23] In our discussion throughout this study, unless otherwise noted as in this example, the urban fringe is the boundary of an urban area.

study is concerned. Thus, we present in the subsequent chapters empirical test results based on urbanized area data.

Previously, we suggested that limiting sampled countries to industrialized economies would have helped simplify empirical procedures by assuming away income and transportation technology or, precisely speaking, assuming relatively highly levels of those variables. This point becomes more relevant when we focus on U.S. data because of high and homogeneous income and transportation technology in the United States. It is true that personal or household income levels in cities across the United States are not the same, but we can presume that the differences are minor given the high mobility within the nation and relatively balanced economic growth among the regions. It should be noted that the high mobility implies that regional real income difference is smaller than regional nominal income difference. It is also obvious that the same urban transportation technology is available to all U.S. cities, although different technology or commuting modes would be adopted depending on each city's status.

Using U.S. data provides some advantages while requiring further theoretical clarifications that may not have been necessary in the alternative case. First, the size of an urban area in terms of population matters. As the population of the urban area increases, its density and the spatial size rise. These changes affect the modal choice of the city. In a country with land scarcity, a large city has high density even in the suburbs. Then, transit will be economical in the suburbs as well. Therefore, the poor are not confined in the inner city. By contrast, in a country with land abundance, the density in a large urban area is unlikely to be high enough to make mass transit economical in the suburbs. On the other hand, the car will be virtually the only mode in small urban areas in this country.

In short, urban poverty concentration will be stronger in a larger city in a country with land abundance, whereas the effect of the population of a city is reversed in a country with land scarcity. Since the United States is a country with land abundance, we could expect urban poverty concentration to be stronger in a larger city. If we had tested our theory with a sample of major cities among the industrialized countries, the effect of the city size would not have mattered much, due to the inherently large city sizes of the sample cities.

The same consideration is required with respect to land value. Compare large cities in the United States and other industrialized countries with land scarcity such as Japan. High land prices in Japan make mass transit economical even in the suburbs. Hence, urban poverty concentration will not occur in those Japanese cities. In large U.S. cities, however, the lower density resulting from low land prices leads to the modal choice split. As a result, the poor are concentrated in the central city. Thus, central city-suburbs modal choice changes in the order of car-car, transit-car, and transit-transit as agricultural land value rises. This is to say that indexes of urban poverty concentration would increase for a while and decrease with the increase in agricultural land value. In other words, the relationship between agricultural land value and urban poverty concentration is not monotonic. Roughly speaking, regardless of city sizes and land prices, suburban densities in almost all U.S. cities are so low that mass transit is not a viable option. The real question is whether the central city density is high enough to make mass transit economical there. Given the same population size, higher land value at the urban fringe implies a smaller spatial size and higher central city density. That is, in the United States, higher land value results in more reliance on mass transit in the central city, which implies stronger urban poverty concentration.

As mentioned before, the age of an urban area matters only when conditions for redevelopment in the center do not exist. Thus, the city age would have little significance to the income-distance patterns of non-U.S. cities with high land scarcity. By contrast, we can expect older U.S cities to have stronger poverty concentration. The effect of land value or land scarcity on filtering is straight forward, regardless of the samples; the lower the land value, the stronger are the filtering effect and urban poverty concentration. Recall that low value in U.S. cities leads to weaker urban poverty concentration in the context of the modal choice theory applied to the U.S urban areas. Thus, for U.S. cities, the overall effect of land value is ambiguous. This statement requires a careful interpretation, since international comparison implies that the high land value is responsible for lack of urban poverty concentration in the context of both the modal choice and our filtering theory. Note that 1) international comparison is to compare representative national land prices, which are high and low and 2) inter-urban comparison with the United States is to compare low and lower (or very low and not so low) prices.

The ambiguity of the overall effect of land value on urban poverty concentration does not pose a problem. Since land value affects income disparities via modal choice and filtering, we test the two theories separately first. If the test results of both theories turn out to confirm our predictions, the ambiguity issue would not matter. After performing the two separate tests, a model that reflects both theories and the overall effect of land value is tested. This way, insights that are more meaningful will be gained. Last, to gain a more comprehensive picture of the income-disparities in the United States, we test a model reflecting both the blight theory and our natural evolution theories.

The Estimation Techniques

We have information about the variables to be included and the signs of the coefficients. However, we have little information on the precise functional forms of our models. We are not even sure about the non-linearity of the relationships, except for the relationship between land value and modal choice and income disparities. The Box-Cox transformation is an appropriate estimation technique when the functional forms of relationships are unknown.

The Box-Cox transformation determines what functional form is most appropriate, by transforming some of or all the variables in a relationship. In this transformation, a variable Z is transformed to $Z^{(\lambda)} = (Z^{\lambda} - 1)/\lambda$. $Z^{(\lambda)} = \ln Z$ when $\lambda = 0$, since $\lim_{\lambda \to 0} \frac{(Z^{\lambda} - 1)}{\lambda} = \ln Z$. If all variables are transformed by the same λ, which is 0, the functional form becomes a Cobb-Douglas in nature, which implies a log-linear relationship. If $\lambda = 1$, the relationship is linear. Using these properties, significance tests can be performed on λ to check for linear and log-linear functional forms.

The simple Classical Box-Cox model transforms only the explanatory variables by the same λ. In an extended Box-Cox model, all variables receive the same power transformation. A variation of the Box-Cox model, known as the Box-Tidwell model, does not transform the dependent variable but transforms each of the explanatory variable by a different λ. An even more flexible transformation is defined if a different λ is assigned to each of the variables, including both the dependent variables and the explanatory variables. This model is called the Box-Cox and Box-Tidwell transformation. We used the Box-Cox and Box-Tidwell transformation, whenever possible, since it is the most flexible and general form of the Box-Cox transformations.

However, using the Box-Cox and Box-Tidwell transformation it involves a computational problem. The Box-Tidwell method, by which we mean both the Box-Cox and Box-Tidwell transformation and the Box-Tidwell transformation, requires that all explanatory variables be positive. More importantly, the Box-Tidwell method often does not converge, due to floating point overflows. Thus, we settled for the extended Box-Cox technique when we faced the overflow problem. In other words, we present the test results from the Box-Cox and Box-Tidwell transformations, whenever possible. The results from the extended Box-Cox technique are presented only when both the Box-Cox and Box-Tidwell transformation and the Box-Tidwell transformation fail. We also included ordinary linear square test results to compare the results to those from the Box-Cox tests.

In fact, the Box-Cox transformation is the most widely used technique testing non-linearity. However, we skipped the non-linearity tests, since 1) we have a substantial number of relationships to test and 2) our main concern is on the effects of the explanatory variables. That is, we focused on the signs of the coefficients in the empirical models. Since we are interested in the signs, we employed one-tail tests, which implies the typical null and alternative hypotheses of our models are:

(i) $H_0: \beta_i > 0$

(ii) $H_1: \beta_i \leq 0$

where β_i is the coefficient of the transformed variable of the *i*th explanatory variable.

Note that we constructed our empirical models in a way that the expected signs of explanatory variables are positive except land value in filtering equations. Exceptions are noted when the specific tests are discussed.

CHAPTER VII

EMPIRICAL ANALYSIS OF THE MODAL CHOICE MODEL

Introduction

In this chapter, our modal choice theory is tested. We begin with definitions and sources of variables. Modal choice depends on the city size and land scarcity. To see the remaining effect of the past urban transportation structure on the current modal choice, it might be better to include the city age as another explanatory variable as far as U.S. data are concerned. Population of an urban area and its land value at the urban fringe will represent the city size and land scarcity. Unlike population, land value at the urban fringe is not directly available. Thus, we explain how land value at the urban fringe is estimated. The procedure to estimate a proxy for the city age variable is also explained. Two measures of central city-suburbs income disparity are introduced. One is based on per capita income, and the other, poverty statistics. Since we will define income-disparity as either the ratio of suburban income to central city income or the ratio of the percentage of the poor in central city to that in suburbs, higher income disparity implies a stronger positive income-distance relationship from now on in this study, otherwise noted.

The city size, land value, and city age, which we will call basic explanatory variables, do not directly affect income-disparity. They have impacts on modal choice, which in turn influences income-disparity. Thus, we decided to test out modal choice theory in two steps. The first step is to test the effects of the city size, land value, and city age on a measure of modal choice. The second step is to test the relationship between income disparity and modal choice. We will test the effects of the basic explanatory variables on income disparity in Chapter IX, where the combined modal choice and filtering model is tested.

The Data and the Variables

Our first empirical task is to test the relationship between modal choice and its explanatory variables. The dependent variable in this case should represent the urban transportation structure or modal choice. The U.S. census reports present 'means of transportation' data on UAs, MAs, and their components. The means of transportation data consist of five subcategories; 1) Car, truck, or van, 2) Public transportation 3) Walked, 4) Other means, and 5) Worked at home. The census reports do not directly present data on 1) and 2) but do for their subcategories. Thus, we have data on the two main commuting modes, car and mass transit. According to the 1990 census reports, 94.6 % of commuters living in urbanized areas use either cars or mass transit. Thus, it does not appear to be a problem to ignore other means of commuting or workers who do not commute.

TCT is our modal choice variable. We defined *TCT* as the ratio of transit users to car commuters in a UA. It is evident that a higher value of *TCT* means that the city relies relatively more on mass transit. Since the car is the dominant commuting mode in U.S. cities, the value of *TCT* is quite low in most UAs. However, *relatively* high values of *TCT* can be interpreted as more reliance on mass transit. In almost all UAs, suburbanites rely less on mass transit than do their counterparts in the central. In other words, the relative importance of cars increases in accordance with distance from the center. In very small UAs, however, the modal choice difference between central city and suburbs is very small, since the car is virtually the exclusive commuting mode in both the central city and the suburbs. In fact, in 14 out of 396 UAs, the central city commuters use cars relatively more than the suburbanites do. The interpretation of these data requires some caution, though. For all 14 UAs, the ratio of transit users to car commuters in the central city and the suburbs is virtually equal, which implies no modal choice difference between the central city and the suburbs.

Table 7.1 Modal Choice and Value of *TCT*

Pattern	A	B	C	D	E
TCT	very low	low	mid-range	high	very high
Central city	car	car/transit	Transit	transit	transit
Suburbs	car	car	Car	car/transit	transit

Although *TCT* does not compare the central city and suburbs, higher values of *TCT* imply a pattern closer to the modal choice of mass transit-central city vs. cars-suburbs in our theoretical analysis. Considering the dominance of car commuting in the United States, very low values of *TCT* imply car-only both in the central city and the suburbs. Table 7.1 shows the relationship between *TCT* and the commuting patterns or the modal choices. The relationship presented in the table assumes relatively high levels of income. If no one can afford a car or even the poorest find car commuting affordable and preferable at all distance, modal choice would not affect income-distance residential patterns. The three columns in the middle represent the possibility of the income disparity between the central city and suburbs.

In our view, the four important variables that determine the modal choice or *TCT* are transportation technology, income, city size, and land scarcity. Income in the United States is high enough for the relationship in Table 7.1 to be true. In our tests, we exclude variables for transportation technology and income, since we believe the inter-urban differences in the United States are not large enough to affect modal choice. The larger the city size is, the more efficient or less costly mass transit is, especially in the central city. The appropriate variable for a city size is the population of the city. *POP* is the population of an urbanized area and represents city size in our empirical analysis. Data for *TCT* and *POP* are available in the *1990 Census of Housing Summary Tape File 3C-2*, which reports data on U.S. urbanized areas and their components. *TCT* is expected to be positively related to *POP*.

Land scarcity or high land value also implies relatively high efficiency of mass transit. Thus, *TCT* would rise with the increase in land value. Suppose land value is high to a degree that Pattern B or C in Table 7.1 is probable. If the car is not available or too costly to the poor, the poor live in the central city. Therefore, Pattern B and C imply the emergence of the positive income-distance relationship. How can Pattern A be possible when we assume the car is too costly to the poor? This is a situation where both groups find cars more economical. If a bus stop is three miles away from home and the bus runs only once a day, even the poor would find cars less costly. Of course, this cannot be true in a very poor country. They would either walk or use mass transit.

A more subtle explanation would shed more light on this difference. Suppose City R and City P have the same population, say 100,000, so that the scale economies of mass transit cannot be reached. Suppose also, City R is in a rich country and City P is in a poor country. The mass transit costs that residents of the two cities face are different, even if we assume everything is equal other than the income levels. Finding mass transit costly or inconvenient, some residents in City R would adopt a car as their means of commuting. Then more other residents would also switch to a car because of the decreased demand for and, accordingly, reduced efficiency of mass transit. In other words, the cost of mass transit depends on what your neighbors do. If all your neighbors use a car or there are few residents in your neighborhood, it is very likely that your mass transit cost is high. This is due to the economies of scale inherent in mass transit. On the other hand, in City P where most people are poor, more people will use mass transit. Then the cost of mass transit would be kept low (not as low as in large cities in the poor country but lower than in City R in the rich country).

The assumption that the car is not available to the poor is too simplistic, and it is not a necessary condition for our theoretical conclusions regarding the linkage among land scarcity, modal choice, and income disparity. It is sufficient and realistic to assume a situation where most income groups can afford a car but the poor are more sensitive to car commuting cost, which can be high, compared to the alternative mass transit cost. In other words, the relative cost of cars and mass transit borne by different income groups is what matters. In fact, the same person who commuted by car in a small city could use mass transit when he moves to a large city because commuting by car is more costly than in the small city. In large cities, car commuters have to bear high insurance and parking costs. In addition, the cost of mass transit is lower in big cities. On the other hand, being very responsive to the non-monetary cost of mass transit, a high-income worker is likely to use a car whether he lives in a small or large city.

For land scarcity, *LV* is used. It is a calculated value of agricultural land surrounding an urbanized area. The total supply of land in a given country is almost fixed but the land supply for a city is not constant. Geography and the agricultural use of land outside the urban fringe are related to the demand for and supply of land in an urban area. For almost all economic goods, their prices represent their scarcity. Likewise, land scarcity can be measured by land price. However, land is peculiar in the sense that it is immobile. Since it is immobile, an acre of agricultural land at different locations in a given county commands different prices.

Thus, we need to use a variable that can present land scarcity of each city. We decided to use the agricultural land value at the urban fringe as a variable for land scarcity. This procedure has some merit. It is very difficult to obtain data on land prices within U.S. urban areas because 1) most urban land is combined with capital, i.e., structures, 2) assessment is done for the whole package, not for separate components, land and capital, and 3) very few transactions occur in underdeveloped or vacant urban land.

It is interesting that 2) is not true in Korea and Japan, where land is very scarce and expensive. For instance, in Korea, explicit market prices or assessed values of land are available for urban land whether or not it has a structure on it. Mills and Hamilton (1989, p. 132) state "Very few studies exist in which a researcher has gathered the data for a scatter diagram of land value versus from the CBD … because adequate samples are so rare." They argue that the reason for the scarcity of adequate samples is simply that the vast majority of urban land is already built upon so that very few sales of uncovered land occur. His argument has much validity, but it ignores the fact that explicit prices of land, even if it is covered with capital, can and do exist, as in Korea and Japan. We believe that relatively high scarcity of land in those countries makes the difference. After all, more information will be available for a good that is considered vital.

In short, data on urban land prices are scarce in the United States. Fortunately, however, data on agricultural land value at the county level are available. We can estimate the land value at the urban fringe using the data. *1992 Census of Agriculture* reports average market values of an acre of agricultural land for all U.S. counties except for few counties where virtually no agricultural activity occurs. The land value data are available for 1982, 1987, and 1992. The data for 1987 were chosen to maintain consistency with *1990 Census of Population and Housing* data.

The problem with this is that many UAs and MAs consist of more than one county and that agricultural land values of the counties are not equal. Facing this problem, Brueckner and Fansler (1983) chose to limit the samples to UAs contained in a single, relatively small county while doing their empirical analysis on urban sprawl. With other restrictions, they used only 40 UAs. We cannot follow this approach because we are interested in the effects of the city size. UAs contained in a single county are small. Our empirical analysis would be meaningless if samples are limited to those small UAs.

Thus, we decided to impose some weights on farmland values of counties, FLV, to estimate a single value for a given UA. If an urbanized area consists of n counties, its land value at the urban fringe, LV was estimated as

$$LV = (\alpha_1 FLV_1 + \alpha_2 FLV_2 + \ldots + \alpha_n FLV_n)/(\alpha_1 + \alpha_2 + \ldots. + \alpha_n)$$

where α_i is the *i*th county's weight.

α_i was determined by the *i*th county's portion of the length of the whole urbanized area boundary. For instance, if the length of the whole urban boundary is 4miles and a county covers half of the boundary, the county's farm land value received a weight of 2. If a county was totally contained in an UA, the weight was obviously zero, since the county contained no urban boundary. Since the boundary of urbanized areas is nether a straight line or an arc, it is difficult to measure the exact length. Besides, the exact length is pointless because the boundary has numerous dents and small curves. Thus, we used approximate lengths as the weights.. Although it was impossible to assign a precise weight on each county, we made an effort to make the weights reasonable in every case. Besides, in most cases there was not much difference of farmland values among counties containing the boundary of an UA.

Is the agricultural land value variable, *LV*, a good proxy for representing land scarcity of an UA? Our answer is yes. First, there is no alternative. Second, as seen in the theoretical monocentric models, higher agricultural land rent results in higher land values inside the urban area by making the city more compact. That is, it has correlation with urban land value. Another important factor influencing urban land value is the city size in terms of population. Since we have already included the city size variable, *POP*, in our analysis, we see no significant problems with the fact that land value inside the urban areas does not enter into our empirical model. Third, using agricultural land value fits the theoretical exposition in the traditional monocentric models. A single, exogenous value of agricultural land rent is one of the premises employed by those models.

In our theoretical discussion of the modal choice, we focused on the city size and land value as determinants of modal choice. This approach is proper if durability of capital is assumed away. If durability of capital is considered, however, it may be appropriate to include a variable representing the city age. Current urban transportation structures partly reflect the past ones. Mass transit systems require heavy initial fixed costs. Thus, other things being equal, transit service density could be higher in a city with old transit systems because high fixed costs are sunk costs now. If urban development occurred rather evenly throughout the country, the modal choice variances among cities would depend little on the ages of the cities. However, that was not the case with U.S. urban areas, as mentioned in the previous chapter. In general, urban areas first developed in the Northeast and Midwest. Older U.S. cities used to have higher density because of lower income and less developed transportation systems. Those older cities were more transit-oriented than their newer counterparts. Thus, we can expect that the reliance on transit of older U.S. cities may be higher. Thus, we decided to test the effects of the city age on *TCT* as well.

It is difficult to measure how old a city is. The growth rates or patterns vary from city to city. The age could indicate either the current physical status of the city or the years the city has existed. A city formed earlier can look young if it has grown rapidly recently. On the other hand, a city that emerged not so early but grew little might look old. Some less than satisfactory but acceptable measures could be available, although no hard and fast standards exist. Some authors used the year when the population of an urban area reached a certain number to estimate the city age. According to this procedure, however, smaller cities are bound to be younger. That method would be acceptable only the city sizes of the sample cities are similar. The large variance in city sizes in our sample makes it a bad choice. Thus, we believe that the year when the population of an urban area reached a certain percentage of the current population is a better indicator of the age of the urban area.

A problem with this measure is that it is almost impossible to estimate the ages of all urbanized areas. Many small or new urbanized areas were not designated as urbanized areas 20 or 30 years ago, mainly because they were small back then. Not all cities or areas that are urban in nature are designated as urbanized areas because they do not meet the size requirements set by the Census Bureau. That is, the urban areas that were urbanized in the past were likely to be urban in nature. Thus, we decided to define *AGE*, our city age variable, as the number of years from the decennial census year the urban population of the State containing the urban area at hand began to exceed half of the urban population in 1990. In fact, we use the age of state as a proxy for the city age. This measure is acceptable, considering migration patterns and urbanization depends considerably on regional development.

After testing the effects of *POP*, *LV*, and *AGE* on *TCT*, we empirically analyze the relationship between *PYSC* or *POVCS* and *TCT*. Both variables are based on 1990[24] U.S. census data and represent the central city–suburb income disparity. *PYSC*, a straightforward measure of income disparity, is the ratio of per capita income in the suburb to that in the central city. *POVCS* is the ratio of the percentage of persons with income below poverty level in the central city to that in the suburbs. Poverty statistics in

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[24] 1990 census income data are based on income in 1989.

U.S. census reports are based on the definition of the economy food plan, the least costly of four nutritionally adequate food plans designed by the Agricultural Department. The poverty level for families of three or more persons is set at three times the cost of the economy food plan. The level for smaller families is set at slightly higher than three times the cost of the economy food plan. The average poverty threshold for a family of four persons was $12,674 in 1989. Since *POVCS* is based on poverty statistics, not on mean or median income, it appears to be a good measure of urban poverty concentration, inner-city decline, or the relative poverty status between the central city and suburbs.

For *PYSC* and *POVCS*, a ratio greater than unity means a positive income-distance pattern while a ratio smaller than unity implies a negative pattern. Of course, the ratio of unity implies that there is no income disparity between the central city and suburbs. Considering the typical positive income-distance pattern observed in the United States, one might presume that most UAs have ratios greater than unity. However, 126 UAs out of 394 UAs have the ratios less than one when *PYSC* is used. If *POVCS* is used, the number of UAs with the ratios less than one is reduced to 37. This may be because *PYSC* is based on per capita income, which is a mean; a mean is influenced strongly by extreme values. Median income disparities or *POVCS* appear to describe more aptly the income-distance patterns. It is an overstatement to say that almost all U.S. cities have the positive income distance relationship. However, further observations of the income disparity data reveal that most UAs with the ratios less than one are small and that their ratios are close to one, which implies weak or virtually zero income disparities.

Before testing the relationship between *PYSC* and *TCT*, we need to emphasize the implication of *TCT* again. *TCT* is the ratio of the number of mass transit commuters in a whole urbanized area to the number of car commuters in the same area. If *TCT* is zero, it implies the car is the only mode in that area. If mass transit is the only mode, the value of *TCT* will be infinity. A very high value of *TCT* implies the 'transit-central city transit-suburbs' pattern, Pattern E in Table 7.1. However, this possibility is automatically excluded in our sample because the car is the dominant mode in the United States. *TCT* is less than unity and small in every UA in the United States. Thus, as far as our data is concerned, a higher value of *TCT* implies a pattern closer the "mass transit –central city vs. car-suburbs' pattern in our theory.

Modal Choice and its Explanatory Variables

Modal choice in an urbanized area depends on its land value and size. As mentioned before, the age variable is optional. This relationship is written as:

$$TCT = TCT(POP, LV) \tag{7.1}$$

Since our theory contends that a higher land rent and a larger city size result in more reliance on mass transit, we expect the signs of the coefficients of both explanatory variables to be positive. The regression results are presented in Table 7.2 and 7.3[25]. The number of observations is 394, although 396 UAs in total existed in1990. This is because the urban fringes, suburbs, were not defined for two UAs, Anchorage and Galveston. Table 7.2 presents the results of the Box-Cox and Box-Tidwell test. As expected, the signs of both coefficients are positive and significant at the 1% level, confirming our predictions. They are significant at the 1% level. The *t*-value for *POP* is very high,

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[25] OLS estimates are presented for readers to compare the results to those from the Box-Cox estimation Unless some important implications exist, we will not discuss the OLS results throughout this study.

reflecting the fact that larger cities rely more transit, because of their higher density, than smaller cities. Table 7.3 reports the OLS test results. Again, the signs are positive and correct. Overall, both tests confirm the positive relationships between the reliance on mass transit and its explanatory variables, city size and land scarcity.

Table7.2 Regression Results, Dependent Variable: *TCT*
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
POP	0.050222	0.004286	11.72***	0.12763
LV	0.11459E-03	0.2454E-04	4.670***	0.93970
Constant[a]	-4.5775	0.1209	-37.88***	

Dependent Variable $\lambda = 0.160$

$R^2 = 0.3417$ and Adjusted $R^2 = 0.3383$

394 Observations

*** Significant at the 0.01 Level

[a] Two-tail tests throughout this study.

Table7.3 Regression Results, Dependent Variable: TCT
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
POPT	0.21775E-07	0.1230E-08	17.70***
LV	0.41489E-05	0.9066E-06	4.576***
Constant	0.010561	0.002188	4.827***

Dependent Variable: *TCT*

$R^2 = 0.5023$ and Adjusted $R^2 = 0.4998$

394 Observations

*** Significant at the 0.01 Level

As we mentioned before, a variable *AGE* can be added as another explanatory variable to the model when durability of capital and historic aspects of urbanization in the United States are taken into account. This revised relationship is written as

$$TCT = TCT(POP, LV, AGE) \tag{7.2}$$

We also expect the coefficient of *AGE* to be positive, since we believe that the current status in older U.S. cites would reflect their past relatively higher reliance on transit because it takes a long time for urban transportation structures to adjust to new equilibrium densities. The regression results are presented in Table 7.4 and 7.5. As expected, all the signs are positive, and they are significant at 1% level. The positive and significant coefficients of *AGE* suggest that older U.S. cities rely relatively more on transit than newer cities.

Table7.4 Regression Results, Dependent Variable: *TCT*; *AGE* Added
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
POP	0.079127	0.006390	12.38***	0.0928
LV	0.40687E-04	0.9689E-05	4.199***	1.0491
AGE	0.0057019	0.9143E-03	6.236***	1.0657
Constant	-5.1428	0.1460	-35.24***	

Dependent Variable λ: 0.160

$R^2 = 0.4011$ and Adjusted $R^2 = 0.3965$

394 Observations

*** Significant at the 0.01 Level

Table7.5 Regression Results, Dependent Variable: *TCT*; *AGE* Added
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
POP	0.21519E-07	0.1208E-08	17.82***
LV	0.37955E-05	0.8932E-06	4.249***
AGE	0.29957E-03	0.7343E-04	4.080***
Constant	-0.14491E-02	0.3643E-02	-0.3978

Dependent Variable: *TCT*

$R^2 = 0.5227$ and Adjusted $R^2 = 0.5190$

394 Observations

*** Significant at the 0.01 Level

Income Disparities and Modal Choice

Now, we will test the relationship between income disparities and modal choice. The relationship is written as

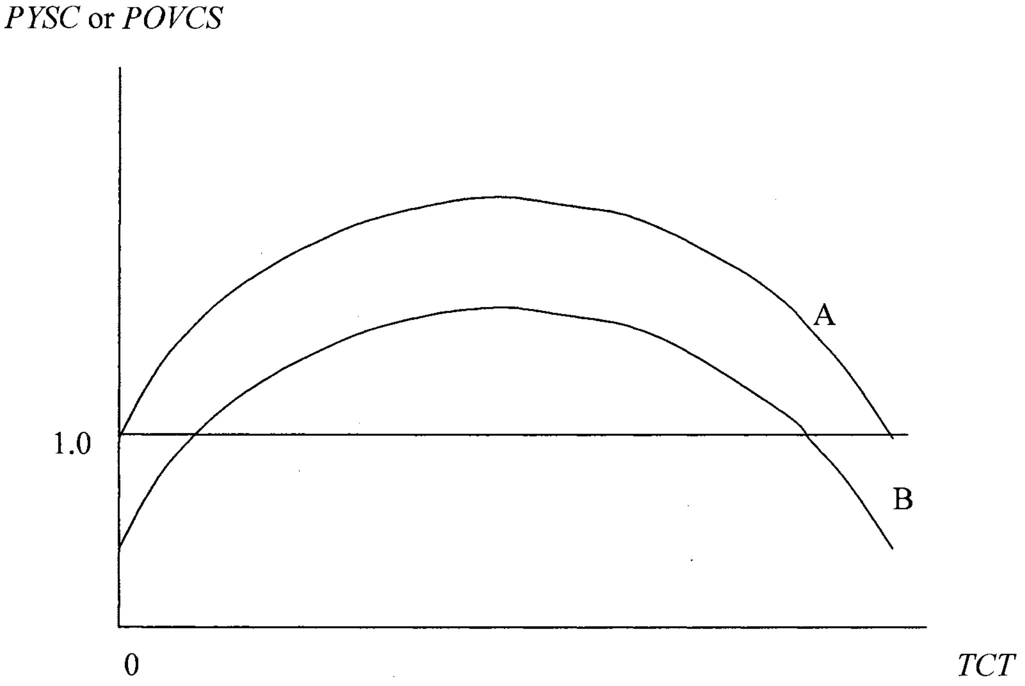
$$PYSC = PYSC(TCT) \tag{7.3}$$

or

$$POVCS = POVCS(TCT) \tag{7.4}$$

The functional relationship is not simple in the sense that the relationship is nonlinear and non-monotonic. Figure 7.1 represents the nonlinear relationship between the two. Our theory predicts that *PYSC* and *POVCS* would be closer to one when *TCT* is close to zero. As *TCT* increases, *PYSC* and *POVCS* would become greater as well. However, after a certain high point of *TCT*, *PYSC* and *POVCS* would begin to decrease because of transit use in both the central city and suburbs. What is that value of *TCT*? The answer is an empirical one, which cannot be predicted by a theory. Assuming the modal choice is the only factor affecting the income disparity, which is very unrealistic, the relationship between *PYSC* or *POVCS* and *TCT* is given as Curve A in Figure 7.1. If there are counterbalancing factors, which are not considered in our theory, Curve B would be possible due to those parameters. As for U.S. cities, all values of *TCT* are very low, thus we do not need to be concerned about the decreasing portion of the curves in Figure 7.1.

Figure 7.1 Relationship between Income Disparity and Modal Choice



Since the relationship is nonlinear and the functional form is unknown, we turned to the convenient non-linear Box-Cox specification. However, a linear estimate might be acceptable as an approximation given the fact that all values of *TCT* are very low. Because of the nature of U.S. data, we expect the sign of the coefficient to be positive.

The regression results using *PYSC* as the dependent variable are presented in Table 7.6 and 7.7.

Table7.6 Regression Results, *PYSC* and *TCT*
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.071897	0.008692	8.272***	-0.05294
Constant	0.45184	0.04256	10.62***	

Dependent Variable : *PYSC* ($\lambda = 0.430$)

$R^2 = 0.1486$ and Adjusted $R^2 = 0.1464$

394 Observations

*** Significant at the 0.01 Level

Table 7.7 Regression Results, *PYSC* and *TCT*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	1.7466	0.3511	4.975***
Constant	1.0900	0.01671	65.24***

Dependent Variable : *PYSC*

$R^2 = 0.0594$ and Adjusted $R^2 = 0.0570$

394 Observations

*** Significant at the 0.01 Level

The Box-Cox and Box-Tidwell estimation results are shown in Table 7.6. The positive sign of the coefficient implies that cities with comparatively high reliance on mass transit have stronger positive income-distance relationships. As expected, the sign of the coefficient is positive, and it is highly significant.

The regression results using *POVCS* as the dependent variable are presented in Table 7.8 and 7.9. The number of observations are 389, smaller than in the test with *PYSC*, since *POVCS* is not defined for seven UAs; the poverty rates in the suburbs are zero in those areas. Since *POVCS* is the ratio of the poverty rate in the central city to that in the suburbs, higher value of *POVCS* suggests that urban poverty concentration is stronger. Thus, we expect the coefficient to be positive, and it is positive as expected. Compared to the previous test with *PYSC*, the *t*-value and R^2 are slightly higher. The income distribution of persons above the poverty level would affect *PYSC* but not *POVCS*. If we are interested in the residential choice of the poor, *POVCS* would provide better information.

Table 7.8 Regression Results, *POVCS* and *TCT*
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.15267	0.01717	8.893***	-0.051783
Constant	1.3514	0.08350	16.18***	

Dependent Variable : *POVCS* ($\lambda = -0.110$)

$R^2 =$ 0.1697 and Adjusted $R^2 = 0.1675$

389 Observations

*** Significant at the 0.01 Level

Table 7.9 Regression Results, Dependent Variable: *POVCS* and *TCT* OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	7.7542	2.133	3.635***
Constant	2.1035	0.1021	20.60***

Dependent Variable : *POVCS*

$R^2 =$ 0.0330 and Adjusted $R^2 = 0.0305$

389 Observations

*** Significant at the 0.01 Level

In Table 7.6-9, R^2s are very low, although the *t*-value for *TCT* is high. Let us suggest a few reasons for the low R^2. First, R^2s are not so high for cross-sectional data. Second, most importantly, the model 7.3 and 7.4 are subject to the problem arising from the omission of relevant independent variables. The relationship specified here has only one independent variable. The income disparity between the central city and the suburbs are influenced by a number of factors. The filtering effect is not considered here. Blight variables have not been included, either. Although they do not trigger urban poverty concentration and some of them are merely the symptoms, not the causes, they reinforce existing disparities. Third, the effect of modal choice on income disparity may be weaker now than before because most households can afford a car now in the United States. This issue was discussed earlier in this study. Last, there are a disproportionately large number of small UAs in our sample. The car is the virtually exclusive mode in small

UAs. Thus, *TCT* is smaller in small UAs, which is confirmed by the earlier test results in Table 7.3-6. Income disparities in those areas are smaller, which is confirmed by the significance of TCT in Table 7.6, but small UAs may give high disturbance in the test. R2 could be low in the case. Despite the low R^2, the test results confirmed our prediction that income disparities would be higher when the reliance on transit increases in U.S. cities are concerned.

CHAPTER VIII

EMPIRICAL ANALYSIS OF THE FILTERING MODEL

Introduction

In this chapter, two new variables representing filtering are defined. One is *HU70*, and the other is *HUYR*. The former measures the fraction of old housing units in an urbanized area; the latter provides information on the relative age of central city housing to that of suburban housing. Each variable has its pros and cons as a measure of filtering. This issue is briefly discussed. We need another variable to test our filtering theory. It is a variable that could reflect the changes in land value or equilibrium density. Due to lack of relevant data, however, that variable is not defined. The reason that the omission of that variable may not be significant is suggested. As is the case with the modal choice model, the filtering theory is tested in two steps. First, the test results of the relationship between filtering and the city age and land value are presented. Then, the estimates of the link between filtering and income-disparities are presented.

The Data and the Variables

Two variables measuring the magnitude of filtering are used in our tests. *HU70* is the percentage of all housing units, in an urban area, built before 1970. In other words, *HU70* is the percentage of all housing units, in an urban area, 21 years old or older as of 1990. It is arbitrary to decide whether a housing unit is old. The median year housing units were built in the U.S. urbanized areas is 1964. The census reports categorize the age of housing units by the decade. Thus, roughly speaking, housing units built from the earliest to 1959 or 1969, could be considered old or not new. We chose the latter as a basis for our filtering variable. Filtering is a cumulated process, and *HU70* captures this aspect very well. However, it is defined for the entire urban areas and does not reflect relative ratios of concentration of old housing between the central city and the suburbs.

Thus, another measure *HUYR* is added to measure the magnitude of the filtering. *HUYR* is obtained by deducting the median year housing units were built in the central city from that in the suburbs. Higher value of *HUYR* implies that central city housing units are much older than suburban housing units. Negative value of *HUYR* suggests that suburban housing is older. Given the nature of U.S. cities, only a few UAs have negative values of *HUYR*. As mentioned in Chapter 6, the Box-Tidwell method requires that all independent variables be positive. Thus, the Box-Cox method transforming all variables by the same λ is used for the regression with *HUYR* as an explanatory variable.

There has been ample evidence that filtering promotes the positive income-distance relationship in the United States. The theory and empirical evidence is nothing new. Our interest is in the role of land scarcity in the filtering process. Other things being equal, a higher land value results in less filtering because it promotes redevelopment. Thus, it is expected that *LV*, current land value at the urban fringe, is negatively related to *HU70* and *HUYR*. The filtering process is dynamic and cumulative. Thus, older cities would show stronger tendency of the positive income-distance relationship; *AGE* is positively related to *HU70* and *HUYR*, which in turn are is positively related to *PYSC* and *POVCS*.

Recall, however, that the statement that older cities would show stronger tendency of the positive income-distance relationship is relevant under certain conditions, which are found in the United States. This issue was discussed in Chapter 6. The link between *AGE* and *HU70* or *HUYR* is broken when land is value is very high and continues to rise.

If old housing units in the central city are frequently redeveloped, the old housing units will not be concentrated in the central city. In other words, when the distance from the center decreases, the average age of housing units will not increase as fast as in U.S. cities. Strict zoning codes in suburbs and relatively low land values in the United States cause filtering to intensify the positive income-distance relationship.

Another important factor is the changes in equilibrium densities or land values. This was discussed in detail before, and it suffices to indicate that a city with a greater decrease in the equilibrium densities in the central city would face an obstacle to redevelopment. However, measuring the changes in land value gradients was an impossible task due to lack of relevant data. Thus, we had to exclude a land value or equilibrium structural density change variable in our tests. Despite the omission of this variable, we can infer some valid conclusions from the fact that the gradual decline in central city land values has been characteristic of big old eastern cities. It is also our belief that the gradual decline in central city land values is strongly related to the city age variable. Newer cities are less likely to have experienced changes in equilibrium densities after all.

Filtering and its Explanatory Variables

We test the relationship between filtering and the city age and land value, first. The model is as follows.

$$HU70 = HU70\ (LV, AGE) \tag{8.1}$$

or

$$HUYR = HUYR\ (LV, AGE) \tag{8.2}$$

The expected sign of the coefficient is negative for *LV* but positive for *AGE*. The estimates for (8.1) are listed in Table 8.1 and 8.2. As predicted, the coefficient of *LV* is negative, and that *AGE* of is positive. They are also significant at the 0.01 level. This confirms the prediction that 1) redevelopment will be difficult in cities with low land value at the urban fringes and that 2) housing units will be older in older U.S. cities. Recall, again, that, in general, housing units do not have to be older in older cities. The positive sign of the coefficient of *AGE* is predicted only if conditions for filtering exits. Note that the *t*-values for *AGE* is very high, this is understandable, given the definition of *HU70* and the nature of U.S. cities.

Table 8.1 Regression Results, Dependent Variable: *HU70*
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
LV	-0.46233	0.1592	-2.905***	-0.51536
AGE	0.079892	0.003641	21.94***	0.20538
Constant	0.085427	0.2987	0.2860	

Dependent Variable $\lambda = 1.690$

$R^2 = 0.5519$ and Adjusted $R^2 = 0.5496$

394 Observations

*** Significant at the 0.01 Level

Table 8.2 Regression Results, Dependent Variable: *HU70*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
LV	-0.57346E-05	0.3473E-05	-1.651*
AGE	0.0056808	0.2930E-03	19.39***
Constant	0.34333	0.01455	23.60***

$R^2 = 0.4904$ and Adjusted $R^2 = 0.4878$

394 Observations

*** Significant at the 0.01 Level
* Significant at the 0.1 Level

The regression results of the model with *HUYR* as the dependent variable are presented in Table 8.3 and 8.4. The combined Box-Cox and Box-Tidwell estimation failed, but the Box-Tidwell estimation succeeded. These estimates are listed in Table 8.3. Again, the signs of the coefficients are correct. However, R^2 and *t*-values are lower than the estimates from the model with *HU70* as the dependent variable. *LV* is significant at 0.05 level, but the *t*-value is very close to the critical value at the significance level of 0.025. *AGE* is still significant at the 0.01 level. *HUYR* reflects the age difference between the central city housing and the suburban housing, and *HU70* indicates the overall physical status of the whole urban area. Hypothetically speaking, *HUYR* of cities with very old housing units whose ages are the same at all locations are zero, whereas *HU70* will be high in those cities. Thus, *HU70* is more sensitive to *AGE*.

Table 8.3 Regression Results, Dependent Variable: *HUYR*
Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
LV	-0.93809E-19	0.4804E-19	-1.953**	5.0654
AGE	0.018968	0.002123	8.936***	1.5835
Constant	4.3214	0.6725	6.426***	

Dependent Variable λ: not transformed

$R^2 = 0.1717$ and Adjusted $R^2 = 0.1675$

394 Observations

*** Significant at the 0.01 Level
** Significant at the 0.05 Level

Table 8.4 Regression Results, Dependent Variable: *HUYR*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
LV	-0.15492E-03	0.2457E-03	-0.6306
AGE	0.18076	0.02072	8.722***
Constant	1.7829	1.029	1.732**

$R^2 = 0.1631$ and Adjusted $R^2 = 0.1588$

394 Observations

*** Significant at the 0.01 Level
** Significant at the 0.1 Level

In sum, the estimates in this section suggests 1) high land value deters filtering, 2) older cities tend to have older housing, and 3) central city-suburban housing units age differences are greater in older cities. Note that 2) and 3) are plausible only if 1) is true for a given data set.

Income disparities and Filtering

This section is devoted to the relationship between income disparities and filtering. *HU70* and *HUYR*, which were the dependent variables in the previous section, are now the explanatory variables. Since we have two measures for income disparities and filtering, the relationship to test is written as

$$PYSC = PYSC(HU70) \tag{8.3}$$

$$POVCS = POVCS(HU70) \tag{8.4}$$

$$PYSC = PYSC(HUYR) \tag{8.5}$$

$$POVCS = POVCS(HYYR) \tag{8.6}$$

The predicted signs of the coefficients are all positive, which implies filtering results in higher income disparities. We begin with the model with *HU70* as the explanatory variable. The estimates of (8.3) are listed in Table 8.5 and 8.6. The sign of the coefficient is positive, as predicted. It is also significant at the 0.01 level. We have the similar results in Table 8.7 and 8.8, which present the estimates of (8.4) The *t*-value is a little higher for the model using *POVCS* as the dependent variable. Again, these models are subject to the omitted variable problem, since filtering is not the only factor affecting income disparities. The overall conclusion from the regression result in Table 8.5-8 is that urban poverty concentration is stronger in cities where housing units tend to be older.

Table 8.5 Regression Results, *PYSC* and *HU70*
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
HU70	2.4340	0.3141	7.749***	3.4942
Constant	0.68420	0.07421	9.219***	

Dependent Variable: *PYSC* (λ = 0.500)

$R^2 = 0.1328$ and Adjusted $R^2 = 0.1306$

394 Observations

*** Significant at the 0.01 Level

Table 8.6 Regression Results, *PYSC* and *HU70*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
HU70	0.60612	0.08835	6.861***
Constant	0.78915	0.05251	15.03***

Dependent Variable: *PYSC*

$R^2 = 0.1072$ and Adjusted $R^2 = 0.0692$

394 Observations

*** Significant at the 0.01 Level

Table 8.7 Regression Results, *POVCS* and *HU70*
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
HU70	1.8991	0.2211	8.588***	1.5453
Constant	1.3276	0.08362	15.88***	

Dependent Variable: *POVCS* ($\lambda = -0.110$)

$R^2 = 0.1601$ and Adjusted $R^2 = 0.1579$

389 Observations

*** Significant at the 0.01 Level

Table 8.8 Regression Results, *POVCS* and *HU70*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
HU70	2.9640	0.5427	5.461***
Constant	0.60755	0.3234	1.878**

Dependent Variable: *POVCS*

$R^2 = 0.0716$ and Adjusted $R^2 = 0.0692$

389 Observations

*** Significant at the 0.01 Level
** Significant at the 0.1 Level

Now let us turn to the regression results obtained by using *HUYR*, which is the housing unit age difference. Relationship (8.5) and (8.6) are tested for this purpose. Since high *HUYR* implies that central city housing is much older, the predicted sign is positive. The estimates of (8.5) are presented in Table 8.9 and 8.10, and those of (8.6) are listed in Table 8.11 and 8.12. As expected, the sign of the coefficient is positive in all the cases. It is also significant at the 0.01 level. The *t*-values are higher than before. The estimates in Table 8.10 perform best. The *t*-value is highest at 11.46. In addition, The R^2 is almost twice that in Table 8.5. In other words,

$$POVCS = POVCS(HYYR) \tag{8.6}$$

Table 8.9 Regression Results, *PYSC* and *HUYR*
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
HUYR	0.013035	0.001427	9.132***	0.4200
Constant	-0.0060174	0.01773	-0.3394	

Dependent Variable: *PYSC* ($\lambda = 0.4200$)

$R^2 = 0.1754$ and Adjusted $R^2 = 0.1733$

394 Observations

*** Significant at the 0.01 Level

Table 8.10 Regression Results, *PYSC* and *HUYR*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
HUYR	0.013447	0.001552	8.665***
Constant	1.0138	0.01927	52.60***

Dependent Variable: *PYSC*

$R^2 = 0.1608$ and Adjusted $R^2 = 0.1586$

394 Observations

*** Significant at the 0.01 Level

Table 8.11 Regression Results, *POVCS* and *HUYR*
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
HUYR	0.031243	0.002727	11.46***	-0.1200
Constant	0.34370	0.03381	10.16***	

Dependent Variable: *POVCS* ($\lambda = -0.1200$)

$R^2 = 0.2532$ and Adjusted $R^2 = 0.2513$

389 Observations

*** Significant at the 0.01 Level

Table 8.12 Regression Results, *POVCS* and *HUYR*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
HUYR	0.070383	0.009806	7.178***
Constant	1.6587	0.1216	13.64***

Dependent Variable: *POVCS*

$R^2 = 0.1175$ and Adjusted $R^2 = 0.1152$

389 Observations

*** Significant at the 0.01 Level

In conclusion, our test results in this section confirm the conventional wisdom that older housing units concentrated in the central city attract the poor. In other words, filtering promotes urban poverty concentration. Mills and Hamilton (1989, p.138) summarize this effect by stating that "Low-income housing tends to be old housing, and old housing tend to be located in the central parts of American cities. Cook and Hamilton (1984) contend that "these forces are more than adequate to explain the existing pattern of income segregation.."

CHAPTER IX

EMPIRICAL ANALYSIS OF THE COMBINED MODEL

Introduction

In the preceding two chapters, we tested the modal choice theory and the filtering theory separately to examine the empirical evidence for each theory. Both theories share explanatory variables and fall into the category of the natural evolution theory. They work together. Therefore, we need to test a model in which the effects of both modal choice and filtering are reflected. We would call this model 'the combined model' from now on.

Modal choice and filtering have direct impacts on income disparities. When measures of modal choice and filtering are used as explanatory variables, they will be called the intermediary variables, since they work as the intermediates between the income disparity and the basic explanatory variables such as land value, urban size, and age variables. In the following section, the relationship between the income disparity and the intermediary variables are tested.

Although our modal choice and filtering variables are expected to be positively related to the income disparity variables, we expect the land value variable to affect the filtering and modal choice variables in different directions as far as U.S. data are concerned. Theoretically, therefore, we cannot predict the sign of LV when our income disparity variables are regressed on it. This is not to say that LV is unrelated to income disparities. A section is devoted to this issue to clarify this point. In the final section, we directly regress our income disparity variables on the basic explanatory variables.

The Combined Model with the Intermediary Variables

In this section, we regress the income disparity variables on the modal choice and filtering variables, the intermediary variables. Since we have two measures of the income disparity and filtering, the relationship to test is expressed in four ways. They are

$$PYSC = PYSC(TCT, HU70) \tag{9.1}$$

$$POVCS = POVCS(TCT, HU70) \tag{9.2}$$

$$PYSC = PYSC(TCT, HUYR) \tag{9.3}$$

$$POVCS = POVCS(TCT, HUYR) \tag{9.4}$$

The regression results of (9.1) are in listed Table 9.1 and 9.2. Since the Tidwell method failed, the Box-Cox estimates are presented. The expected signs of the coefficients are positive, which implies that concentration of old housing and high reliance on mass transit leads to the positive income-distance pattern in U.S. urban areas. Recall, however, that *TCT* is expected to be positively related to *PYSC* only because the agricultural land price at the urban fringes in the United States are generally quite low. As predicted, the signs are positive. They are also significant at the 0.01 level.

The regression results listed in Table 9.3 , 9.4, and 9.5 are the estimates obtained from the model using *POVCS* as the dependent variable and *HU70* as an explanatory variable. The coefficients are, correctly, positive and significant. Unlike the estimation of (9.1), the Box-Cox and Box-Tidwell transformation worked. Thus, to compare the performance of (9.1) and (9.2) with the same estimation technique, the Box-Cox results are presented in table (9.4).

Table 9.1 Regression Results, *PYSC*(*TCT*, *HU70*)
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.29174	0.04759	6.130***	0.360
HU70	0.23115	0.05167	4.473***	0.360
Constant	0.84780	0.09681	8.757***	

Dependent Variable: *PYSC* (λ = 0.360)

$R^2 = 0.1701$ and Adjusted $R^2 = 0.1659$

394 Observations

*** Significant at the 0.01 Level

Table 9.2 Regression Results, *PYSC*(*TCT*, *HU70*)
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	1.3065	0.3442	3.796***
HU70	0.53431	0.08891	6.010***
Constant	0.79486	0.05166	15.39***

Dependent Variable: *PYSC*

$R^2 = 0.1389$ and Adjusted $R^2 = 0.1345$

394 Observations

*** Significant at the 0.01 Level

Table 9.3 Regression Results, *POVCS*(*TCT*, *HU70*)
Box-Cox and Box-Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.12232	0.01734	7.053***	-0.046066
HU70	1.9189	0.2891	6.637***	2.0539
Constant	1.8093	0.1052	17.19***	

Dependent Variable: *POVCS* (λ = -0.120)

$R^2 = 0.2549$ and Adjusted $R^2 = 0.2510$

389 Observations

*** Significant at the 0.01 Level

Table 9.4 Regression Results, *POVCS*(*TCT*, *HU70*)
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.11512	0.01667	6.904***	-0.070
HU70	0.36825	0.07055	5.220***	-0.070
Constant	1.4392	0.08171	17.61***	

Dependent Variable: *POVCS* (λ = -0.070)

$R^2 = 0.2236$ and Adjusted $R^2 = 0.2196$

389 Observations

*** Significant at the 0.01 Level

Table 9.5 Regression Results, *POVCS*(*TCT*, *HU70*)
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	5.5927	2.122	2.635***
HU70	2.6572	0.5510	4.822***
Constant	0.63095	0.3211	1.965**

Dependent Variable: *POVCS*

$R^2 = 0.0880$ and Adjusted $R^2 = 0.0832$

389 Observations

*** Significant at the 0.01 Level
** Significant at the 0.1 Level

Now consider the regression results of (9.3) and (9.4). That is, the filtering variable *HU70* is replaced by *HUYR*. Again, the predicted sign of the coefficient is positive for both explanatory variables, *TCT* and *HUYR*. The regression results of (9.3) are listed in Table 9.6 and 9.7. The signs are correct and significant at the 0.01 level. The results confirms that personal income disparity, is greater when 1) the reliance on transit is higher or 2) the age difference between central city and suburban housing is greater. It is also shown that the *t*-values for both explanatory variables are similar when the Box-Cox estimation technique is used. The regression results of (9.4) are listed in Table 9.8 and 9.9. The dependent variable is *POVCS.* Again, the signs are correct and significant at the 0.01 level, which confirms that relatively older housing in U.S. central cities is associated with relatively higher poverty rates in central cities.

Table 9.6 Regression Results, *PYSC*(*TCT*, *HUYR*)
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.16692	0.02751	6.067***	0.2300
HUYR	0.010629	0.0014	7.592***	0.2300
Constant	0.44708	0.07762	5.760***	

Dependent Variable: *PYSC* ($\lambda = 0.2300$)

$R^2 = 0.2495$ and Adjusted $R^2 = 0.2457$

394 Observations

*** Significant at the 0.01 Level

Table 9.7 Regression Results, *PYSC*(*TCT*, *HU70*)
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	1.2521	0.3320	3.771***
HU70	0.012349	0.001554	7.948***
Constant	0.98986	0. 2000	49.50***

Dependent Variable: *PYSC*

$R^2 = 0.1902$ and Adjusted $R^2 = 0.1861$

394 Observations

*** Significant at the 0.01 Level

Table 9.8 Regression Results, *POVCS*(*TCT*, *HUYR*)
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.076669	0.01093	7.017***	-0.130
HUYR	0.026247	0.002645	9.925***	-0.130
Constant	0.81890	0.07497	10.92***	

Dependent Variable: *POVCS* (λ =-0.130)

$R^2 = 0.3379$ and Adjusted $R^2 = 0.3344$

389 Observations

*** Significant at the 0.01 Level

Table 9.9 Regression Results, *POVCS*(*TCT*, *HUYR*)
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	5.2168	2.059	2.533***
HUYR	0.065719	0.00991	6.631***
Constant	1.5592	0.1270	12.28***

Dependent Variable: *POVCS*

$R^2 = 0.1319$ and Adjusted $R^2 = 0.1274$

389 Observations

*** Significant at the 0.01 Level

In sum, the estimation results of the combined model indicates that urban poverty concentration in the United States is higher when 1) transit usage is higher (higher *TCT*) and 2) housing units in the whole urban area tend to be older (higher *HU70*) or central city housing is relatively older than suburban housing (higher *HUYR*). These results correspond to the implications of the filtering theory and our modal choice theory.

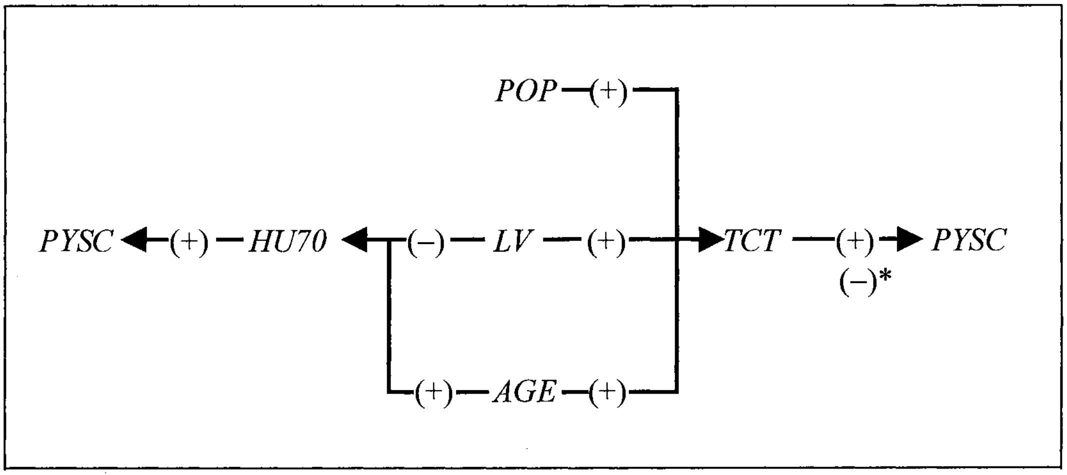
The Effects of Land Value on Income Disparities

While we are interested in the effects of land scarcity and other variables on the income disparity, we have not directly tested the relationship so far. For instance, we tested modal choice as a function of the city size, (optionally) age, and land scarcity, which we call 'basic explanatory variables.' The modal choice variable, which was the dependent variable at the first stage, was used as an explanatory variable for the income disparity function. Similar steps were taken with the filtering model as well.

There were reasons for this procedure. First, the relationship between the basic explanatory variables and the income disparity is an indirect one. For instance, land scarcity does not directly affect the urban residential pattern. It does via its effects on modal choice and filtering, which have impacts on the income disparity. Thus, we intended to examine each linkage. If somehow the linkage between the income disparity and the modal choice is broken, the city size and land scarcity would not influence the residential pattern, if the effects of land scarcity on filtering are ignored. For instance, if only one commuting mode is available due to some reasons, the city size would not matter to the residential pattern.

Second, the sign of the coefficient of the land value variable could be ambiguous in a broader context. This ambiguity compelled us to examine the links step by step. The relationships tested so far are illustrated in the following diagram. The plus and minus signs inside the parentheses represent the nature of the relationships.

Figure 9.1 Relationships among the Variables



* if land value is in the higher range

Note that the relationships illustrated in Figure 9.1 are to explain the regional variance among U.S urban areas. *PYSC* and *HU70* can be replaced by *POVCS* and *HUYR*, respectively. The effect of changes in land value or equilibrium structural density is not represented in the diagram, since we were unable to construct a corresponding variable. However, the conventional wisdom is that older U.S. cities experienced sharper declines in central city land prices and equilibrium structural densities, which implies that *AGE* is positively correlated to the potential land value change variable. The link between *AGE* and *TCT* will be pointless in a country where urbanization occurred rather evenly throughout the country. As mentioned before, the vast land supply, the smaller population of the past, and the subsequent increase in population made newer cities develop and grow faster in the United States. Since older cities had to rely more on mass transit and the past affects today, we included the link between *AGE* and *TCT* in our tests. Recall also that the positive effect of *AGE* on *HU70* is valid only when land abundance permits active filtering, as is the case with the United States. In short, the effects of *AGE* on the diagram are relevant only with land abundance.

According to our natural evolution theory, the residential pattern is influenced mainly by two variables: modal choice and filtering. Land scarcity affects both variables. *LV* is positively related to *TCT*, which is, in case of the United State, positively related to the income disparity variables, *PYSC* and *POVCS*. Thus, it is evident that *LV* is positively related to *PYSC* and *POVCS*. The income-distance relationship is influenced by filtering. *LV* is negatively related to *HU70* and *HUYR*, which are positively related to *PYSC* and *POVCS*.

When land value is very high as in Japan, there is no ambiguity as to the effects of land value. High land value weakens the positive income-distance relationship because 1) the poor can live in the suburbs and still use mass transit and 2) redevelopment is easier in the central city. If land value is low as in the United States, theoretically speaking the total effects of land value are inconclusive. In other words, *LV* can explain international differences but may not be able to empirically explain regional differences in the United States. However testing separately the modal choice model and the filtering model enabled us to confirm our theory, although the empirical models for the separate tests are subject to the problem of omitting relevant variables.

The Combined Model with the Basic Explanatory Variables

Since the implications of 1) regressing directly the income disparity variable on *LV* and 2) pros and cons of separate tests have been discussed, we present, in this section, the estimates of the combined filtering model with the basic explanatory variables. The relationships to test are expressed as

$$PYSC = PYSC(POP, LV, AGE) \tag{9.5}$$

$$POVCS = POVCS(POP, LV, AGE) \tag{9.6}$$

The coefficients are expected to be positive for *POP* and *AGE*; the combined effect of *AGE* is believed to be positive since it is positively related to both *TCT* and the filtering variables, *HU70* and *HUYR*. Although they were not specified to avoid redundancy, the null hypotheses have been H_0: $\beta_i > 0$ or $\beta_i \leq 0$, as mentioned in Chapter 7. However, the null hypothesis regarding *LV* is expressed as

$$H_0: \ \beta(LV) \neq 0 \tag{9.7}$$

because the sign of the coefficient of *LV* is theoretically not determined at low values of *LV*, as is the case with our data set. Thus, the two-tail test is used for *LV*.

Table 9.10 Regression Results, *PYSC(POP, LV, AGE)*
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
POP	0.92442E-03	0.2599E-03	3.557***	0.290
LV	0.90219E-02	0.2003E-02	4.503***	0.290
AGE	0.61684	0.9188E-02	6.713***	0.290
Constant	-0.63706	0.7578	-8.406***	

Dependent Variable: *PYSC* ($\lambda = 0.290$)

$R^2 = 0.2076$ and Adjusted $R^2 = 0.2015$

394 Observations

*** Significant at the 0.01 Level

Table 9.11 Regression Results, *PYSC*(*POP*, *LV*, *AGE*)
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
POP	0.17231E-07	0.1147E-07	1.502**
LV	0.32339E-04	0.8486E-05	3.811***
AGE	0.47216E-02	0.6976E-03	6.768***
Constant	0.86724	0.3461	25.06***

Dependent Variable: *PYSC*

$R^2 = 0.1612$ and Adjusted $R^2 = 0.1548$

394 Observations

*** Significant at the 0.01 Level
** Significant at the 0.1 Level

Table 9.12 Regression Results, *POVCS* (*POP*, *LV*, *AGE*)
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
POP	0.56226	0.1139	4.938***	-0.130
LV	0.23467	0.8326	2.819***	-0.130
AGE	0.59662	0.8475	7.040***	-0.130
Constant	-5.6128	0.7246	-7.746***	

Dependent Variable: *POVCS* (λ =-0.130)

$R^2 = 0.2047$ and Adjusted $R^2 = 0.1985$

389 Observations

*** Significant at the 0.01 Level
** Significant at the 0.1 Level

**Table 9.13 Regression Results, *POVCS*(*POP*, *LV*, *AGE*)
OLS Estimates**

Independent Variable	Estimated Coefficient	Standard Error	T-Value
POP	0.11206E-06	0.7246E-07	1.547*
LV	0.51277E-04	0.5367E-04	0.9554
AGE	0.19998	0.4412E-02	4.533***
Constant	1.3162	0.2198	5.988***

Dependent Variable: *POVCS*

$R^2 = 0.0660$ and Adjusted $R^2 = 0.0587$

394 Observations

*** Significant at the 0.01 Level
** Significant at the 0.1 Level

The regression results of (9.5) are presented in Table 9.10 and 9.11, while those of (9.6) are shown in Table 9.12 and 9.13. The coefficients of *POP* and *AGE* are, as expected, positive and significant at the 0.01 level. The coefficient of *LV* is positive and significant as well. This result suggests that the effect of *LV* on *TCT* more than offsets its effect on *HU70* or *HUYR*. However, that could be a rushed judgement. We believe that the effect of *AGE* is much larger in the filtering model than in the model choice model, because filtering is cumulative by nature. The current urban poverty concentration is a result of decades of filtering. In the United States, older cities tend to have higher land value. The model in the above omits a land value change variable due to data limitations. Older cities are believed to have experienced sharper declines in land value or equilibrium structural density in the central cities. In short, it is probable that high land value is positively correlated to *AGE* and the missing variable in our empirical models. The correlation between *LV* and *AGE* are not considered in the above tests.

In this chapter, we presented empirical results of our combined model. First, we tested the relationship between income disparity and the intermediary variables: *TCT* and *HU70* or *HUYR*. It turned out that all the intermediary variables are highly significant determinants of the income-distance relationship. That is, in the United States, higher reliance on mass transit and more filtering are associated with urban poverty concentration. These results confirm the theoretical conclusions of our modal choice theory and filtering theory. Second, the combined models with the basic explanatory variables were tested. The finding in our estimation showed that agricultural land value, city size, and city age are positively associated with urban poverty concentration. The significant, positive relationship between urban poverty concentration and city size or age fits the predictions made by our theories. As far as U.S. data are concerned, the sign of the direct relationship between urban poverty concentration and agricultural land value is theoretically indeterminate. Although the coefficient of *LV* was positive and significant, the sign might have resulted from the omission of a land value change variable.

CHAPTER X

EMPIRICAL ANALYSIS OF THE EXTENDED MODEL

Introduction

Our theory focused on natural evolution variables. The empirical models we have tested so far have only natural evolution variables. However, suburbanization and residential patterns depend on many factors, some of which can be blight variables such as racial composition, crime rates, tax burdens, pollution, and public education. We will extend our model to include some of these blight variables and refer to this model as 'the extended model." This chapter presents the empirical results of this model.

Measures of racial composition, tax rates, and crimes commonly have been used as blight variables. In the following section, we introduce our measures of those blight variables. Their sources are also discussed. The next two sections present the empirical results of the extended models. First, we test the effects of both the intermediary variables and the blight variables on income disparities. Second, the income disparity variables are regressed on the basic explanatory variables and the blight variables. In previous empirical studies by other authors, crime variables more often than not performed poorly. Depending on the measure of income disparity, our crime yielded different results. An implication of this is also discussed in this chapter.

The Data and the Variables

In the extended model, both natural evolution variables and blight variables are considered. Our natural evolution variables were defined in the previous chapters. Thus, it is necessary to construct relevant blight variables. For a race variable, we used

NWHCS, the percentage of nonwhite population in the central city divided by that in the suburbs. A higher value of *NWHCS* means nonwhite population is relatively more concentrated in the central city. According to the flight from blight theory, *NWHCS* would lead to higher degrees of suburbanization and stronger urban poverty concentration.

For a tax variable, *OCOSTCS* was calculated. The relevant tax variable in the blight theory is property tax rate differentials between the central city and the suburbs, since most income and sales taxes are imposed by the federal or state government. The exact property tax rates are determined at the school district level. Because property taxes are financed mostly for public education, a property tax variable can be believed to be associated with the quality of public education. Thus, an education variable may not be needed if a property tax variable is used. A number of school districts exist in a given urban area. Thus, residents in the central city or suburbs in the same city do not face equal property tax rates, and it is very difficult to obtain data on property tax rate differentials for all urbanized areas. To obtain tax rate differential data, it is necessary to trace each school district's property tax rates and calculate an appropriate weighted average for the central city and suburbs. Mills and Price (1982) stated "To be able to compute the tax variable, there must be approximate coincidence between boundaries of school districts and those of the central city governments." They found that only 36 metropolitan areas in their original sample of 62 satisfied this criterion.

Fortunately, however, the census reports provide the data on selected monthly owner costs, related to property tax rates. Selected monthly owner costs is the sum of payments for mortgages, deeds of trust, contracts to purchase, or similar debts on the property, real estate taxes, insurance on the property, utilities and fuels. U.S. census presents 'selected monthly owner costs of units with a mortgage' and 'selected monthly owner costs of units not mortgaged.' Since mortgage payments occupy large portion of the selected owner costs, we decide to use 'selected monthly owner costs of units not mortgaged.' That is, our 'selected monthly owner costs' exclude mortgage payments. If the effective property tax rate is 1%, the monthly property tax will be about 1/12 (= 0.0833) cents per dollar of housing value. The unweighted average selected monthly owner cost is a little more than 0.3 cents. Thus, it appears that approximately a third of the owner cost falls into property taxes.

If the property tax rate is 2 %, two thirds of the owner cost represent property taxes. Assuming components other than property taxes are independent of the location of housing units within the urban area, it is acceptable to use owner costs as a proxy for property taxes. *OCOSTCS* denotes the owner cost per dollar of housing value in the central city divided by that in the suburbs. A high value of *OCOSTCS* implies that central city residents bear relatively higher tax burdens per dollar of their housing value than suburbanites. Therefore, *OCOSTCS* is expected to be positively related to *PYSC* and *POVCS.*

The last blight variable included in the test is a crime variable. The blight theory proponents argue that the middle and high-income class flee to the suburbs to avoid high crime rates in the central city. Data on crimes are not reported in the census. They are available on *FBI Uniform Crime Reports*. Crime index of the central city and suburbs are reported at the MA level but not at the UA level. Thus, we made an effort to match *Uniform Crime Reports* data with urbanized areas by comparing metropolitan areas and corresponding urbanized areas. Since some small UAs do not have a corresponding MA, the inclusion of a crime variable reduced the number of observations. *CRIMECS* denotes crime index of a central city divided by that in suburbs. A high value of *CRIMECS* implies that central city is relatively more prone to crime hazards. According to the blight theory, *CRIMECS* is positively related to *PYSC* and *POVCS.*

There are many central city blight variables. Including all the blight variables in an empirical model would require substantial data collection costs. To quote Mills and Price (1984), "It is widely believed that high crime, high taxes and large minority groups in central cities are important causes of rapid suburbanization of U.S. metropolitan areas. Our blight variables, *CRIMECS, OCOSTCS,* and *NWHCS,* cover the most widely mentioned blight variables. It is noteworthy that our eventual dependent variable is the income disparity, while most previous empirical studies used the degree of suburbanization as their dependent variable.

The Extended Model with the Intermediary Variables

The relationship to test is written as follows.

$$\mathit{PYSC} = \mathit{PYSC}(\mathit{TCT}, \mathit{HU70}, \mathit{NWHCS}, \mathit{OCOSTCS}, \mathit{CRIMECS}) \qquad (10.1)$$

$$\mathit{POVCS} = \mathit{POVCS}\,(\mathit{TCT}, \mathit{HU70}, \mathit{NWHCS}, \mathit{OCOSTCS}, \mathit{CRIMECS}) \qquad (10.2)$$

$$\mathit{PYSC} = \mathit{PYSC}(\mathit{TCT}, \mathit{HUYR}, \mathit{NWHCS}, \mathit{OCOSTCS}, \mathit{CRIMECS}) \qquad (10.1)$$

$$\mathit{POVCS} = \mathit{POVCS}\,(\mathit{TCT}, \mathit{HUYR}, \mathit{NWHCS}, \mathit{OCOSTCS}, \mathit{CRIMECS}) \qquad (10.2)$$

The expected signs of the coefficients are all positive.

Table 10.1-5 shows the estimates of (10.1) and (10.2). Because of missing values for some blight variables, the number of observations is reduced to 294. All the signs are positive and correct, except for *CRIMECS* in Table 10.1. *TCT* and *NWHCS* are consistently significant at the 0.01 level. In general, the modal choice and filtering variables appear to outperform the bight variables, although the *t*-values of *NWHCS* are quite high. Race variables have been significant in many previous tests of suburbanization models. However, as we mentioned earlier, the good performance of a race variable should not be overstated, since the causality seems to run in the other direction as well. The average income of nonwhite persons is lower than that of whites. Nonwhite persons are more concentrated in central cities. Thus, the high performance of the race variable appears to be obvious.

When *POVCS* is used as the dependent variable and the estimations technique is the Box-Cox transformation, the coefficient of *HU70* has the correct sign, but it is insignificant. However, *HU70* is significant at the 0.01 level in the other tests. The Box-Cox and Box Tidwell estimate of *OCOSTCS* is insignificant in Table 10.1, although *OCOSTCS* is significant with the other tests. Normally, we present only the Box-Cox and Box Tidwell estimates if they are available. However, the Box-Cox estimates of (10.1) are listed in Table 10.2, since the insignificance of *HU70* in Table 10.1 appears to be an exception.

Another point to be made is that *CRIMECS* reports either the wrong sign or the insignificant *t*-values when *PYSC* is the dependent variable. This is consistent with the fact that crime variables performed poorly in the previous tests of other authors, as mention in Chapter 2. When *POVCS* is the dependent variable, however, the coefficients of *CRIMECS* are significant. The implication of this is discussed in the next section.

Table 10.1 Regression Results, the Extended Model I, *PYSC*
Box-Cox and Box Tidwell Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.78357	0.1105	7.089***	-0.0031994
HU70	0.61377	0.2071	2.963***	2.5977
NWHCS	0.17689	0.2015	8.777***	-0.25596
OCOSTCS	0.68769E-10	0.1651E-09	0.4165	8.8470
CRIMECS	-0.2500E-04	0.1627E-04	-1.537	5.2877
Constant	0.46792	0.7370	6.349***	

Dependent Variable: *PYSC* (λ = 0.300)

R^2 = 0.4302 and Adjusted R^2 = 0.4204

294 Observations

*** Significant at the 0.01 Level

Table 10.2 Regression Results, the Extended Model I, *PYSC*
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.043623	0.006361	6.858***	-0.110
HU70	0.082014	0.04104	1.998**	-0.110
NWHCS	0.13888	0.01674	8.297***	-0.110
OCOSTCS	0.33801	0.04854	6.963***	-0.110
CRIMECS	0.045800	0.03184	1.439*	-0.110
Constant	0.24539	0.04911	4.997***	

Dependent Variable: *PYSC* ($\lambda = -0.110$)

$R^2 = 0.5075$ and Adjusted $R^2 = 0.4990$

294 Observations

*** Significant at the 0.01 Level
** Significant at the 0.025 Level
* Significant at the 0.1 Level

Table 10.3 Regression Results, the Extended Model I, *PYSC* OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	1.4786	0.3456	4.27***
HU70	0.47119	0.1138	4.142***
NWHCS	0.21977	0.4536E-02	4.845***
OCOSTCS	0.36414	0.1900	1.916**
CRIMECS	-0.11127	0.1432	0.7770
Constant	0.73045	0.6676	10.94***

Dependent Variable: *PYSC*

$R^2 = 0.2526$ and Adjusted $R^2 = 0.2396$

294 Observations

*** Significant at the 0.01 Level
** Significant at the 0.05 Level

Table 10.4 Regression Results, the Extended Model I, *POVCS*
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.13681	0.1462	9.356***	-0.050
HU70	0.85336	0.7531	1.133	-0.050
NWHCS	0.27542	0.2784	9.891***	-0.050
OCOSTCS	0.74697	0.8231	9.075***	-0.050
CRIMECS	0.14988	0.5312	2.822***	-0.050
Constant	0.87579	0.9043	9.685***	-0.050

Dependent Variable: *POVCS* (λ = -0.050)

$R^2 = 0.6387$ and Adjusted $R^2 = 0.6324$

294 Observations

*** Significant at the 0.01 Level

Table 10.5 Regression Results, the Extended Model I, *POVCS*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	7.5361	1.413	5.333***
HU70	1.6363	0.4652	3.518***
NWHCS	0.12764	0. 1855	6.882***
OCOSTCS	0.28847	0. 7770	3.713***
CRIMECS	0.13194	0. 5856	2.253**
Constant	0.0037055	0.2730	0.01358

Dependent Variable: *POVCS*

$R^2 = 0.3737$ and Adjusted $R^2 = 0.3629$

294 Observations

*** Significant at the 0.01 Level
** Significant at the 0.025 Level

Since *HU70* does not reflect the composition of new and old housing in a UA, the estimates of (10.3) and (10.4), where *HU70* is replaced by *HUYR*, are presented in Table 10.6-9. Again, the coefficients of *TCT* and *NWHCS* are consistently correct and significant at the 0.01 level. When *POVCS* is the independent variable, the Box-Cox estimate of *HU70* was significant only at the 0.1 level. Now the estimates of *HU70* are significant at the 0.01 level regardless of the estimation technique and the dependent variables. *HUYR* appear to be a better measure of filtering. *OCOSTCS* performs better than before. Its estimates have the correct sign and are significant at the 0.01 level. When the *PYSC* is the dependent variable, *CRIMECS* yields the wrong sign. However, the sign is correct and significant at the 0.01 level with *POVCS* as the dependent variable, although its *t*-values are lower than those of the other variables.

Table 10.6 Regression Results, the Extended Model I, *PYSC*
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.051038	0.007586	6.728***	-0.070
HUYR	0.0045333	0.001440	3.149***	-0.070
NWHCS	0.12848	0.01616	7.951***	-0.070
OCOSTCS	0.31015	0.04758	6.519***	-0.070
CRIMECS	-0.038344	0.02999	-1.278	-0.070
Constant	0.17284	0.04532	3.814***	

Dependent Variable: *PYSC* ($\lambda = -0.070$)

$R^2 = 0.5145$ and Adjusted $R^2 = 0.5061$

294 Observations

*** Significant at the 0.01 Level

Table 10.7 Regression Results, the Extended Model I, *PYSC* OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	1.3739	0.3320	4.139***
HUYR	0.011421	0.001816	6.289***
NWHCS	0.022325	0.004250	5.252***
OCOSTCS	0.042446	0.01835	2.313**
CRIMECS	0.0063530	0.01356	-0.4684
Constant	0.87835	0.04202	20.90***

Dependent Variable: *PYSC*

$R^2 = 0.3037$ and Adjusted $R^2 = 0.2916$

294 Observations

*** Significant at the 0.01 Level

** Significant at the 0.025 Level

Table 10.8 Regression Results, the Extended Model I, *POVCS* Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
TCT	0.14947	0.01691	8.838***	-0.010
HUYR	0.015275	0.002460	6.209***	-0.010
NWHCS	0.23883	0.02605	9.169***	-0.010
OCOSTCS	0.67297	0.07837	8.587***	-0.010
CRIMECS	0.13841	0.04876	2.839***	-0.010
Constant	0.73404	0.08434	8.704***	

Dependent Variable: *POVCS* ($\lambda = -0.010$)

$R^2 = 0.6783$ and Adjusted $R^2 = 0.6727$

294 Observations

*** Significant at the 0.01 Level

Table 10.9 Regression Results, the Extended Model I, *POVCS* OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
TCT	6.3374	1.272	4.981***
HUYR	0.061821	0.006960	8.882***
NWHCS	0.11813	0.01629	7.251***
OCOSTCS	0.31775	0.07033	4.518***
CRIMECS	0.13316	0.05198	2.562***
Constant	0.38816	0.1611	2.410***

Dependent Variable: *POVCS*

$R^2 = 0.4873$ and Adjusted $R^2 = 0.4784$

294 Observations

*** Significant at the 0.01 Level
*   Significant at the 0.1 Level

The estimates of the extended models in this section reconfirm the predicted effects of modal choice and filtering. The results in this section suggest that the natural evolution theory and the blight theory work together. It is difficult to decide which category of variables contributes more to the income disparity. Especially, the results listed in Table 10.8 show that *t*-values are high and similar for the explanatory variables, except for *CRIMECS*. However, it should be reminded that the causality of the blight variables takes effect only after the central city-suburban income disparity sets in. On the other hand, the natural evolution variables have clear causality.

The Extended Model with the Basic Explanatory Variables

Now let us replace *TCT* and *HU70* or *HUYR* with the basic explanatory variables in the combined natural evolution model. The relationship is expressed as

$$PYSC = PYSC(POP, LV, AGE, NWHCS, OCOSTCS, CRIMECS) \tag{10.5}$$

$$POVCS = POVCS\,(POP, LV, AGE, NWHCS, OCOSTCS, CRIMECS) \tag{10.6}$$

The expected signs of the coefficients are all positive, expect for *LV*. The regression results are presented in Table 10.10-13.

Table 10.10 Regression Results, the Extended Model II, *PYSC*
Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
POP	0.13271	0.05375	2.469***	-0.130
LV	0.17798	0.03729	4.773***	-0.130
AGE	0.10134	0.04018	2.522***	-0.130
NWHCS	0.12495	0.01782	7.011***	-0.130
OCOSTCS	0.39322	0.04912	8.006***	-0.130
CRIMECS	-0.046737	0.03280	-1.425	-0.130
Constant	-1.9597	0.3435	-5.705***	

Dependent Variable: *PYSC* ($\lambda = -0.130$)

$R^2 = 0.4968$ and Adjusted $R^2 = 0.4863$

294 Observations

*** Significant at the 0.01 Level

Table 10.11 Regression Results, the Extended Model I, *PYSC*
OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
POP	0.14795E-07	0.1103E-07	1.341*
LV	0.40954E-04	0.9596E-05	4.268***
AGE	0.0035204	0.7775E-03	4.528***
NWHCS	0.021648	0.004464	4.849***
OCOSTCS	0.041278	0.01895	2.179**
CRIMECS	-0.0087170	0.01415	-0.6159
Constant	0.80462	0.05017	16.04***

Dependent Variable: *PYSC*

$R^2 = 0.2601$ and Adjusted $R^2 = 0.2446$

294 Observations

*** Significant at the 0.01 Level
** Significant at the 0.25 Level
* Significant at the 0.1 Level

Table 10.12 Regression Results, the Extended Model I, *POVCS* Box-Cox Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value	λ
POP	0.21338	0.05104	4.180***	-0.080
LV	0.17319	0.04718	3.671***	-0.080
AGE	0.20349	0.06006	3.388***	-0.080
NWHCS	0.24244	0.03049	7.952***	-0.080
OCOSTCS	0.83271	0.08565	9.723***	-0.080
CRIMECS	0.13398	0.05628	2.381***	-0.080
Constant	-3.0160	0.4435	-6.800***	

Dependent Variable: *POVCS* (λ = -0.080)

$R^2 = 0.6005$ and Adjusted $R^2 = 0.5921$

294 Observations

*** Significant at the 0.01 Level

Table 10.13 Regression Results, the Extended Model I, *POVCS* OLS Estimates

Independent Variable	Estimated Coefficient	Standard Error	T-Value
POP	0.11560E-06	0.4612E-07	2.507***
LV	0.11905E-03	0.4011E-04	2.968***
AGE	0.013042	0.3250E-02	4.013***
NWHCS	0.12688	0.01866	6.799***
OCOSTCS	0.30446	0.07920	3.844***
CRIMECS	0.13697	0.05916	2.315**
Constant	0.31721	0.2097	1.513*

Dependent Variable: *POVCS*

$R^2 = 0.3519$ and Adjusted $R^2 = 0.3384$

294 Observations

*** Significant at the 0.01 Level
** Significant at the 0.025 Level
* Significant at the 0.1 Level

As expected, *POP* and *AGE* yield the positive sign. They are also significant at the 0.01 level, although *POP* is significant only at the 0.1 level with the OLS Model whose dependent variable is *PYSC*. Similarly to the test results of the combined model, *LV* is positive and significant. The blight variables perform well except for *CRIMECS*. The crime variable *CRIMECS* performed inconsistently. The sign of the coefficient of *CRIMECS* is supposed to be positive but the wrong sign is reported when *PYSC* is the dependent variable. By contrast, *CRIMECS* performs relatively well with the models whose dependent variable *POVCS*. The same phenomenon was observed in the preceding section.

This is interesting because only five of 294 UAs in the sample have values of *CRIMECS* lower than one, which means that the crime rate is higher in the central city for virtually all UAs. Common sense suggests that the rich and middle-class households would be more sensitive to the higher crime rates in the inner-city. *POVCS* is the ratio of the poverty rate in the central city to that in the suburbs. Crime tends to be highly concentrated in the poverty-stricken areas. If crime rates are stable after the neighborhood income exceeds a certain low level, which seems to be the case in reality, the effect of crime rates on residential choice would not matter unless the neighborhood is poverty-stricken. Then, *POVCS* would reflect this relationship between crime and residential choice, while *CRIMECS* is not much sensitive to the average or mean income disparity data.

The tax variable *OCOST* yields the correct sign and is significant, most of the time at the 1% level. Considering that *OCOST* is not an accurate measure of tax rate differentials but a proxy for them, the estimates from *OCOST* appear to be good. In our view, higher tax burdens in the central city seems to the most important variable among the blight variables.

In this chapter, we presented the empirical results of the extended models, where our natural evolution variables and blight variables are considered together. The modal choice variable *TCT* performed well, confirming the effect of modal choice on income disparity. Of the two filtering variables, *HUYR* yielded higher *t*-values than *HU70* did. City size and age variables, *POP* and *AGE*, fared well. Of the blight variables, the racial variable *NHWCS* consistently yielded coefficients with high t-values. The tax variable *OCOST* performed relatively well, except for the Box-Cox and Box-Tidwell estimate with *PYSC* as the dependent variable. The performance of the crime variable, *CRIMECS*, varies with the dependent variable. When the dependent variable is *PYSC*, the coefficients of *CRIMECS* were insignificant and sometimes they had the wrong sign. By contrast, the significant, positive relationship between urban poverty concentration and *CRIMECS* were found when *POVCS* was the dependent variable. This suggests a possibility that relatively poor performance of crime variables in past studies resulted from wrong specifications: incorrect dependent variable. The crime rate disparity may not be able to explain suburbanization or income resident gradient of a whole urban area. However, our test results suggest that crime is likely to affect residential choice in the sense that wealthy and middle class households avoid poverty stricken areas partly because of the high crime rates in those areas.

While reviewing blight theory, we pointed out that many blight variables do not trigger a positive income-distance pattern. However, we also contended that those blight variables reinforce a positive income-distance pattern, once it is caused by natural evolution variables. As Mills and Mieszkowski (1993) stated, blight variables and natural evolution variables are not mutually exclusive; and they may work together. Our contention adds perspective to this by explaining how natural evolution theory and blight theory are related. The empirical results in this chapter show that blight variables and natural evolution variables work together indeed.

CHAPTER XI
SUMMARY AND CONCLUSIONS

Summary

Suburbanization in the United States has some distinct features. The key distinction is found in urban residential location patterns. In most U.S. cities, the average personal or household income tends to rise as distance from the CBD increases. This positive income-distance relationship is often reversed in cities in other countries. Although conventional urban economic theories provide various and plausible explanations, they fail to explain why the positive income-distance relationship is especially strong in the United States.

The flight from blight theory focuses on social and economic problems in the central city. However, most of the those problems in the central city are also found in central cities in other countries, but the positive income-distance pattern does not emerge in many of the cities. Besides, the causality between the income-distance pattern and the social and economic problems in the central city are is not clear. In fact, the causality runs in both directions. The central city has attracting forces, too. If the wealthy people live in the central city due to some reasons, many of the blight variables will be more prevailing in the suburbs. That is, the blight theory has some limitations.

On the other hand, the traditional monocentric model approach emphasizing income elasticity of housing demand was refuted by empirical research. Filtering theory has long been successful explaining the positive income-distance relationship. The transportation innovation theory of LeRoy and Sonstelie has received much attention, too. However, the two theories have their limitations.

A careful examination of the role of land scarcity in urban areas reveals that land abundance in the United States promotes the U.S. style filtering and virtual monopoly of automobile in the suburbs in America. Low land value combined with large urban size results in a modal choice split: mass transit in central city vs. car in suburbs. If the poor find commuting by car costly, they would reside in the central city. On the other hand, low land value becomes an obstacle to redevelopment of old housing units in the central city and, accordingly, promotes filtering. The effects of income on suburbanization and urban poverty concentration were ambiguous in the context of the traditional monocentric approach. By combining income increases, land scarcity, and modal choice, we were able to remove this ambiguity.

With the advances in transportation technology and increases in income, the U.S. residents were able to take greater advantage of the abundant land supply. Central city residents easily could move to far suburbs and old Northeastern and Midwestern cities were not forced to absorb much of increasing national urban population. Thus, equilibrium structural densities in many U.S central cities declined over time. This trend made redevelopment unprofitable, which implies concentration of old housing units in the central cities and old inner suburban rings.

In sum, land abundance in the United States contributed to the positive income-distance relationship through its effects on modal choice and filtering. By introducing land scarcity to the two most widely cited natural evolution theories, we were able to explain why the positive income-distance relationship is stronger in the United States.

Besides, our extended models show how rapid and extensive suburbanization, urban poverty concentration, urban transportation systems, and filtering are interrelated by a common factor.

Conclusions

Our study finds that the two important natural evolution theories are deeply related to land scarcity. In the case of U.S. cities, land abundance is responsible for fast and extensive suburbanization, heavy reliance on automobile, concentration of old and deteriorated housing units in the central city, abandonment, central city poverty concentration, and the positive income-distance pattern. These findings suggest important policy implications.

The extent of urban sprawl and deterioration of the central city have been a subject of controversy. Some believe the urban sprawl in U.S. cities is determined by an orderly market process, which efficiently allocates resources. Advocates of the natural evolution theory take this view. They consider the decline of the central city an inevitable phenomenon. Thus, they tend to oppose the government intervention to reverse the trend.

Others believe that the urban sprawl in U.S. is too costly and that the deterioration of the central city is deplorable. Urban economists with this view tend to endorse the fight from blight theory. Their concerns are two fold. First, they argue the cost of suburbanization is too heavy. High construction costs of freeway systems, costs of providing utilities to low density suburbs, decreasing agricultural land, damage to the environment, etc. are often mentioned. They also find the situation in declining central cities to be not only unjust but inefficient. Some of them argue that the fate of central cities and their suburbs are so deeply intertwined that decay of the central cities also hurt their suburbs.

It is not easy to conclude which view is correct. Urban residents would decide their residential locations and make many other urban economic decisions to maximize their utility. They would make rational and efficient decisions. However, their decisions would not reflect true social costs. Many goods available in urban areas are (semi-) public goods such as freeway, public education, police service, and public parks. We also know various negative and positive externalities exist in urban economies. Thus, only estimating the true social costs of suburbanization or urban sprawl would give us the answer to the controversy.

However, our findings suggest any government intervention to reverse the trend will be very costly. Urban sprawl is a matter of low-density urban development. Low urban density is responsible for central city decay and urban poverty concentration. Land abundance, which cannot be a bad thing after all, in the United States, is the cause of low urban equilibrium densities. It is natural to use an abundant resource with low intensity. In that sense, the current urban sprawl in the United States reflects efficient use of resources. Therefore, it can be said that curbing the urban sprawl and revitalizing central cities by government interventions would be a very costly task.

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