A STUDY ON CBD LAND VALUE VARIATIONS

by

KAZUHIKO FUJIKI

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN BUSINESS ADMINISTRATION

in

THE FACULTY OF GRADUATE STUDIES

Commerce and Business Administration

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

August, 1989

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Commerce and Business Administration

The University of British Columbia
2075 Wesbrook Place
Vancouver, Canada
V6T 1W5

Date: August, 1989

ABSTRACT

This thesis examines CBD (Central Business District) land value variations. The objectives of this study are (1) to compare monocentric and nonmonocentric models and (2) to analyze the determinants of CBD land value variations. Transactions of vacant land from 1975 to 1987 in Central Ward (*Chuo Ku*), Tokyo, comprise the data base for this study.

A monocentric model and nonmonocentric model are compared using a negative exponential function and trend surface analysis (based on a double power series of location coordinates). For the comparison, three-dimensional pictures and contour maps are utilized as well as statistics of goodness-of-fit and predictive powers. To analyze determinants of CBD land value variations, we employ a hedonic-price approach.

Trend surface analysis is superior to the monocentric model in terms of goodness-of-fit and predictive powers. However, centrality is still an important determinant. Proximity to subway or railway stations, or to the Ginza shopping area, are also important factors. Other influential determinants include time of sale, lot shape, corner location, road width, and floor area ratio.

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ACKNOWLEDGEMENTS

I would like to give my thanks to those who commented on earlier drafts of my thesis and those who have helped me by criticizing my ideas in classroom discussions. In particular, I would like to mention Jim Clyton, Reagan Pratt, Gary Tung, and Yuming Fu, who also helped me with typing the final version after my return to Japan. I also wish to thank Dr. Lawrence Jones and Dr. Tae Hoon Oum for their encouragement and thought-provoking comments. I owe a special debt of gratitude to Dr. Robert Helsley, who acted as chairman of my thesis committee, for a steady supply of valuble advice.

During my stay at University of British Columbia, I received financial support from The Japan Real Estate Institute, which also permitted me to use their data in my analysis.

I. INTRODUCTION

A. BACKGROUND

Land price variations have frequently been the target of research. Researchers are continually attracted to the subject, because of the public interest in urban land values and a widespread interest in predicting the future physical growth of a city. Land values affect land uses, which in turn affect the structure of a city. A small business or factory may have to leave a downtown area because the present value of its site in some other use is greater than the present value of projected cash flows from its business activity. A municipal government may have to select an economically inefficient highway route to avoid a highly valued residential area. The detour will affect subsequent commercial and residential development near the road.

An understanding of land price variations is important to many public and private professions. Equipped with such an understanding, municipal officials are better able to evaluate transactions involving public funds. Tax officials are able to promote fair taxation on land. Real estate appraisers can better estimate land values by knowing the price level of the whole city or area in which the appraised property exists.

To date, researchers have tended toward a monocentric model to explain land price variations. The monocentric model assumes that places of employment will be found in the central business district (the "CBD") and that employees will commute to and from the CBD. It concludes that land and housing prices and population density fall with the distance from the CBD.

This thesis originates in part from the concern that the traditional monocentric model does not account for externalities and other price influencing factors which distort a monotonically decreasing land price gradient. We felt that the traditional monocentric model should be replaced by another model. Another concern is the fact that the CBD has long been neglected as a research subject. Until recently, most studies have been interested not in the CBD but in residential properties, usually in outlying areas of a city. These studies treat the CBD as a point from which to measure the distance to each property. In contrast, this study tries to investigate land price variations within the CBD and to treat the CBD as a plane rather than a point.

B. PURPOSE

The larger purpose of this study is to examine intra-urban land price variations, with particular focus on land price variations within the CBD, and to treat the CBD as a plane rather than a point. The paper deals with the following two specific questions:

(1) Is the traditional monocentric model less effective than nonmonocentric models in explaining land price variations?

(2) Can centrality, externalities, site- and neighborhood-specific characteristics effectively explain land price variations within the CBD?

Both questions involve the search for an alternative to the traditional monocentric model. The difference between them is that the second considers factors other than location. In other words, the first question takes only the location of each site into account, whereas the second question includes other price influencing factors.

The first question asks whether or not a complex land price structure exists, one which cannot be explained by the traditional monocentric model. The second question explores the determinants of the complex price variations within the CBD.

C. OUTLINE

This thesis contains five chapters. Chapter II introduces the conceptual framework for this study. Chapter III reviews past empirical research. Chapter IV analyzes land price variations in the Tokyo CBD. Chapter V summarizes and gives concluding remarks.

II. CONCEPTUAL FRAMEWORK

This chapter examines past theoretical studies on intra-urban land price variations. This is done in order to provide a theoretical foundation for the empirical analysis in Chapter IV. This chapter is divided into three sections. Section A examines past studies which focused on centrality and land values. Section B discusses the negative exponential land rent function and its extensions. Section C discusses recent theoretical studies dealing with land values in the context of nonmonocentric models.

A. LAND RENT FUNCTIONS IN MONOCENTRIC MODELS

In monocentric models of urban land use, land rent and land use are completely determined by access to the "center" of a city. In this section, we review four monocentric models. Mohring (1961) pioneered the land rent gradient study. He dealt exclusively with residential land values. Alonso (1964) introduced and explained commercial land value variations. Two more recent studies done by Solow (1973) and Henderson (1985) focused on land values within a CBD.

1. Mohring (1961) gives us the simplest monocentric model. His model is based on the following assumptions:

(1) All economic and recreational activities, including

household shopping, take place in a CBD which is considered a point.

(2) Outside the CBD, land is used only for identical single-family dwellings with fixed lot sizes.

(3) Land surrounding the CBD is worthless for any purpose other than the existing home sites.

(4) Each family, which has uniform taste and income, places the same value on its travel time and makes the same number of trips to the CBD.

(5) The cost of a trip to the CBD is proportionate to the travel time required to make it.

In equilibrium, equal utility must be realized in every household. Since Mohring assumes fixed lot sizes, the total amount of variable costs incurred in each household must also be the same at every location in equilibrium. Land rents and transportation costs are variable within each household according to its location. In short, regardless of the location of a household, the sum of land rents and transportation costs is identical for every family:

$$R_i + 2NT_iV_T = R_j + 2NT_jV_T.$$

where

R_t = Rent for site "t" (t = i and j);

N = Annual number of trips taken to the CBD;

T_t = Travel time from site "t" to the CBD (t = i and j);

and

V_T = Value placed on travel time.

This implies

$$R_i - R_j = 2N(T_j - T_i)V_T \qquad [2.1]$$

Equation [2.1] indicates that the difference in land rents in two different places depends solely on the difference in travel time from each place to the CBD.

To determine land rent for each site, Mohring uses the assumption that the opportunity cost of land is zero: "those living at the city limits need pay no rent for the land they use."[1] By fixing land rent at the city limit at zero, we can derive Mohring's land rent equation as follows:

From Equation [2.1],

$$R_i - R_{max} = 2N(T_{max} - T_i)V_T$$

where

R_{max} = Rent for city limit sites; and

T_{max} = Travel time from city limit sites to the CBD.

Since $R_{max} = 0$,

$$R_i = 2N(T_{max} - T_i)V_T.$$

Because both N (annual number of trips to the CBD) and V_T (value of travel time) are given in this case, land rent of each site is determined solely by travel time to the CBD. In other words, land rent declines linearly as a distance to

[1] Mohring (1961), p.238.

the CBD increases(see Figure 2.1).

2. Alonso (1964) explains land price variations within a city using a bid rent (or price) curve concept. In the case of urban firms (including retail, wholesale, office, financial, and manufacturing firms), a bid price curve is an iso-profit curve. The firm is indifferent to locations and rent as long as the point is on the same bid price curve. A bid price curve has a downward slope for the following reasons:

(1) Volume of business declines as the distance from the city center increases because "accessibility of the site to potential customers will decrease with distance from the center."[2]

(2) Operating costs increase as the distance from the city center increases because transportation costs increase.

A land rent gradient in a city is derived by combining the bid rent (or price) curves of various land uses, including commercial, industrial, residential, and agricultural uses. Alonso concludes that land use offering the highest bid rent curve can occupy the city center, and that land at any point in a city is allocated to the highest

[2] Alonso (1964), p.44.

Figure 2.1
Land Rent Function by Mohring

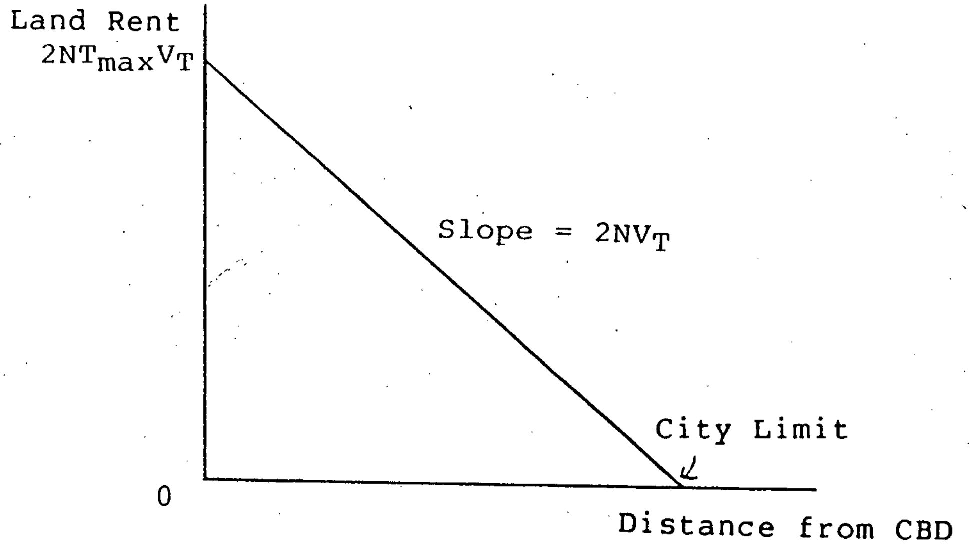
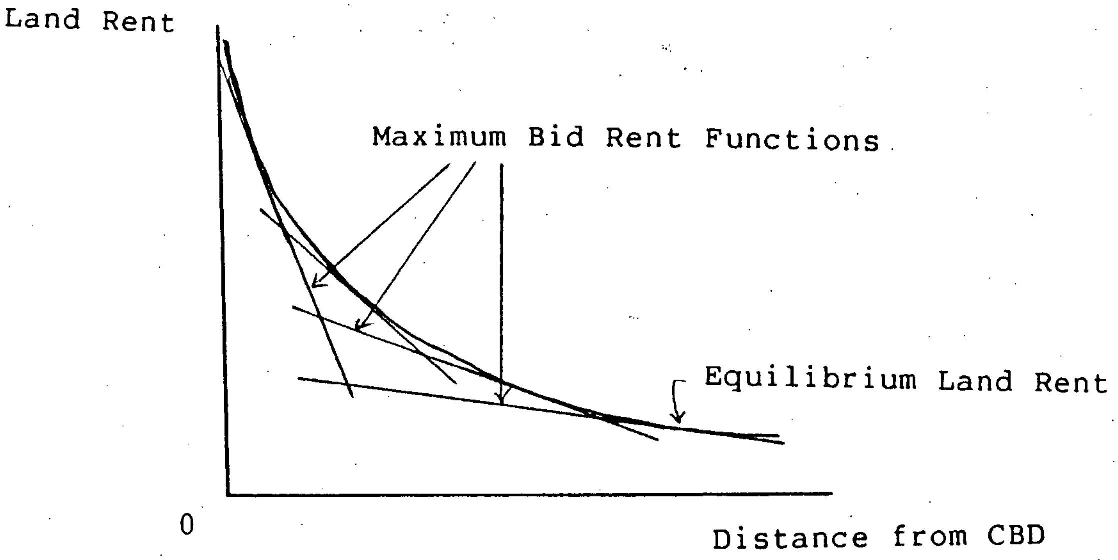


Figure 2.2
Land Rent Function by Alonso



bidder. Geometrically, an equilibrium land rent function is an envelope of maximum bid rent functions for various uses (see Figure 2.2).

3. Solow (1973) analyzes land rent variations within a CBD using a simple monocentric model. As Mohring did, Solow also makes several assumptions to keep his analysis as simple as possible. His assumptions are as follows:

(1) Everyone works in the CBD.

(2) The CBD is a featureless plane with a single central point.

(3) The CBD produces a single commodity.

(4) This commodity is produced with labor and land.

(5) The production function follows constant returns to scale.

(6) The commodity must be transported to the central point.

(7) A single wage rate prevails in the CBD.

(8) All markets are competitive.

(9) The commodity price is the given 'national' price.

We can infer from the above assumptions that Solow only examines the manufacturing industry in the CBD.

He introduces the following unit profit function.

$$\Pi = p - C[w, r(x)] - t(x) \qquad [2.2]$$

where

Π = Profit per unit output,

p = Product price,

C = Minimum cost function (excluding transportation costs),

w = Wage rate,

r(x) = Rent,

x = Distance from the central point,

t(x) = Transportation costs.

In the long-run, profit is reduced to zero because of competition. In the equilibrium, Equation [2.2] can be written as:

$$p = C[w, r(x)] + t(x) \qquad [2.3]$$

Since both p (product price) and w (wage rate) are constant, the differentiation of Equation [2.3] yields

$$0 = C_r \cdot r'(x) + t'(x)$$

Rearranging terms, we obtain,

$$r'(x) = -t'(x)/C_r$$

Because transportation costs rise as the distance from the central point increases, $t'(x) > 0$. Since minimum costs rise with input prices, $C_r > 0$. Therefore, $r'(x) < 0$. Land rents fall with increasing distance from the central point within the CBD.

4. Henderson (1985) also considers a land rent function within the CBD. In his analysis, identical firms in the CBD are assumed to produce one type of export good (x) following the linear homogeneous production function:

$$x(u) = G(N) \cdot x[k(u), n(u), l(u)]$$

where

x(u) = Amount of goods produced at a site "u" miles from the central point of the CBD;

G(N) = Hicks neutral shift factor ($\partial G/\partial N > 0$) which takes external scale economies into account;

N = Population of the city in which the CBD exists;

k(u) = Capital input;

n(u) = Labor input; and

l(u) = Land input.

Another important assumption is that the produced goods must be transported to the central point of the CBD from which to be exported or to be sold locally. Henderson assumes that it costs firms "t_x" of a unit of "x" to ship one unit of "x" one unit of distance. Therefore, the net price after transportation costs is $p_x \cdot (1 - t_x \cdot u)$ where p_x is a unit price of "x."

With perfect competition, the net price must be equal to unit costs in equilibrium:

$$p_x \cdot (1 - t_x \cdot u) = C[N, p_n, p_k, p_l(u)] \quad [2.4]$$

where

C[·] = Minimum unit cost function;

N = Population of the city;

p_n = Unit cost of labor;

p_k = Unit cost of capital; and

$p_l(u)$ = Unit land rent at a site "u" miles from the central point of the CBD.

Differentiating Equation [2.4],

$$-p_x \cdot t_x = [\partial C/\partial p_l(u)] \cdot [\partial p_l(u)/\partial u] \quad [2.5]$$

Using Shephard's lemma,[3]

$$\partial C/\partial p_l(u) = l(u)/x(u) \quad [2.6]$$

Substituting [2.6] into [2.5], we obtain

$$\partial p_l(u)/\partial u = -x(u) \cdot p_x \cdot t_x / l(u) \quad [2.7]$$

Multiplying l(u) on both sides of [2.7],

$$l(u) \cdot [\partial p_l(u)/\partial u] = -x(u) \cdot p_x \cdot t_x \quad [2.8]$$

Equation [2.7] indicates that unit land rent decreases with the distance from the central point of the CBD. From Equation [2.8], we notice that the increase in a total rent by moving a unit distance towards th CBD boundary is equal to the decrease in transportation costs of moving a unit distance towards the CBD boundary.

[3]Shephard's lemma states that the derivative of the unit cost function with respect to a production factor price equals the per unit demand for the factor.

The above four studies provide examples of land price functions in monocentric models. Mohring (1961) discussed a residential land rent function which has an inverse linear relationship to distance from the CBD. Alonso (1964) included commercial land in his analysis. He demonstrated that an equilibrium land rent has a negative slope. Assuming all products are transported to a central point, both Solow (1973) and Henderson (1985) illustrated a negatively-sloped land rent function within a CBD. However, these studies do not specify functional forms of land rent gradients. In the next section, we will examine the Mills-Muth type negative exponential function.

B. NEGATIVE EXPONENTIAL LAND RENT FUNCTION AND ITS EXTENSIONS

As Clark (1967) pointed out in his early work, "A theory was first proposed by Winkler (in 1957) that land values were at their highest in the center of the area, and that with increasing distance from it they fell off, not exponentially, as does population density, but in a double logarithmic relationship."[4] Since then, however, no study has been done to support Winkler's idea. On the contrary, several studies have successfully illustrated that land rent falls exponentially with increasing distance from the

[4]Clark (1967), p.382.

central point. The first half of this section reviews negative exponential land rent function. The second half examines the criticisms and extensions of the concept of negative exponential function.

1. Negative Exponential Land Rent Function

Mills (1972) derives an exponential land rent function in the context of a monocentric model. He assumes that a) urban area is located on a featureless plane and has a predetermined center; b) commuting cost depends only on the straight line distance between the location of housing and the city center; c) all the land that is located "u" miles from the city center commands the same rent and is used with the same capital/land ratio because all the land is homogeneous; d) input and output markets are perfectly competitive; e) the capital rental rate "r" is independent of both the distance from the city center and the amount of land used in the entire urban area; f) all workers receive the same income "w" and have the same tastes; and g) the income elasticity and price elasticity of demand for housing are constant.

Based on the above assumptions, Mill's model of urban structure is formulated in the following way:

(1) The production function of housing services takes the

form of the Cobb-Douglas function:

$$X_S(u) = A \cdot L(u)^{a} \cdot K(u)^{1-a} \;;\; 0<a<1 \qquad [2.9]$$

where

$X_S(u)$ = Production of housing services at distance u from the CBD,

L(u) = Input of land,

K(u) = Input of capital, and

A, a = Constants.

(2) In equilibrium, since households cannot increase their utility by changing their location, the decrease or increase in the cost of housing services resulting from such a move is offset by the increase or decrease in commuting costs.

$$[dP(u)/du] \cdot X_D(u) + t = 0 \qquad [2.10]$$

where

P(u) = Price of housing services at distance u,

$X_D(u)$ = Demand function for housing services per worker living at u, and

t = Cost per two miles of commuting.

(3) The demand function for housing services is assumed to take the form of a power function of income and price.

$$X_D(u) = B \cdot W^{\theta_1} \cdot P(u)^{\theta_2} \qquad [2.11]$$

where

B = Constant,

W = Income,

θ_1 = Income elasticity of demand for housing, and

θ_2 = Price elasticity of demand for housing.

(4) Substituting [2.11] into [2.10], we obtain,

$$[dP(u)/du]\cdot B\cdot W^{\theta_1}\cdot P(u)^{\theta_2} + t = 0 \qquad [2.12]$$

(5) Because of competitive markets, the value of the marginal product of a factor should be equal to the factor's price. Using this relationship and Equation [2.9], we can derive P(u) and dP(u)/du as follows:

$$P(u) = [A\cdot a^{a}\cdot(1 - a)^{1-a}]^{-1}\cdot R(u)^{a}\cdot r^{1-a} \qquad [2.13]$$

$$dP(u)/du = A^{-1}\cdot[a\cdot r/(1 - a)]^{1-a}\cdot R(u)^{-(1-a)}\cdot[dR(u)/du] \qquad [2.14]$$

(6) Substituting [2.13] and [2,14] into [2.12] and solving the differential equation resulting from the substitution, we obtain the following two equilibrium land rent functions:

$$R(u) = [\bar{R}^{\beta} + \beta\cdot t\cdot E\cdot(\bar{u} - u)]^{1/\beta} \text{ if } \beta \neq 0 \qquad [2.15]$$

$$R(u) = \bar{R}e^{t\cdot E\cdot(\bar{u}-u)} \qquad \text{if } \beta = 0 \qquad [2.16]$$

where

R(u) = Land rent "u" miles from the center,

$\bar{R}$ = Land rent of non-urban use,

$\beta = a\cdot(1 + \theta_2)$,

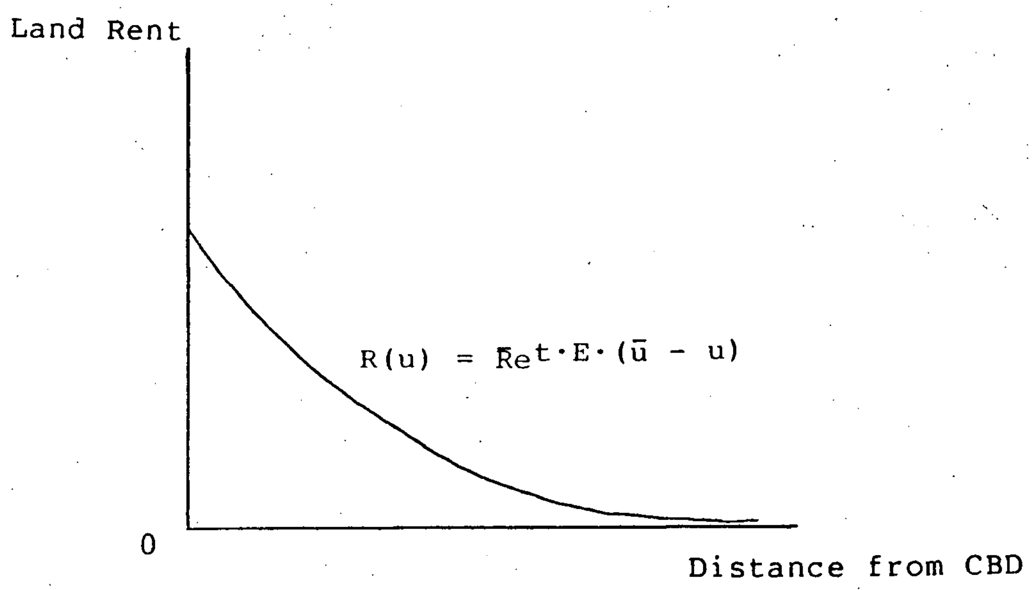
t = Cost per two miles of commuting,

$E = a\cdot B\cdot W^{\theta_1}\cdot[A\cdot a^{a}\cdot(1 - a)^{1-a}]^{-(1+\theta_2)\cdot r\cdot(1-a)\cdot(1-\theta_2)}$, and

$\bar{u}$ = Distance from the city center to the edge of the urban area.

According to Mills, "studies of housing demand suggest

Figure 2.3
Negative Exponential Land Rent Function



that θ_1 (income elasticity of demand for housing) may be about 1.5 and θ_2 (price elasticity of demand for housing) about -1.0."[5] Since $\beta = a\cdot(1 + \theta_2)$, $\theta_2 = -1.0$ means $\beta = 0$. This result implies that we can estimate land rent variations using Equation [2.16], which takes the negative exponential form (see Figure 2.3).

2. Criticisms and Extensions of Negative Exponential Function

(a) Functional Form

Based on Mills (1972), the negative exponential land rent function has been derived as we saw in Part 1 of this

[5]Mills (1972), p.81.

section. As we observed, the negative exponential function is valid if and only if β is equal to zero. In other words, the negative exponential function is plausible only when θ_2 (the price elasticity of demand for housing) is -1.0. The validity of this assumption is doubtful, however.[6]

Kau and Sirmans (1979) and Okawara (1981) examined whether $\beta = 0$ is an appropriate assumption or not. Using the Box-Cox transformation, the Kau and Sirman's study found that β differs significantly from zero at the 5% level for four out of six sets of land value data in Chicago. Applying the same technique to Tokyo data sets, Okawara concluded that β differs significantly from zero at the 1% level. The assumption that $\beta = 0$ is mostly rejected at a very significant level in both studies.

Aside from its functional form, the Mills type land rent function has many drawbacks. One of them arises from the assumption that the city is located on a featureless plane. "Featureless" means the nonexistence of both natural and man-made features. The latter features include neighborhood environments as well as the laws and regulations at work within the city. The Mills type land

[6]For instance, Kau and Lee (1976) found that half of 50 United States cities which they examined had the price elasticity of demand for housing greater than -1.0.

rent function is regarded as location rent function and does not account for the effects of environment, laws and other regulations on land values.

(b) Externalities

1. Polinski and Shavell (1976) and Richardson (1977) added the concept of "amenities" to the location rent function. The two studies suggest the possibility of positively-sloped land rent functions as the distance from the city center increases. In both studies, a household determines its location to maximize its utility function subject to a budget constraint. Richardson includes population density as a proxy for neighborhood conditions. In Richardson's model, the less populated a neighborhood is, the better the environment becomes. Since Polinski and Shavell include all amenities in one general expression, their study is more useful for investigating industrial or commercial land value variations. Therefore the following explanations will use the Polinski and Shavell model.

In their paper, the indirect utility function V is expressed as:

$$V(k) = V[p(k), y - T(k), a(k)] \qquad [2.17]$$

where

k = Distance from the CBD,

$p(k)$ = Price per unit of housing (housing rent) at location "k"

$y - T(k)$ = Net income before transportation costs at location "k", and

$a(k)$ = Index of amenities at location "k".

In equilibrium, a household cannot increase its utility by changing location. In other words, every household achieves the same level of utility, implying $dV(k)/dk = 0$. Differentiating [2.17] with respect to k and solving for $p'(k)$, we obtain the slope of housing rents as follows:

$$p'(k) = T' \cdot [\partial V(k)/\partial (y - T(k))]/[\partial V(k)/\partial p(k)] - a'(k) \cdot [\partial V(k)/\partial a(k)]/[\partial V(k)/\partial p(k)] \qquad [2.18]$$

$\partial V(k)/\partial (y - T(k)) > 0$ because an increase in net income before transportation costs increases utility given housing rent and amenities. $\partial V(k)/\partial p(k) < 0$ since an increase in housing rent decreases utility given income and amenities. $\partial V(k)/\partial a(k) > 0$ because an increase in amenities increases utility given income and housing rent. Therefore the first term in the right hand side of [2.18] is negative. The sign of the second term, $-a'(k) \cdot [\partial V(k)/\partial a(k)]/\partial V(k)/\partial p(k)]$ is positive. The incorporation of amenities results in an ambiguous slope of the rent function. The condition for a negatively-sloped rent function is:

$$T' \cdot [\partial V(k)/\partial(y - T(k))]/[\partial V(k)/\partial P(k)] > a' \cdot [\partial V(k)/\partial a(k)]/[\partial V(k)/\partial p(k)]$$

i.e.

$$T' \cdot [\partial V(k)/\partial(y - T(k))] > a' \cdot [\partial V(k)/\partial a(k)] \qquad [2.19]$$

Equation [2.19] shows that the slope of the housing rent function is negative "as long as a small movement away from the CBD results in a greater utility loss from higher transportation expenses than it does in a gain from improved amenities."[7]

2. Stull (1974) analyzed the effects of zoning regulations on land values. His model contains manufacturing and residential sectors. The manufacturing sector is located in the CBD surrounded by the residential area. Assuming a linear city, he examines the influence of land zoned for manufacturing on residential land values. The result of his analysis shows that the land rent gradient has a positively-sloped portion close to the CBD. This result, contradictory to the negative exponential function, appeared because industrial use exerts negative externalities on residential use.

3. Henderson (1977) analyzed how air pollution affects the residential land rent gradient. Firms located in the CBD

[7]Polinski and Shavell (1976), p.122.

are assumed to produce two goods: consumer goods and pollutants. Henderson also assumes that households with identical incomes and preferences are located around the CBD. Each household faces the following indirect utility function:

$$V = V[I,\ p_1(u),\ p_x,\ p_y,\ e(u),\ a(u)] \qquad [2.20]$$

where

I = Income;

$p_1(u)$ = Land rent of a site "u" miles from the city center;

p_x = Housing price;

p_y = Prices of other consumer goods;

$e(u)$ = Leisure; and

$a(u)$ = Disamenity caused by air pollution.

In equilibrium, $dV/du = 0$. Differentiating [2.20], we obtain

$$0 = [\partial V/\partial p_1(u)]\cdot[\partial p_1(u)/\partial u] + [\partial V/\partial e(u)]\cdot[\partial e(u)/\partial u] + [\partial V/\partial a(u)]\cdot[\partial a(u)/\partial u]$$

Moving the first term on the right-hand side to the left-hand side,

$$-[\partial V/\partial p_1(u)]\cdot[\partial p_1(u)/\partial u] = [\partial V/\partial e(u)]\cdot[\partial e(u)/\partial u] + [\partial V/\partial a(u)]\cdot[\partial a(u)/\partial u] \qquad [2.21]$$

Using Roy's Identity,[8] we can write the amount of land used, $l(u)$, as follows:

[8]Roy's Identity indicates the following equality:
The amount of consumption of a good is equal to the negative of the ratio of "the marginal utility of the good" against "the marginal utility of income."

$$l(u) = -[\partial V/\partial p_1(u)] \,/\, [\partial V/\partial I]$$

Therefore we can rewrite [2.21] as

$$\partial p_1(u)/\partial u = \frac{[(\partial V/\partial e(u))\cdot(\partial e(u)/\partial u) + \partial V/\partial a(u))\cdot(\partial a(u)/\partial u)]}{[l(u)\cdot(\partial V/\partial I)]} \qquad [2.22]$$

When there is no pollution, the sign of Equation [2.22] is always negative. This is because we can delete the second term of the numerator on the right-hand side in this case. After the deletion, the numerator is negative and the denominator is positive. However, with pollution, the sign is inconclusive because the second term of the numerator is positive. Equation [2.22] indicates that the inclusion of the negative externality of air pollution made the slope of land rent gradient ambiguous.

In summary, the studies done by Polinski and Shavell, Richardson, Stull, and Henderson demonstrate that externalities such as neighborhood amenities and pollution make the slope of land rent function ambiguous.

C. LAND RENT FUNCTIONS IN NONMONOCENTRIC MODELS

In Sections A and B, we reviewed land rent functions of monocentric models. Those models have the following two points in common:

a) a city has a predetermined central point; and

b) land values (or housing prices) vary in order to offset the differences of transportation costs from various locations to the central point.

In nonmonocentric models, there is no central point to which all people travel and all products are shipped. Rather these models try to explain why the CBD exists. Some aspects of agglomeration economies provide a basis for explaining the existence of the CBD. Agglomeration economies can be defined as production benefits arising from the scale and proximity of the economic activities in an urban area.

This section examines how nonmonocentric models analyze land value variations within a CBD. It is divided into two parts according to the source of agglomeration economies. Two studies to be reviewed in the first part regard interaction among firms as the source of agglomeration economies. The source for the study in the second part is the level of knowledge in each firm.

1. O'Hara (1979) and Tauchen and Witte (1984) examine office locations within a square CBD. The two studies assume that a firm benefits solely from its employees contacts with other firms' employees. Although the two papers have many common points, the latter paper deals only with office rent

functions. Therefore, most of the descriptions in this part are based on O'Hara's work, which explains land rent functions as well.

The CBD is assumed to be a square, centered at (x=0, y=0), with a grid road system. Identical firms are uniformly distributed within the CBD. (This assumption of uniformity is relaxed later.) Employees in each firm travel (in a rectilinear manner) to contact employees of other firms. The frequency of transactions between firms is constant. Both models neglect congestion costs incurred from travelling. The builders who provide the office space pay land rents to absentee landlords.

First of all, O'Hara analyzes the case of uniformly distributed firms. In this case, he finds that employees' travel costs rise as the square of a firms radial distance from the center of the CBD increases. This can be expressed as:

$$T(x,y) = [C \cdot S/2] + [(C/S) \cdot (x^2 + y^2)] \qquad [2.23]$$

where

$T(x,y)$ = Average travel cost per transaction for a firm located at (x,y),

C = Round-trip cost per unit distance,

S = Length of one side of the square CBD, and

x, y = x (east-west) and y (north-south) coordinates (the origin is the central point of the CBD).

In equilibrium, a firm's profit, $\pi(x,y)$, equals zero. Therefore,

$$\pi(x,y) = q(F) - N \cdot T(x,y) - R(x,y) = 0$$

which in turn implies,

$$R(x,y) = q(F) - N \cdot T(x,y) \qquad [2.24]$$

Substituting [2.23] into [2.24], we obtain

$$R(x,y) = q(F) - (N \cdot C \cdot S/2) - (N \cdot C/S) \cdot (x^2 + y^2) \qquad [2.25]$$

where

$R(x,y)$ = Office rent at (x,y),

$q(F)$ = Seminet revenue (net revenue before travel costs and office rent), and

N = Number of transactions.

Further, in equilibrium, the profit of office building constructors, $\Pi(x,y)$, is also reduced to zero. Thus

$$\Pi(x,y) = G \cdot R(x,y) - K(G) - W(x,y) = 0.$$

which implies

$$W(x,y) = G \cdot R(x,y) - K(G) \qquad [2.26]$$

Substituting [2.25] into [2.26], we obtain

$$W(x,y) = G \cdot \{q(F) - (N \cdot C \cdot S/2) - (N \cdot C/S) \cdot (x^2 + y^2)\} - K(G) \qquad [2.27]$$

where

$W(x,y)$ = Land rent at (x,y),

G = Density of firms, and

$K(G)$ = Cost of providing office space of density G.

Equations [2.25] and [2.27] represent office rent function and land rent function, respectively. Since $q(F)$, N, C, S, G, $K(G)$ are all constant, $R' < 0$, $R'' < 0$, $W' < 0$, and $W'' < 0$ are easily derived. Hence, both office rent and land rent functions clearly have downward slopes which are concave from below.

Now the assumption of uniform firm distribution is relaxed. In this case, the density of office space, G, becomes another endogenous variable. The office space market is in equilibrium when the marginal cost of providing office space equals office rent:

$$K'[G(x,y)] = R(x,y) \qquad [2.28]$$

For simplicity, office construction cost is written as:

$$K(G) = a \cdot G^b, \qquad b > 1 \qquad [2.29]$$

The zero profit condition becomes:

$$W(x,y) = G(x,y) \cdot R(x,y) - K[G(x,y)] \qquad [2.30]$$

Using Equations [2.28], [2.29], and [2.30], we can derive the following expressions for the first and second order derivatives of the land rent function with respect to x:

$$\partial W/\partial x = (b - 1) \cdot R \cdot (\partial G/\partial x) \qquad [2.31]$$

$$\partial^2 W/\partial x^2 = (b - 1) \cdot [(\partial R/\partial x) \cdot (\partial G/\partial x) + R \cdot (\partial^2 G/\partial x^2)] \qquad [2.32]$$

Since $b > 1$, $R > 0$, and $\partial G/\partial x < 0$, $\partial W/\partial x$ is always negative.

Therefore, the land rent gradient has a negative slope. However, since $b > 1$, $\partial R/\partial x < 0$, $\partial G/\partial x < 0$, $R > 0$, and $\partial^2 G/\partial x^2 < 0$, we cannot determine if [2.32] is positive or negative. In other words, the curvature of land rent function cannot be exactly determined in the case of non-uniform firm distribution. Tauchen and Witte (1984) arrived at a similar conclusion. Analyzing office rent function, they conclude that: a) at the center of the CBD, the slope is zero; b) at the edges of the CBD, the slope is upward towards the center of the CBD; and c) at other points the slope depends on the distribution of firms, the distribution of contacts, and the seminet revenue[9] function.

From the discussion in this part, we found that the assumption of uniform firm distribution guarantees the concave land rent function, but that relaxing the assumption makes the curvature of the slope ambiguous. The assumption of uniform firm distribution is inappropriate for actual CBD's. Therefore, the studies we have examined lead us to the conclusion that it is difficult to establish a land rent function with an unambiguous curvature within a CBD.

2. Helsley (1986) considers a nonmonocentric model with an endogenous firm distribution, and where the production

[9]The seminet revenue means "revenue net of spatially invariant costs (Tauchen and Witte (1984), p.72)."

and exchange of knowledge is the source of agglomeration economies. In his model, a firm's productivity depends on the level of knowledge at the location of the firm within the CBD, where knowledge is accumulated from other firms. The quantity of knowledge exchanged among firms decreases with increased distance between firms because of increasing contact costs. In equilibrium, the level of knowledge and the most productive locations claim the highest land rent, land rent also attains its maximum at the center and declines as the distance from the center increases.

In summary, the three nonmonocentric studies reviewed in this section all show that the central point claims the highest land value within the CBD even without the monocentric assumption. The first two studies showed that the curvature of land rent function is not definitely determined in the case of non-uniform firm distribution. The third study demonstrated that a land rent curve declines according to the level of knowledge. These three nonmonocentric models confirm the importance of centrality and raise questions concerning the shape of land rent function within a CBD.

III. PAST EMPIRICAL RESEARCH

This chapter reviews past empirical studies on intra-urban land price variations. Its purpose is a) to introduce how monocentric and nonmonocentric models were tested in these studies and b) to examine independent variables in the hedonic regression equations. In selecting empirical studies, first priority was given to studies of commercial or industrial land price variations and their determinants. Because the number of empirical studies in this category is very limited, this chapter also includes several studies which examine office rent variations and residential land value variations. However, the inclusion of these studies reinforces this chapter's arguments because their methods of selecting independent variables are still useful when analysing CBD land value variations. The past empirical studies to be reviewed in this chapter are summarized in chronological order in Table III.1.

A. EMPIRICAL TESTS OF MONOCENTRIC AND NONMONOCENTRIC MODELS

1. Traditional Monocentric Models

The traditional monocentric model attempts to explain land value variations in terms of distance from a central point to the site. The theoretical papers by Mohring (1961), Alonso (1964), Solow (1973), Henderson (1985), and Mills

Table III.1
Summary of Past Empirical Research

STUDY	STUDY AREA	DATA	FEATURES
Mills (1969)	Chicago	Estimated land values in Hoyt* (1836, 1857, 1873, 1910, and 1928)	Historical data study, distance from the center only.
Mills (1969)	Chicago	132 vacant land values in Olcott** (1966)	Zoning and distance from the center as independent variables.
Downing (1973)	The City of Milwaukee, Wisconsin	406 vacant land transactions data (1958 - 1962)	Variations in land values for retail use.
Dewees (1978)	Toronto	1864 home sales from M.L.S. listings	Changes in land rent gradients before and after the construction of a subway line.
Jackson (1979)	The city of Milwaukee, Wisconsin	Average housing rents in 147 census tracts	Trend surface analysis as an alternative access measure.
McDonald (1979)	Chicago	253 observations (1960) and 258 observations (1970) in Olcott**	Polynomial functions of distance from the CBD.
Clapp (1980)	Los Angeles	105 office rents	Office rent variations in a decentralized city.
Asabere (1981)	Accra, Ghana	211 vacant land transactions (1974 - 1978)	Ordinary hedonic regression anlysis applied to an African city.
Hembd and Infanger (1981)	Jessamine County, Kentucky	2016 vacant land transactions (1973 - 1978)	Trend surface analysis as a check on the orthodox hedonic equation.
Schmenner (1981)	Cincinnati metropolitan area, Ohio	47 rents and 71 transactions (1975 - 1976)	Insignificant relationship between rent (or value) of manufacturing site and centrality.
Hough and Cratz (1983)	Chicago	139 office rents (1978)	Hedonic rental equation within a CBD.

Table III.1

Summary of Past Empirical Research (Continued)

Brennan et al. (1984)	Chicago	29 office rents (3 years)	Distance from the main street is included as an independent variable.
Cannaday and Kang (1984)	Urbana-Champaign, Illinois	19 office rents (1979 - 1980)	Office rent variations in a small city.
Asabere and Harvey (1985)	Halifax, Nova Scotia	123 lot sales from M.L.S. listings (over 7.5 years)	Ordinary hedonic regression anlysis applied to a Canadian city.
Kowalski and Colwell (1986)	Wayne County, Michigan	24 undeveloped land transactions (1975 - 1984)	Scale and frontage effects on industrial land value.
Johnson and Ragas (1987)	New Orleans, Louisiana	110 actual vacant land transactions (1972 - 1983)	CBD land data, trend surface analysis, and three-dimensional pictures.
Peiser (1987)	North Dallas	466 vacant land transactions	Separate analysis for industrial, commercial, and office land values.

NOTES:

* : Homer Hoyt, One Hundred Yeras of Land Values in Chicago, (University of Chicago Press, 1933)

** : Olcott's Land Value Blue Book of Chicago , (Chicago: G.C. Olcott & Co.)

(1972) reviewed in Chapter II form the conceptual framework of the traditional monocentric model.

Mills (1969) conducted two empirical studies of Chicago land values. In the first study, he used historical Chicago land value data in order to test a negative exponential land value function. The explanatory power in terms of R^2 was quite high for the 19th century data. However, it declined drastically for the 20th century data. The second analysis in his paper utilized Olcott's data[10] and included zoning dummy variables as well as distance to the CBD from each site in the regression equation. The goodness-of-fit was greatly improved in this case.

The decreasing explanatory power of the negative exponential functional form was confirmed by McDonald (1979). He also used Olcott's Chicago land values data in his study. In his analysis of residential land value data, a fourth-degree polynomial function of distance from the CBD turned out to be the best model both for 1960 and 1970 data sets. Nonresidential land values were also examined in the study. McDonald found that a fourth-degree polynomial function of distance dominated the monocentric model in

[10] See the notes of Table III.1 for the complete names of the data sources utilized by Mills (1969) and McDonald (1979).

explaining nonresidential land value variations in 1960. The study pointed out that there are positively-sloped portions in both residential and nonresidential land value gradients.

The above two studies demonstrated the inapplicability of the negative exponential function to recent data in Chicago. The inclusion of zoning dummy variables improved the performance of the regression analyses, as did the employment of higher degree polynomial functions. This implies the existence of externalities and/or other price influencing factors such as zoning regulations.

2. Trend Surface Analysis

Three empirical studies in Table III.1 [Jackson (1979), Hembd and Infanger (1981), and Johnson and Ragas (1987)] used a technique called trend surface analysis. As we have already seen in Chapter II, a model is called monocentric when it has a prespecified central point to which all people travel and all products are sent. If a model does not have such a predetermined central point, it is considered a nonmonocentric model. Because the studies which utilize trend surface analysis do not specify a central point, they can be regarded as nonmonocentric. The nonmonocentric models of O'Hara (1979), Tauchen and Witte (1984), and Helsley (1986) form the conceptual framework of trend surface analysis.

Trend surface analysis is "a special case of ordinary least square regression analysis with restriction of the independent variable to locational indices."[11] In other words, trend surface analysis, like the traditional monocentric model, tries to explain land value variations based solely on variations in location or access. However, in this type of analysis, accessibility from each site to the central point or other points is not measured. The location of each site is identified by Cartesian coordinates. More specifically, a land value regression using trend surface analysis takes the following form:

$$Z=b_0+b_1x+b_2y+b_3x^2+b_4xy+b_5y^2+b_6x^3+b_7x^2y+b_8xy^2+\cdots$$

where Z is land value and x and y are the Cartesian coordinates of each observation.

Jackson's (1979) study of housing price variations in the city of Milwaukee compared two accessibility measures. One employs commonly used monocentric measurements, such as distance from each site to the CBD. The other method is trend surface analysis. Using the average housing rent in each census tract as the dependent variable, the ordinary regression analysis and trend surface analysis were

[11] Schroeder and Sjoquist (1976), p.383.

performed. The monocentric analysis failed to explain housing rent variations in the study area. On the other hand, a fourth-degree polynomial equation of trend surface analysis produced a high R^2 and significant coefficients with expected signs. The failure of monocentric accessibility measure is a result of the location of employment centers and expressways.

Hembd and Infanger (1981) used trend surface analysis to complement as well as examine the traditional monocentric land value regression model. They demonstrated that land values peak in areas other than the two urban centers that they examined in the traditional regression model. This finding gives an indication of the complexity of the actual land value surface. Their study area lies in a urban-fringe area. In such an area, behavioral factors such as subdivision approval seem to have a great impact on land value variations.

Johnson and Ragas (1987) investigated land value variations within the New Orleans CBD using trend surface analysis. Based on the adjusted R^2 and maximum-likelihood criteria, a sixth-degree polynomial equation of trend surface analysis was a better predictor than the behavioral models they studied.[12] Using three-dimensional pictures, Johnson and Ragas demonstrated that the effect of major street corridors overwhelms that of the central point of the CBD.

The above three studies applied trend surface analysis to three different areas. Jackson (1979) used residential rent data in a city. Hembd and Infanger (1981) applied the analysis to urban-fringe area data. Johnson and Ragas (1987) surveyed CBD land values. In spite of the different study areas, all three studies revealed:

1) the existence of complex land value surfaces which cannot be detected by the traditional monocentric models and

2) the usefulness of trend surface analysis in land value research.

B. INDEPENDENT VARIABLES IN THE PAST HEDONIC-PRICE STUDIES

The previous two models, i.e., the traditional monocentric models and trend surface analysis, explain land value variations in a purely spatial context. Both of them

[12] In the behavioral models, the independent variables included the distance from the central point of the CBD to the site, dummy variables for major street corridors, distances from externalities, and zoning and time dummy variables. The variables in the behavioral models will be further explored in Part B of this section.

consider only the relationship between land value and land location. In other words, those models assume homogeneity of neighborhoods and identical physical characteristics of lots within the CBD. In reality, however, each neighborhood has its own features. As well, we rarely find two lots exactly the same in terms of physical characteristics. The heterogeneity of both neighborhoods and lots within the CBD limits the explanatory power of both traditional monocentric models and trend surface analysis.

In addition to the diverse characteristics of neighborhoods and lots, a statistical problem stems from trend surface analysis. Because of its specification (i.e., the double power series), trend surface analysis suffers from a collinearity problem. The problem does not concern us as long as the analysis is restricted to deriving predicted values. However, because of the collinearity problem, the coefficients of independent variables of trend surface analysis provide us with no significant information. Therefore, we must resort to another model to obtain meaningful coefficients that can explain determinants of CBD land value.

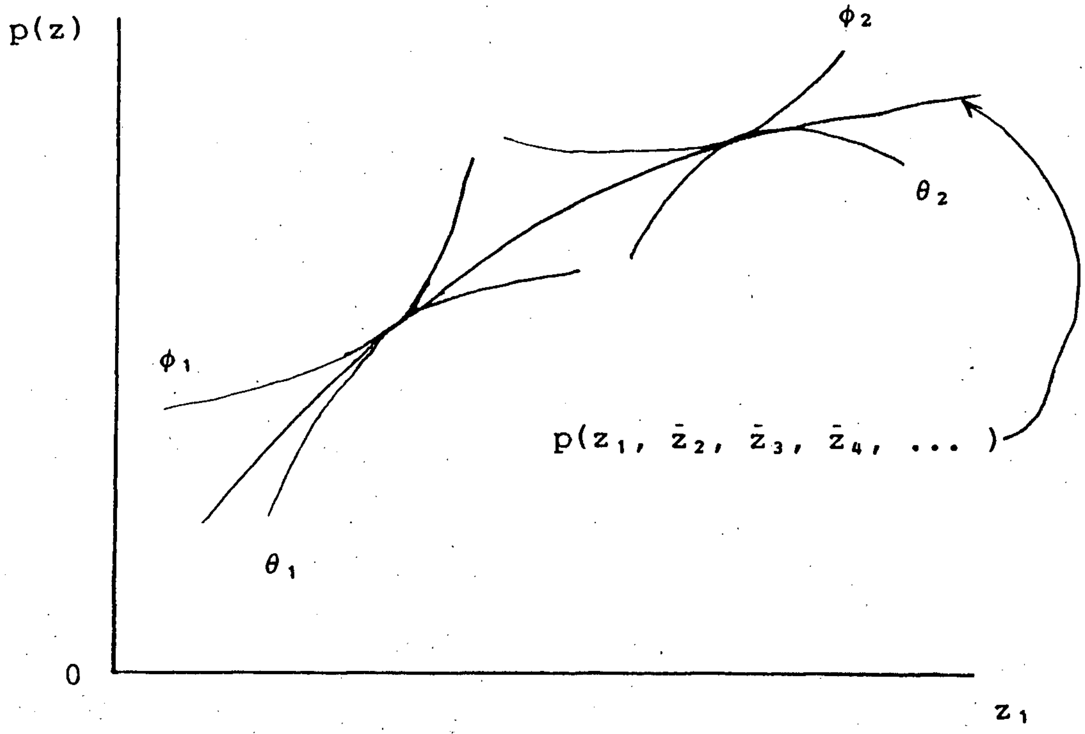
The hedonic-price approach is the most widely employed technique to analyze land value determinants. "The word hedonic has to do with pleasure; i.e., a hedonic price is related to the pleasure derived from the various attributes of a given commodity."[13] In other words, the hedonic approach examines the relationship between the prices and attributes of a commodity to explain differences in the price of the commodity.

The hedonic-price approach assumes that market participants accept a hedonic price function as given.[14] A hedonic-price function, for instance, $p(z_1, \bar{z}_2, \bar{z}_3, \bar{z}_4, ...)$ in Figure 3.1, represents market clearing conditions for an attribute of a commodity. The function can be defined as a set of points of tangency between buyers' bid functions [θ_1 and θ_2 in Figure 3.1] and sellers' offer functions [ϕ_1 and ϕ_2 in Figure 3.1]. The empirical studies reviewed in this part used the simple hedonic approach. In this approach, a coefficient is assumed to be the marginal willingness to pay for a particular attribute. Using the hedonic-price approach, we can untangle the "bundle of attributes."

The empirical studies in Table III.1 gives us an insight for choosing independent variables in the hedonic regression equation. The attributes considered in these

[13]Cannaday and Kang (1984), p.68.
[14]The description in this paragraph is based on the argument in Follain and Jimenez (1985), pp.78-81.

Figure 3.1
Hedonic, Buyer Bid, and Seller Offer Functions



Notes

$z_1, z_2, z_3, z_4, \ldots$ = Attributes of a commodity,
$P(\cdot)$ = Hedonic price function,
θ_1 and θ_2 = Buyers' bid functions, and
ϕ_1 and ϕ_2 = Sellers' offer functions.

studies can be classified as follows:[15]

(1) Accessibility

(i) Centrality,

(ii) Proximity to transportation facilities, and

(iii) Accessibility to externalities.

(2) Site-specific price influencing factors

(i) Size,

(ii) Lot shape, and

(iii) Location on a block.

(3) Neighborhood-specific price influencing factors

(i) Road width,

(ii) Prestigious address and major street corridors, and

(iii) Zoning.

The hedonic-price approach considers behavioral factors [items (2) and (3)] as well as location factors [item (1)], whereas the traditional monocentric models and trend surface analysis consider accessibility only. Each category is examined in turn in the rest of this chapter.

(1) Accessibility

(i) Centrality

Although several studies refuted the importance of centrality [e.g., Schmenner (1981), Cannaday and Kang

[15]The attributes are limited to those which can be applied to research on CBD land values. Therefore, the list did not include factors such as income and pollution.

(1984), Kowalski and Colwell (1986), and Peiser (1987)], all CBD land value studies in Table III.1 obtained a significant coefficient of the variable of distance to the central point [Hough and Kratz (1983), Brennan et al. (1984), and Johnson and Ragas (1987)]. A study of office rents in Los Angeles demonstrated that centrality is the most important variable in the regression equation [Clapp (1980)].

(ii) Proximity to transportation facilities

Hough and Cratz (1983) included "distance to the nearest commuter railway station" in their independent variables, but the coefficient of the variable was insignificant. To the contrary, the following two studies confirmed the importance of proximity to transportation facilities. Schmenner (1981) found that "distance to expressways" is significant. Dewees (1978) investigated the impact of subways on residential land values in Toronto. The study ascertained the importance of distance from the site to the subway line in determining property values.

(iii) Accessibility to Externalities

Among the empirical studies summarized in Table III.1, only Johnson and Ragas explicitly included externality variables in the regression equation.[16] According to their study, three sources of externalities in the New Orleans CBD are a) the Louisiana Superdome, b) the Mississippi River, and c) a large housing project. Externality benefits are derived from the Superdome and the Mississippi River. The Superdome offers inexpensive public parking space and a large shopping area and the Mississippi River enhances the aesthetics of nearby sites. On the other hand, the housing project is generally considered to be a disadvantage as it widely conceived as a source of crime. Although the coefficients of the river variable had an expected negative sign, it was not significant. The other two variables were highly significant.

(2) Site-specific Price Influencing Factors

(i) Size

Some studies examined the relationship between land area and unit price. Downing(1973), Asabere (1981), Asabere and Harvey (1985), and Kowalski and Colwell (1986) all observed a highly significant inverse relationship between size and unit price. However, the inverse relationship was not significant in the office

[16] Downing (1973) tried to incorporate the disadvantages of brewing or tanning operations into his study but he was not successful.

land study done by Peiser (1987).

(ii) Lot shape

Only Asabere and Harvey (1985) investigated the influence of lot shape on land value. They obtained a significant coefficient with a negative sign for an "irregular shape" dummy variable.

(iii) Location on a block

Peiser (1987) included "corner lot" dummy variables in his regression equations. The coefficients of the variables were significant only in the industrial land regressions. Downing (1973) used the distance from the corner lot to a site on the same block to ascertain the advantages of proximity to the corner lot. As a result, he found a significant coefficient of the variable.

(3) Neighborhood-specific Price Influencing Factors

(i) Road width

Peiser (1987) employed three kinds of dummy variables for road width, depending on the number of traffic lanes. He obtained significant coefficients on the road width dummies for all his industrial land regression equations and for two out of four office land regression equations. Instead of road width, Downing

(1973) measured traffic volume. Using 24-hour weekdays volume , he observed that the amount of traffic has an important positive influence on retail land values.

(ii) Prestigious address and major street corridors

Clapp (1980) found that land in Beverly Hills commanded a higher land price than land elsewhere in Los Angeles. Johnson and Ragas (987) included dummy variables for two major street corridors within the CBD to determine differences in land values. The results varied according to functional forms. Generally speaking, the difference in land values was more significant for one major corridor than for another.

(iii) Zoning

Zoning regulations are also expected to affect land value. Almost all regression equations in the studies in Table III.1 contained zone classification dummy variables. Density variables were included in two studies [Johnson and Ragas (1987) and Peiser (1987)] in order to incorporate development expectations. In Johnson and Ragas' study, the density variables were highly significant, whereas in Peiser's study, the variables were significant only in the commercial land regressions.

C. SUMMARY

In this chapter, we reviewed 16 empirical studies on land value variations. Using Chicago data, two studies demonstrated the decreasing explanatory power of the negative exponential functional form. Trend surface analysis illustrated complex land value variations in various areas (including a CBD). The test of monocentric and nonmonocentric models proved that the traditional monocentric model cannot adequately explain intra-urban land value variations. The examination of the past empirical studies leads us to believe that it is worthwhile to consider accessibility, and site- and neighborhood-specific price influencing factors when we analyze the determinants of CBD land values.

IV. EMPIRICAL ANALYSIS

The purpose of this chapter is to investigate land price variations within the Tokyo CBD by analyzing vacant land sales data during the period from 1975 to 1987. Two topics are considered in this chapter:

a) Can nonmonocentric models perform better than monocentric models? and

b) Can accessibility and site- and neighborhood-specific factors explain land price variations within the CBD?

Predicted land price variations are derived using the traditional monocentric model and trend surface analysis, which were both examined in Chapter III. The predictive powers of the two models will be compared statistically in this chapter. The hedonic regression analysis will uncover other important determinants of CBD land price variations.

The chapter contains four sections. Section A describes the study area. Section B explains the data used. Section C deals with the methodologies of empirical the analyses of this chapter. Section D presents and interprets the estimation results.

A. STUDY AREA

When we look at the central part of Tokyo, we find one major industrial and business concentration centered around Tokyo Station. Figure 4.1 shows the area considered in this study. In the figure, however, the area located to the west of the railway lines is not included in the study area. The reasons the western part of the CBD is excluded are:

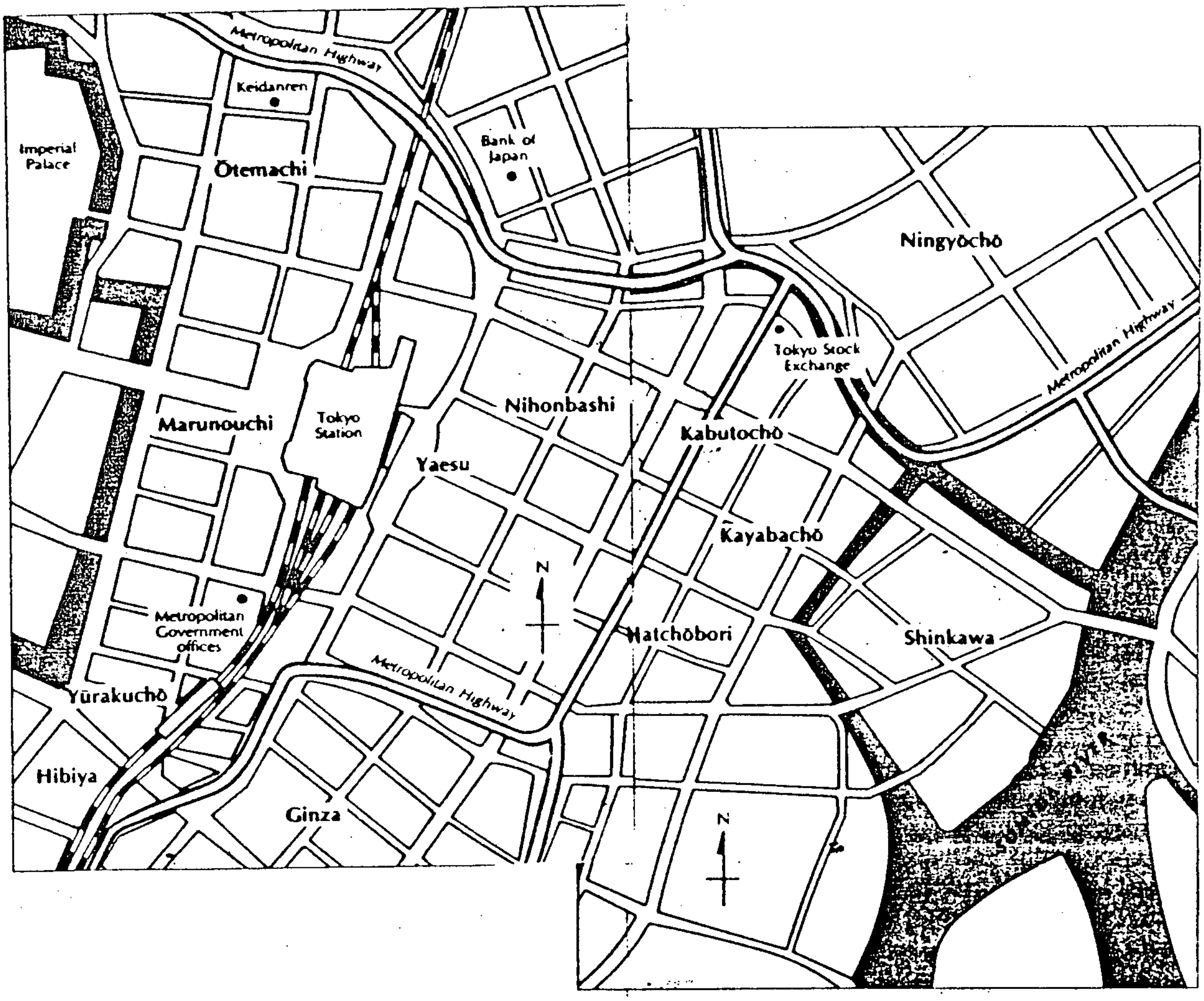
a) data unavailability(because most of the land to the west of Tokyo Station is owned by major companies for their headquarters, very few transactions are recorded) and

b) the western area belongs to another municipality.

The study area includes all of Central Ward (*Chuo Ku*) excluding a small island in Sumida River. Central Ward is one of 23 wards in Tokyo Special Ward Area.[17] As the name of the ward indicates, Central Ward is located almost at the center of Tokyo Special Ward Area. It is almost rectangular in shape with a length of 3,500 meters and a width of 1,600 meters. According to the 1981 Establishment Census of Japan, the number of business establishments in Central Ward totals 42,247, with a total employment of 690,000. As Table IV.1 indicates, Central Ward has a diversified industrial

[17]A special ward is one type of municipality in Tokyo Prefecture. It has almost the same administrative and legislative powers as a city.

Figure 4.1
Map of Study Area



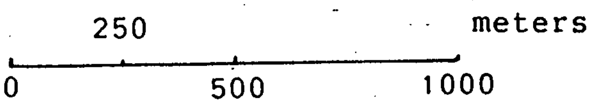


Table IV.1
Industries and Employment in Central Ward, 1981

Industry	Number of Establishments	Number of Workers
Agriculture, Forestry, and Fishing	32(0.08)*	1,126(0.16)
Mining	26(0.06)	1,4310.21)
Construction	1,244(2.94)	37,018(5.36)
Manufacturing	4,138(9.80)	103,070(14.39)
Wholesale and Retail	22,612(53.52)	297,053(43.02)
Finance and Insurance	1,323(3.13)	73,763(10.68)
Real Estate	2,016(4.77)	16,718(2.42)
Transportation and Communication	1,494(3.54)	40,669(5.89)
Utilities	23(0.05)	1,922(0.28)
Services**	9,298(22.01)	113,263(16.40)
Public Sector	41(0.10)	4,500(0.65)
TOTAL	42,247(100.00)	690,533(100.00)

Notes:

* Percentages are in paranthses. ** "Services" includes both private and business services.

Source: 1981 Establishment Census of Japan.

structure. "Wholesale and Retail" has the largest share of workers and establishments while "Services" and "Manufacturing" are second and third in size respectively.

Each district in the ward can be classified according to its major industry. For example, the Ginza, which is located in the south-western corner of the map, is the most prestigious shopping area. Offices are concentrated in the Yaesu, Nihon-bashi, and Kabutocho areas. Ningyocho and the area north of it (not shown on the map) specialize in the garment industry. A concentration of printing establishments can be found in Kayabacho and Hatchobori. The area to the south of the Ginza district specializes in food processing and food wholesaling.

In the study area, the public transportation system is densely developed. Besides the railway lines shown on the map, there are 7 subway lines and numerous bus routes.

B. THE DATA

The data utilized in this study consists of vacant land transactions that took place in the study area between 1975 and 1987. It was compiled by the Japanese Association of Real Estate Appraisers. The data contains information such as vacant land price per square meter, address, date of

Table IV.2
Summary Statistics for the Data

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
P	836	5296568.69617	6145409.94638	211750.00000	57579000.000
SIZE	836	140.09809	261.99944	15.00000	6708.000
ROAD	836	12.08732	9.08500	2.00000	45.000
CORNER	836	0.11842	0.32330	0.00000	1.000
SHAPE	836	0.03349	0.18003	0.00000	1.000
FAR	836	6.34211	1.01141	4.00000	9.000
CENDIS	836	1365.03589	446.80490	273.00000	2303.000
GINZA	836	0.17344	0.37886	0.00000	1.000
STADIS	836	255.08852	134.50328	14.00000	763.000
FINDIS	836	1000.63278	514.17610	154.00000	2310.000
GINZADIS	836	1652.36124	865.36274	91.00000	3912.000

P = land price in Japanese Yen per square meter.
SIZE = Lot size in square meters.
ROAD = Road width in meters.
CORNER = Dummy variable (1 = corner lot).
SHAPE = Dummy variable (1 = irregular lot).
FAR = Floor area ratio.
CENDIS = Distance from the central point of the CBD (in meters).
GINZA = Dummy variable (1 = lot in the Ginza).
STADIS = Distance from the nearest station (in meters).
FINDIS = Distance from the financial center (in meters).
GINZADIS = Distance from the Ginza shopping area (in meters).

transaction, names of vendor and purchaser, width of road on which the site abuts, shape, size, distance to the nearest station, and zoning regulations. There is not, however, any information on the financing of each transaction. All the transactions are for vacant (or to-be-cleared) land. Only "arm's length" transactions are included. The number of observations totals 836. Table IV.2 summarizes the data.

C. METHODOLOGY

This section discusses the methods of solving two problems:

1) Comparison of monocentric and nonmonocentric models; and

2) Analysis of determinants of CBD land value variations.

1. Comparison of Monocentric and Nonmonocentric Models

Monocentric and nonmonocentric models are compared in terms of explanatory power for land value variations within the Tokyo CBD. In this study, "trend surface analysis" represents nonmonocentric models.

a. Monocentric Model

The explanatory variables in the traditional monocentric model are limited to "distance to the central point of the CBD from the site" and "time of sale." Mills' negative exponential function is applied, as well as linear and polynomial functions.

- Negative exponential function

$$LN(P) = \beta_0 + \beta_1 T + \beta_2 d + e$$

- Linear function

$$P = \beta_0 + \beta_1 T + \beta_2 d + e$$

- Polynomial function

$$P = \beta_0 + \beta_1 T + \beta_2 d + \beta_3 d^2 + \beta_4 d^3 + \cdot \cdot \cdot + e$$

where

P = Land price per square meter;

T = Time variable (e.g., 1=1975 1st quarter, 2=1975 2nd quarter, ...);

d = Distance to the central point of the CBD; and

e = Error term.

The error terms are assumed to be normally distributed, uncorrelated random variables with common variance. We utilize the ordinary least squares method.

b. Trend Surface Analysis

As discussed in Chapter III, trend surface analysis also uses the ordinary least square method. (X,Y) location coordinates and time variables are both treated as independent variables, whereas land value is treated as the dependent variable. X and Y coordinates are assigned based on a Cartesian plane which is arbitrarily placed in the CBD. Six regression equations according to the degree of power can be expressed as follows:

- Linear

$$P = \beta_0 + \beta T + \beta_1 X + \beta_2 Y + e$$

- Second degree polynomial

$$P = \beta_0 + \beta T + \beta_1 X + \beta_2 Y + \beta_3 X^2 + \beta_4 XY + \beta_5 Y^2 + e$$

- Third degree polynomial

$$P = \beta_0 + \beta T + \beta_1 X + \ldots + \beta_6 X^3 + \beta_7 X^2 Y + \beta_8 XY^2 + \beta_9 Y^3 + e$$

- Fourth degree polynomial

$$P = \beta_0 + \beta T + \beta_1 X + \ldots + \beta_{10} X^4 + \beta_{11} X^3 Y + \beta_{12} X^2 Y^2 + \beta_{13} XY^3 + \beta_{14} Y^4 + e$$

- Fifth degree polynomial

$$P = \beta_0 + \beta T + \beta_1 X + \ldots + \beta_{15} X^5 + \beta_{16} X^4 Y + \beta_{17} X^3 Y^2 + \beta_{18} X^2 Y^3 + \beta_{19} XY^4 + \beta_{20} Y^5 + e$$

- Sixth degree polynomial

$$P = \beta_0 + \beta T + \beta_1 X + \ldots + \beta_{21} X^6 + \beta_{22} X^5 Y + \beta_{23} X^4 Y^2 + \beta_{24} X^3 Y^3 + \beta_{25} X^2 Y^4 + \beta_{26} XY^5 + \beta_{27} Y^6 + e$$

where

P = Land price per square meter,

T = Time variable (e.g., 1=1975 1st quarter, 2=1975 2nd quarter, ...) or time dummy variables,

X = X coordinate,

Y = Y coordinate, and

e = Error term(normally distributed, uncorrelated random variables with common variance).

The linear equation represents a plane, whereas the maximum numbers of extrema from the five subsequent equations are 1, 4, 9, 16, and 25, respectively. The last number is large enough to explain land price variations in a narrow area such as a CBD. The above six regression equations will be used to ascertain which degree of polynomial equation is most satisfactory statistically.

2. Analysis of Determinants of CBD Land Value Variations

The model we employ to clarify determinants of CBD land value variations is hedonic regression analysis. The independent variables in the analysis can be divided into the following three general categories as introduced in Chapter III:

$P = f(A; S; N)$

where

P = Land price per square meter;

A = Accessibility;

S = Site-specific price influencing factors; and

N = Neighborhood-specific price influencing factors.

(a) Accessibility

Accessibility variables will include the distances from the site to the center of the CBD,[18] the nearest station, the center of Ginza Shopping Area, and the center of the financial district.[19] The signs of the coefficients of these four variables are expected to be negative. Because there are no slums or residential development projects in the CBD,

[18]The site of Tokyo Station is regarded as the center of the CBD in this study because of its importance as a transportation node.

[19]The site of the Tokyo Stock Exchange is regarded as the center of the financial district.

no negative externalities are specified.

(b) Site-Specific Price Influencing Factors

Site-specific price influencing factors determine the development suitability of a lot and, hence, affect its price. Variables in this category are size, shape, and corner location. Dummy variables are designed to determine the potential effects of shape and corner location. "1" is assigned to irregular shaped-lots, while "0" is assigned to rectangular or square lots. In the same way, "1" is assigned to corner locations and "0" to middle locations within a block. Signs of the coefficients of "size" and "shape" are expected to be negative, while a positive sign is expected for the "corner location."

(c) Neighborhood-Price Influencing Factors

Road width is used as a proxy for both the profitability and development suitability of sites in a neighborhood. Offices or shops on a wider road enjoy much more advertising benefits than those on a narrower road because of visibility to passengers and traffic. The zoning bylaw limits development depending on road width. Stricter building regulations are imposed on a site which abuts on a narrower road than a site on a wider road. Thus, a positive sign is expected for this variable.

A dummy variable is designed to confirm the differences in land value between the Ginza, the most prestigious shopping area in Tokyo, and all areas elsewhere in the study. "1" is assigned to lots in the Ginza, while "0" is assigned to lots elsewhere. A positive sign is expected for this dummy variable.

All the land in the CBD is designated as "Commercial Area" according to the zoning bylaw in the study area. The factor that differentiates each neighborhood in terms of zoning regulations is Floor Area Ratio, which can be defined as the ratio of the maximum total floor area in a building to the area of the building site. Floor area ratio ranges from 4 to 9 in this study area. A positive sign is expected for this variable.

(d) Summary

Variables in the hedonic regression analysis can be summarized as follows:

P = Land price in Japanese Yen per square meter (Land prices range from 211,750 Yen per sq. meter to 57,579,000 Yen per sq. meter with a mean value of 5,296,569 Yen per sq. meter.);

T = Time variable (e.g., 1=1975 1st quarter, 2=1975 2nd quarter, ...);

DISCEN = Distance from the central point of the CBD (Tokyo Station) to each site (a straight-line distance in meters);

DISGIN = Distance from the center of the Ginza Shopping Area to each site (a straight-line distance in meters);

DISFIN = Distance from the Financial Center (Tokyo Stock Exchange) to each site (a straight-line distance in meters);

DISSTA = Distance from the nearest station to each site (a straight-line distance in meters);

SIZE = Size of the lot in square meters;

SHAPE = Dummy variable (1 = irregular lot. 28 out of 836 observations are irregularly-shaped lots);

CORNER = Dummy variable (1 = corner lot. 99 out of 836 observations are corner lots.);

RD = Road width in meters;

GINZA = Dummy variable (1 = lot in the Ginza, 0 = lot elsewhere);

FAR = Floor area ratio;

The ordinary least squares method is also utilized in the hedonic regression analysis. The error terms in the regression equations are assumed to be normally distributed, uncorrelated random variables with common variance.

Table IV.3
Regression Results (a)
Traditional Monocentric Model

	Linear	Negative Exp.	Box-Cox
Dep. Variable	P	LN(P)	P^{λ}
CONSTANT	1849400	13.901	10.015
	(2.8728)***	(166.83)***	(254.70)***
TIME	250790	0.058098	0.027616
	(21.014)***	(37.539)***	(37.812)***
CENDIS	-3760.4	-0.00068429	-0.00032388
	(-9.8948)***	(-13.885)***	(-13.926)***
Adjusted R^2	0.3719	0.6417	0.6449
Log of Likelihood Function	-14058.0	-13302.5	-13299.8
λ	–	–	-0.05

NOTES:
- t-statistics are in parenthses.
- *** indicates significant at 1% level.
- N = 836 for all estimates.
- P = Land price (Yen per square meter)
- TIME = Time variables (1 = 1975 1st quarter, 2 = 1975 2nd quarter, ..., 52 = 1987 4th quater)
- CENDIS = Distance to the central point of the CBD

D. ESTIMATION RESULTS

1. Comparison of Monocentric and Nonmonocentric Models

a. Traditional Monocentric Model

Table IV.3 shows the regression results for the traditional monocentric models.[20] All coefficients are

[20]Other regression equations, such as the quadratic and higher degree polynomial equations, were also attempted. There were no significant differences between these

significant at the 1% level in every regression equation. In the linear equation, the average quarterly increase in land prices during the period from 1975 to 1987 is 250,790 Yen per square meter. By moving one meter from the central point, land prices are decreased by 3,760 Yen per square meter. In the negative exponential regression, on the other hand, land prices rise about 5.8% every quarter year and decrease 0.07% every meter from the central point.

To choose the better functional form between the linear equation and the negative exponential function, we utilize the Box-Cox transformation and the log-likelihood ratio test. Since the dependent variables are different, R^2 cannot be used for this purpose.

The likelihood ratio test for significance is based on the theory that, under null hypothesis, twice the difference in the logarithmic likelihood between a null hypothesis and an alternative hypothesis is distributed as χ^2 with one degree of freedom. In order to get 99% confidence interval for λ, we should consider all the values of λ_0 which satisfy the following condition:

$$L_{max}(\hat{\lambda}) - L_{max}(\lambda_0) < (1/2) \cdot \chi^2(a)$$

where,

[20](cont'd) equations and the negative exponential equation in terms of the goodness-of-fit and predictive power.

L_{max} : Log-likelihood Function;

λ_0 : Value specified in H_0; and

$\hat{\lambda}$: Value which maximizes the likelihood.

For $a = 0.01$, $(1/2)\chi^2 = 3.315$. Using the above inequality, we can test the corresponding value (λ_0) to determine whether or not it falls within the appropriate confidence interval.

Based on Box-Cox transformation, it was found that the maximum logarithmic likelihood occurred at $\lambda = -0.05$ and $L_{max}(\lambda)$ is equal to -13299.8 (see Table IV.3).

When $\lambda_0 = 0$ (i.e., Negative Exp.),

$$L_{max}(-0.05) - L_{max}(0)$$
$$= -13299.8 - (-13302.5)$$
$$= 2.7 < (1/2)\ \chi^2\ (0.01) = 3.315$$

When $\lambda_0 = 1$ (i.e., Linear),

$$L_{max}(-0.05) - L_{max}(1)$$
$$= -13299.8 - (-13302.5)$$
$$= 758.2 > (1/2)\ \chi^2\ (0.01) = 3.315$$

Therefore, $\lambda_0 = 0$ is within the 99% confidence interval, whereas $\lambda_0 = 1$ is outside the interval. In other words, the linear equation is rejected at 0.01 level. The logarithmic likelihood ratio test demonstrated that the negative exponential function is the better functional form for the monocentric models.

Figure 4.2

Normal Probability Plots - Traditional Monocentric Model

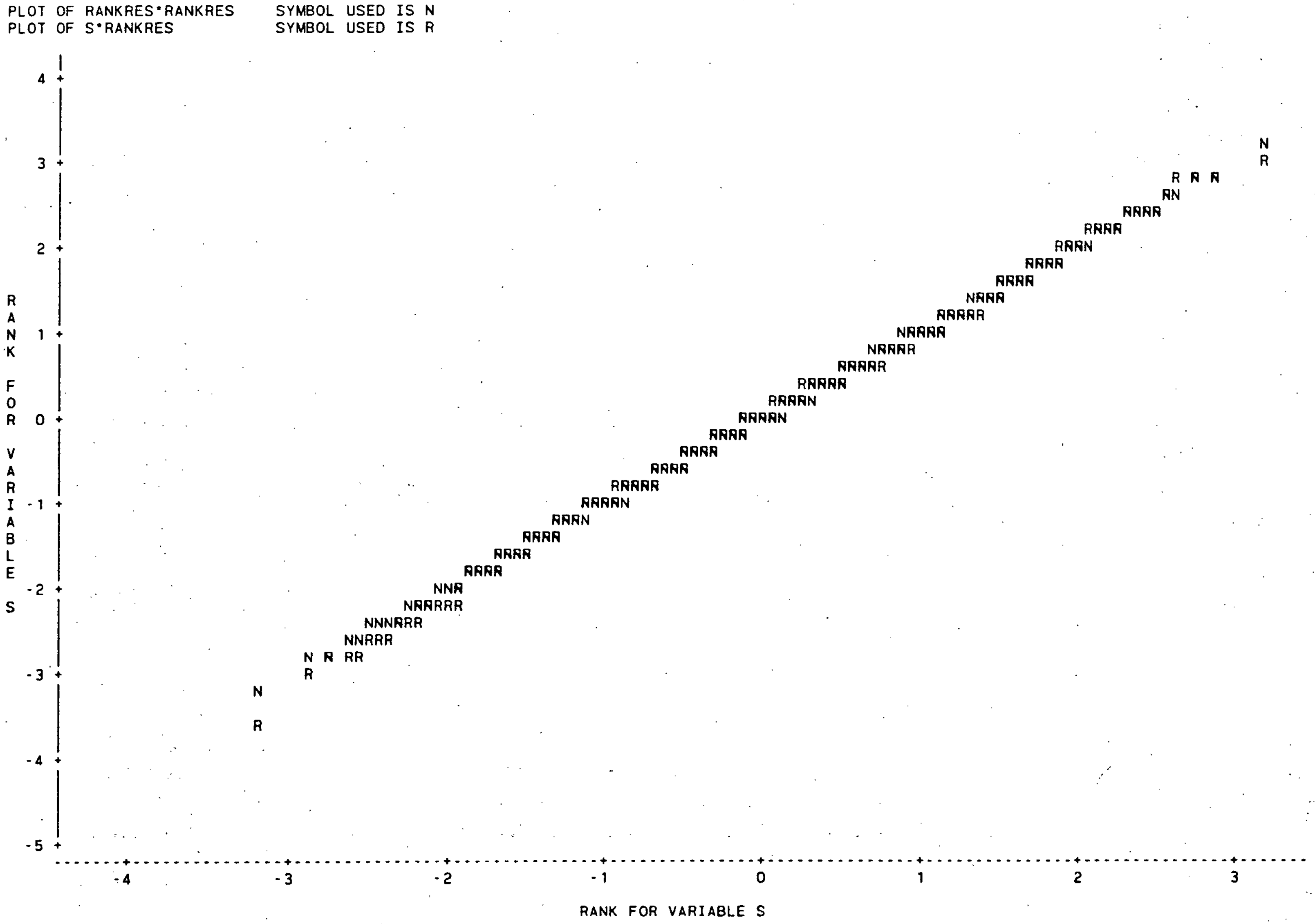
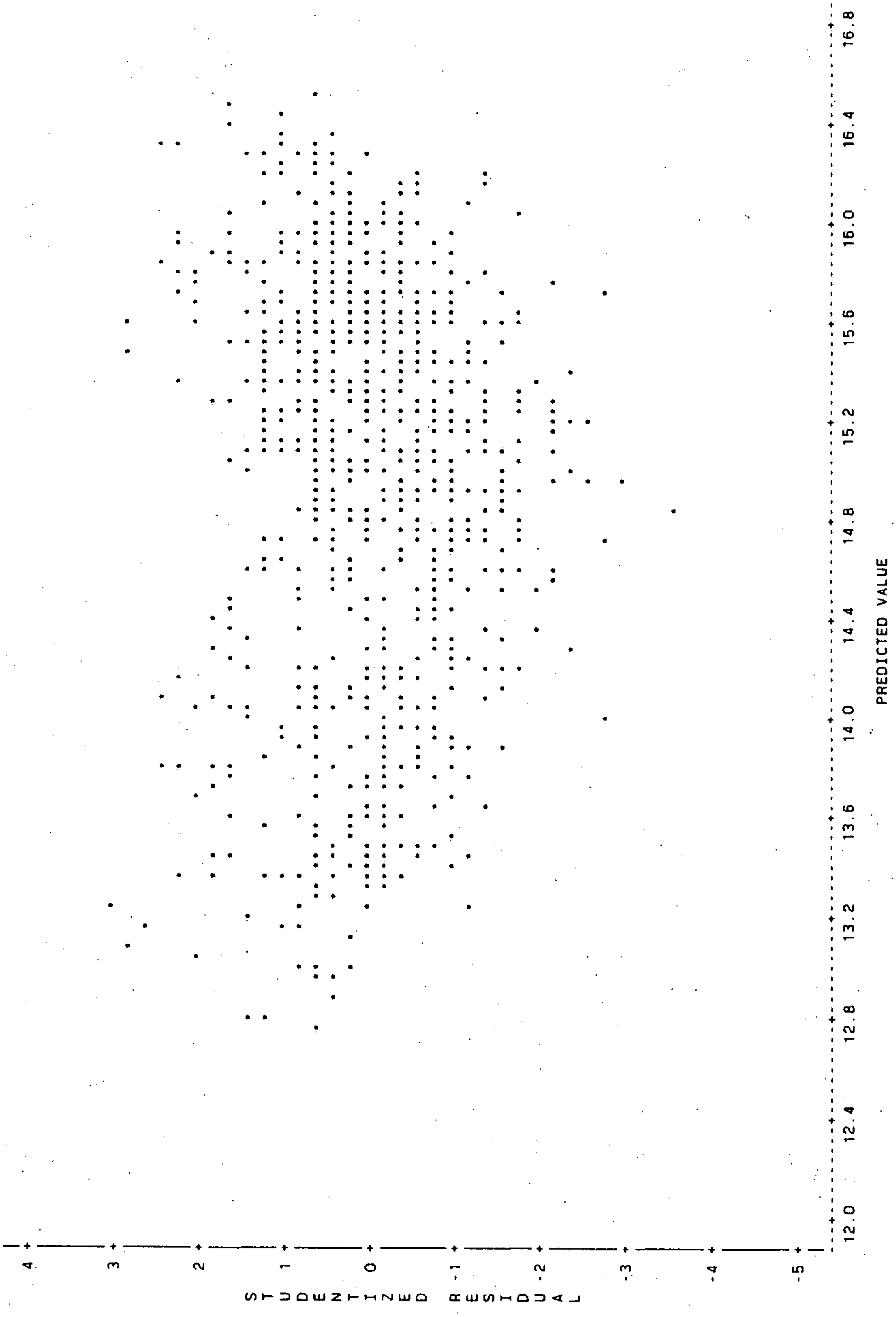


Figure 4.3

Residual Plots - Traditional Monocentric Model



The normal probability plots(Figure 4.2) and residual plots(Figure 4.3) of the negative exponential equation confirmed the normality and randomness of the error term. No outliers were found based on the critical value for the outlier using "R-student."

b. Trend Surface Analysis

The regression results of trend surface analysis (1st to 6th degree polynomial) appear on Table IV.4. All regression equations are significant in terms of their F-values. The choice among the six polynomial equations estimated in this section is based on contributed F-values. A contributed F-value is defined as:

$$F = [R_e^2/df_1]/[(1-R_t^2)/df_2].$$

where

R_e^2 = extra R^2 given by surface of order n+1 over one of order n.

R_t^2 = Total R^2 accounted for by surface.

df_1 = degrees of freedom associated with the added components, 3 for a quadratic over a linear, 4 for a cubic over a quadratic, and so on.

df_2 = degrees of freedom associated with the residuals calculated as total degrees of freedom less the number of independent variables.

When we look at "Contributed F-values" in Table IV.4, we

Table IV.4
Regression Results (b)
Trend Surface Analysis

	1st Degree	2nd Degree	3rd Degree	4th Degree	5th Degree	6th Degree
INTERCEPT	14.2466***	15.0739***	14.4132***	11.3179***	15.0469***	6.3460
TIME	0.5859E-01***	0.5929E-01***	0.5891E-01***	0.5944E-01***	0.5957E-01***	0.5987E-01***
X	-0.8445E-03***	-0.2029E-02***	-0.1387E-02***	0.5714E-02**	-0.6269E-02	0.1877E-01
Y	0.2691E-03***	0.6663E-03***	0.1626E-02***	0.2786E-02**	0.1916E-02	0.1541E-01
X^2		0.1771E-06***	-0.3707E-06	-0.5293E-05**	0.9494E-05	-0.3019E-04
XY		0.2528E-06***	0.4633E-06	-0.3776E-05	-0.6481E-06	0.4726E-05
Y^2		-0.2484E-06***	-0.8802E-06***	0.8157E-06	-0.1107E-05	-0.3314E-04***
X^3			0.2068E-09*	0.1609E-08	-0.8555E-08	0.3060E-07
X^2y			-0.3598E-09**	0.1733E-08	0.3952E-08	-0.4352E-07
XY^2			0.3494E-09***	0.8771E-10	-0.3525E-08	0.6122E-07**
Y^3			-0.1489E-10	-0.5044E-09**	0.1848E-08	0.2630E-08
X^4				-0.1668E-12	0.3798E-11	-0.1658E-10
X^3y				-0.1597E-12	-0.4485E-11	0.3405E-10
X^2Y^2				-0.2746E-12	0.4849E-11*	-0.3567E-10
XY^3				0.2519E-12	0.1919E-11**	-0.6089E-11
Y^4				-0.7824E-14	-0.1052E-12	0.1521E-12
X^5					-0.6603E-15*	0.3787E-14
X^4Y					0.1341E-14*	-0.6908E-14
X^3Y^2					-0.1678E-14***	0.2262E-14
X^2Y^3					0.8348E-15**	0.8892E-14
XY^4					-0.1220E-16	-0.2591E-14
Y^5					-0.2702E-16	0.4331E-15
X^6						-0.8359E-18
X^5Y						-0.4685E-18
X^4Y^2						0.2697E-17
X^3Y^3						-0.4285E-17***
X^2Y^4						0.2264E-17***
XY^5						-0.6705E-18*
Y^6						0.7444E-19
F-value	742.225	438.324	271.484	187.463	135.624	104.501
Adjusted R^2	0.7267	0.7586	0.7641	0.7701	0.7722	0.7763
Contributed F		36.516***	4.809***	4.280***	1.131	2.216**

Notes: *** = Significant at 0.01 level. ** = Significant at 0.05 level. * = Significant at 0.1 level.
X = X coordinate. Y = Y coordinate.

find that the value of the 5th degree polynomial is not significant(1.131). Therefore, the 4th degree polynomial is chosen as the most reliable specification for trend surface analysis.

The normal probability plots and residual plots appear in Figure 4.4 and 4.5, respectively. There is no indication that they violate the normality and randomness assumptions of the error term. No outliers were detected in the data set.

c. Comparison of the Two Models

1. Adjusted R^2, Akaike Information Criterion, and PRESS statistics are utilized to select between the traditional monocentric model and trend surface analysis.

- Akaike Information Criterion can be defined as follows[21]:

$$AIC = [(-2/T) \cdot \log L_1(y, \hat{\theta}_1)] + [2K_1/T] \qquad [4.1]$$

where

T = Number of observations;

K_1 = Number of independent variables; and

$L_1(y, \hat{\theta}_1)$ = Likelihood function.

For the linear statistical model, Equation [4.1] can be reduced to

[21] Amemiya, T. (1980), p343.

Figure 4.4

Normal Probability Plots - Trend Surface Analysis

PLOT OF RANKRES*RANKRES   SYMBOL USED IS N
PLOT OF S*RANKRES   SYMBOL USED IS R

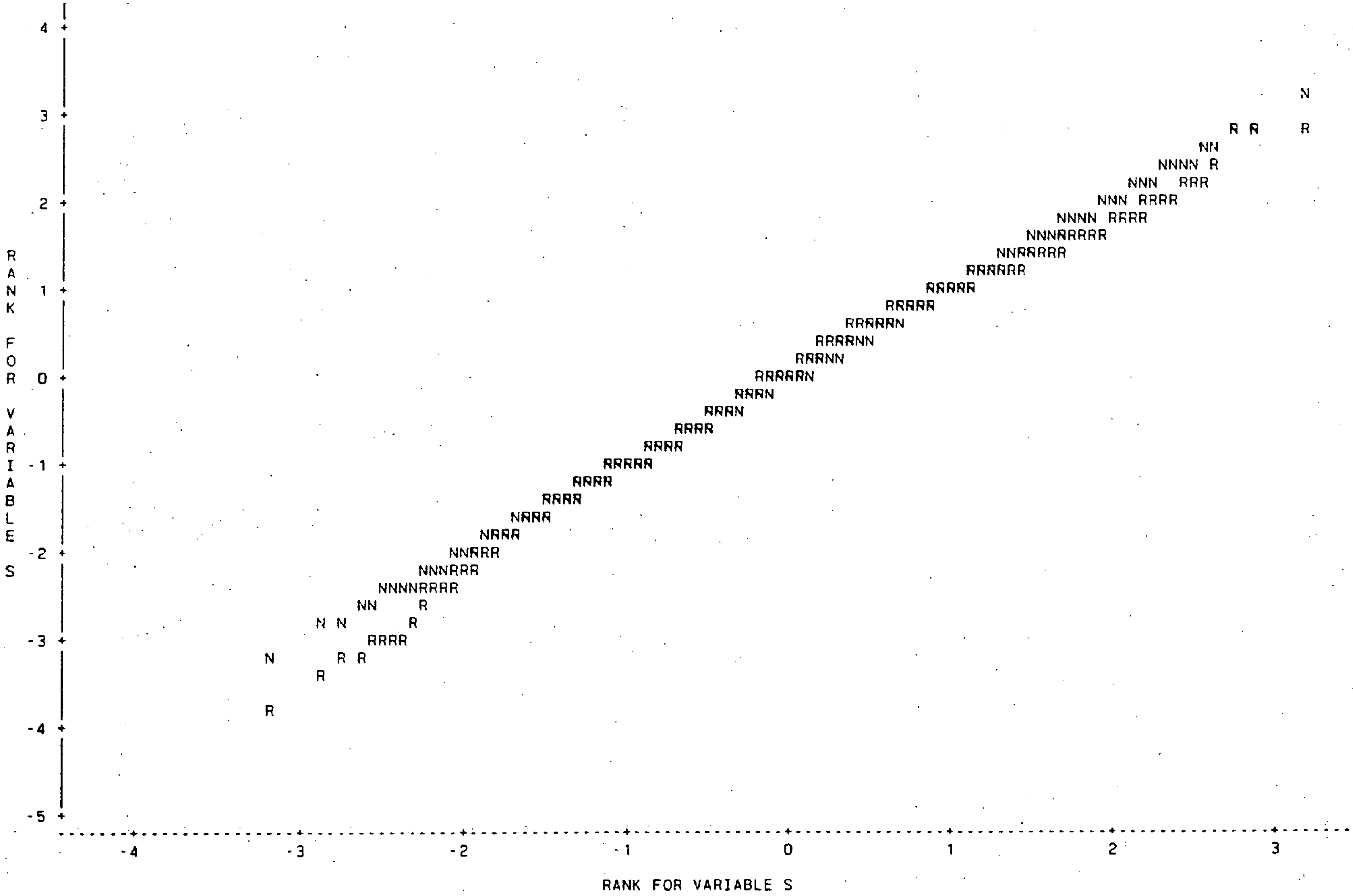
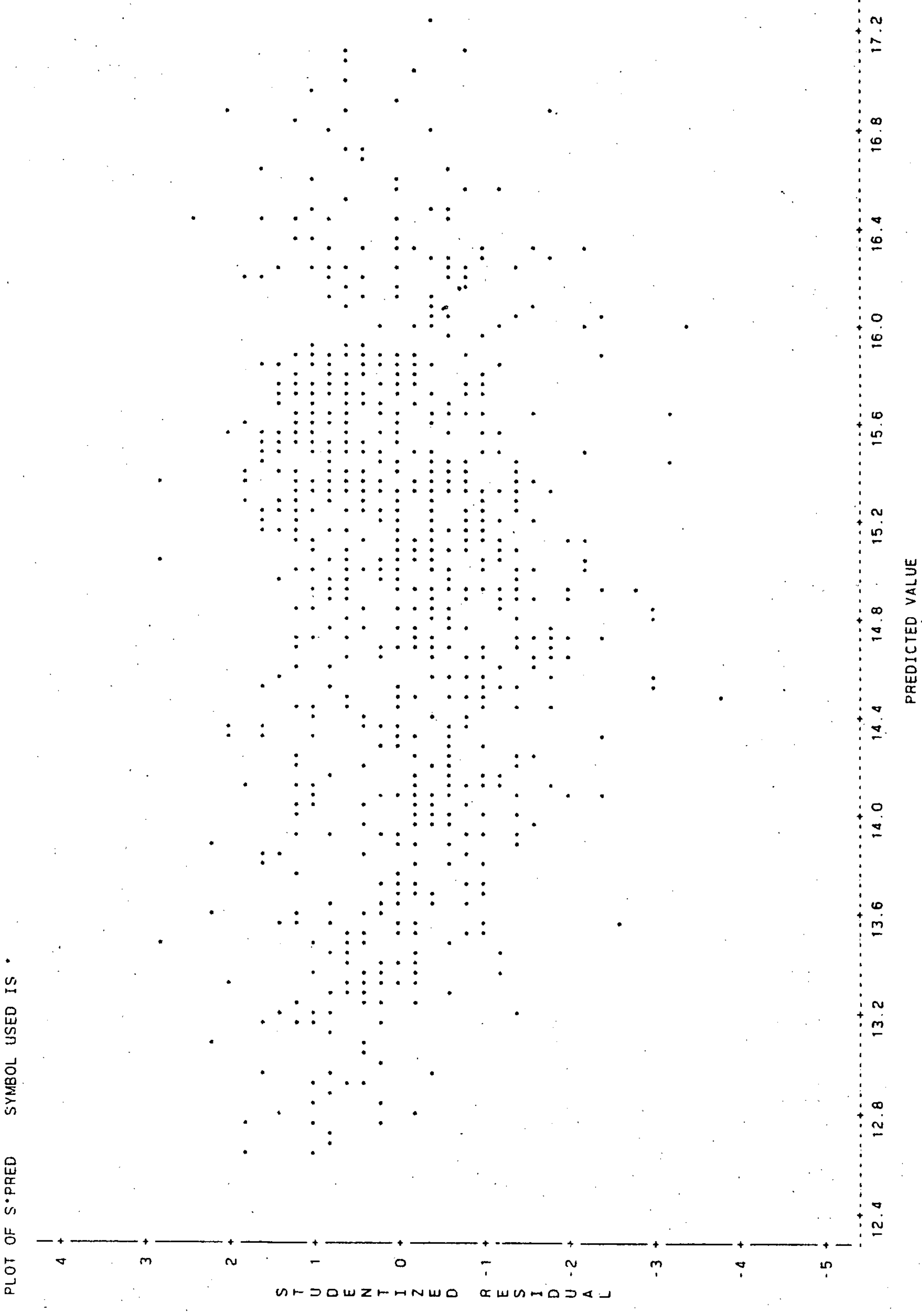


Figure 4.5

Residual Plots - Trend Surface Analysis



$$AIC = \log[(y'M_1y)/T] + 2K_1/T \qquad [4.2]$$

where

y = Vector of observations;

$M_1 = I - X_1(X_1'X_1)^{-1}X_1'$; and

$y'M_1y$ = Residual sum of squares.

If K_1 (number of independent variables) is constant, a smaller AIC indicates a smaller residual sum of squares ($y'M_1y$). In other words, a smaller AIC means better goodness-of-fit. By including the second term on the right-hand side of Equations [4.1] and [4.2], AIC explicitly incorporates the penalty for increasing the number of independent variables. Using AIC, we can compare models which have different numbers of independent variables. Akaike Information Criterion requires us to select the model for which the value of the above AIC is minimum.

• PRESS (Prediction Sum of Squares) statistic is defined as[22]:

$$PRESS = \sum_{i=1}^{n} (y_i - \hat{y}_{i,\,-i})^2$$

where

n = Number of observations;

y_i = Actual value of "ith" observation; and

$\hat{y}_{i,\,-i}$ = Predicted value of "ith" observation using the data "ith" observation deleted.

[22]Myers, R.H. (1986), p.107.

The PRESS statistic reflects the prediction capabilities of a model. It is the sum of prediction errors $(y_i - \hat{y}_{i,\,-i})$. The predicted value, $\hat{y}_{i,\,-i}$, is derived by not using the observation y_i. "Thus, in this way, the observation y_i was not simultaneosly used for fit and model assessment, this being the true test of validation."[23] The best model is the one with the smallest PRESS.

Adjusted R^2, AIC, and PRESS are shown below in order to compare a) the traditional monocentric model (negative exponential function) and b) trend surface analysis (4th degree polynomial).

MODEL	$\bar{R}^2$	AIC	PRESS
Monocentric	0.6417	-0.9154	334.57
TSA	0.7701	-1.3293	229.39

Comparing these statistical figures, we find that trend surface analysis is consistently superior to the traditional monocentric model. We can conclude that trend surface analysis is the better model for explaining land value variations in the Tokyo CBD based on the three statistics.

2. In addition to the above statistics, predicted land values based on the traditional monocentric model and trend surface analysis are calculated and compared with actual

[23] Myers, R.H. (1986), p.106.

land values in the following way:

i) The study area is divided into 45 subareas.

ii) All previous land transaction prices are converted to 1987 prices using land price indices which were compiled by the Japan Real Estate Institute. The indices record semi-annual land price increases for typical commercial land in the study area.

iii) The average of the 1987 land values obtained in Step ii) is calculated for each subarea.

iv) Two kinds of predicted 1987 land values are calculated for each subarea. One is based on the best functional form of the traditional monocentric model, using the distance from the central point of each subarea to the center of the CBD. The other is based on the preferred degree of polynomial equation of trend surface analysis, utilizing location coordinates of the central point of each subarea.

v) Three-dimensional pictures and contour maps are produced. In each case a comparison will be drawn between the actual land values and the predicted land values. A software package called "DISSPLA" is utilized to obtain these pictures.

Figures 4.6 and 4.7 represent actual average land values in 1987, whereas Figures 4.8 through 4.11 represent

Figure 4.6

ACTUAL LAND VALUE IN 1987

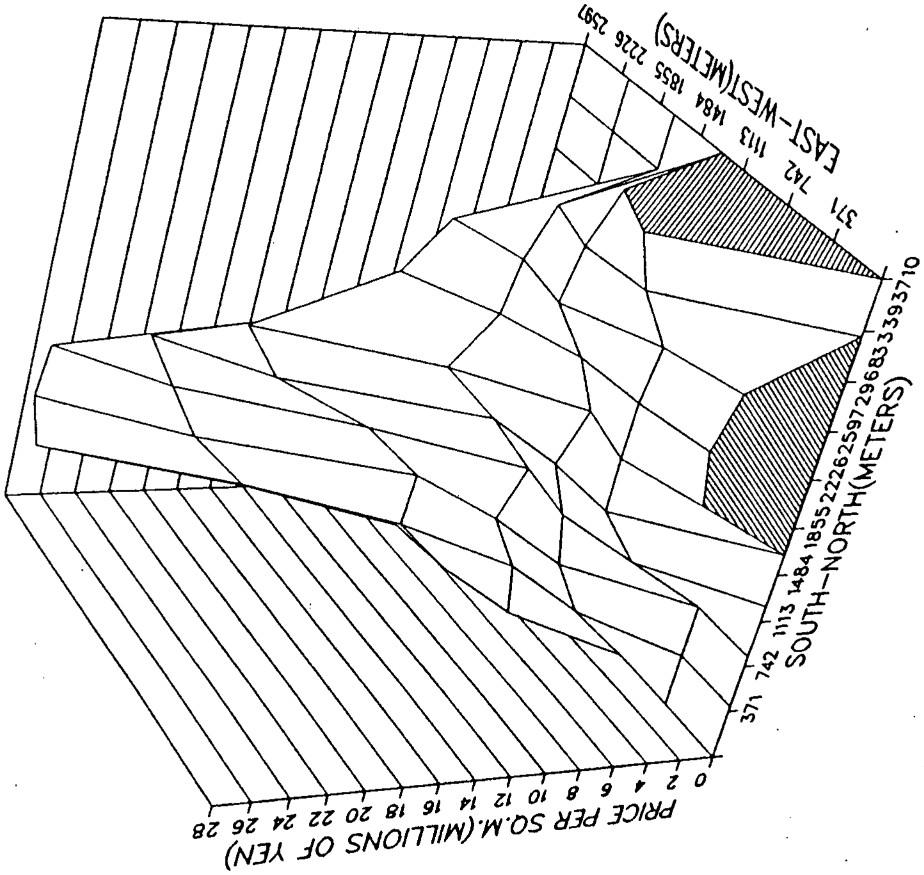


Figure 4.7

ACTUAL LAND VALUE IN 1987

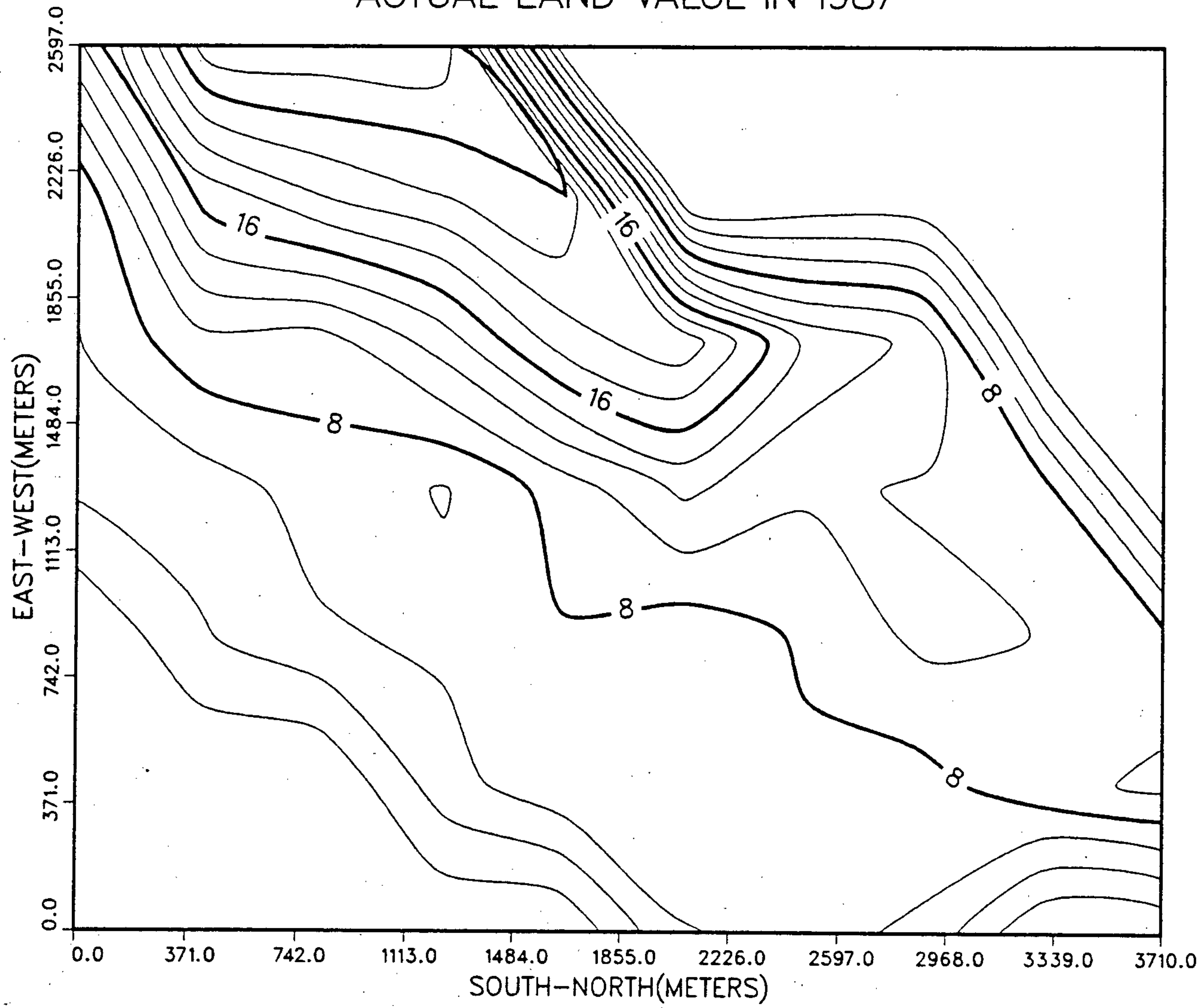


Figure 4.8

PREDICTED LAND VALUE IN 1987 (MONOCENTRIC MODEL)

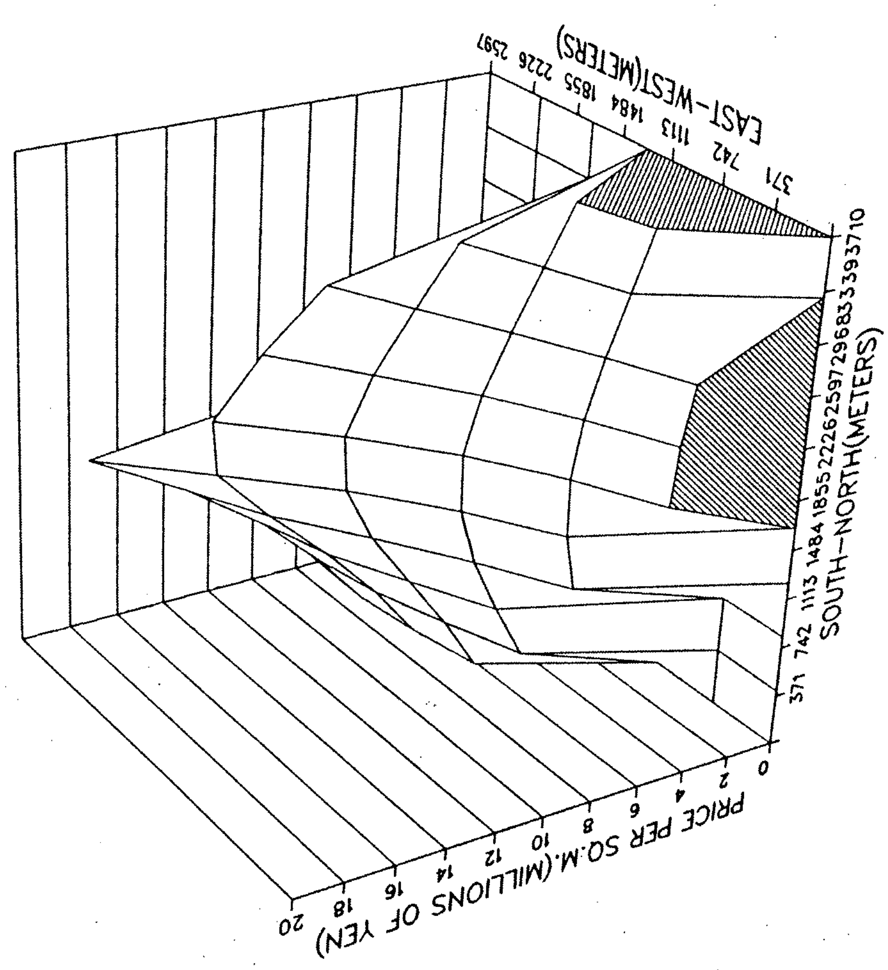


Figure 4.9

PREDICTED LAND VALUE IN 1987 (MONOCENTRIC MODEL)

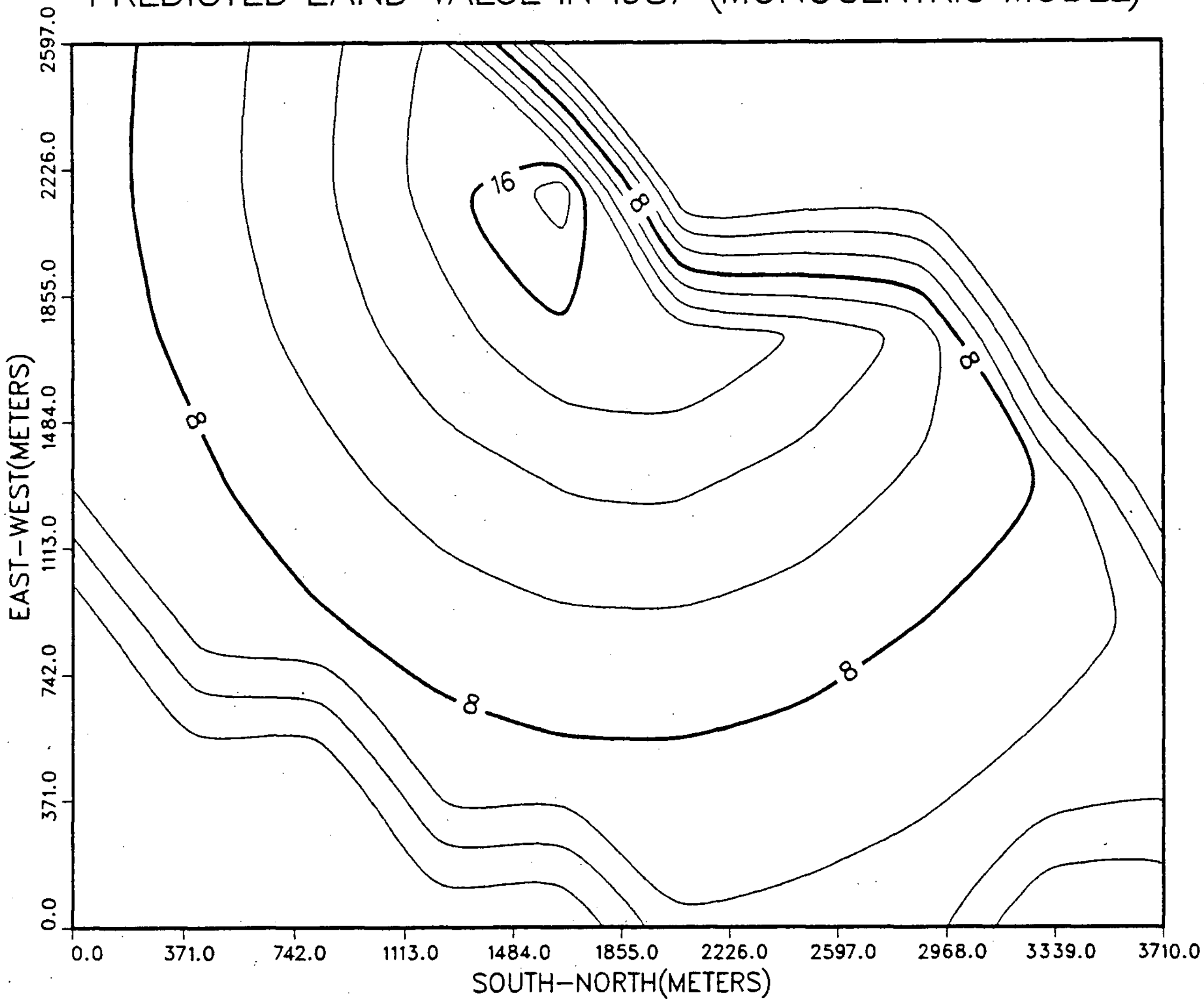


Figure 4.10

PREDICTED LAND VALUE IN 1987 (TSA)

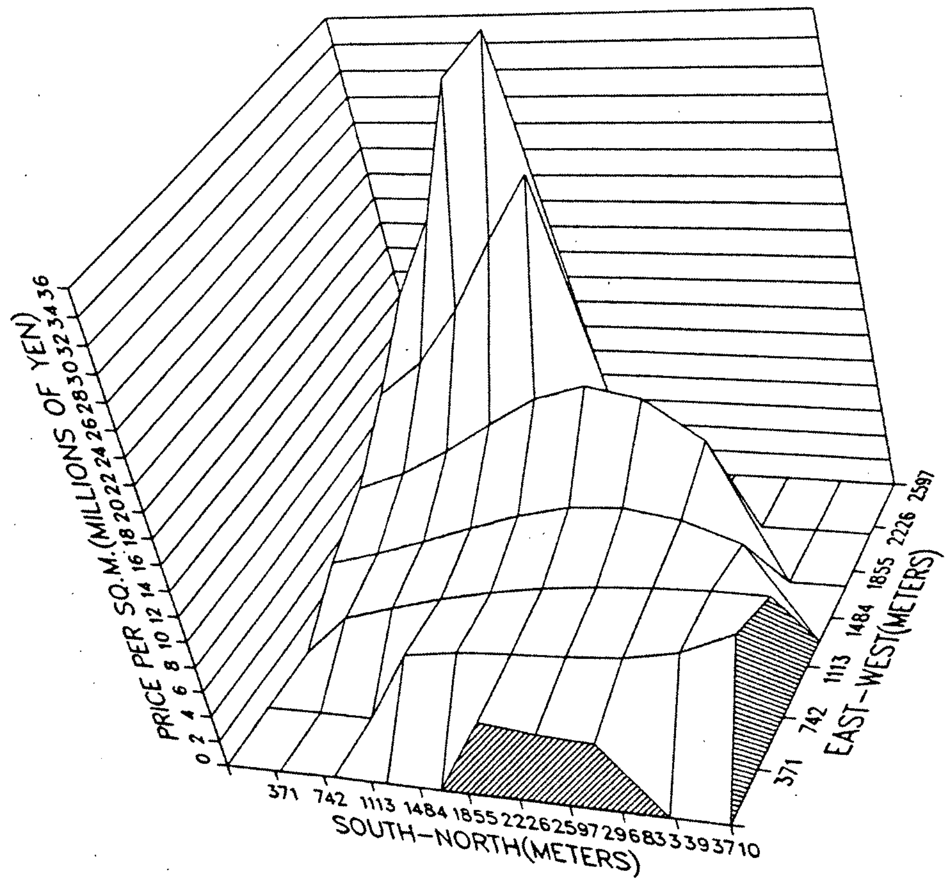
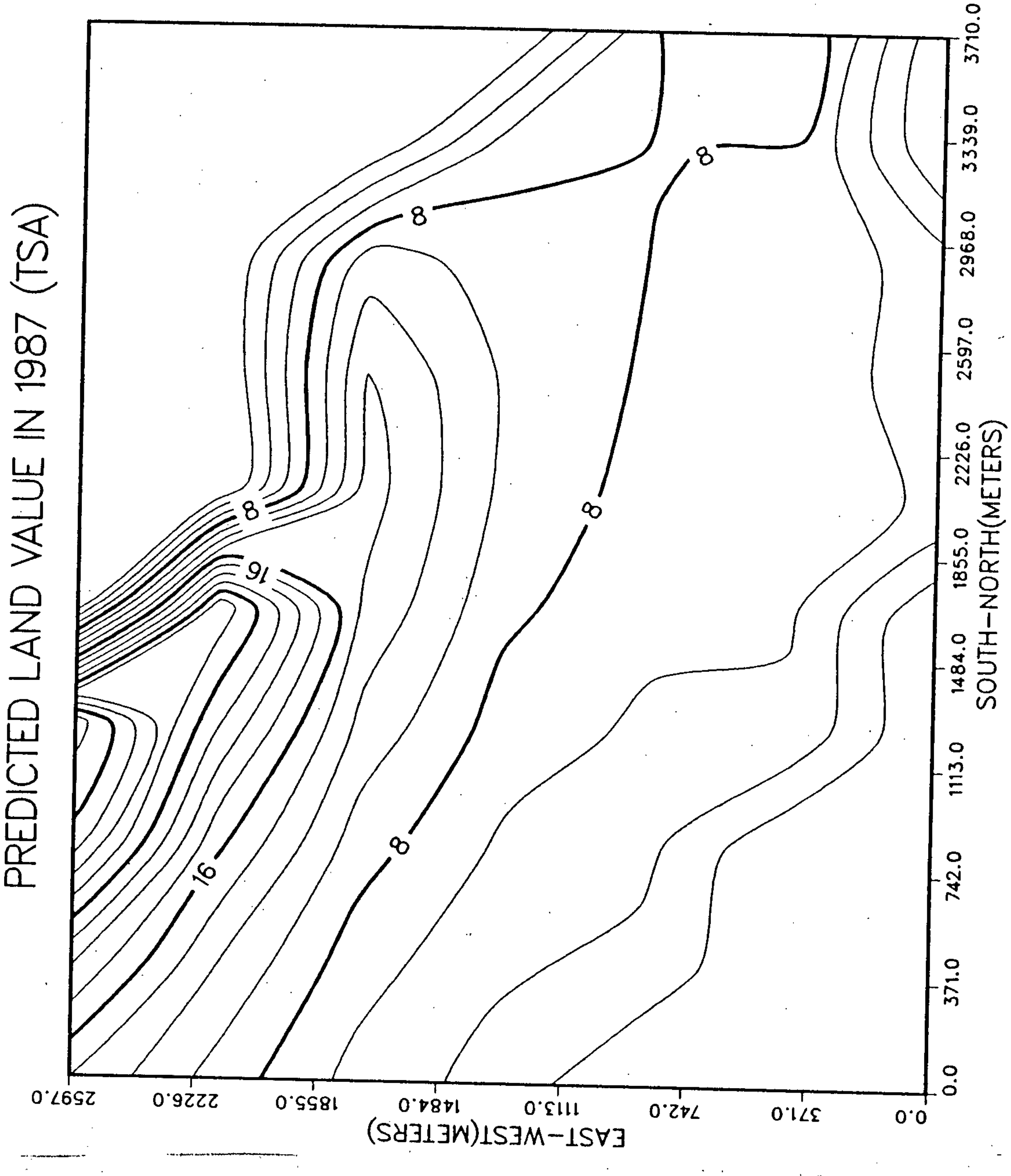


Figure 4.11


PREDICTED LAND VALUE IN 1987 (TSA)
8
16
SOUTH–NORTH(METERS)
0.0
371.0
742.0
1113.0
1484.0
1855.0
2226.0
2597.0
2968.0
3339.0
3710.0
EAST–WEST(METERS)
0.0
371.0
742.0
1113.0
1484.0
1855.0
2226.0
2597.0

values predicted by the traditional monocentric model (Figures 4.8 and 4.9) and trend surface analysis (Figures 4.10 and 4.11) for the same year. Comparing predicted land values, we notice that trend surface analysis produced a three-dimensional shape and contour map more similar to actual land values than the traditional monocentric model. Both actual land values and land values predicted by trend surface analysis show a peak in the Ginza area, whereas the traditional monocentric model does not capture the high land prices in the Ginza area.

From this analysis of statistical figures and predicted land values, we recognize the superiority of trend surface analysis. This result verifies that there are externalities and other factors which affect land values within the CBD. In other words, the test of monocentric and nonmonocentric models proved the existence of complex land value variations within the CBD.

2. Analysis of Determinants of CBD Land Value Variations

Several combinations of independent variables discussed in Part 2 of Section C in this chapter were regressed on the natural log of land price per square meter. Because we included some distance variables , we encountered collinearity problems.

In order to determine the existence of collinearity, we used two statistical devices: Variance Inflation Factor(VIF) and Condition Number. VIF is defined as[24]:

$$VIF = 1/(1 - R_i^2)$$

where R_i^2 is R^2 produced by regressing the independent variable x_i against other independent variables. VIF has a limitation that it cannot distinguish between several simultaneous collinearities. VIF which is greater than 10 indicates harmful collinearity.[25]

Condition Number is based on eigenvalues and defined as:

$$\text{Condition Number} = [(\text{Largest Eigenvalue})/(\text{Smallest Eigenvalue})]^{1/2}$$

Condition Number of 30 or more indicates moderate to strong collinearity.[26]

We employed "10" for VIF and "30" for Condition Number as cut-off values for deciding whether or not collinearity exists in a regression analysis. Three equations are presented in Table IV.5. They cleared the above cut-off values. Other specifications, such as regression equations containing both DISCEN and FAR variables, produced very

[24]Myers (1986), p.78.
[25]Neter et al. (1985), p.392 and Kennedy (1985), p153.
[26]Weisberg (1985), p.200.

Table IV.5
Regression Results (c)
Hedonic Approach

	Equation (1)	Equation (2)	Equation (3)
INTERCEPT	13.3344	13.6203	11.4231
	(170.926)***	(166.359)***	(74.202)***
TIME	0.06003	0.05983	0.05897
	(48.505)***	(44.895)***	(47.099)***
CENDIS	-0.00049	-0.00031	—
	(-11.779)***	(-5.343)***	
GINZADIS	—	-0.00023	—
		(-7.966)***	
STADIS	-0.00067	-0.00085	-0.00065
	(-5.002)***	(-5.799)***	(-4.634)***
SIZE	0.00010	0.00008	0.00009
	(1.577)	(1.077)	(1.384)
CORNER	0.24457	0.25708	0.25014
	(4.274)***	(4.174)***	(4.293)***
SHAPE	-0.54022	-0.57593	-0.48385
	(-5.640)***	(-5.584)***	(-4.952)***
ROAD	0.02202	0.02276	0.01326
	(10.763)***	(10.343)***	(6.017)***
GINZA	0.66347	—	0.58148
	(14.256)***		(11.625)***
FAR	—	—	0.21973
			(10.215)***
Adjusted R^2	0.7773	0.7423	0.7690
Condition Number	11.694	12.718	26.085

NOTES:

- t-statistics are in parenthses.
- *** indicates significant at 1% level.
- N = 835 for all estimates.
- P = Land price (Yen per square meter)
- TIME = Time variables (1 = 1975 1st quarter, 2 = 1975 2nd quarter, ..., 52 = 1987 4th quater)
- CENDIS = Distance to the central point of the CBD
- GINZADIS = Distance to the central point of the Ginza.
- STADIS = Distance to the nearest station.
- SIZE = Lot size.
- CORNER = (1 = Corner lot, 0 = Otherwise)
- SHAPE = (1 = Irregular shape, 0 = Regular shape)
- ROAD = Road width.
- GINZA = (1 = lot in the Ginza, 0 = Lot elsewhere)
- FAR = Floor Area Ratio

large VIF's and Condition Numbers. FAR and DISCEN indicate high correlation because the central part tend to be assigned a higher FAR than the peripheral area of the CBD.

The coefficients in all three equations are highly significant with the exception of the SIZE variable. The signs of all coefficients except those of the SIZE variable had the results as we expected. The hedonic regression analyses explain 74% - 78% of land price variations of the study area. Based on the critical value for the outlier test, one outlier was detected. Table IV.5 gives the results of the regression analysis which employed the data with the outlier deleted. The normal probability plots and residual plots did not show any violation of the assumption of the error term.

(a) Basic Equation

First we will consider Equation (1) in Table IV.5 as a basic model. According to the analysis, land prices increase about 6% every quarter, i.e., about 26% a year, on the average during the study period. This annual figure is larger than the actual land price increase, which was calculated as 20% based on the land price indices compiled by the Japan Real Estate Institute.

Land prices decrease about 0.05% every meter from the central point, other things being equal. They fall 0.07% every meter from a station within the CBD, other variables being constant. The location of the railway or subway stations were confirmed to be important. This is an expected result because most of commuters use railways or subways and because employees travel within the CBD using them. In every equation which included the DISFIN variable, the sign of the variable was incorrect. It is conjectured that this incorrect sign was a result of the overwhelming impacts of DISCEN and DISGIN.

SIZE is the only variable which had an insignificant coefficient. The insignificance of lot size can be explained by the fact that even piecemeal lots tend to be developed in the study area. Even small buildings built on those sites can charge market rents. Therefore, scale economies in lot size are not realized.

Since both CORNER and SHAPE are dummy variables, we cannot employ their coefficients directly as percentage effects on the dependent variable. We used the following formula in Halvorsen and Palmquist (1980) to convert the coefficients into percentage effects:

$$g = 100 \cdot [(\exp C) - 1]$$

where

g = Percentage effect on the dependent variable and

C = Coefficient of a dummy variable.

Employing the above formula, we found that a corner lot is about 28%[27] more valuable than a site in the middle of a block and that an irregular-shaped lot is about 42%[28] less valuable than a regular-shaped lot.

Each meter of road width adds 2.2% to land prices. For instance, a lot abutting on a 15 meter wide road costs 42%[29] more than a lot abutting on a 4 meter wide road. Another variable included in neighborhood-specific price influencing factors is GINZA. Using the above Halvorsen and Palmquist's formula, we can estimate that land in the Ginza costs about 94%[30] more than land elsewhere.

(b) Other Equations

Equation (2) deleted the GINZA dummy variable from Equation (1) and included the DISGIN variable. Because now we have three accessibility variables instead of two, the value of the coefficients changed. Other variable being equal, land prices decrease about 0.02% every meter away from the center of the Ginza.

[27] $100 \cdot [\exp(0.24457) - 1] = 27.7\%$.
[28] $100 \cdot [\exp(-0.54022) - 1] = -41.7\%$
[29] $100 \cdot (1 + 0.022)^{16} = 41.6\%$
[30] $100 \cdot [\exp(0.66347) - 1] = 94.2\%$

Equation (3) deleted the DISCEN variable from Equation (1) and included FAR. Since both ROAD and FAR variables are proxies for development suitability of a neighborhood, the inclusion of FAR made the coefficient smaller than that of Equation (1). The high land value in the Ginza area was partly explained by FAR because most of the area is assigned to high FAR values. Therefore, the coefficient of FAR variable is smaller than that of Equation (1). The coefficient of the FAR variable indicates that a one unit increase in FAR results in about a 22% increase in land prices.

V. SUMMARY AND CONCLUSIONS

This thesis has examined land price variations within the CBD. Its general motivation stemmed from a) the existence of externalities and other price influencing factors which cannot be explained by the traditional monocentric model and b) the fact that very few studies have been done on CBD land prices.

Traditional monocentric model literature stressed the importance of centrality. Rents decline monotonically with distance from the central point. In the context of CBD land value variations, the model predetermines the central point from which produced goods are exported. Transportation costs to the central point are crucial in order to derive a land rent gradient of the model. A negative exponential function is often utilized to estimate land rents because of its simple form. However, the functional form was criticized by both U.S. and Japanese researchers. In addition, externalities such as air pollution distort the simple monotonic function. Nonmonocentric models illustrate land values without specifying the central point. The concept of agglomeration economies plays an important role in demonstrating the ambiguity of the curvature of land rent gradients.

Using these models as the conceptual framework, past empirical studies were reviewed focusing on appropriate specifications for the purpose of exploring: a) comparison of monocentric and nonmonocentric models and b) analysis of determinants of CBD land value variations. A negative exponential function was one specification for the monocentric models. The double power series of location coordinates, called trend surface analysis, was the specification for nonmonocentric models. Trend surface analysis employs directed distance rather than one-dimensional straight distance which is inherent to the traditional monocentric model. We do not need to specify the central point in trend surface analysis. Each location is identified based on a Cartesian plane placed on the CBD.

However, neither a negative exponential function or trend surface analysis can effectively analyze the second question, i.e., determinants of CBD land value variations. This is because both functions include only the location factors of these determinants in the analysis. Employing the hedonic-price approach, we examined three categories of determinants: 1) accessibility; 2) site-specific price influencing factors; and 3) neighborhood-specific price influencing factors.

The data of the Tokyo CBD was utilized to answer the above two questions. The data contains 836 vacant land transactions taking place from 1975 to 1987. Trend surface analysis turned out to be superior to a negative exponential function in terms of adjusted R^2, AIC, and PRESS statistics. Predicted values of trend surface analysis were much more realistic than those of a negative exponential function. The nonmonocentric specification was better able to explain land value variations within the CBD.

Among the three categories all variables were highly significant except the coefficient of lot size. The goodness-of-fit of the regression equation was satisfactory. Centrality was important for the Tokyo CBD land value. Accessibility to a station and proximity to the Ginza area were also crucial determinants. As we expected, corner location, lot shape, road width, and floor area ratio appeared as influential determinants on the CBD land values.

In conclusion, we believe that this thesis contributes to research on land value variations. Trend surface analysis was proved to be a useful approach for predicting land value variations. Another major finding of this thesis is that three categories of land value determinants are applicable to the CBD data. We believe that professions such as assessors and appraisers can utilize the techniques explored in this thesis as a support when they determine specific land values.

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