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The metropolitan suburbanization of population and employment in U.S.

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1. INTRODUCTION

1.1 General Background

Since World War II, the U.S. urban population and employment generally tends to become less centrally located and this continues as an historical trend.

Before 1920, there existed increasing concentration and increasing centralization[1] in Metropolitan Standard Areas (MSAs)[2]. Between 1920 and 1970, it was increasing concentration and decreasing centralization (i.e., decentralization). Since 1970, decentralization clearly continued, however, its pace had slackened[3].

Hence residents have been moving from central cities to the suburbs within most U.S. Metropolitan areas. Many urban economists called this 'suburbanization' or 'decentralization' in metropolitan areas. Many economists have focused their research

[1] According to 'Urban Economics and Public Policy', Helibrun (1989) defines centralization as a rise in the proportion of metropolitan population in central cities and concentration is the population growth between metropolitan and non-metropolitan area.

[2] MSAs are defined in the 1980 Census of Population and Housing. The general concept of a metropolitan area is one of a large population nucleus, together with adjacent communities which have a high degree of economic and social integration. Each MSA has one or more central counties containing the area's main population with a central city of at least 50,000 inhabitants.

[3] The actual figures in the trend of population and employment growth are provided in 'Urban Economics and Public Policy', Helibrun (1989, pp. 28-35).

on the phenomenon of suburbanization and made many contributions. The more distinguished are Edwin S. Mills, Richard Muth, D. Bradford and H. Kelejian, James B. Kau and Cheng F. Lee, and Donald J. Bogue, and so on.

Many causes of suburbanization have been suggested including income growth, population measure, or other social determinants such as high crime rates, high non-white residency in central cities, education, taxes, etc. Income growth might draw higher income people away from the central city if these households prefer quiet environments or large living space to intense land uses in the central city. The larger populated MSAs might have a higher rate of suburbanization. Social problems such as discrimination with a high proportion of blacks in the central city and higher crime rates in the central city could be a cause of suburbanization. Mills and Price (1984) did much to contribute to the explanation of suburbanization. Muth (1961) also used some surrogates for commuting to explain the phenomenon, such as the car registration per capita, mileage of local transit systems per square mile, etc.

Suburbanization did not only occur in the resident population but also in employment sectors. Firms might locate near to the place where people live, so employment is expected to follow the population and further suburbanization will occur.

Mills and Price conducted their studies of suburbanization in 1970. This study measures the degree of suburbanization among MSAs in the 1970-1980 period, to explain the phenomenon with similar explanatory variables and to compare the results with those of Mills and Price.

It is difficult to define 'suburbanization' or 'decentralization'. Bogue (1954) tried to define it as the settlement and commercial and industrial development of areas peripheral to central cities. He explained suburbanization by two characteristics.

> The first is the degree and the second is the rate, or speed, of suburbanization. At any given moment, an SMA may be highly suburbanized as a result of past suburban growth, yet may be suburbanizing at a slow rate at the present. Conversely, an SMA that now has only very small suburbs and a low degree of suburban development may be undergoing a very rapid rate of suburbanization.

Data sources usually dichotomize information by central city and out of central city within an SMSA or MSA. In this study, suburbanization means the population or employment moving from the central city to the suburbs beginning from the boundary of the central city. The problem is how to define a central city. According to the definition from 'County and City Data Book', (U.S. Department of Commerce, 1977), central cities are generally a political subdivision of a State within a defined area over which a municipal corporation has been established to provide local governmental functions, facilities and services. The central city is recognized as the city with the largest population in the MSA. The suburb is then viewed as the remainder of the metropolitan area. More precise definitions of the two areas are precluded due to the restriction on available data.

This study is organized as follows: in Chapter Two, the literature is reviewed in three sections: measure of suburbanization, empirical results and conclusion; Chapter Three provides the model specification divided into household location and employment density gradient; Chapter Four is the empirical analysis which contains alternative dependent variables, independent variables, data collection, empirical results, a conclusion, and additional calculations.

2. LITERATURE REVIEW

2.1 Introduction

As stated in the introduction in the preceding chapter, we observed the phenomenon of suburbanization, both in population and in employment, that occurred prevalently within the metropolitan area after World War II although it had slightly predated the war. In this chapter, some of the previous studies of suburbanization are reviewed as follows. First, alternative measures of suburbanization are discussed. Then, the estimation techniques related to the explanation of the metropolitan suburbanization is presented. A final section offers some conclusions.

2.2 Measure of Suburbanization

There are three major methods to measure the suburbanization reviewed in this study. They are method of percentage change employed by Bogue in 1953, the negative exponential models created by Colin Clark in 1951, and the model from David Bradford and Harry Kelejian.

2.2.1 Method of percentage change

First, the method of percentage change is reviewed. Bogue, who denoted suburbanization as being the settlement and commercial and industrial development of areas peripheral to central city, took various percentage changes and growth rates to describe the urban distribution of population and employment. These different measures are the rate of growth and change in percent; the former is the rate of suburbanization and the latter is the degree of suburbanization. Bogue said,

> ...in seeking to explain this trend toward suburban growth, two different aspects should be considered, and each of them should be analyzed separately. The first is the degree and the second is the rate, or speed, of suburbanization.

The measures included the percent change in the total population and employment of the ring, change in percent of the S.M.A. population and employment residing in the ring, and the difference between growth rates of the central city and its ring, etc.

2.2.2 Negative exponential model

The above method is a traditional approach to interpreting the phenomenon of residential and employment suburbanization. However, Edwin Mills (1970) pointed out that, as a measure of suburbanization, percentage change of people living or working within central city and in the surrounding suburbs would generate a restriction; for example, percentage change has different meaning for various sizes of SMSAs, and the problem of annexation of the SMSA and so on. Therefore, Mills and Price (1984) took the approximately negative exponential model as a measure.

In 1951, Colin Clark first suggested the concept of a negative exponential function in which residential population density declines exponentially with distance from the city center. The model is defined as

> $y = Ae^{-bx}$, where y is the density of residential population in thousands per square mile, x is distance in miles from the center of the city. A and b are mathematically related to the total population of the city.

Clark (1951) tried to measure the trend of population growth from some cities in Europe and Australia to fit this model. Even so, no rationale for this model was offered as an explanation for the phenomenon of suburbanization.

After Clark's work, some advanced papers tried to develop the concept theoretically and empirically. Under some reasonable assumptions, Muth (1961) tried to obtain the function of housing output per unit of land and housing demand per capita, by maximizing firm's profit function and consumer's utility function. Then, he took the logarithm of the density, which is the ratio of output of housing per unit of land relative to the housing demand per capita, to derive Clark's negative exponential model.

Edwin Mills and Price (1982), who devoted much to the research of the structure of the urban economy, also carefully explored the problem of suburbanization. Edwin Mills (1972) developed the idea that the density of population and economic activity falls off smoothly and at a decreasing rate as one moves out from the city center. Although his model is closely analogous to Clark's function, Mills defined and interpreted the parameters clearly. His model is

> $D(x) = D_0e^{-bx}$ where $D(x)$ is density x miles from the center, e is the base

> of the natural logarithm, and b and D_0 are constants to be estimated from data. the parameters b and D_0 are normally positive. D_0 is density at, or near, the urban center and b is the common measure of suburbanization. An urban area is more suburbanized the smaller is b, which is referred to as the density gradient.

Indeed, he thought that the negative exponential model provides a good approximation to the degree of suburbanization.

Neidercorn (1971) attempts to erect the theoretical underpinnings for Clark's findings. Under some simplifying assumptions, he derived equations for urban land rents, net and gross population densities, as well as net and gross employment densities that have an approximately negative exponential distribution.

In addition to the above scholars, much work focused on the discussion of the model. Based on this model, Lawrence White (1977) attempted to compare the alternative empirical estimates of urban density gradients, in the monte carlo experiment: non-linear ordinary least square (OLS), and two point estimates. He concluded that generally two point estimates perform well in estimating the density gradients.

Other authors have emphasized the interpretation of density functions, such as Orley Ashenfelter (1976), Mark W. Frankena (1978), David L. Greene and Joern Barnbrock (1978), Mahlon R. Straszheim (1974),etc. Applications include Mark Dynarski (1986) who explored the relation between household formation and suburbanization, Paul K. Asahere and K. Owusu-Banahene (1982) who provided evidence on the population density function of African cities, Martin J. Beckman (1969) who derived the distribution of urban rent and residential density, and others like James B.

Kau, Cheng F. Lee and Rong C. Chen (1982), David Harrison, Jr. and John F. Kain (1974), etc. Moreover, John E. Anderson (1982) extended the analysis to provide a Cubic-Spline urban-density function to estimate urban densities on the basis of the negative exponential model. Most of the papers above are discussions based on various aspects of population distribution within an urban area.

Even though the negative exponential form seems to be a good method for estimating population density gradients, Peter Kemper and Roger Schmenner (1974) found that,

> ...the density gradient has reached the point of diminishing returns as a tool of the urban economist.... A declining exponential function fails to explain much of the spatial variation of manufacturing density.

Despite this conclusion, they still used the model to estimate the density gradients for manufacturing industry. The results are approximately consistent with both expectations and with a number of other studies of industry location.

2.2.3 Model due to David Bradford and Harry Kelejian

David F. Bradford and Harry H. Kelejian (1973) introduced a different measure of suburbanization which took the ratio of the central city population or employment to the population or employment in the urban area, $POP_{c.c.}/POP_u = F$ where $POP_{c.c.}$ is the population living in central city, POP_u is the population of the urbanized area. F is formulated as the ratio of central city area to urban area in the power of β, i.e., $(L_c/L_u)^{\beta}$. Conversely, the parameter β reflects the degree of centralization, with $0 < \beta < 1$ implying the city contain a higher proportion of population than of land area, with increasing β toward one indicating greater suburbanization and a decrease indicating greater centralization.

W. Norton Grubb (1982) also employed this measure to study the suburbanization of population and employment. However, Grubb pointed out a problem with this model, that is,

> some SMSA have larger fractions of population in their central cities simply because their cities comprise a larger fraction of the total land area.

He also provided a way to standardize the difference.

2.3 Empirical Results

Empirical analysis problems are involved in estimation techniques, and data collection. Estimation proceeded in two stages. First, we have three methods indicated above to obtain the alternative dependent variables. Then, the dependent variables were regressed on the independent variables in the regression equation $b = F(x_i)$ where b is the degree of suburbanization, and x describes various variables which possibly influenced and explained the phenomenon of suburbanization.

In this section, we review the empirical analysis in two subsections, one for population gradients and the other for employment gradients.

2.3.1 Population gradients

For the negative exponential model, three estimation techniques exist to estimate the density gradient, g, and density for the central city, D_0. They are ordinary least square (OLS) with a log-linear transformation of the model, non-linear least square estimation, and an integration technique due to Mills.

These three techniques depend on the available data. If all census data for population and employment sectors are available for each SMSA and suburbs, then the OLS and non-linear model can be used. Otherwise, the integration technique is an appropriate model for aggregated data.

Using census tract data to estimate the density gradient is the older method, either for OLS or the non-linear model. Most of the negative exponential studies used census tract data, like Colin Clark (1951), Muth (1961), Randolph C. Martin (1973) for population density, and Peter Kemper and Roger Schmenner (1974) for manufacturing industry.

These models need to distinguish population in the city center and concentric rings of the SMSAs and calculate the average density at each concentric circle[1]. Then, within each central city randomly selected census tracts, like Muth (1961), determine the average (gross) population density and the distances from the center of the census tracts to the center of the Central Business District (CBD). Randolph Martin (1973) distinguish census tracts for cities and suburbs because he wanted to see the different

[1]This average density is a kind of gross density, or population divided by all land. Actually, we should take the net density, in which the denominator is the land used for residential or employment sector's purpose.

spatial distribution of population between cities and suburbs[2].

These authors regressed the natural logarithm of census tract density on distance from CBD centers by the log-linear or non-linear model. Clark (1951), Muth (1961), and Randolph Martin (1973) used the log-linear model. For non-linear model, John Anderson (1982) pointed out that log-linear negative exponential form is not the optimal form to use for fitting urban-density patterns of many cities. Therefore, he used

> Box and Cox transformation of dependent variable, generalized density functions can be estimated with a special case of the transformation yielding the negative-exponential form.

This model followed from the non-linear pattern, which is the so called Cubic-Spline urban density function. As with John Anderson, Lawrence White (1977) has calculated density gradients from the non-linear model to compare with two-point estimates.

Often it is hard to collect the census tract data, either for population or employment. So, Edwin Mills (1970) developed a two-point estimates for dichotomous central city-suburb data which are more readily available. This method integrates the negative exponential model from zero to the boundary of the city as the total population in central city, and similarly, to integrate the model from zero to infinity to obtain total population in the metropolitan area. As Edwin Mills (1970) discussed $N(u) = D(u)\theta u$ where $D(u) = D_0e^{-\gamma u}$ the total population within k miles of the city

[2]Martin said census tracts were further distinguished by whether they were within the corporate city (city tracts) or outside the city but within the urbanized area (suburban tracts).

center,

$$N(k) = \int_0^k N(u)du = \theta D/\gamma^2[1 - (1 + k\gamma)e^{-\gamma k}] \tag{2.1}$$

and the total population in metropolitan area is the integral from zero to infinity, i.e.,

$$N = \theta D/\gamma^2 \tag{2.2}$$

As N(k), N, θ, and k are known, solve the two equations (2.1) and (2.2) for γ. Mills adopted the iteratively numerical analysis method - Newton Raphson to solve for γ and D. From the Newton Raphson technique, statistical results like R^2, t-ratio, hypothesis test, etc., are not available, but it is a way of overcoming insufficient data. Lawrence White (1977) analyzes how good the two-point estimate are compared to linear and non-linear model estimates.

After obtaining the density gradient, the second stage is to regress all the independent variables which are possible factors in explaining the difference in density gradients among cities. Those factors which have been employed are mainly divided into two classes - basic economic variables and central city social variables. The former includes income growth, size of SMSA, the interaction between population and employment suburbanization, which Muth (1961) and Mills and Price (1984) have used to explain the difference in density gradients. Generally, it is expected that the suburbanization increases with income level, population in the SMSA, as well as lag effects from population and employment. For the central city social variables, Mills and Price (1984) tried to test whether high crime, high taxes, and large minority groups in central cities are causes of rapid suburbanization in U.S. metropolitan areas. So they found that only non-white minorities in central cities have an effect on suburbanization. Muth (1961) took the age of SMA and some transport variables like vechicle miles operated per mile of line, car registration per capita in the SMA, miles of line of local transit systems per square mile, etc. These transport variables are expected to have a negative relation to density gradients, so increased accessibility decentralizes the metropolitan areas.

All studies cited above are based on the negative exponential model. Bradford and Kelejian model took the ratio of $log(POP_{c.c.}/POP_{smsa})$ relative to $log(\frac{AREA_{c.c.}}{AREA_{smsa}})$ as the dependent variable with independent variables as indicated above. W. Norton Grubb (1982) concluded that the income and nonwhite variables might generate the out-migration from central city.

2.3.2 Employment gradients

The empirical results of the employment and industry sectors are derived in a similar manner, either from the negative exponential model or from the Kelejian and Bradford model. Peter Kemper and Roger Schmenner (1974) have estimated the density gradient for manufacturing industry. Edwin Mills and Richard Price (1984) categorized the industry into four sectors, manufacturing and construction, wholesale and retail trade, private service and public administration. All density gradients for these sectors are explained by the wage rate, size of SMA, crime rates, education attainment, and tax rate. The results appear that there are nothing shown significant effects on suburbanization except for the basic economic variables, income level and the population lag variable.

2.3.3 Summary

There are many ways to measure the suburbanization of population and employment. In this study, we have reviewed methods of percentage change, the negative exponential model, and the Bradford and Kelejian model. Whatever method is used, a two stage procedure is needed to estimate the gradient and then its major determinants. In general, the factors which have an effect on suburbanization of population and employment are the income growth and interaction between population and employment.

3. MODEL SPECIFICATION

3.1 Introduction

Based on the review of various measures in the preceding chapter, it is difficult to identify a single best measure to estimate suburbanization. In this study, the same measures as used by Mills and Price will be employed and compared to analyze differences among them. A critical appraisal is also provided. This chapter gives a summary of the derivation of the negative exponential model for household and employment location. The chapter is arranged as follows: (1) household location, (2) employment location.

3.2 Household Location

In this section, the negative exponential model is discussed in three subsections. They are equilibrium of household, population density gradient of the negative exponential model, and a comparison between the density gradient and percentage change.

3.2.1 Equilibrium of household

Alonso William (1964) demonstrated the equilibrium of household under certain budget constraints. Assume consumers have a utility function $U = U(Z, Q, K)$ with an increasing marginal disutility to distance, t, under the budget constraint $Y = P_z Z + P(t)Q + K(t)$ where Y is money income, Z is goods or services, P_z is price of Z, P(t) is price of land at distance t, Q is consumption of land, and K(t) is commuting cost at t. Again, assume P(t) declines negative exponentially with distance and K(t) increases linearly with distance. The relation between $P'(t)$ and $K'(t)$ is shown in Figure 3.1.

In Figure 3.1, if people move farther from the CBD locating at t in the range, $0 < t < t_0$, the saving from decreasing P(t) is greater than the increasing marginal expenditure for commuting cost. Beyond t_0, the expenditure increases as commuting cost is greater than the saving from decreasing P(t).

According to Figure 3.1, if Z is fixed at $Z = Z_0$, we can infer the budget line for the relation between land demand, Q, and distance, t, as $Q = \frac{Y - P_z Z_0 - K(t)}{P(t)}$. In Figure 3.2, the relation between Q and t is a concave curve[1] with this budget constraint and the equilibrium of household is shown in Figure 3.3. $U = U_1$ is the optimal combination which is the tangency of the utility function and budget line. The optimal distance from CBD is t_1 and optimal consumption of land is Q_0. This is the equilibrium of household to consume housing and to locate at a distance, t_1, from the CBD.

[1]From the first order derivation of the budget constraint, $Q' = \frac{-P'(t)Q(t) - K'(t)}{P(t)}$. Since $P'(t)$ is negative, if $-Q(t)P'(t)$ is greater than $K'(t)$, i.e., the net saving from decreasing P(t) is greater than the increasing cost of commuting, then $Q'(t)$ is positive. Otherwise, $Q'(t)$ has a negative slope which means the budget constraint curves downward.

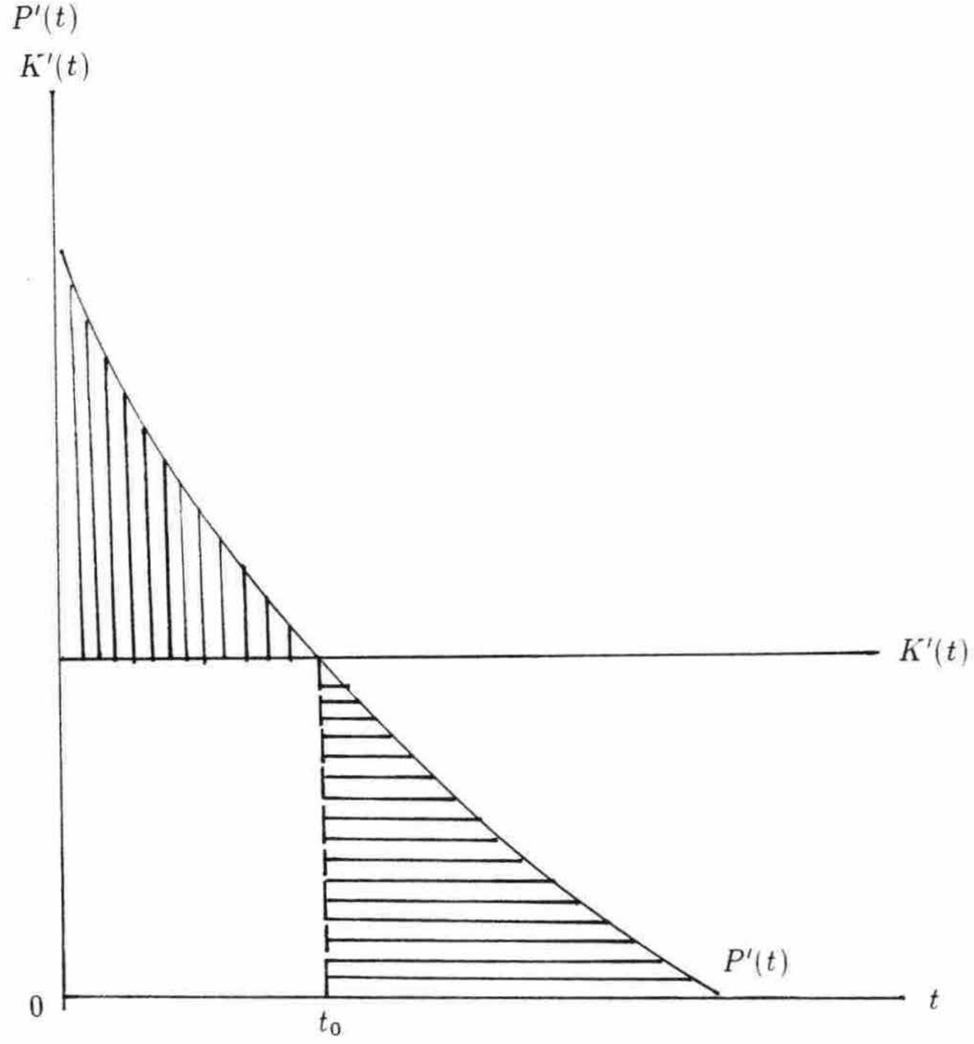

Figure 3.1: First Derivative of Land Price Gradient P(t) and Commutation Cost Gradient K(t)

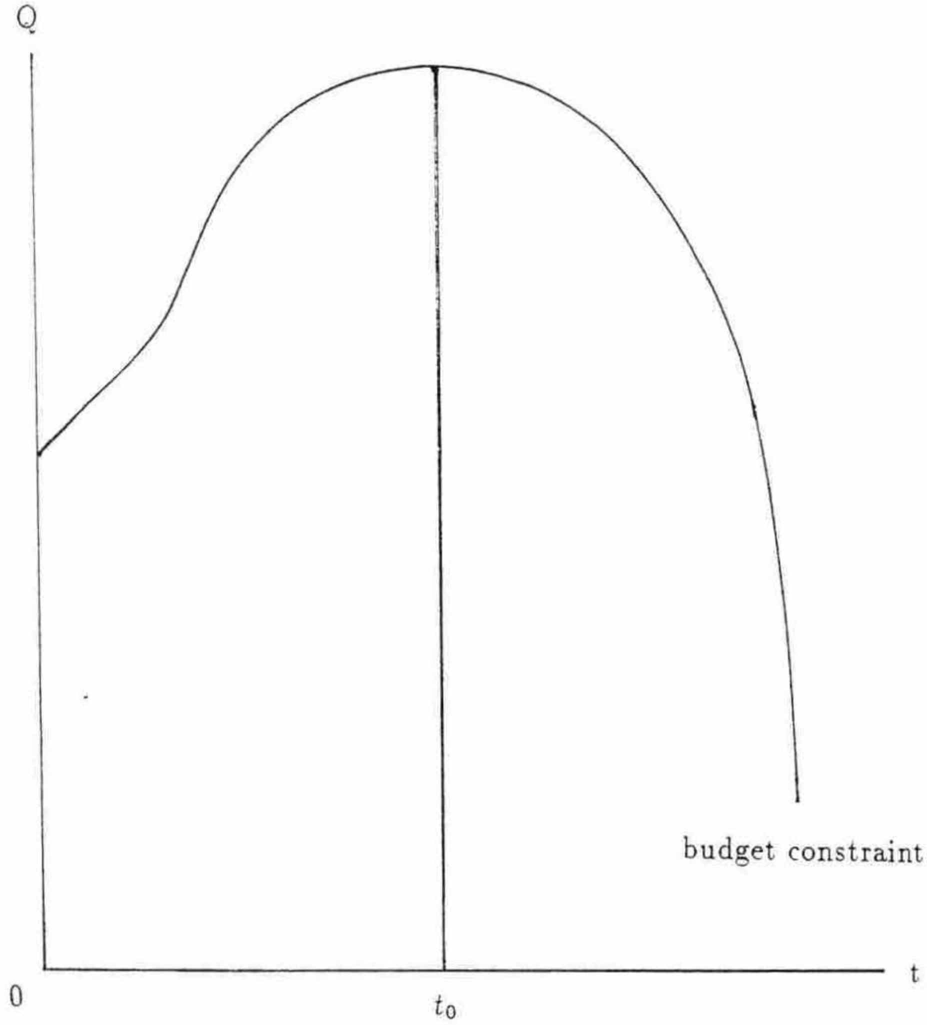

Figure 3.2: Budget Constraint for Q when $Z = Z_0$

3.2.2 Population density gradient

Muth (1961) used housing output per unit of land divided by housing consumption per capita as the measure of population density. First, he assumed housing is produced with a constant-returns-to-scale Cobb Douglas production function using land and capital as inputs. Land and capital are bought and housing is sold on competitive markets. The price of capital is fixed but land and housing prices vary with distance from the CBD. Housing demand per capita has a unitary price elasticity and all households have identical incomes. Then, land rent and housing price in equilibrium will be declining exponentially with distance from the CBD. Population density, which is defined as the ratio of output of housing per unit of land relative to the housing demand per capita, also declines exponentially with distance from CBD.

For equilibrium of firm, we get

$$Q = a_0 L^{a_1} R^{a_2}$$

$$L = \frac{a_1 PQ}{w}$$

$$R = \frac{a_2 PQ}{r}$$

Where a_0, a_1, a_2 are constants and $a_1 + a_2 = 1$. Q = unit of housing output (P = price of Q) L = non-land inputs (w = price of L) R = land inputs (r = price of R)

Taking logarithms, then

$$Q^* = a_0^* + a_1 L^* + a_2 R^* \tag{3.1}$$

$$L^* = a_1^* + P^* + Q^* - W^* \tag{3.2}$$

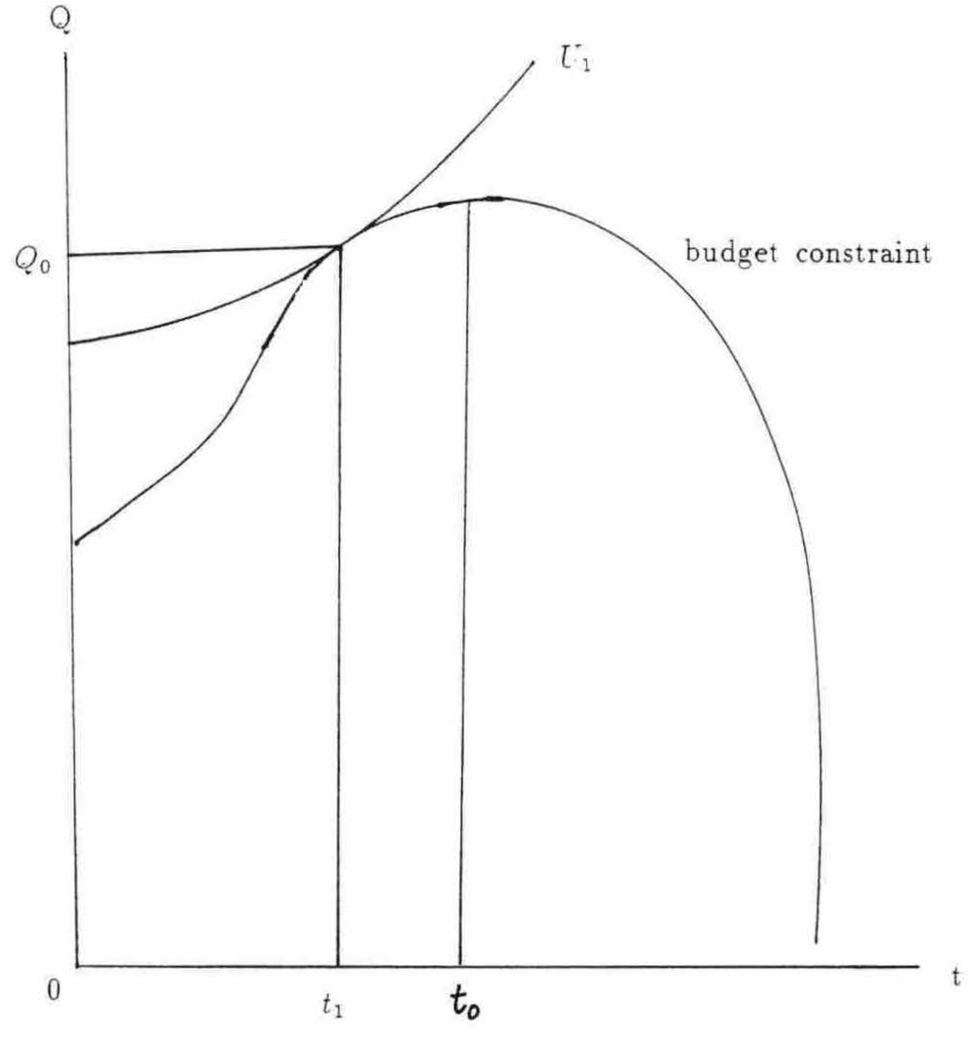

Figure 3.3: Equilibrium of the Household for Purchases of Q and Location

$$R^* = a_2^* + P^* + Q^* - r^* \tag{3.3}$$

Substituting eq.(3.2) and (3.3) into eq.(3.1), we get

$$r^* = constant1 + \frac{1}{a_2}P^* - \frac{a_1}{a_2}w^* \tag{3.4}$$

And, substituting eq.(3.4) into eq.(3.3),

$$R^* = Q^* - constant2 + \frac{a_1}{a_2}P^* - \frac{a_1}{a_2}w^*$$

where constant2 = a_1^* - constant1 So,

$$(\frac{Q}{R})^* = constant2 - \frac{a_1}{a_2}w^* + \frac{a_1}{a_2}P^*$$

Assuming the price of non-land inputs is fixed and P declines negative exponentially with distance.

$$P = P_0 e^{-ck},$$

where c is constant and k is distance

Taking logarithm and first order derivative with respect to distance, k,

$$\frac{\partial P^*}{\partial k} = -c$$

So,

$$\frac{\partial (Q/R)^*}{\partial k} = -\frac{a_1}{a_2}c$$

Similarly, if per capita demand for housing has a unit price elasticity, then housing demand per capita in logarithmic form with first derivative to distance is

$$\frac{\partial (Q/P)^*}{\partial k} = c$$

As defined, D is $\frac{(Q/R)}{(Q/P)}$. Taking logarithm of D and taking the first order derivative with respect to distance, k,

$$\frac{\partial D^*}{\partial k} = \frac{\partial (Q/R)^*}{\partial k} - \frac{\partial (Q/P)^*}{\partial k} = (-a_1/a_2)c - c = -[(a_1/a_2) + 1]c = -g \qquad (3.5)$$

Integrate equation (3.5),

$$\int D(k)^* dk = \int -g dk = constant - gk = D(k)^*$$

So,

$$D(k) = D_0 e^{-gk},$$

where $D_0 = e^{constant}$

As shown above, the population is distributed negative exponentially with distance from the CBD. However, this model is somewhat unrealistic, for example, as it omits a consideration of dispersed employment, and the assumption of commuting cost which is assumed to increase linearly might be represented by a non-linear form.

Neidercorn (1971) assumed that travel cost is negative exponential and tried to maximize the utility which considered living space and leisure time subject to constraints of income, fixed time and commuting cost. Finally, his conclusion also follows the negative exponential law.

Many urban economists employed the negative exponential model to describe the degree of suburbanization. However, different measures probably provide different results, that is, density gradient might not distinguish the difference between alternative measures of suburbanization. This is the subject of the next section.

3.2.3 Comparison among measures

In this section, we compare the measures between the ratio of the population in the suburbs relative to the population in the central city and two-point estimates from the model $D(u) = D(0)e^{-gu}$. There are two cases in which the density gradient does not distinguish the case where population ratios are different.

Case I: cross-section comparison for two different types of cities

Assume two urban areas, a and b have circular shapes and have the same density gradients; see Figures 3.4 and 3.5. In Figure 3.4, B and A are midpoints on the radius of the center city and the suburbs. The population equals the density times the area. So, center city population is

$$P_{c.c.} = D(u_1)(\pi u_3^2) = D(0)e^{-gu_1}(\pi u_3^2)$$

and, the suburban population is

$$P_s = D(u_2)(\pi u_4^2 - \pi u_3^2) = D(0)e^{-gu_2}(\pi u_4^2 - \pi u_3^2)$$

$$\frac{P_s}{P_{c.c.}} = \frac{e^{-gu_2}(\pi u_4^2 - \pi u_3^2)}{e^{-gu_1}(\pi u_3^2)}$$

In Figure 3.5, a similar calculation for C and D are

$$\frac{P_s}{P_{c.c.}} = \frac{D(u_2')[\pi(u_4')^2 - \pi(u_3')^2]}{D(u_1')[\pi(u_3')^2]} = \frac{D'(0)e^{-gu_2'}[\pi(u_4')^2 - \pi(u_3')^2]}{D'(0)e^{-gu_1'}\pi(u_3')^2}$$

See Figure 3.4, Urban area a has a more compact type of city structure in which $P_s/P_{c.c.}$ is less than one. However, in Figure 3.5, urban area b, the spatial radius of the suburbs is greater than that of central city. The ratio of $P_s/P_{c.c.}$ is greater than one. The density gradients are the same which means suburbanization is measured

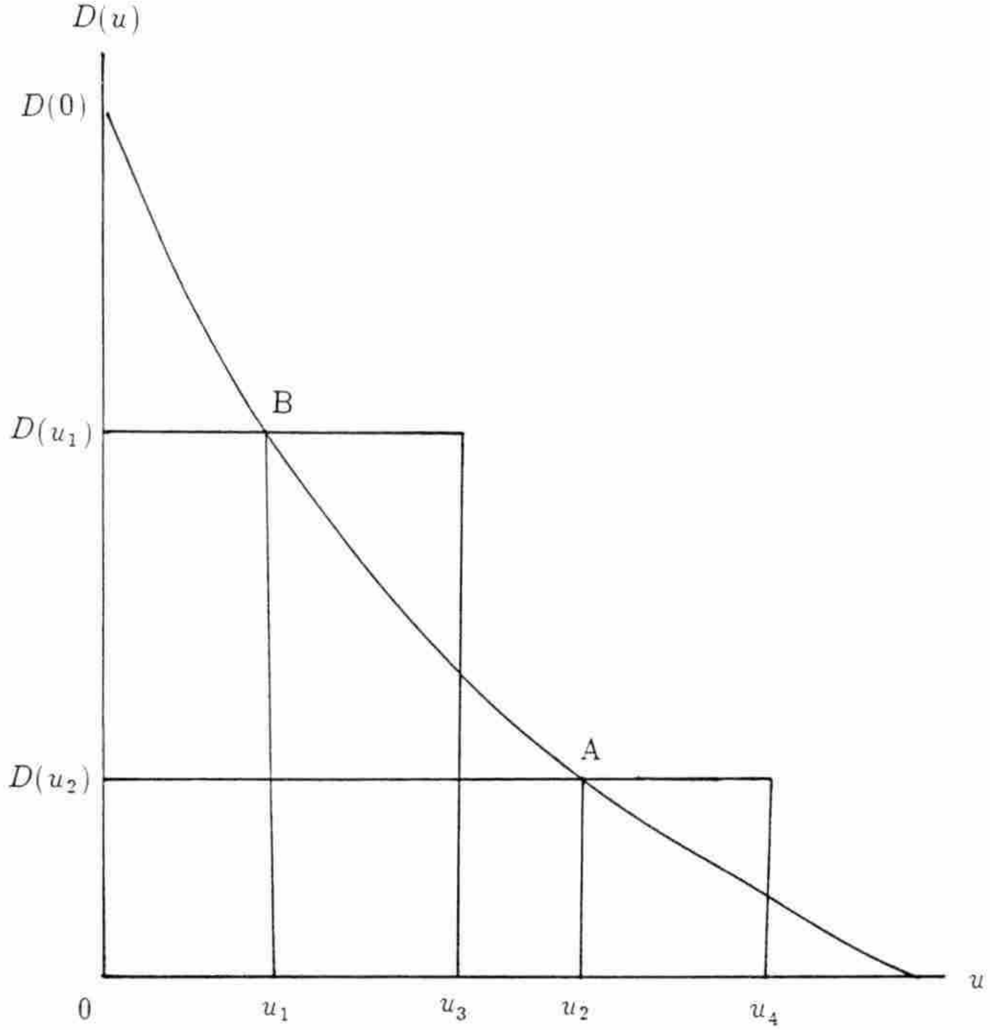

Figure 3.4: Density Gradient for City a

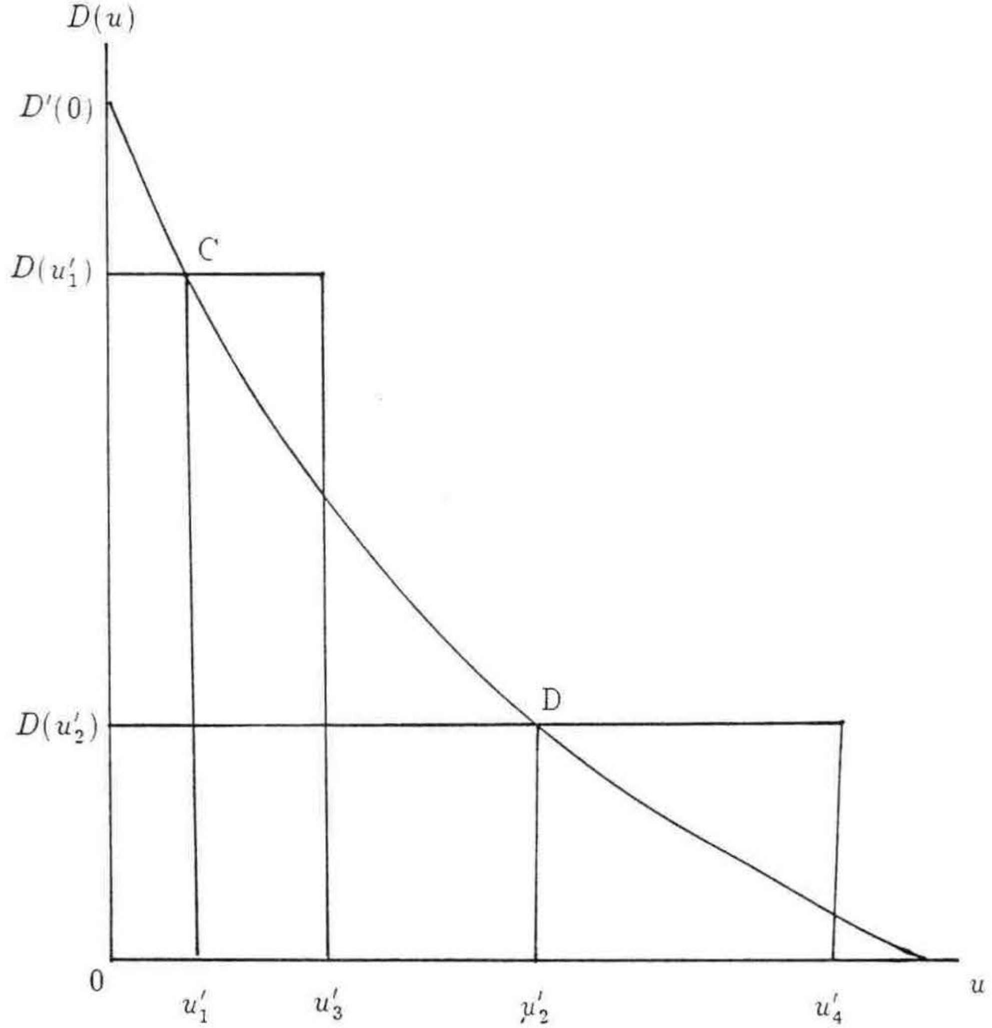

Figure 3.5: Density Gradient for City b

identically, while the other measure, the population ratio of $P_s/P_{c.c.}$, gives different results.

Examples are the cities of Sacramento, CA and St. Louis, Missouri in 1980.

Sacramento:

the density gradient for the average distance of radius = 0.138

$P_s/P_{c.c.} = 738,261/275,741 = 2.677$

St. Louis:

the density gradient for the average distance of radius = 0.138

$P_s/P_{c.c.} = 1,903,375/453,085 = 4.201$

For these two cities, suburbanization is the same by the measure of density gradient but the population ratios are different.

Case II: comparison over time in a single city

Assume the boundary of central city and urban area in the single city is unchanged from 1970 to 1980 and there is an equal growth rate for the central city and suburbs. See Figure 3.6.

In 1970:

Central city population $= (\pi u_2^2)D(A) = (\pi u_2^2)D(0)e^{-g_1 u_1}$

Suburban population $= (\pi u_4^2 - \pi u_2^2)D(B) = (\pi u_4^2 - \pi u_2^2)D(0)e^{-g_1 u_3}$

$$(P_s/P_{c.c.})_{1970} = \frac{(\pi u_4^2 - \pi u_2^2)D(B)}{(\pi u_2^2)D(A)}$$

In 1980:

Suppose there is an equal percent population growth, say α percent, for both the central city and suburban, so,

$D(A') = \alpha D(A) =$ central city population $= P_{c.c}$

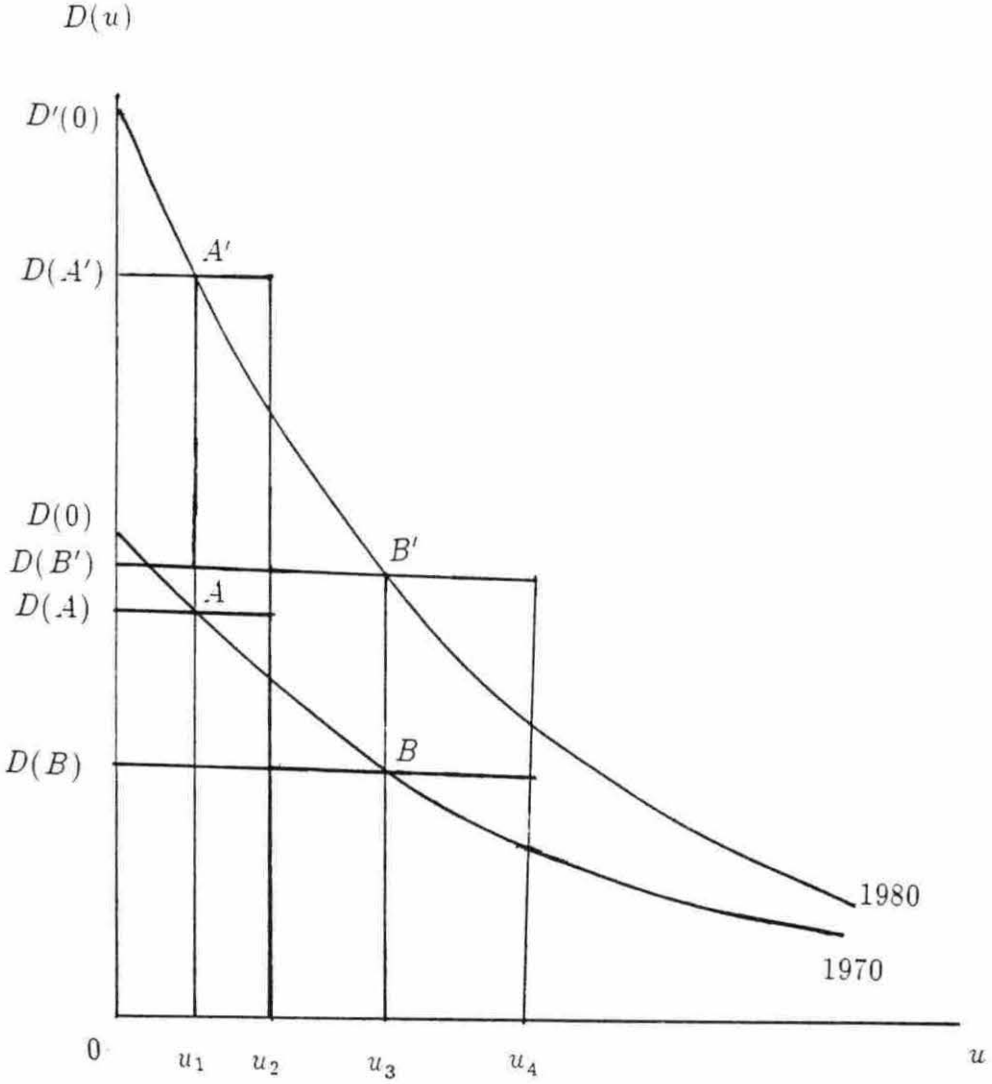

Figure 3.6: Over Time Measure Comparison in a Single City

$$D(B') = \alpha D(B) = \text{suburban population} = P_s$$

$$(P_s/P_{c.c.})_{1980} = \frac{(\pi u_4^2 - \pi u_2^2)D(B')}{(\pi u_2^2)D(A')} = \frac{(\pi u_4^2 - \pi u_2^2)D(B)}{(\pi u_2^2)D(A)} = (P_s/P_{c.c.})_{1970}$$

Proportionate changes give the same percent change, but they are not the same gradient because $\overline{AA'}$ must be greater than $\overline{BB'}$ and the gradient in 1970 must be flatter than the gradient in 1980. In this case, we would infer from gradients that less suburbanization has occurred from 1970 to 1980 but from the percent change that there was no change in suburbanization over the time period.

From these two cases, density gradients can not distinguish the difference with a measure of population ratio, $P_s/P_{c.c.}$, and proportionate changes in P_s and $P_{c.c.}$.

3.3 Employment Density Gradient

Neidercorn (1971) demonstrated that the net and gross employment density gradients are distributed negative exponentially if firms maximize profits. First, he determined the land rent gradient as having an approximately negative exponential form. Then, he derives the net and gross employment density by using a negative exponential rent gradient. However, it is derived under a restrictive assumption that a negative exponential transport cost function exists for commuting. Also, only one commodity is produced in the city and the amount of land used for industrial and commercial purposes at various distances is proportional to the total land available. Since urban land is competitive for different uses such as business sectors, various industries or housing, etc., the maximum rent should be paid at each location from different bid rent curves; see Figure 3.7. If the assumed bid rent gradients for each activity are linear, it may result in a negative exponential multi-activity rent curve.

Hence, the single commodity in Neidercorn's assumption can not assure that the total rent gradient will be of the negative exponential form. As activities are added in figure 3.7, the linear segments could get successively shorter and approach the negative exponential form. Similarly a series of negative exponential gradients could be constructed with a multi-activity curve which is non-linear but not negative exponential.

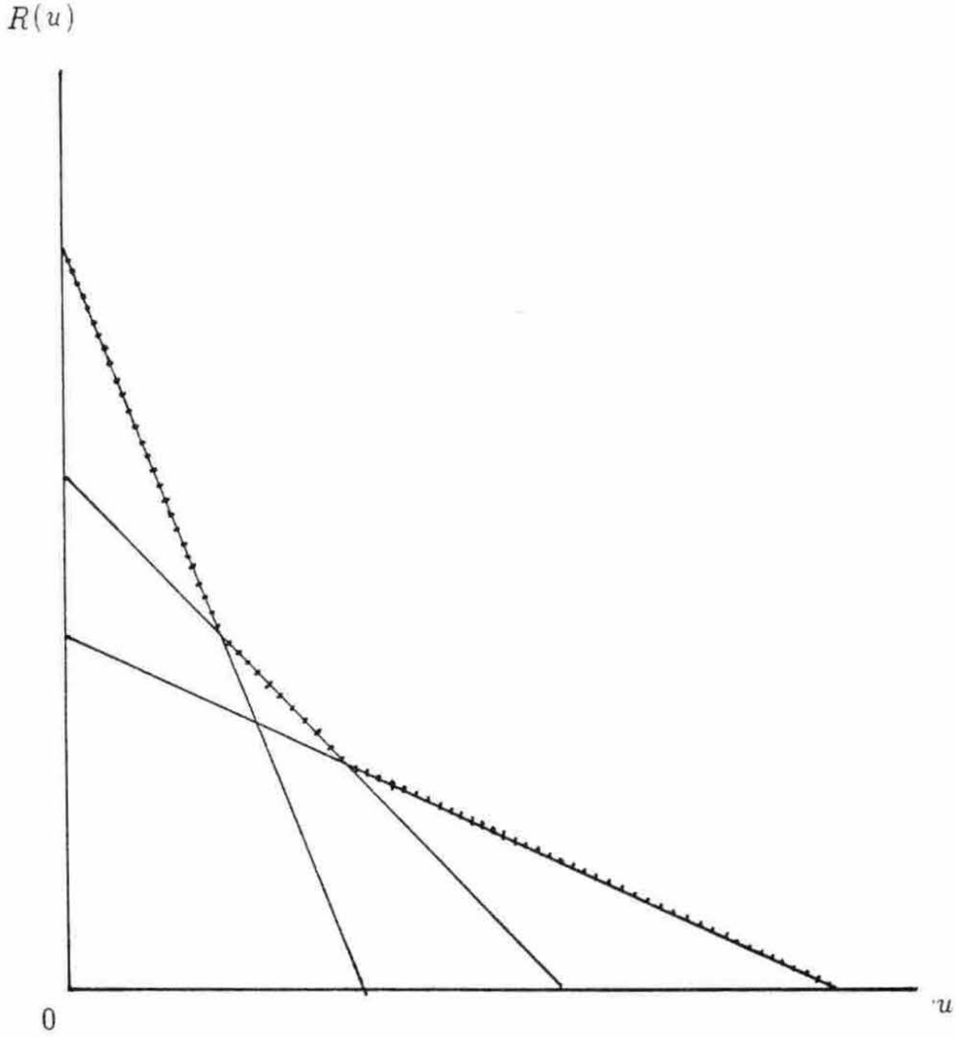

Figure 3.7: Multi-Activity Bid Rent Curve

4. EMPIRICAL RESULTS

4.1 Introduction

The preceding chapter reviewed some of the theories and models already used for measuring suburbanization. In this chapter, various measures will be employed to estimate and to compare the structural change with that of Mills and Price in 1970. The chapter is organized as follows: (1) the alternative dependent variables, (2) the independent variables, (3) data collection, (4) empirical results, (5) additional calculations.

This is an empirical study for explaining the phenomenon of suburbanization in 1980. The multiple regression technique is used to analyze differences in suburbanization among metropolitan areas. The objective is to analyze the impacts on suburbanization from alternative sets of independent variables.

4.2 The Alternative Dependent Variables

There are four measures used here to estimate suburbanization in 1980. They are as follows.

(1) Two-point estimate

This is the measure from the negative exponential model which is $D(u) = D_0 e^{-gu}$

where D(u) is density at u miles from CBD, D_0 is density of central city, u is distance and g is the density gradients. Taking logarithms of the model,

$$logD(u) = logD_0 - gu$$

If census tract data are available, we can estimate the density gradient, g, and constant term for central city density by constructing circular ring from CBD, if each SMSA is of circular shape. However, it is difficult to collect the population and employment data on many census tracts for a large numbers of cities. The dichotomous central city and suburb data can be collected from census data. Therefore, density gradients are attained directly from the logarithmic model, $g = \frac{lnD_0 - lnD(u)}{u}$, where D_0 and D(u) can be calculated from population or employment in central city or suburbs divided by land area[1], and the radius u for central city and suburbs could be calculated from land area equal to πu^2 by assumption of a circular urban area.

Edwin Mills introduced an iterative technique based on the Newton-Raphson method to estimate density gradients. In calculations done by this method, however, the density value for employment is too small to obtain a convergent stable value. There is a high correlation between population gradients calculated from the Newton method and the values directly estimated from the calculation above. Therefore, we infer density gradients from the latter (model calculation) might be substituted for gradients estimated from the Newton-Raphson method.

(2) Estimate from Bradford-Kelejian specification

Bradford and Kelejian employed the model $(\frac{POP_{c.c.}}{POP_{smsa}}) = (\frac{Land_{c.c.}}{Land_{smsa}})^{\beta}$. Taking logs

[1]The density is gross density due to the gross land used. However, the land should be net of street surface, government buildings, residential uses, etc. Usually we do not know these magnitudes, ideally, net land area is the relevant denominator.

of both sides, then $\beta = \frac{log(POP_{c.c.}/POP_{smsa})}{log(Land_{c.c.}/Land_{smsa})}$ and is similar to the density gradient. But β implies a degree of centralization instead of the degree of suburbanization for density gradient. If $\beta < 1$ means that the cities contain a higher proportion of population than of land area. The greater is the value of β, the greater is suburbanization in the city so the signs on independent variables will have the opposite signs compared to regression with density gradients as the dependent variable.

(3) Ratio of population in suburbs, P_s, to population in central city, $P_{c.c.}$

This measure is directly from census data and comparable for all cities in the sample. Suburbanization increases as $P_s/P_{c.c.}$ increases.

(4) Difference between growth rate in suburbs and growth rate in central city

Growth rate in suburbs = $(POP_{sub,1980} - POP_{sub,1970})/POP_{sub,1970}$

Growth rate in central city = $(POP_{c.c.1980} - POP_{c.c.1970})/POP_{c.c.1970}$

The larger is this difference, the more suburbanization has occurred between 1970 to 1980.

These four alternative measures are chosen to be the dependent variables representing the degree of suburbanization.

4.3 Independent Variables

The same set of independent variables as in Mills and Price will be used here. From the derivation of the negative exponential model, some variables explain the degree of suburbanization, such as, income level, Y, population size, P, wage rate, W, etc. Other social variables have also been used including non-white population, crime, education, and tax rate, etc., which encourage suburbanization.

The specification for the population gradient is

$$F_p = f(Y, P, NW, C, ED, T, LAG_{p,-1}, LAG_{e,-1})$$

and for the employment gradient is

$$F_e = f(P, NW, C, ED, T, WG, LAG_{p,-1}, LAG_{e,-1})$$

where F_p = measure of suburbanization for population in metropolitan area,i

F_e = measure of suburbanization for employment in metropolitan area,i

Y = real income per capita in metropolitan area,i

P = total population in i

NW = percent non-white in central city in i / percent non-white in suburbs in i

C = crime rate in central city in i / crime rate in suburbs in i

ED = percent people above 12 years education completed in central city in i / percent people above 12 years education completed in suburbs in i

T = tax rate in central city in i / tax rate in suburbs in i

WG = wage rate in central city in i / wage rate in suburbs in i

$LAG_{p,-1}$ = lagged population of the corresponding measures for 10 years

$LAG_{e,-1}$ = lagged employment of the corresponding measure for 10 years

Real income per capita, Y, is money income per capita divided by the consumer price index (C.P.I.) which is a measure of the average change in prices over time in a fixed market basket of goods and services. The crime rate is the sum of violent crime and property crime divided by the total population. Violent crimes include the offenses of murder, forcible rape, robbery, and aggravated assault. Property crimes include offenses of burglary, larceny-theft, and motor vehicle theft. The education variable represents the percent of population having years of schooling completed above 12 years[2]. The tax rate is the effective tax rate which is the quotient of total net annual property tax bill divided by the sales price of property. The tax rate are available for 1971, 1976 and 1981 and the data we need are for year 1980. Therefore, we use these three annual observations for 25 cities to estimate the tax rate for the year 1980 by regression techniques. The wage rate is the total wages paid to production workers divided by the number of production workers in manufacturing. This wage rate in 1980 is also estimated from the available years 1967, 1972, 1977 and 1982 by regression techniques.

All these variables are the ratio of the value in central cities relative to that in the suburbs because they must be relatives for these two zones across the entire sample of cities.

4.4 Data Collection

In this study, much time was spent in data collection as the sample includes 56 cities in U.S. Most of the data sources are from U.S. Bureau of Census, 1980 Census of Population and Housing, such as population, non-white population, total employment. Per capita income is taken from U.S. Department of Commerce, Bureau of Economic Analysis, Local Area Personal Income. The consumer price index is from C.P.I. Detailed Report. The crime rate is found in U.S. Federal Bureau of Investigation, Uniform Crime Reports, 1980-1981. Tax rates are calculated from U.S. Bureau of Census, Census of Government 1971, 1976, and 1981. The wage rate is

[2]Note that the education variable for Mills and Price is the ratio of average educational attainment in central city relative to that in the suburbs.

estimated from the U.S. Bureau of Census, Census of Manufacture, 1977, 1972, 1977 and 1982.

4.5 Empirical Analysis

In this section, the empirical results will be presented and analyzed first. Then, some structural comparisons to the conclusions of Mills and Price are presented. Finally, some findings are summarized.

4.5.1 Empirical results

The estimation begins with the calculation of the various dependent variables for different suburbanization measures which is presented in Section 4.1. The regression equation using the independent variables are then discussed in Section 4.2. This subsection is analyzed in two parts. The first is the population regression equation and the second is the employment regression equation.

The population regression estimates are shown in Table 4.1 with the parentheses enclosing the t-ratios. The R^2 for the four measures are 0.7444, 0.7877, 0.9439 and 0.6848, respectively. The coefficient on income level, Y, has the wrong sign for all four measures. Income growth in metropolitan area should lead to more suburbanization, but income in MSAs increases result in households moving closer to the central city. Population size, P, also has the wrong sign in the last three measures, the exception being for the two-point estimate. The wrong sign for the coefficient on Y and P might be explained by wealthy people moving back to the central city with the growth of population and income. The ratio of non-white population, except for the measure of the difference between the growth rate in the suburbs and in the central city, also has the wrong sign. The crime rate, C, except for the two-point estimate, has the anticipated signs in three of the measures, but is not statistically significant. The ratio of percent of population with education completed as 12 years and above has the expected sign except for the last measure. The higher the percent of educated people in the central city the larger will be the central city's population. The tax variable has the incorrect sign in all four equations. As to the lag variable, most of the population lag variables have the expected sign which means that a higher degree of suburbanization in previous period has the positive influence to the degree of suburbanization over time. Also, $LAG_{p,-1}$ is statistically significant at the one percent significance level with the measure of $P_{sub}/P_{c.c.}$. The employment lag variable has the correct sign in the first two measures, but not for the last two measures.

In Table 4.2 the tax variable is deleted so that the sample size could be increased from 25 to 56. The two-point regression equation has some notable changes. The population and crime variables now have the expected signs and the variable, $b_{p,-1}$ is statistically significant at the one percent level. However, ED now has the wrong sign. For the Bradford-Kelejian measure, Y and P have the expected signs and P and $LAG_{e,-1}$ are statistically significant under the ten and five percent levels. However, ED and $LAG_{p,-1}$ have the wrong sign. For $P_s/P_{c.c.}$, P has the correct sign, but ED, has an unexpected sign. For the measure of differences between growth rates, the variable P has the right sign, and variable NW has the wrong sign.

In summary, the variable P has the expected sign for four measures after deletion of the tax variable. The lag variables, $LAG_{p,-1}$, and $LAG_{e,-1}$ have important impacts

Table 4.1: Regression Estimate for Population in 1980

dependent variable	two-point estimate	Bradford-Kelejian estimate	$P_s/P_{c.c.}$	difference between growth rate
constant	-0.13	0.2668	1.6719	0.1184
	(-1.267)	(1.777)		(0.089)
Y	0.00206*	-0.0000922	-0.0226^{**}	-0.0034
	(1.597)	(-0.057)	(-2.044)	(-0.0253)
P	$-1.44 * 10^{-9}$	$-1.42 * 10^{-9}$	$-6.11 * 10^{-8}$	-1.062^{*}
	(-0.201)	(-0.146)	(-1.036)	(-1.513)
NW	0.00966***	-0.00538	-0.0177	0.018
	(2.851)	(-1.123)	(-0.576)	(0.463)
C	0.00579	0.0164	0.0144	0.1356
	(0.305)	(0.604)	(1.124)	(0.642)
ED	0.01377	-0.0439	-0.171	0.72
	(0.306)	(-0.675)	(-0.396)	(1.269)
T	0.027	-0.0874	-0.391	-0.0883
	(0.563)	(-1.263)	(-0.927)	(-0.168)
$LAG_{p,-1}$	0.421	0.6567	4.1838***	-0.135^{**}
	(1.185)	(0.563)	(4.911)	(-2.441)
$LAG_{e,-1}$	0.816	0.0286	-2.9779^{***}	-0.562^{***}
	(1.155)	(0.025)	(-3.332)	(-4.17)
R^2	0.7444	0.7877	0.9439	0.6848
Sample Size	25	25	25	25

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

Table 4.2: Population Regression Estimate, Deleted Tax, in 1980

	two-point estimate	Bradford-Kelejian estimate	$P_s/P_{c.c.}$	difference between growth rate
constant	-0.022	0.1227	0.6747	0.55
	(-0.429)	(1.364)	(0.524)	(0.404)
Y	0.000999	0.000418	-0.01122	-0.0093
	(0.946)	(0.295)	(-0.557)	(-0.458)
P	$-6.197 * 10^{-9*}$	$8.58 * 10^{-9*}$	$6.84 * 10^{-8}$	$5.196 * 10^{-8}$
	(-1.513)	(1.377)	(0.788)	(0.607)
NW	0.00504*	-0.00055	-0.00287	-0.011
	(2.87)	(-0.176)	(-0.066)	(-0.267)
C	-0.000586	0.00326	0.00814	0.005
	(-0.312)	(0.92)	(0.32)	(0.103)
ED	-0.0035	0.0176	0.06397	0.623
	(-0.132)	(0.368)	(0.092)	(0.854)
$LAG_{p,-1}$	0.8534***	-1.0228	1.5027	−0.186**
	(4.743)	(-1.09)	(1.055)	(-2.115)
$LAG_{e,-1}$	0.2018	1.6174**	-0.328	-0.302
	(0.494)	(1.755)	(-0.221)	(-1.338)
R^2	0.8037	0.5991	0.6142	0.1445
Sample Size	56	56	56	56

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

on suburbanization. Population size is also significant in some measures. Except for these variables, the others provide only weak evidence as to their influence on suburbanization among cities.

For the employment regression equations, the estimates are shown in Table 4.3 as well as Table 4.4 after deleting the tax rate.

In Table 4.3, the ratio of wage rates has the anticipated sign in the Bradford-Kelejian estimate but not for the other dependent variables. The higher wage rate in the central city is expected to encourage firm locations outside the central city, but the higher wage rate in the central city actually causes employment centralization. Since the wage rate is for the manufacturing only and total employment includes retail, wholesale, and services employment,etc. The unexpected sign is not surprising. All the population size variables, P, in Table 4.3, indicate that larger populations in the metropolitan area cause employment centralization. The high proportion of non-white in the central city promotes suburbanization with the two-point estimate, but the opposite occurs for the other measures. The crime rate, C, uniformly has the anticipated results and is statistically significant in third and fourth equations under the five percent level.

The education variable, ED, has the right sign, except in the fourth equation. The tax rate has the wrong sign for all measures. The interaction between lagged population and employment mostly shows a positive influence and provides strong evidence of suburbanization in the measure $EM_{sub}/EM_{c.c.}$. As to the effect of lagged employment, it is significant in two-point density gradient measure.

In Table 4.4, which deletes the tax rate, all the variables which have the wrong

Table 4.3: Employment Regression Estimate in 1980

	two-point estimate	Bradford-Kelejian estimate	$EM_{sub}/EM_{c.c.}$	difference between growth rate
constant	-0.0228	0.2784	0.781	1.1058
	(-1.029)	(2.036)	(0.966)	(0.792)
W	0.00628	0.012	-0.2243	-0.67^{*}
	(0.793)	(0.226)	(-0.701)	(-1.385)
P	$1.128 * 10^{-9}$	$-1.82 * 10^{-9}$	$-8.471 * 10^{-8*}$	-1.343^{*}
	(0.667)	(-0.183)	(-1.441)	(-1.537)
NW	-0.00055	-0.004	-0.00578	-0.003
	(-0.714)	(-0.843)	(-0.198)	(-0.069)
C	-0.00498	0.031	0.393^{**}	0.446^{**}
	(-1.148)	(1.15)	(2.461)	(1.776)
ED	0.0064	-0.094	-0.1544	0.7957^{*}
	(0.558)	(-1.292)	(-0.351)	(1.355)
T	0.0124	-0.1009^{*}	-0.891^{**}	-0.829
	(1.118)	(-1.455)	(-2.162)	(-1.162)
$LAG_{p,-1}$	-0.039	0.387	2.185^{***}	0.02
	(-0.52)	(0.292)	(2.642)	(0.065)
$LAG_{e,-1}$	0.9398^{***}	0.3557	-0.8098	-0.624^{***}
	(5.627)	(0.275)	(-0.932)	(-3.427)
R^2	0.853	0.8181	0.9561	0.6604
Sample Size	25	25	25	25

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

Table 4.4: Employment Estimate, Deleted Tax, in 1980

	two-point estimate	Bradford-Kelejian estimate	$EM_{sub}/EM_{c.c.}$	difference between growth rate
constant	-0.0044	0.1586	0.0689	0.0876
	(-0.304)	(2.268)	(0.072)	(0.081)
W	-0.0054	0.0417	0.626	0.0799
	(-0.782)	(1.071)	(1.107)	(0.128)
P	$-1.259 * 10^{-9}$	$1.088 * 10^{-8**}$	$8.475 * 10^{-8}$	$9.255 * 10^{-8}$
	(-0.904)	(1.685)	(0.898)	(0.906)
NW	-0.00024	0.00081	0.0155	0.0066
	(-0.401)	(0.255)	(0.326)	(0.133)
C	-0.00063	0.0034	0.023	0.00655
	(-0.953)	(0.939)	(0.433)	(0.114)
ED	0.0133*	-0.051	-0.554	0.5568
	(1.311)	(-0.976)	(-0.703)	(0.711)
$LAG_{p,-1}$	-0.017	-1.287	0.67	1.03***
	(-0.291)	(-1.23)	(0.407)	(-2.716)
$LAG_{e,-1}$	0.767***	1.917**	0.592	0.081
	(5.464)	(1.866)	(0.344)	(0.28)
R^2	0.6751	0.6636	0.6436	0.1898
Sample Size	56	56	56	56

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

sign in Table 4.3, switch to the expected sign except for $LAG_{p,-1}$. The population size and lagged employment variables in the Bradford-Kelejian estimate are statistically significant under the five percent level. The $LAG_{e,-1}$ and ED variables are statistically significant in the two-point measure under the one and ten percent levels, respectively.

In summary, most of variables have the expected signs after deleting the tax rate in the employment regression equations. The results suggest that the effect from lagged employment is a major factor in encouraging firms or employment to locate away from the central city.

4.5.2 Structural comparison with result from Mills and Price

The population equation from Mills and Price are shown in Table 4.5 and Table 4.6 and the employment estimates are shown in Table 4.7 and Table 4.8.

Table 4.5 corresponds to Table 4.1. Although the two-point measure between them is not exactly the same, there is not so large a difference that we can not compare them. The variable, ED, has the expected sign in Table 4.1 but not for the measure from Mills and Price. Both the crime rate, C, and tax rate, T, have the wrong signs in both tables. Compared to the measure from Mills and Price, the Y and NW variables have the wrong sign in Table 4.1 and population size has a very small impact on suburbanization. The effect of $LAG_{p,-1}$ on population suburbanization not only is smaller but also is not statistically significant as in the Mills and Price equation. However, the effect of lagged employment is stronger than that in Table 4.5. For the Bradford-Kelejian measure, both tables do not differ much. Unexpected signs are mixed between these two tables. The education effect has a weaker impact on suburbanization and $LAG_{p,-1}$ has similar coefficients. Lagged employment also has less influence on population suburbanization.

Table 4.6 is corresponds to Table 4.2 for deleting the tax rate from the population regression equation. Compared to the results due to Mills and Price, the crime rate and lagged employment have the anticipated signs, but the effects are not very important. The variable, $LAG_{p,-1}$, seems to have a stronger effect on suburbanization than in 1970.

For the comparison of employment suburbanization, Table 4.3 corresponds to Table 4.7 and the Table 4.8 corresponds to Table 4.4.

Table 4.5: Population Regression Estimate from Mills and Price in 1970

dependent variable	density gradient estimate	Bradford-Kelejian estimate
constant	0.1159	0.439
	(0.86)	(1.47)
Y	-0.0005	-0.0435
	(-0.02)	(-0.88)
P	-0.0209	0.0013
	(-1.07)	(0.24)
NW	-0.0016^{*}	-0.0002
	(-1.6)	(-0.07)
C	0.0069	-0.0059
	(1.03)	(-0.34)
ED	-0.117^{*}	-0.3311^{**}
	(-1.52)	(-1.8)
T	0.0072	-0.0086
	(0.46)	(-0.24)
$LAG_{p,-1}$	0.7704^{***}	0.6565^{***}
	(12.66)	(4.02)
$LAG_{e,-1}$	0.0154	0.506
	(0.35)	(1.59)
R^2	0.9652	0.785

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

Table 4.6: Population Regression Estimate, Deleted Tax From Mills and Price

dependent	density gradient
constant	0.192
	(1.42)
Y	-0.0073
	(-0.36)
P	-0.0513^{***}
	(-2.4)
NW	-0.0013^{*}
	(-1.52)
C	0.0115^{**}
	(1.85)
ED	-0.1289^{*}
	(-1.61)
$LAG_{p,-1}$	0.7242^{***}
	(9.26)
$LAG_{e,-1}$	-0.0141
	(-0.26)
R^2	0.9173

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

Table 4.7: Employment Regression Estimate from Mills and Price in 1970

dependent variable	density gradient	Bradford-Kelejian
constant	0.4117	-0.0739
	(3.3)	*
W	0.0772*	-0.0173
	(1.44)	(-0.34)
P	−0.0889***	0.0387**
	(-2.66)	(1.71)
NW	−0.0035***	-0.003
	(-2.62)	(-0.19)
C	0.0186**	-0.0061
	(1.75)	(-0.52)
ED	−0.4635***	0.0281
	(-3.98)	(0.24)
T	0.0165	-0.006
	(0.66)	(-0.25)
$LAG_{p,-1}$	0.5076***	0.1323***
	(5.23)	(1.23)
$LAG_{e,-1}$	0.3247***	1.2384***
	(4.77)	(5.97)
R^2	0.9503	0.8621

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

For the two-point estimate, the crime rate and education variables switch to the expected signs but P and $LAG_{p,-1}$ have the wrong signs in Table 4.3. The NW variables has less influence on employment suburbanization and the $LAG_{e,-1}$ has a stronger effect.

For Bradford-Kelejian, the wage rate, W, crime rate, C, and education, ED, variables have the anticipated sign, but none of these variables are statistically significant. Variable P has the wrong sign and $LAG_{p,-1}$ has a larger coefficient but is not significant statistically. The variable $LAG_{e,-1}$ becomes insignificant statistically with a weaker explanatory influence.

Table 4.4 corresponds to Table 4.8 which also deletes the tax rate from the employment regression equation. Comparing the two-point density measures, the wage rate, crime rate and education have the expected sign in Table 4.4 and ED is statistically significant under the ten percent level.

The variable $LAG_{p,-1}$ has the wrong sign but the lagged employment variable is significant under the one percent significance level and has stronger effect on employment suburbanization.

As to the expected sign for each variable, it is shown in Table 4.9. The variables higher income, higher population size, higher percent non-white poplation in central city, higher tax rate in central city, and higher crime rate in central city, are expected to have higher degree suburbanization, i.e., the smaller value of density gradient. The variable of education, lagged population, and lagged employment, have positive relation with the density gradient. For measures of Bradford-Kelejian, population ratio, and difference growth rate between central city and suburbs, have opposite

Table 4.8: Employment Estimate, Deleted Tax from Mills and Price

dependent variable	density gradient
constant	0.4198
	(3.10)
W	0.0102
	(0.21)
P	-0.1051^{***}
	(-3.26)
NW	-0.0032^{***}
	(-2.76)
C	0.0246^{***}
	(2.7)
ED	-0.3826^{***}
	(-3.46)
$LAG_{p,-1}$	0.4007^{***}
	(3.48)
$LAG_{e,-1}$	0.2943^{***}
	(5.03)
R^2	0.9025

* Ten percent significance level.
** Five percent significance level.
*** One percent significance level.

Table 4.9: The Expected Sign of Each Variable for Different Measures

	two-point estimate	B-K estimate	$\frac{P_s}{P_{c.c.}}$	difference between growth rate
Y	-	+	+	+
P	-	+	+	+
NW	-	+	+	+
C	-	+	+	+
ED	+	-	-	-
T	-	+	+	+
$LAG_{p,-1}$	+	+	+	+
$LAG_{e,-1}$	+	+	+	+

sign with the measure of two-point estimate.

4.5.3 Some findings

In this study, four variables are chosen to measure suburbanization of population and employment in 1980. The two-point density estimate and the population proportion ratio $P_{sub}/P_{c.c.}$, are not highly correlated. There are six examples, in 1980, showing differences in these measures in Tables 4.10, 4.11, 4.12.

For example, in Table 4.11, the same density gradient, $b_p = 0.138$ is found in Portland, OR, San Antonio, TX, Sacramento, CA, and St. Louis, MO, but $P_{sub}/P_{c.c.}$ is equal to 2.392, 0.364, 2.6774, and 4.2009, respectively. Also, these cities have different structures as indicated by crime rates, non-white ratios, taxes, etc., and should be expected to have different degrees of suburbanization.

The density gradient measure indicates that there are no difference among them, so the density gradient can not really measure suburbanization among cities. This should be a subject of further research in the future.

Table 4.10: Different Structure for the Same Density Gradient

density gradient	$b_p = 0.2$	$b_p = 0.2$	$b_p = 0.2$	$b_p = 0.01$	$b_p = 0.01$
city	Miami, FL	Rochester, NY	Wichita, KS	Pheonix, AR	San Diego, CA
NW	1.76	10.17	4.71	1.45	1.71
ED	0.747	0.707	1.157	0.867	1.13
C	1.494	2.887	2.266	1.621	1.315
T	1.32			1.19	0.98
Y	75.07	43.757	44.014	39.019	37.243
P_{sub} / $P_{c.c.}$	3.687	3.018	0.473	0.91	1.13
radius of central city	3.3	3.42	5.52	9.33	10.138
radius of MSA	25.49	30.73	27.92	53.98	36.83
density in central city	10112.7	7068.5	2754.2	2437.4	2736.1
density in MSA	831.47	330.77	167.85	165.34	442.08

Table 4.11: Different structure for the Same Density Gradient

density gradient	$b_p = 0.138$	$b_p = 0.138$	$b_p = 0.138$	$b_p = 0.138$
city	Portland, OR	San Antonio, TX	Sacramento, CA	St.Louis, MO
NW	3.5	1.75	2.67	3.875
ED	1.138	0.707	0.988	0.674
C	1.966	1.929	1.55	3.11
T	1.0		1.03	
Y	42.165	31.889	40.611	42.935
$P_{sub}/P_{c.c.}$	2.392	0.364	2.677	4.2
radius of central city	5.479	9.158	5.467	4.414
radius of MSA	34.0856	28.3614	33.0617	39.634
density in central city	3546.8	2991.5	2869.3	7379.2
density in MSA	340.16	426.05	298.09	474.37

Table 4.12: Different Structure for the Same Density Gradient

density gradient	$b_p=$ 0.149	$b_p=$ 0.149	$b_p=$ 0.248	$b_p=$ 0.248	$b_p=$ 0.193	$b_p=$ 0.193
city	Birmingham Al	Washington D.C.	Flint MI	Providence RI	Louisville KY	Richmond VA
NW	3.73	3.32	8.8	9.5	4.83	3.25
ED	0.98	0.815	0.863	0.899	0.951	0.983
C	2.96	20.205	2.416	1.78	1.346	2.048
T	1.72			1.17	0.99	
Y	35.861	51.828	39.89	38.517	36.29	41.526
$P_{sub}/P_{c.c.}$	1.98	3.795	2.27	4.86	2.04	1.88
radius of central city	5.346	4.42	3.236	4.464	4.37	4.381
radius of MSA	32.694	29.93	19.4	15.37	21.05	26.13
density in central city	2887.4	10180.7	4911.1	8296.5	4974.2	3647.5
density in MSA	251.54	1089.41	441.31	1213.8	646.42	295.79

4.5.4 Conclusions

Among four alternative suburbanization measures, we can not conclude which one is the best. In the population regression with taxes included, the coefficient sign switches are quite unstable. Generally, the lagged population variable is still the most important factor determining suburbanization. Also, when taxes are excluded, better results are obtained compared to the Mills and Price results which indicated no sign changed.

For the employment regression, the regression results are much better after excluding the tax rate variable, even though R^2 is lower. In general, the lagged employment has a significant impact on the employment suburbanization with much less significance attributable to the other explanatory variables.

4.6 Additional Calculations

Since the empirical results turn out to be unstable and do not show the expected signs for most of the sociological variables, alternative regression specifications have been attempted. This section explores the relation between all variables. First, we explain why variables are employed or deleted from the regression equation by measures of the correlation coefficients among variables. Then, we specify how sociological variables may indirectly influence suburbanization through bid rent gradients.

As concluded in preceding section, the regression results may be unstable when both economic and sociological independent variables are included in the regression. It might happen that the correlation between the independent variables exceeds that between the dependent variable and independent variables, which might cause a multicolinearity problem. In the regressions we discussed in the preceding section, the independent variable used is the ratio of the central city relative to the suburbs. However, their signs and t-ratios are often unstable. Therefore, each independent variable for the central city or suburbs is used, such as the crime rate in central city (CRM8CC) and crime rate in the suburbs (CRM8SUB), percent people educated above 12 years in central city (EDDCC) and the same variable in suburbs (EDSUB), non-white in the suburbs (NW80SUB), etc.

If there really exists a higher correlation between the independent variables than for the dependent and independent variable, there is little reason to use both highly correlated variables together in the regression.

Tables 4.13, 4.14, 4.15, and 4.16 show the product moment correlation coefficients among the various variables used in the regression. Table 4.13 shows the reason why our two-point estimate (the density gradient) is regressed on the variables YRAT8 (ratio of real income in central city to that in the suburbs), NW80SUB (percent of non-white in the suburbs), LANDS8 (land areas in MSA), and lagged population and employment density gradient. Due to their high correlation and correct signs with the density gradient in the table, they are employed in the regression which parameter estimates are shown in Equation 4.1.

$$LOGDAV = X + Y \tag{4.1}$$

Where X = 0.068 + 0.016 YRAT8 - 0.1 NW80SUB - 0.00001 LANDS8,

Y = 0.85 LOG7POP + 0.018 LOG7EM.

Even the other variables have the right sign with the density gradient but they are so strongly correlated with the other independent variables that they cause multi-

Table 4.13: Correlation Coefficient of Model Two Point Estimate

	LOGDAV80	POP80	YRAT8	CRM8SUB	NW80CC
POP80	-0.453	1.0	-0.144	0.253	0.436
YRAT8	-0.393	-0.144	1.0	0.04	-0.44
CRM8SUB	-0.29	0.253	0.04	1.0	0.105
NW80CC	-0.11	0.436	-0.44	0.105	1.0
LANDS8	-0.71	0.31	0.499	0.297	-0.029
LOG7POP	0.863	-0.454	-0.37	-0.2	-0.049
LOG7EM	0.555	-0.489	0.058	-0.24	-0.247

Table 4.13 (continued)

	NW80SUB	LANDS8	LOG7POP	LOG7EM
POP80	0.367	0.31	-0.454	-0.49
YRAT8	0.138	0.50	-0.37	0.058
CRM8SUB	0.32	0.297	-0.2	-0.242
NW80CC	0.47	-0.029	-0.05	-0.247
NW80SUB	1.0	0.276	-0.37	-0.253
LANDS8	0.276	1.0	-0.56	-0.23
LOG7POP	-0.369	-0.56	1.0	0.688
LOG7EM	-0.25	-0.23	0.688	1.0

colinearity when included in the same regression equation. In the regression equation 4.1, the higher the ratio of income per capita the higher the degree of suburbanization. The higher percent non-white in the suburbs also increases suburbanization. These two variables have the opposite sign. The larger is the MSA , the more suburbanization occurs. The lagged population and employment effects are expected to be positive. In this regression, the crime rate and education variables are not included in the regression because they have a negative sign with the dependent variable in Table 4.13.

In Table 4.14, we include the crime rate in the suburbs (CRM8SUB), percent non-white in central city (NW80CC), the lagged population and employment variables in the Bradford-Kelejian regression. Equation 4.2 shows that the R^2 is 0.6348 and a higher crime rate in the suburbs increases suburbanization. The ambiguous sign will be explained later. A higher percent non-white in the central city increases suburbanization. The lag population variable has a negative effect with the dependent variable which means that the higher the degree of suburbanization in 1970 the lower the degree of suburbanization in 1980. It is possible that people went back to central city during this period due to the household structural change caused by reduced family sizes In this regression, the crime and non-white variables are significant under five percent significance level. In Equation 4.2, the population variable is deleted because it is highly correlated with NW80CC (0.44), but has only a correlation of 0.29 with the dependent variable.

$$KL80 = X + Y \tag{4.2}$$

Where X = 0.08 + 1.22 CRM8SUB + 0.1 NW80CC,

Y = - 0.45 KL7POP +1.03 KL7EM.

Similarly, multicolinearity could occur between income and CRM8SUB (0.45), education (ED80) and the lag population and employment variable (0.38, 0.41). Therefore, population size, income and education are excluded from the regression.

Table 4.15 shows the relation between the ratio of population in suburbs to population in central city, $P_s/P_{c.c.}$, and the independent variables. In Equation 4.3, the income, education and the percent non-white variables are deleted due to the higher correlation between education ED80 and crime rate in central city CRM8CC (0.42), percent non-white in central city NW80CC and population size POP80 (0.44).

As to the exclusion of the income variable, it always has a negative relation

Table 4.14: Correlation Coefficient of Model Bradford-Kelejian

	KL80	POP80	REALY	YMSA8	CRM8SUB
POP80	0.29	1.0	0.24	-0.14	0.25
REALY	0.244	0.24	1.0	-0.2	0.45
YMSA8	0.22	0.36	0.66	1.0	0.20
CRM8SUB	0.30	0.25	0.45	0.04	1.0
CRM8CC	0.21	0.12	0.286	0.03	0.06
ED8CC	-0.11	0.02	-0.008	0.74	0.33
ED80	-0.32	-0.19	-0.32	0.88	-0.04
NW80CC	0.33	0.44	0.23	-0.44	0.10
NW80	0.24	-0.11	0.05	-0.47	-0.23
KL7POP	0.74	0.19	0.24	-0.38	0.15
KL7EM	0.75	0.20	0.24	-0.41	0.15

Table 4.14 (continued)

	CRM8CC	ED80	NW80CC	NW80	KL7POP	KL7EM
POP80	0.12	0.19	0.44	-0.11	0.19	0.20
REALY	0.29	-0.32	0.23	0.05	0.24	0.24
YMSA8	0.33	-0.26	0.29	0.11	0.18	0.20
CRM8SUB	0.06	-0.04	0.10	-0.23	0.15	0.15
CRM8CC	1.0	-0.10	0.42	-0.08	0.14	0.12
ED8CC	0.19	0.70	-0.31	-0.56	-0.20	-0.22
ED80	-0.10	1.0	-0.40	-0.48	-0.38	-0.41
NW80CC	0.42	-0.4	1.0	0.09	0.16	0.19
NW80	-0.08	-0.48	0.09	1.0	0.35	0.37
KL7POP	0.14	-0.38	0.16	0.35	1.0	0.995
KL7EM	0.12	-0.41	0.19	0.37	0.995	1.0

Table 4.15: Correlation Coefficient of Model Percentage Change

	PCT81	POP80	CRM8CC	EDSUB	NW80CC	NW80SUB	PCT71POP	PCT71EM
POP80	0.11	1.0	0.12	0.235	0.44	0.37	0.067	0.081
CRM8CC	0.263	0.12	1.0	0.422	0.416	0.31	0.263	0.235
EDSUB	0.11	0.235	0.422	1.0	0.109	0.203	0.103	0.103
NW80CC	0.189	0.44	0.416	0.109	1.0	0.47	0.158	0.191
NW80SUB	-0.132	0.367	0.31	0.203	0.47	1.0	-0.11	-0.13
PCT71POP	0.93	0.067	0.263	0.103	0.158	-0.11	1.0	0.993
PCT71EM	0.894	0.081	0.235	0.103	0.191	-0.13	0.993	1.0

with $P_s/P_{c.c}$ in the table. In Equation 4.3, the total population. the crime rate in central city, and the lagged total population variables encourage suburbanization even though none of these variables are statistically significant. As to the negative effect from lag employment variable, it could be explained by competitive land users between the employment and residential sectors in the central city. This effect results in the lagged employment variable having a negative sign in this regression.

$$PCT81 = X + Y \tag{4.3}$$

Where X = 0.32 + 5.0 * 10^{-8} POP80 − 0.57 CRM8CC,

Y = 1.35 * PCT71POP - 0.22 * PCT71EM.

Similarly, Table 4.16 shows the correlation among the independent variables and

Table 4.16: Correlation Coefficient of Model Difference Growth Rate Between the Central City and the Suburbs

	DIFFRT82	POP80	YRAT8	NW80SUB	DIFF72P	DIFF72EM
POP80	0.06	1.0	-0.14	0.37	0.08	0.01
YRAT8	0.30	-0.14	1.0	0.14	-0.21	-0.29
NW80SUB	-0.03	0.37	0.14	1.0	-0.20	-0.14
DIFF72P	-0.43	0.08	-0.21	-0.20	1.0	0.37
DIFF72EM	-0.20	0.01	-0.29	-0.14	0.37	1.0

table 4.16 (continued)

the difference growth rate between the central city and the suburbs (DIFFRT82). In equation 4.4, the variable percent non-white in the suburbs (NW80SUB) is excluded due to the high correlation with the population variable (0.37).

$$DIFFRT82 = X + Y \tag{4.4}$$

Where X = -1.04 + 7.9 * 10^{-8} POP80.

Y = 1.79 YRAT8 - 0.83 DIFF72P + 0.03 DIFF72EM.

The result also shows that increasing population size (POP80) and income ratio of the central city to the suburbs (YRAT8) will increase suburbanization. The lagged population has a negative and the lag employment has positive relation with the dependent variable.

Many independent variables were used to try to improve the empirical results, such as the log of population size, tax rates,etc. Also, grouping the data according to the population size failed to provide better results. The inter-correlation among independent variables noted here may be due to ambiguous expected signs that were not suggested by Mills and Price and other authors. These ambiguous effects from independent variables will be discussed in next paragraph.

The influence from the basic economic variables, population size and income level, could be explained from the derivation of the negative exponential model. As for the sociological variables, such as the crime rate, non-white population or tax rate, it is less clear as to how these variables are likely to affect suburbanization. So we hope to specify the ambiguous influence from the sociological variables.

The bid rent gradient is $R(u) = (P^*A - W) - t^*A^*u$ where P is the price of product (A), W is non-land cost, t is the ton mile transit charge and u is the mileage. For the crime rate, if a higher crime rate in the central city increased non-land cost, then it will result in W increasing and the bid rent gradient for the central city shifts inward, i.e., the R(u) for central city decreases. As commercial rents decline firms substitute land for labor and employment densities decline. If the rent decline is substantial, it is possible that residential densities might increase if the crime incidence is confined to commercial properties. Also, the ratio of the crime rate in the central city to that in the suburbs may increase in several ways. The crime rate is the number of crimes per capita, so increased suburbanization results in a higher crime rate in the central city either by increasing the number of crimes in the central city with constant population or decreasing the population in the central city with number of crimes constant. The latter is simply a population shift away from central city introducing a spurious correlation with the dependent variables. Or, an increasing central city crime rate also suggests a lower central city rate of return to crime. If criminal activity is competitive, criminals may similarly seek suburban subjects which would tend to discourage migration fro the central city to the suburbs. All these could help explain the ambiguous sign of the crime rate variable in some regression equations.

Similarly, the high tax rate in the central city may deter suburbanization because the beneficial programs financed by high taxes in the central city attracts people back to the central city. High taxes in central cities can provide better services such as good roads, utilities, police-fire protection, etc., which is not found in the low tax suburbs. Also, it might offer parks, good schools, museums, etc., to keep people staying in central locations.

As to the education variable, if the percent of educated people in the central city increases the supply of educated people, the returns to the educated people decrease due to the supply effects. This could draw people out of the central city. And, the external effects might provide an additional argument. The opportunity costs to educated people of voluntary participation in the municipal institutions is high with a lower probability of success as educated people in the central city rises, so an increasing percent of educated people in the central city may actually reduce per capita effort in providing these externalities. All of these effects from the educational variable might result in an ambiguous sign of the regression coefficients in our equations.

The traditional argument is that a high proportion of non-whites in the central city will increase suburbanization. Yet, if employment decentralization raises suburban rents, non-whites may reside in the central city and commute to the suburbs. Due to the competition for land between people and firms in the suburbs, population decentralization may be deterred. Thus, the expected sign may be positive instead of negative.

From the above, the expected sign suggested by previous authors my be suspect. There are many other effects on these independent variables which suggest some ambiguity. The above suggests that additional causal linkages might have to be specified among independent variables perhaps using multi-equation or path analytical techniques. This might be a fruitful approach in further research.

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7. APPENDIX: DATA SET

7.1 Data

The variables are defined and related data are listed below.

Dependent variable

KL80: Population estimate of Bradford-Kelejian model in 1980

LOGDAV80: Density gradient of two-point estimate in 1980

DIFFRT82: Difference growth rate between the central city and the suburbs in 1980

PCT81: Ratio of population in the suburbs relative to the population in central city in 1980

Independent variable

KL7POP: Population estimate of Bradford-Kelejian model in 1970

KL7EM: Employment estimate of Bradford-Kelejian model in 1970

LOG7POP: Population estimate of two-point estimate in 1970

LOG7EM: Employment estimate of two-point estimate in 1970

PCT71POP: Population ratio of the suburbs relative to the central city in 1970

PCT71EM: Employment ratio of the suburbs relative to the central city in 1970

DIFF72P: Population difference growth rate between the suburbs and the central city in 1970

DIFF72EM: Employment difference growth rate between the suburbs and the central city in 1970

YMSA: Nominal income level in metropolitan areas in 1980

CPI: Consumer Price Index in 1980

NW80: Ratio of percent non-white in the central city relative to that in the suburbs in 1980

ED80: Ratio of percent educated people above 12 years in the central city relative to that in the suburbs in 1980

CRM80: Ratio of crime rate in the central city relative to that in the suburbs in 1980

TAX: Ratio of tax rate in the central city relative to that in the suburbs in 1980

Data set are listed in next page.

OBS	KL80	LOGDAV80	DIFFRT82	PCT81	KL7POP	KL7EM	LOG7POP	LOG7EM	PCT71POP	PCT71EM
1	0.37	0.204	0.18675	1.784	0.320883	0.323	0.181	0.036	1.4661	1.480
2	0.44	0.104	0.94136	3.776	0.294389	0.295	0.113	0.033	1.7972	1.810
3	0.30	0.173	0.32223	1.763	0.245932	0.247	0.159	0.053	1.2861	1.298
4	0.30	0.149	0.33931	1.980	0.248199	0.235	0.143	0.050	1.4567	1.343
5	0.48	0.169	0.16332	3.908	0.447022	0.444	0.154	0.011	3.2954	3.264
6	0.38	0.399	0.17667	1.774	0.362888	0.364	0.313	0.067	1.4859	1.495
7	0.34	0.213	0.22500	2.473	0.293114	0.297	0.198	0.040	1.9155	1.965
8	0.30	0.112	0.24219	1.364	0.258936	0.255	0.097	0.032	1.0727	1.054
9	0.38	0.155	0.23800	2.636	0.337431	0.330	0.141	0.036	2.0602	1.992
10	0.40	0.160	0.24474	2.309	0.337479	0.354	0.148	0.033	1.7489	1.889
11	0.25	0.139	0.35670	0.936	0.199212	0.194	0.120	0.046	0.6977	0.675
12	0.37	0.079	1.83949	2.290	0.185390	0.174	0.087	0.035	0.8426	0.778
13	0.39	0.185	0.19817	3.082	0.337999	0.333	0.182	0.046	2.4904	2.429
14	0.31	0.132	0.62648	2.292	0.241880	0.233	0.122	0.043	1.3850	1.317
15	0.38	0.118	0.37557	2.618	0.305472	0.307	0.111	0.022	1.7786	1.799
16	0.19	0.239	0.76732	0.770	0.123720	0.119	0.214	0.093	0.4263	0.409
17	0.32	0.248	0.36766	2.268	0.263457	0.258	0.233	0.076	1.5691	1.525
18	0.57	0.058	6.04655	6.723	0.183995	0.183	0.098	0.038	0.9368	0.935
19	0.19	0.168	-0.11501	1.358	0.195226	0.183	0.157	0.062	1.4886	1.352
20	0.34	0.215	0.30909	2.309	0.290575	0.284	0.196	0.059	1.7281	1.671
21	0.41	0.263	0.30260	4.324	0.349825	0.349	0.263	0.061	3.2013	3.202
22	0.24	0.082	0.44786	0.821	0.181049	0.165	0.073	0.029	0.6101	0.546
23	0.23	0.106	0.33402	0.665	0.189824	0.187	0.080	0.031	0.4905	0.483
24	0.46	0.078	0.29311	1.961	0.384054	0.378	0.068	0.013	1.4727	1.437
25	0.42	0.069	0.01634	1.520	0.442327	0.434	0.047	0.006	1.4971	1.456
26	0.35	0.193	0.48100	2.036	0.263053	0.261	0.182	0.059	1.2866	1.273
27	0.15	0.134	0.78559	0.413	0.100325	0.075	0.104	0.049	0.2351	0.172
28	0.38	0.200	0.33500	3.687	0.325782	0.301	0.191	0.039	2.7860	2.434
29	0.28	0.180	0.22107	1.196	0.246062	0.237	0.152	0.038	0.9574	0.909
30	0.29	0.084	3.22388	0.866	0.090606	0.087	0.078	0.035	0.2078	0.201
31	0.41	0.330	0.42234	2.311	0.389486	0.398	0.221	0.037	1.5818	1.641
32	0.33	0.122	0.45237	1.129	0.246270	0.246	0.105	0.035	0.7621	0.763
33	0.41	0.062	0.46780	1.069	0.328548	0.318	0.048	0.013	0.7499	0.721
34	0.21	0.202	0.41960	0.813	0.150471	0.131	0.183	0.080	0.5551	0.469
35	0.31	0.133	0.18915	1.794	0.272690	0.271	0.121	0.038	1.4724	1.460
36	0.19	0.010	0.50589	0.911	0.144974	0.129	0.095	0.041	0.6636	0.573
37	0.41	0.150	0.16303	4.340	0.381316	0.376	0.140	0.028	3.6167	3.522
38	0.34	0.138	0.44099	2.392	0.265263	0.256	0.135	0.045	1.6374	1.556
39	0.47	0.248	0.16720	4.862	0.657501	0.650	0.085	0.038	4.0821	3.996
40	0.29	0.193	0.65811	1.883	0.204574	0.209	0.186	0.048	1.0764	1.110
41	0.31	0.200	0.42789	3.018	0.248578	0.244	0.193	0.047	1.9796	1.927
42	0.13	0.138	0.16179	0.364	0.123078	0.095	0.106	0.049	0.3208	0.241
43	0.36	0.138	0.26785	2.677	0.318509	0.308	0.127	0.036	2.1468	2.040
44	0.37	0.138	0.36525	4.201	0.303961	0.308	0.139	0.038	2.7976	2.874
45	0.36	0.114	1.09854	4.743	0.256087	0.231	0.116	0.042	2.1704	1.832
46	0.29	0.010	0.23538	1.127	0.258616	0.246	0.081	0.019	0.9487	0.887
47	0.34	0.136	-0.33656	1.057	0.402298	0.427	0.095	0.008	1.3884	1.524
48	0.34	0.120	0.31948	2.255	0.272322	0.248	0.123	0.030	1.6785	1.456
49	0.19	0.240	0.45333	0.996	0.147388	0.135	0.218	0.093	0.6859	0.614
50	0.28	0.238	0.21384	2.780	0.258050	0.246	0.220	0.070	2.2275	2.061
51	0.31	0.211	0.25032	2.064	0.274923	0.237	0.191	0.069	1.6589	1.328
52	0.24	0.186	0.49129	1.232	0.179221	0.171	0.172	0.034	0.8000	0.756
53	0.18	0.131	1.17254	0.910	0.104825	0.094	0.124	0.056	0.4300	0.387
54	0.28	0.249	0.15631	3.233	0.386147	0.370	0.121	0.026	2.7100	2.530
55	0.41	0.149	0.30730	3.795	0.347751	0.328	0.145	0.038	2.7800	2.519
56	0.12	0.200	0.16077	0.473	0.105541	0.093	0.173	0.079	0.4000	0.355

OBS	DIFF72P	DIFF72EM	YMSA	CPI	NW80	ED80	CRM80	TAX
1	0.330	1.010	9260	254.32	8.850	0.820	1.6876	
2	0.289	0.853	9867	243.80	4.530	0.890	2.4028	
3	0.383	0.654	9886	249.05	5.090	0.610	1.5862	
4	-0.820	0.742	8743	243.80	3.730	0.980	2.9609	1.72
5	-0.130	0.258	10770	238.75	10.000	0.743	2.6881	
6	-0.420	0.382	13989	237.23	10.330	0.480	2.1309	
7	0.277	0.348	9634	236.62	7.380	0.740	1.9565	
8	0.404	0.525	11418	245.49	5.560	0.686	1.2934	
9	0.318	0.747	9856	252.93	7.000	1.096	1.8337	
10	0.414	0.664	11181	254.32	5.810	0.449	2.7047	1.08
11	-0.140	0.751	9335	252.93	8.000	0.929	1.9368	0.90
12	-0.570	0.584	11499	257.07	4.880	1.069	1.7470	
13	0.375	0.578	9481	252.93	6.330	0.717	2.5000	1.15
14	0.802	0.705	11446	260.22	3.570	1.005	1.7755	
15	0.274	0.492	11020	253.54	11.000	0.669	1.6585	
16	0.135	0.749	10834	7093.00	4.800	0.831	1.9653	1.39
17	0.333	0.853	10114		8.800	0.863	2.4159	
18	-0.840	0.795	10228	257.07	3.880	0.877	1.6633	
19	-0.170	0.138	9860	248.33	1.120	1.217	1.8038	
20	0.082	0.847	9436	253.54	6.330	1.043	2.2393	
21	0.363	0.567	11258	237.23	12.430	0.460	3.6592	
22	0.213	1.220	11931	266.48	2.790	1.067	2.0334	
23	0.415	0.163	10050	252.93	11.500	1.050	0.7567	
24	0.115	1.035	9600	249.17	3.950	0.938	1.8280	1.16
25	0.314	0.089	11290	247.31	1.390	1.086	1.3429	1.06
26	0.356	0.591	9179	252.93	4.830	0.951	1.3463	0.99
27	-0.610	-0.140	8715	243.97	2.180	1.064	2.5672	0.97
28	0.304	0.360	9775	130.22	1.760	0.747	1.4936	1.32
29	0.309	0.620	10845	250.25	13.500	0.678	1.4917	1.09
30	-0.650	-2.300	8686	243.80	2.820	1.290	2.2610	1.00
31	0.322	0.550	10356	237.23	12.670	0.741	2.8538	
32	0.676	1.080	9750	266.48	3.830	1.043	1.5099	
33	0.004	0.46	10410	257.07	2.220	1.067	1.7672	1.10
34	0.087	0.06	9934	249.06	3.750	1.015	1.8212	0.93
35	0.253	0.33	10127	241.43	4.200	0.609	1.2054	
36	0.394	0.34	9650	247.31	1.450	0.867	1.6214	1.19
37	0.183	0.24	10128	248.58	5.000	0.956	2.7200	
38	0.370	0.47	10731	254.50	3.500	1.138	1.9662	1.00
39	1.237	0.34	9196	238.75	9.500	0.899	1.7822	1.17
40	-0.020	0.41	10118	243.65	3.250	0.983	2.0480	
41	0.289	1.37	10354	236.62	10.170	0.707	2.8865	
42	0.305	1.52	8498	266.48	1.750	0.707	1.9292	
43	-0.070	0.65	10085	248.33	2.670	0.988	1.5497	1.03
44	0.419	0.63	10475	243.97	3.875	0.674	3.1073	
45	0.530	1.15	8349	260.22	2.270	1.328	1.8572	0.89
46	0.221	0.25	9948	267.11	1.710	1.130	1.3148	0.98
47	-0.770	-0.57	12253	248.33	1.530	0.748	1.1779	1.40
48	0.857	0.75	11738	250.87	3.730	1.253	1.6558	0.87
49	0.277	0.33	8860	250.87	1.630	1.110	1.8862	
50	0.350	0.42	8902	237.23	9.350	0.955	2.0324	
51	0.433	0.55	9222	250.87	1.455	0.944	2.1451	
52	-0.390	1.07	9553	253.54	6.630	1.009	2.2596	1.29
53	-0.580	-0.29	10564	249.17	1.610	1.714	2.8297	0.93
54	0.790	0.17	8191	237.23	9.440	0.900	1.1986	
55	0.574	0.89	12628	243.65	3.320	0.815	20.2045	
56	-0.190	0.27	10967	249.17	4.710	1.157	2.2657	1.23