Volume Title: Determinants of Investment Behavior

Volume Author/Editor: Robert Ferber, editor

Volume Publisher: NBER

Volume ISBN: 0-87014-309-3

Volume URL: http://www.nber.org/books/ferb67-1

Publication Date: 1967

Chapter Title: The Distribution of Population Within Urban Areas

Chapter Author: Richard F. Muth

Chapter URL: http://www.nber.org/chapters/c1238

Chapter pages in book: (p. 271 - 299)

PART III

Consumer Assets

The Distribution of Population Within Urban Areas

RICHARD F. MUTH

INSTITUTE FOR DEFENSE ANALYSES

I

Most papers on the subject of investment are concerned with how much of it takes place. This one, however, is primarily interested in where investment in housing occurs. More precisely, it is concerned with the distribution of population within urban areas, especially the distribution of population between the central city (the largest political city) and its suburbs, and the total amount of land used by the urban area. One of the most striking phenomena of recent years has been the relatively large growth in population of the suburban parts of urban areas and the accompanying rapid increase in land area used for residential and other urban purposes. It is not generally realized, however, that the outer parts of central cities have tended to grow at greater relative rates than those parts closest to the city center.

In many popular and some scholarly discussions of urban growth and related problems, the rapid growth of the outer parts of urban areas of recent years is viewed as haphazard or capricious and unplanned, implying that it is necessarily bad. In other, more sophisticated discussions, urban decentralization is viewed primarily as a "flight from blight"—that is, as an attempt by people to escape the poor housing, the age, excessive population densities, or other undesirable features of central cities. Both kinds of discussion often suggest that urban decentralization has gone too far and urge various kinds of governmental action to reverse it. As economists, most of us would be tempted to seek an explanation for urban decentralization in factors such as changes in the relative costs of living in different parts of urban areas. One obvious factor that might affect these relative costs is the growth of automobile transportation and the building of express highways. In addition, governmental programs, such as the federal income tax advantage to owner-occupied housing and the FHA and VA mortgage programs, have probably encouraged decentralization.

This paper presents some of the results of my study of the spatial aspects of urban housing markets that are relevant to the analysis of urban decentralization. Section II contains a very brief summary of the theoretical framework which underlies the empirical work described later. Section III discusses some of the factors that would be expected to be related to the relative rate of decline in population densities with distance from the city center, describes the measures of these factors used here, and presents a preliminary regression analysis made in an attempt to appraise their empirical importance. This analysis is continued in section IV, which also examines the effects of these and other factors on the distribution of population between the central city and its suburbs and the total land used by urban areas. In this last I am especially interested in the extent to which suburbanization is simply an extension beyond its borders of the distribution of population within the central city and to what extent it is something different. My conclusions and some of their implications are summarized in the final section.

Admittedly, my analysis has few implications for the determinants of the total volume of investment in nonfarm residential real estate. Apart from providing some explanation for where such investment takes place, it may also be suggestive of the form in which housing investment takes place. If, for example, my analysis were to imply a continuation of past rates of urban decentralization, it would also suggest that investment in housing in the future would continue to be disproportionately in the form of new units rather than additions and alterations to existing units and in houses rather than apartments. Continued decentralization might also imply greater investment in new public facilities in newly built communities and greater expenditures under governmental programs such as urban renewal, which are designed in part to halt decentralization.

II

Because accessibility to employment and purchasing opportunities has value, the price consumers pay for housing of any given quality would be expected to decline with distance from the central business district (CBD) of an urban area. It can easily be shown that, for any given residential location to be an equilibrium one for the household occupying it, the following must hold:[1]

$$-(p_k/p) = (T_k/pq), \tag{1}$$

where p is the price per unit of housing, p_k is the change in housing price per unit change in distance from the CBD (k), q is the quantity of housing consumed, and T_k is the change in transport costs incurred by the household per unit change in distance. The last is assumed to include both direct money outlay and the money equivalent of time spent in travel. Since T_k is positive, equation (1) implies that housing prices are smaller at greater distances from the CBD. The truth of the proposition stated in the previous sentence can also be seen from the following consideration. If housing prices were invariant with distance but households located at greater distances incurred greater transport costs, it would be in the interest of the latter to offer more for the services of housing closer to the CBD than its occupants currently pay. In the process, housing prices would rise close to the CBD and decline at greater distances from it.

The fall in housing prices with distance from the CBD implies that the rent per unit of residential land must also decline with distance. For, if this were not the case, firms producing housing close to the CBD would earn larger incomes than the more distantly located firms. Rents would then be bid up in locations close to the CBD and bid down in distant locations. Along with the decline in land rents with distance from the CBD, land will be substituted for other productive factors in producing housing, provided that, as seems likely, the variation of construction costs is small relative to that of land rents throughout the urban area. As a consequence of this substitution, the output of housing per unit of land in both physical and value terms declines with distance from the CBD.

The variation of housing prices also affects the per capita consumption of housing in different parts of the urban area. Given real incomes and tastes for housing versus other commodities, equilibrium of the consumer in the presence of declining housing prices requires that housing be substituted for other commodities or that the per capita consumption of housing be greater at locations more distant from the CBD. Secondly, since higher-income CBD-worker households consume more housing per capita than lower income ones, they have an incentive on

[1] This relationship was presented in my earlier paper "The Spatial Structure of the Housing Market," *Papers and Proceedings of the Regional Science Association,* Volume 7, 1961, pp. 207–220. The present paper is a continuation of the earlier one.

this account to locate at greater distances from the CBD where housing prices are lower. However, to the extent that differences in income of CBD-worker households result from wage income differences, higher-income households would value travel time more highly, T_k would be greater for them, and they would tend to locate closer to the CBD on this account alone.[2] On balance, though, the effect operating on location through greater consumption would be expected to predominate. It would seem likely that the income elasticity of marginal transport costs would be less than or equal to unity, while the income elasticity of housing demand is probably at least equal to unity and perhaps as high as two. Finally, like higher-income households, households with stronger tastes for housing consume more of it and have an incentive to locate in locations where housing prices are lower. Thus, in addition to the pure substitution effects of housing prices on quantity consumed, the consumption of housing per capita tends to be greater at greater distances from the CBD because higher-income CBD-worker households and households with stronger tastes for housing tend to locate there.

Population density is identical to the output of housing per unit of land divided by the per capita consumption of housing. The forces summarized in the preceding three paragraphs imply that population densities decline with distance from the CBD, both because the numerator declines and because the denominator increases. In my earlier paper I presented and evaluated estimates of the negative-exponential approximation to the pattern of population densities in large U.S. cities:[3]

$$D(k) = D_0 e^{-D_1 k}, \tag{2}$$

where $D(k)$ is gross population per unit of land at a distance k from the CBD, D_0 is the central density or level of population density when extrapolated to the CBD, and D_1 is the density gradient. The negative-exponential function in distance alone was found to explain about one-half of the variation in gross population density by census tract in forty-six large U.S. cities in 1950 and the fit was about the same in cities of different sizes and in different parts of the country. While too many departures from the negative-exponential pattern of decline were found to be consistent with sampling variability, there was no significant tendency for the log density-distance regressions to exhibit predominantly positive or negative curvature.

[2] I failed to spell this out in my earlier paper.

[3] *Ibid.* I also gave one rationale for this particular functional form. The reader is referred to my earlier paper for a fuller explanation of the estimates I made.

If, in addition to (2), it is assumed that the incremental supply of land to the housing industry is

$$L'(k) = \xi k, \tag{3}$$

where $(\xi/2\pi)$ is the fraction of space surrounding the CBD that is used for residential purposes, certain other relationships can be readily derived. The total population living not more than k miles from the CBD is (assuming the CBD is of negligible width)

$$P(k) = \int_0^k D(v)L'(v)\,dv \tag{4}$$

$$= \frac{\xi D_0}{D_1^2} f(D_1, k),$$

$$\text{where } f(D_1, k) = 1 - (1 + D_1 k)\,e^{-D_1 k}.$$

If one supposes that the central city of the urban area occupies a circular area of radius k_1 surrounding the CBD, its population, P_1, is given by

$$P_1 = \frac{\xi D_0}{D_1^2} f(D_1, k_1). \tag{5}$$

Likewise, on the supposition that the urbanized area is circular with a radius k_2 surrounding the CBD and assuming that (2) holds outside the central city as well, a similar expression for urbanized area population, P, can be derived. Taking P as given by other forces, the latter defines central density, D_0, in terms of P, D_1, ξ, and k_2:

$$D_0 = \frac{PD_1^2}{\xi f(D_1, k_2)}. \tag{6}$$

Hence, using (6), equation (5) can be rewritten as

$$P_1 = \frac{Pf(D_1, k_1)}{f(D_1, k_2)}. \tag{7}$$

The radius of the urbanized area is determined by the strengths and elasticities of urban and agricultural demands for land.[4] For practical purposes, however, an urbanized area is defined by the Bureau of the Census as essentially all the land area surrounding a city for which population densities exceed a certain minimum amount. Substituting this minimum density into equation (2) defines k_2.

[4] This point is discussed in more detail in my "Economic Change and Rural-Urban Land Conversions," *Econometrica*, January 1961, pp. 1–23.

In considering differences among cities and/or over time, provided that the definition of urbanized area remains the same, differentiation of (2) yields (asterisk means natural log of)

$$dk_2^* = \frac{dD_0^*}{D_1k_2} - dD_1^*, \tag{8}$$

while from (6)

$$dD_0^* = dP^* + \left(2 - \frac{\partial f_2^*}{\partial D_1^*}\right) dD_1^* - d\xi^* - \frac{\partial f_2^*}{\partial k_2^*} dk_2^*, \tag{9}$$

where

$$\frac{\partial f_2^*}{\partial D_1^*} = \frac{\partial f_2^*}{\partial k_2^*} = \frac{(D_1k_2)^2 e^{-D_1k_2}}{f(D_1, k_2)}$$

Substituting for dD_0^* in (9) and solving for dk_2^*,

$$dk_2^* = \alpha dP^* - (1 - 2\alpha)dD_1^* - \alpha d\xi^*, \tag{10}$$

where

$$\alpha = \frac{f(D_1, k_2)}{D_1k_2(1 - e^{-D_1k_2})}.$$

Since from the integrated form of (3),

$$dL^* = d\xi^* + 2dk_2^*, \tag{11}$$

where L is the total land area occupied by the urbanized area,

$$dL^* = \beta dP^* - 2(1 - \beta)dD_1^* + (1 - \beta)d\xi^*, \tag{12}$$

where $\beta = 2\alpha$. Similarly, from (7),

$$dP_1^* = dP^* + \left\{\frac{\partial f_1^*}{\partial D_1^*} - \frac{\partial f_2^*}{\partial D_1^*}\right\} dD_1^* + \frac{\partial f_1^*}{\partial k_1^*} dk_1^* - \frac{\partial f_2^*}{\partial k_2^*} dk_2^*, \tag{13}$$

$\partial f_1^*/\partial D_1^*$ being defined analogously with $\partial f_2^*/\partial D_1^*$ in (9). Substituting (10) for dk_2^* in (13),

$$dP_1^* = (1 - \gamma)\, dP^* + 2(\delta - \gamma)\, dD_1^* + 2\delta dk_1^* + \gamma d\xi^*, \tag{14}$$

where

$$\gamma = \frac{D_1k_2}{(e^{D_1k_2} - 1)} \quad \text{and} \quad \delta = \frac{1}{2}\frac{\partial f_1^*}{\partial D_1^*}.$$

Thus, on the assumptions made earlier, equations (14) and (12) express central city population and land used by the urbanized area in terms of the urbanized area population, the relative rate of decline of population densities with distance from the CBD, and the fraction of space surrounding the CBD which is used for residential purposes. (The central city population depends also on the radius of central city, which, in turn, depends mainly upon the vagaries of the political process and, apart from matters relating to municipal finance, has little economic significance.) The density gradient, in turn, may be influenced by many factors. Some of these influences, together with the variables used to describe them, are enumerated in the following section.

III

This section presents some preliminary regression estimates of the quantitative influence of various forces upon the density gradient. First, however, brief mention should be made of some of the reasons for including the variables used in my empirical analysis.

As equation (1) of the last section suggests, the relative rate of decline in housing prices with distance from the CBD varies directly with the marginal cost of transport and inversely with per capita expenditures on housing. It was argued in the last section that, because of the decline in prices with distance, the output of housing per unit of land declines, the per capita consumption of housing increases, and therefore their ratio—population density—declines with distance from the CBD. Furthermore, the more rapid the relative decline in housing prices with distance, the more rapid the decline in land rents and hence the output of housing per unit of land. In addition, the substitution of housing for other commodities because of relative price differences is stronger the more rapid the relative decline in housing prices. The incentive for higher-income CBD-worker households and households with above-average tastes for housing to locate at greater distances from the CBD is also stronger, so an increase in the rate of price decline would produce a more rapid increase in the per capita consumption of housing with distance on both counts. It follows, then, that the density gradient varies directly with the marginal cost of transport and inversely with per capita expenditures on housing. Measured density gradients might also depend on the spatial configuration of nonresidential uses of land and on factors affecting people's tastes for housing in different parts of the urban area.

In my earlier paper I described and gave the reasons for including the following variables in the analysis of differences in density gradients among cities:[5]

Present Designation	*Earlier Designation*	*Name*
MILINE	X_1	Miles of line of local transit systems per square mile of urbanized area, 1950
VEHMIL	X_2	Vehicle miles operated per mile of line, local transit systems, 1950
AGESMA	X_3	Age of the Standard Metropolitan Area (SMA), 1950
GROPOP	X_4	Proportion of SMA population growth in 1920–50
CAREGS	X_5	Car registrations per capita in principal SMA counties, 1950
URBINC	X_6	Median income, families and unrelated individuals, urbanized area, 1949
MANCIT	X_7	Proportion of manufacturing employment in the central city, 1947
RETCBD	X_8	Proportion of SMA retail sales in the central business district, 1954
SUBSTD	X_9	Proportion of central city dwelling units substandard (in need of major repair and/or lacking running water), 1950
MFGEMP	X_{10}	Proportion of urbanized area manufacturing employment (male) in manufacturing, 1950
DENCIT	X_{11}	Average density of the central city
URBPOP	X_{12}	Log_e of urbanized area population, 1950
DENGRA	—	Log_e of the density gradient, 1950.

[5] "The Spatial Structure of the Housing Market," pp. 214–217, especially Table VII.

Throughout the empirical part of this study I shall designate variables by six-letter code names rather than by more conventional symbols.

In addition to the above, I have included several other variables in the subsequent analysis, which are the following:

Designation	*Name*
180CIT	1 if "waterfront" city (see below), 0 otherwise
PEROOM	Proportion of central city dwelling units with more than one person per room, 1950
CITINC	Median income of families and unrelated individuals, central city of the urbanized area, 1949
POPNEG	Proportion of the central city population which was Negro, 1950
AGEDUS	Proportion of the central city's dwelling units which were built prior to 1920, 1950
SMAMFG	Log_e of manufacturing production worker employment in the standard metropolitan area, 1947
REGION	1 for urbanized areas in the South (of Washington, D.C.) and West (St. Louis, Mo.), 0 otherwise
RADCEN	Average distance from the CBD to the boundary of the central city (k_1 of Section II)
CNTPOP	Log_e of the population of the central city of the urbanized area, 1950
LNAREA	Log_e of the land area occupied by the urbanized area, 1950

The reasons for including this latter set as well as some modifications and extensions of my original list of reasons for including the variables used in my previous paper are described immediately below.

The most important variable affecting the average per capita expenditure on housing in a city is income. As noted in the discussion of the effect of income on the optimal location for a household in the preceding section, while an increase in income tends to increase both the marginal costs of transport and expenditures for housing, the latter effect would be expected to be the stronger. An increase in the average level of income in the urban area would thus be expected to reduce the density gradient. There are several other reasons for the demand for housing to grow more rapidly in the outer parts of cities as income increases and, hence, for density gradients to vary inversely with income. If higher-income households have stronger preferences for newer housing, an increase in the average income level of the city would increase the relative demand for new housing, and the latter is typically located in the outer part of the city. Or, if preferences for good- as opposed to poor-quality housing increase with the income level of a household, the concentration of poor-quality housing in the central parts of the city would mean a relative decline in the demand for housing there with an increase in income. Finally, for various reasons higher-income households may have stronger preferences for space than for other characteristics of housing or for single-family housing. Since space is relatively cheaper in the outlying parts of the city, population and housing output might increase more rapidly near the edges of the city with a growth in income for this last reason.

Another important determinant of housing consumption, and thus the price gradient, is the price of housing services. But the impact of differences in housing prices on the price gradient depends critically upon the price elasticity of housing demand. If the latter is -1, as some previous research would suggest,[6] then expenditure for housing, which is price times quantity purchased, would be the same irrespective of the level of housing prices. The most likely alternative to a unit elasticity of housing demand is an elastic one, in which case expenditures on housing would vary inversely and the price gradient would vary directly with the level of housing prices. The greater the price gradient, the greater the incentive for higher-income CBD-worker households or households with stronger preferences for housing to locate at greater distances from the city center, and so the greater the increase in the per household consumption of housing with distance.

The size of the price gradient also affects the rate of decline in the value of housing produced per square mile of land with distance. If housing prices were to increase, for example, because of an increase in property tax rates, the effect on variations in the intensity of residential land use with distance would depend upon the effect on the price gradient only. But if housing prices vary because of an increase in nonland costs or in the supply of land to the housing industry, the effect on the rate of decline in residential land use intensity depends upon the effects of factor cost changes on the optimal way to produce housing in the different parts of the city. Because it would appear that the relative importance of land declines as land rents do with distance from the CBD and, if anything, the elasticity of land supply to the housing industry is likely to increase, it can be shown that an increase in either nonland costs or in the supply of land to the housing industry would reduce the rate of decline in the value of housing output per square mile with distance from the CBD.

[6] See my "The Demand for Non-Farm Housing," Arnold C. Harberger, ed., *The Demand for Durable Goods,* Chicago, 1960, pp. 72–73; and Margaret G. Reid, *Housing and Income,* Chicago, 1962.

Housing prices depend upon construction costs and the level of land rents as well as upon interest and property tax rates. There is virtually no data available on intercity variation in the latter three factors. However, in cities which are built on the edge of a lake or ocean, such as Chicago or Miami, the total supply of land up to any given distance from the CBD is only about half of that in other cities, so that one might expect land rents would be greater in waterfront cities than in others of comparable size. To take account of such conditions, I have used a dummy variable 180CIT which takes the value 1 for waterfront cities and 0 for others.[7] One might also expect that land rents and thus housing prices would be greater in larger cities, and the city size variable discussed below might be expected to reflect this possibility. I have also tried a measure of residential construction costs for 1949 (CONCST) to account for some of the possible variation in housing prices among cities.[8] But since the latter was available for only twenty-eight of the thirty-six cities studied here and did not show up very strongly when included in regressions for these, it was omitted from the comparisons made here.

I initially included city size as a test for the omission of some important variable, for I could not think of any very convincing reasons why the density gradients should be negatively related to size itself. Indeed, to the extent that traffic congestion increases with city size when other measures of transport cost are held constant, marginal transport costs and hence the density gradient might be expected to increase with size. The negative association between size and the estimated density gradient is to be explained, I believe, by the less-than-unit elasticity of substitu-

[7] This is admittedly a very crude procedure. For example, Seattle, which is mostly built on a narrow corridor of land between Puget Sound and Lake Washington, obviously has less land surrounding the CBD than other waterfront cities. On the other hand, Boston is built on a sector of approximately 270 degrees surrounding Massachusetts Bay. More land surrounds Boston's CBD than Chicago's, but still more surrounds the CBD of cities such as Indianapolis. There is also the problem of how to treat cities such as St. Louis whose CBD's are separated from much of the surrounding land area by major rivers. But, because land costs are but a small fraction of the price of housing, it did not seem worthwhile to attempt to construct a more sophisticated land availability variable unless preliminary investigation suggested that this factor might be of decided importance. Cities treated as waterfront cities and assigned the value 1 for the 180CIT variable are: Buffalo, Chicago, Cleveland, Detroit (because of the national boundary), Miami, Milwaukee, San Diego, and Seattle.

[8] This is the Boeckh index for brick structures (1926–29 U. S. average = 100), and I wish to thank its compiler, E. H. Boeckh of Washington, D.C., for making these unpublished data available to me. I found the Boeckh index to be significantly associated with housing consumption both over time and among different cities in 1950 in my "The Demand for Non-Farm Housing."

tion of land for other factors in producing housing. As I have argued in another paper,[9] the elasticity of housing supply is inversely related to the relative importance of land. With a less-than-unit elasticity of substitution in production, the relative importance of land declines with distance from the CBD as land rents do, and, consequently, the elasticity of housing supply per unit of land increases. With an increase in total population and the resulting rise in housing prices in all parts of the city, the output of housing and residential population increase relatively more rapidly in the outer parts of the city.

As is discussed more fully below, my earlier results showed a significant negative relation between SUBSTD and the estimated density gradients. To test the possibility that it is not dwelling-unit condition itself but rather some variable or variables closely related to it that accounts for this association, several other taste variables were introduced into the comparisons later. These relate to characteristics of the inhabitants of poor-quality dwellings rather than to dwelling-unit condition as such. They are: the proportion of central city dwelling units with more than one person per room in 1950 (PEROOM), which is another measure of crowding; the median income of families and unrelated individuals in 1949 for the central city (CITINC); and the proportion of the central city population which was Negro in 1950 (POPNEG).[10] About the last of these, it is frequently argued that the expansion of Negro and other minority groups in the older parts of cities has led the former residents of these areas to seek new neighborhoods and has thus promoted a rise in property values in the outer parts of the city.[11] In these later experiments I also included the proportion of the central city's dwelling units which were built prior to 1920 (AGEDUS) to test the hypothesis that households have an aversion to living in the central city because of the age of its dwelling units.[12]

Equation (15) in Table 1, which was estimated by conventional least squares, was presented in my earlier paper.[13] Of the indicators of

[9] "The Derived Demand Curve for a Productive Factor and the Industry Supply Curve," *Oxford Economic Papers,* New Series 16, July 1964, pp. 221–234.

[10] Data on persons per room was obtained from *Census of Housing: 1950,* Vol. I, Part 1, Washington, 1953, Table 29. The other variables were obtained from *Census of Population: 1950,* Vol. II, Part 1, Washington, 1952, Table 92, and Vol. II, Table 34.

[11] See, in particular, Homer Hoyt, *One Hundred Years of Land Values in Chicago,* Chicago, 1933, p. 317.

[12] Data on age of dwelling units were obtained from *Census of Housing: 1950,* Vol. I, Part 1, Table 30.

[13] "The Spatial Structure of the Housing Market," Table VII, p. 216.

transport cost, the coefficients of VEHMIL and CAREGS each have the expected signs, and the latter is numerically more than twice its standard error. The coefficient of URBINC is negative as would be anticipated, though a little smaller than its standard error. The coefficient

TABLE 1

Initial Regression Analyses of the Determinants of DENGRA[a]

Explanatory Variable	Equation (15)	Equation (16)	Equation (17)
MILINE	.037 (.044)	.038 (.046)	–
VEHMIL × 10^{-6}	−4.8 (4.7)	1.8 (5.9)	2.2 (4.8)
AGESMA	.081 (.070)	.075 (.082)	–
GROPOP	.024 (.89)	−.050 (1.9)	–
CAREGS	−7.0[b] (3.0)	−9.2[b] (3.8)	−9.3[b] (2.5)
URBINC × 10^{-3}	−.40 (.55)	1.5 (1.5)	−.19 (.32)
MANCIT	1.5[b] (.69)	1.5[b] (.74)	1.0[b] (.57)
RETCBD	−2.3 (1.8)	−1.3 (1.9)	–
SUBSTD	−2.8[b] (1.5)	−.87 (2.1)	−2.4[b] (1.3)
MFGEMP	1.4 (.99)	1.4 (1.0)	–
DENCIT × 10^{-3}	−.020 (.046)	−.034 (.055)	–
URBPOP	−.62[c] (.22)	−.63[c] (.23)	−.47[c] (.13)
PEROOM	–	−2.1 (2.8)	–
CITINC × 10^{-3}	–	−1.9 (1.4)	–
POPNEG	–	−2.9[b] (1.8)	−2.8[b] (1.1)
AGEDUS	–	−1.2 (2.3)	–
180CIT	–	–	−.39 (.29)

Notes to Table 1

[a] Data for the following cities were used in the regressions summarized in this and all subsequent tables:

Akron, Ohio	Detroit, Mich.	Philadelphia, Pa.
Baltimore, Md.	Flint, Mich.	Pittsburgh, Pa.
Birmingham, Ala.	Fort Worth, Texas	Portland, Oregon
Boston, Mass.	Houston, Texas	Providence, R.I.
Buffalo, N.Y.	Indianapolis, Ind.	Richmond, Va.
Chicago, Ill.	Los Angeles, Cal.	Rochester, N.Y.
Cincinnati, Ohio	Louisville, Ky.	St. Louis, Mo.
Cleveland, Ohio	Memphis, Tenn.	San Diego, Cal.
Columbus, Ohio	Milwaukee, Wisc.	Syracuse, N.Y.
Dallas, Texas	New Haven, Conn.	Toledo, Ohio
Dayton, Ohio	New Orleans, La.	Utica, N.Y.
Denver, Colo.	Omaha, Nebr.	Washington, D.C.

The selection of cities is described in my "The Spatial Structure of the Housing Market," p. 210; p. 215, n. 17; and p. 217, n. 20.

[b] Significant at the one-tail 0.10 level.

[c] Significant at the two-tail 0.20 level.

of MANCIT is rather strongly positive; but the retail sales variable, while having a strongly positive simple correlation with DENGRA, has the wrong sign in (15). Of the taste variables, only SUBSTD has a coefficient that is large relative to its standard error and is of the right sign. As mentioned earlier, equation (15) indicates a strong tendency for the relative rate of decline in population density to decrease with increasing city size.

The coefficient of SUBSTD in equation (15) appears to be consistent with the "flight from blight" hypothesis—that is, that people have an aversion to living in the central cities of urbanized areas because of the poor quality of its dwelling units. However, many factors are associated with poor housing quality, and I included four of these in equation (16) to try to determine whether it is poor housing quality itself rather than some related factor which people seek to avoid. Indeed, from (16) it would appear that SUBSTD's coefficient in (15) really reflected the racial composition of the central city population. Since Negroes have lower incomes than whites, they tend to inhabit poorer-quality housing. In (16), the coefficient of POPNEG is much larger than that of SUBSTD, both numerically and relative to its standard error. In equation (17), however, from which the variables whose coefficients in (16) are negligible or have the wrong sign have been deleted, the coefficient of SUBSTD is again rather strongly negative.

The coefficients of PEROOM and AGEDUS in (16), while both negative as might be expected, are both smaller than their standard errors. CITINC has the wrong sign for a taste variable, but from (16) it would appear that it is a better income variable than URBINC. On practical grounds, there is little distinction between the two since the simple correlation between them is + .94, and I prefer URBINC on a priori grounds. As will be demonstrated in the following section, however, the effects of these two variables on the distribution of population between the central city and its suburbs and on the total land area occupied by the urbanized area appear to be quite different. Finally, the coefficient of 180CIT, the dummy variable for waterfront cities included in (17), has the sign opposite to that which would be anticipated but is moderately large in relation to its standard error. Since I wanted to include this variable in the further analysis of central city population and urbanized area land area discussed in section IV, I decided to retain it in the density-gradient equation.

IV

One of the most important possible shortcomings of the analysis summarized in the preceding section is the bias that might result from treating certain of DENGRA's explanatory variables as independent in conventional least-squares regressions when, in fact, they are jointly determined. This section will examine this question by re-estimating equation (17) using the method of two-stage least squares. In addition, I will present two-stage least-squares estimates of equations (14) and (12), using first the determinants of DENGRA and then DENGRA itself as explanatory variables. The distribution of population between the central city and its suburbs and the land area used for urban purposes both provide additional tests of my analysis of factors influencing the spread of population within urbanized areas and are of interest for their own sakes.

Of the explanatory variables included in the regression equations summarized in Table 1, one might argue that CAREGS, MANCIT, and SUBSTD should be treated as jointly dependent with DENGRA. Where cities tend to be more spread out or have smaller density gradients for reasons other than lower marginal transport costs, one would expect the demand for automobile transport and thus car ownership to be greater, other things being the same. The negative regression coefficient observed earlier might be due partly, or even wholly, to the effect of DENGRA on CAREGS rather than the reverse. Similarly, it might be argued that the distribution of population exerts a strong influence on the distribution of employment places because employers seek to reduce labor costs by locating close to the residences of their workers. It is hard to analyze the validity of such a contention because little is known empirically about the relative importance of the determinants of location of employment places in cities. I am rather inclined to dismiss it, however, because I suspect that factors such as transport costs on material inputs and final products and land costs for assembly-line type plants are likely to be much more important empirically than intracity differences in wage costs, but there is no good evidence to back up these suspicions. Finally, it is frequently argued that slums result from the decline in demand for land near the city center which has accompanied improvements in transport costs. If so, and if the other measures of transport costs included fail to remove all the variation in DENGRA on this score, then the coefficient of SUBSTD may partly reflect the effects of lower transport costs.

To test possibilities such as these, the regression coefficients of the more important variables discussed thus far were estimated, using the method of two-stage least squares. In applying this method, one must specify and use data on the predetermined variables which appear in other equations of the model. From other work I have done, it would appear that SUBSTD depends upon the following variables discussed earlier: AGESMA, GROPOP, URBPOP, and CITINC. In addition, it would appear that SUBSTD is related to the proportion of the population one year old and over in 1950 who resided in the same dwelling unit in 1949 and 1950, designated as SAMHOU.[14] Conventional least-squares regressions using CAREGS as the dependent variable indicated that, in addition to DENGRA and SUBSTD, coefficients of VEHMIL, URBINC, RETCBD, and DENCIT had meaningful signs and were large relative to their standard errors. These results, not shown here, suggested using these last four variables as predetermined variables in the two-stage least-squares analysis. While it would have been desirable to treat MANCIT as endogenously determined as well, I did not do so

[14] Data were obtained from *Census of Population: 1950*, Vol. II, Part 1, Table 86. This variable, which is negatively associated with SUBSTD, probably reflects the effects of rent control. Its effect was negligible in 1960.

because so little is known about the locational determinants of manufacturing plants within cities.[15]

In addition to the variables already noted, three other predetermined variables were used in the analysis. These are: the natural log of manufacturing production worker employment in the Standard Metropolitan Area (SMAMFG);[16] a dummy variable which takes the value 1 for

TABLE 2

Two-Stage Least-Squares Estimates of Determinants of DENGRA

Explanatory Variable	Equation (18)
VEHMIL $\times 10^{-6}$	4.2 (5.5)
CAREGS[a]	−6.3[b] (3.9)
URBINC $\times 10^{-3}$	−.21 (.34)
MANCIT	.78 (.66)
SUBSTD[a]	−1.5 (1.8)
URBPOP	−.47[c] (.13)
POPNEG	−2.6[b] (1.3)
180CIT	−.43 (.31)

[a] Treated as simultaneously determined.

[b] Significant at the one-tail 0.10 level.

[c] Significant at the two-tail 0.10 level.

[15] Evelyn M. Kitagawa and Donald J. Bogue (*Suburbanization of Manufacturing Activity within Standard Metropolitan Areas,* Oxford, Ohio, 1955, pp. 49–60), using a set of economic and demographic variables similar to those used here, were able to explain only about one-fifth of the variation among SMA's in the proportion of manufacturing employment outside the central city in 1947, and none of the explanatory variables taken separately showed a very strong association with the dependent variable.

[16] The data are taken from *ibid.*

urbanized areas in the South (below Washington, D.C.) and West (beyond St. Louis, Mo.) and 0 for others (REGION); and the average distance from the CBD to the boundary of the central city (k_1 of sec-

TABLE 3

Two-Stage Least-Squares Estimates of the Determinants of CNTPOP, Using Determinants of DENGRA, Equation (19)

Explanatory Variable	Actual Coefficients	Predicted Coefficients[a]
VEHMIL $\times 10^{-6}$	.45 (1.6)	2.2
CAREGS[b]	−1.5 (1.5)	−3.3
URBINC $\times 10^{-3}$	−1.1[c] (.43)	−.11
MANCIT	.39[c] (.18)	.41
SUBSTD[b]	−.88 (.78)	−.78
URBPOP	.92[c] (.063)	.46
POPNEG	.50 (.50)	−1.4
180 CIT	−.023 (.083)	−.43
RADCEN	−.024 (.16)	1.1
CITINC $\times 10^{-3}$	1.2[c] (.37)	–
REGION	−.0081 (.11)	–

[a] Assuming $\gamma = 0.30$, $\delta = 0.56$.

[b] Treated as simultaneously determined.

[c] Significant at the one-tail 0.10 level.

tion II here designated as RADCEN).[17] The reasons for including these last three variables will be described below.

The resulting two-stage least-squares estimates of DENGRA's determinants are shown in Table 2. While the coefficients of CAREGS and MANCIT are both a little smaller numerically than the corresponding conventional least-squares estimates shown in Table 1, the greatest difference is in SUBSTD's coefficient. In equation (18) this coefficient is only about six-tenths as large numerically as in (17), and it is now decidedly smaller than its standard error. Thus, there is considerable doubt whether locational preferences and, hence, the relative decline in population densities in cities is affected at all by the condition of the central city's housing stock. SUBSTD's coefficient in (18) is still large enough numerically to be of some practical importance, however, as explained more fully in the final section. When the actual values of DENGRA were plotted against the ones calculated from equation (18) there was little indication of nonlinearity or heteroscedasticity.

In Table 3 two-stage least-squares estimates of equation (14), using the determinants of DENGRA rather than this variable itself, are presented in the first column. The variable to be explained is CNTPOP, the natural log of the central city population.[18] The coefficients of URBINC, MANCIT, and URBPOP are all significant by the usual standards of evaluation. The last, however, is not significantly different from unity, which is a more appropriate null hypothesis. Of even greater interest to me is the consistency of the estimated coefficients with my equation (14), which in effect assumes that suburban population is determined by extrapolating the behavior of population densities within the central city out to the suburbs, and the coefficients shown in Table 2. The predicted values shown in the second column were derived from the coefficients in Table 2, together with evaluations of γ and δ shown in equation (14). The latter were made using my estimated density gradients, the k_1 or RADCEN measurements described earlier, and similar measurements made of k_2, the urbanized area radius.[19] The

[17] As measured from the Census tract maps in *Census of Population: 1950,* Vol. III, Washington, 1952. For each city, at most eight measurements separated by 45 degrees were made and averaged. The direction of the first measurement was selected at random from among 0 to 40 degrees by five-degree intervals. Measurements were made only in those directions from the CBD in which the urbanized area extended.

[18] The data are from *Census of Population: 1950,* Vol. I, Part 1, Washington, 1952, Table 17.

[19] The measurements were made from the urbanized area maps in *Census of Population: 1950,* Vol. II.

average values of these parameters for the forty-six cities for which I have estimated density gradients are $\gamma = 0.30$ and $\delta = 0.56$.

Comparing the columns in Table 2 giving the actual and predicted coefficient, the coefficients of MANCIT and SUBSTD agree quite closely, while those of CAREGS disagree by about one standard error of the actual coefficient. The actual coefficients of URBINC and URBPOP, however, are much larger numerically than the predicted values. That of URBPOP indicates that the central city population increases more rapidly as the urbanized area population grows than would be expected from the variation of population density within the central city. The coefficient of URBINC suggests that, as income grows, the suburban population grows more rapidly than would be expected from extrapolating the greater relative growth of the outer parts of the central city. One possible explanation for this discrepancy is the inducements to home ownership provided by the federal income tax advantage and federal mortgage programs. Such inducements would tend to increase the relative demand for housing in the outer parts of urban areas because single-family housing is relatively cheaper there. Their impact would be strongest in the suburban areas in the short run because vacant and agricultural land is more readily converted to new residential uses. Many other explanations could be offered, of course. Finally, the coefficient of POPNEG is positive, though not much larger than its standard error, whereas a negative one would be expected. This last suggests that, while an increase in the proportion of the central city population which is Negro may stimulate the demand for housing in the outer parts of the central city, it has no effect per se on the distribution of population between the central city and its suburbs.

One other coefficient in equation (19), that of CITINC, is statistically significant by anyone's standards and, as explained more fully later on, of substantial practical importance. In some initial regressions, using CNTPOP as the dependent variable, a weak but positive coefficient for URBINC was found. Since the latter is contrary to what would be anticipated, CITINC was included in the regression as well as to see if its omission was responsible for the positive coefficient of URBINC. One explanation for the positive coefficient of CITINC is that higher-income households have an aversion to living among lower-income ones within the central city. There are two difficulties with this interpretation, however. An aversion to certain kinds of neighbors would be expected to be related to more visible phenomena such as housing quality or race. But, more important, in equation (16) CITINC's coefficient was rather strongly negative; if the presence of low-income households in the central city increases the demand for housing in the suburban parts of the urbanized area, it would be expected to do so in the outer parts of the central city as well.

A better explanation can be found, I believe, in considering the effect of low-income households on taxes paid by higher-income central city residents. If the incomes of, say, the lower third of central city households were to fall, taxes collected from them directly or indirectly through property taxes would fall. At the same time, central city expenditures for health and welfare purposes, which are financed in substantial part by taxes collected within the central city, would probably rise. The net effect would be an increase in taxes for higher-income central

TABLE 4

Two-Stage Least-Squares Estimates of the Determinants of CNTPOP, Using DENGRA, Equation (20)

Explanatory Variable	Actual Coefficients	Predicted Coefficients[a]
URBPOP	.96[b] (.061)	.70
DENGRA[c]	.22[b] (.099)	.52
RADCEN	.17[b] (.11)	1.1
180 CIT	.080 (.078)	−.21
URBINC × 10^{-3}	−1.1[b] (.38)	–
POPNEG	.78[b] (.30)	–
CITINC	1.3[b] (.33)	–
REGION	.0092 (.10)	–

[a] Assuming $\gamma = 0.30$, $\delta = 0.56$.

[b] Significant at the one-tail 0.10 level.

[c] Treated as simultaneously determined.

city households and business firms. Such a tax increase would have no differential effect on housing demand within the central city but would reduce the attractiveness of central city relative to suburban locations.

In Table 4 an alternative form of equation (19), in which DENGRA itself rather than its determinants is included among CNTPOP's explanatory variables, is shown. Like equation (19), (20) indicates that with an increase in URBINC the demand for suburban housing increases relatively more than would be anticipated from the increased housing demand in the outer parts of the central city. In addition, with DENGRA and URBPOP held constant, an increase in the fraction of the central city population which is Negro leads to an increase in the central city population, again suggesting that the racial composition of the central city affects the relative demand for housing within the central city but less so between the central city and its suburbs. The coefficient of CITINC is again strongly significant in (20) and virtually the same magnitude as in (19). Finally, the coefficient of URBPOP is much larger than would be anticipated on the basis of equation (14), while that of DENGRA is much smaller. Together, these comparisons suggest that the factors making for an outward movement of population away from the CBD operate in the same direction but with less force between the central city and its suburbs than within the central city. This finding is directly contradictory to most popular and scholarly explanations of so-called "suburban-sprawl."

The actual values of CNTPOP were plotted against those calculated from equation (19); the scatter of points exhibited as much linearity and homoscedasticity as one could hope for. The fit was also extremely tight, but this is misleading for two reasons. First, the relevant goodness-of-fit measure for explaining CNTPOP is to be derived from the reduced-form equation for CNTPOP. And, second, the size of the urbanized area population would affect the size of the central city population on virtually any hypothesis, naive or otherwise. In CNTPOP's reduced form, R^2 is 0.99, compared with 0.94 when URBPOP alone is included; thus, the other variables employed by the model account for about four-fifths of the variance of (the log of) CNTPOP which is unaccounted for by urbanized area size alone. Furthermore, R^2 in the reduced form for DENGRA is 0.65, while the reduced form for land area explains about five-sixths of the variance not accounted for by population size. It should also be noted that conventional least-squares estimates for the central city population and land area structural equations (not shown) are substantially different from the two-stage least-squares estimates in several important instances and, where different, accord less closely with my a priori expectation.

I would now like to consider the determinants of the land occupied

TABLE 5

Two-Stage Least-Squares Estimates of the Determinants of LNAREA, Using Determinants of DENGRA, Equation (21)

Explanatory Variable	Actual Coefficients	Predicted Coefficients[a]
VEHMIL $\times 10^{-6}$	−.44 (3.3)	−2.9
CAREGS[b]	5.2[c] (3.1)	4.4
URBINC $\times 10^{-3}$	.38 (.88)	.15
MANCIT	.20 (.43)	−.55
SUBSTD[b]	−.089 (1.2)	1.0
URBPOP	.81[c] (.13)	.98
POPNEG	1.4[c] (.97)	1.8
180 CIT	.036 (.18)	.05
CITINC $\times 10^{-3}$	−.74 (.72)	–
REGION	.37[c] (.24)	–
SMAMFG	.11 (.11)	–

[a] Assuming $\beta = 0.65$.

[b] Treated as simultaneously determined.

[c] Significant at the one-tail 0.10 level.

TABLE 6

Two-Stage Least-Squares Estimates of the Determinants of LNAREA, Using DENGRA, Equation (22)

Explanatory Variable	Actual Coefficients	Predicted Coefficients[a]
URBPOP	.49[b] (.25)	.65
DENGRA[c]	−.61[b] (.37)	−.70
180 CIT	−.18 (.20)	−.24
MANCIT	1.1[b] (.69)	–
SUBSTD[c]	−2.0[b] (1.5)	–
CITINC × 10^{-3}	−.78[b] (.51)	–
REGION	.22 (.24)	–
SMAMFG	.21[b] (.15)	–

[a] Assuming $\beta = 0.65$.

[b] Significant at the one-tail 0.10 level.

[c] Treated as simultaneously determined.

by the urbanized area, LNAREA,[20] summarized in Tables 5 and 6. In the former the determinants of DENGRA are included, while DENGRA itself is used in the latter. Each of the tables shows both the actual two-stage least-squares estimates and the values of the coefficients predicted by equation (12), the coefficients of Table 2, and an average value for β of 0.65.[21] As was the case in the CNTPOP regressions, the actual coefficient of CAREGS would seem to be quite consistent with the predicted value, but in (21) the coefficients of both URBINC and POPNEG agree fairly well with their predicted values. The coefficient of

[20] The data are from *Census of Population: 1950,* Vol. I, Part 1, Table 17.

[21] β was evaluated in a way analogous to that described earlier for γ and δ.

URBPOP is a bit low but differs less drastically from its predicted value than in the CNTPOP regressions. The major disagreements now seem to be the coefficients of MANCIT, which is too large, and SUBSTD, which is too small. The latter indicates that, while the condition of the central city housing stock may influence the relative demand for housing in the outer relative to the inner parts of the central city, it has no effect upon the demand for suburban vs. central city housing. The coefficient of MANCIT might be explained by a smaller degree of substitutability of land for other productive factors in manufacturing than in the production of housing or a smaller variation in land rentals for industrial than for residential land. In either case, a shift of manufacturing plants from the suburbs to the central city coupled with a reverse shift of residences would tend to increase the urbanized area demand for land since the reduction in manufacturing demand would be numerically smaller than the increased residential demand.

Also included among the explanatory variables in Tables 5 and 6 are three which would not be expected to reflect differences in the relative rate of population density decline within the central city. CITINC was included for essentially the same reason here as in the CNTPOP regressions; initial results indicated that increasing values of URBINC are associated with decreasing amounts of urbanized land area. The LNAREA coefficients of CITINC seem to be consistent both in magnitude and sign with those in the CNTPOP regressions. REGION was included because an earlier regression exhibited predominantly positive residuals for urban areas in the South and West. The positive coefficient might result from a lower agricultural demand for land and hence lower land rentals for urban users in areas outside of the Northeast. SMAMFG was included because the positive coefficient for MANCIT observed in earlier regressions was thought to result from its intercorrelation with the former. Adding SMAMFG did indeed make MANCIT's coefficient smaller, though in (21) it remains larger than predicted by equation (12). The positive coefficient of SMAMFG may reflect the fact that manufacturing is more land intensive than other nonresidential uses of land, so that the greater the employment in manufacturing given population size, the greater the demand for urban land.

In Table 6 the coefficients of URBPOP and DENGRA both indicate a smaller response of total land used by the urbanized area than would be anticipated on the basis of the spread of population within the central city. The result here is similar to that observed in equation (20), though in (22) the differences between actual and predicted coefficients are less than one standard error of the former. The other variables included in equation (22) would seem to be consistent with the interpretation I gave for their coefficients in (21). Finally, plotting the actual values of LNAREA against the values calculated from (21) revealed little departure from linearity and homoscedasticity.

V

The principal conclusion I would draw from the material presented above is that urban decentralization is far from haphazard and only in small part a "flight from blight." Rather, the distribution of population in urban areas would appear to be consistent with a set of variables which can be given plausible interpretations in terms of the relative demand and supply of housing in different locations. The distribution of population between the central city and its suburbs and the total land occupied by an urban area are to an important extent, though not solely, explainable by the same forces that affect the spread of population within the central city.

Car registrations per capita, which I have interpreted as a proxy for the costs of automobile transport, is probably the quantitatively most significant variable affecting the intraurban distribution of population. The coefficient of CAREGS was a little over one and a half times its standard error in the DENGRA equation and almost two-thirds larger than its standard error in the LNAREA equation. Though only as large as its standard error in the CNTPOP equation, it was also only a standard error less than the value predicted by the hypothesis that the suburban population distribution is simply an extrapolation of the central city's. More important, however, CAREGS increased from about 0.26 to 0.35 during the 1950's in the cities studied here. Such an increase would be sufficient according to equation (18) to reduce the relative rate of decline of population densities within the central city by about 57 per cent. According to the actual values of coefficients of equations (19) and (21), it would reduce the central city population by about 14 per cent, holding the urbanized area population and other factors constant, and increase the total land used by the urbanized area by about 60 per cent. The observed increase in automobile ownership, then, could indeed have important effects upon urban population distribution.

The size variable (URBPOP) is the most significant of all statistically, and it too is of great practical significance. During the 1950's the increase in urbanized area population averaged about 30 per cent for the cities studied. Such an increase would reduce density gradients by about 15 per cent according to equation (18) and increase the land area occupied by the urbanized area by almost 30 per cent. The central city population would tend to grow only slightly less rapidly or about half as rapidly depending upon whether one believes the actual or predicted coefficient in equation (19). During the 1950's the fraction of SMA manufacturing employment in the central city fell by about 9 percentage points, from 0.71 to 0.62. Such a decline would reduce the density gradient by about 7 per cent and the central city population by a little less than 4 per cent. A growth in income of about 3 per cent per year would, in a decade, raise the 1950 average both for URBINC and CITINC of $3,000 by about $1,000. Such an increase would reduce the relative rate of population density decline by almost 20 per cent; thus, even though URBINC's coefficient is hardly statistically significant in the DENGRA equation, it could still be of some practical importance. In the CNTPOP equation the effects of increases in URBINC and CITINC tend to cancel, while in the LNAREA equation growth in both by the same amount would tend to reduce area by approximately one-third.

On the whole, it is hard to make a strong case statistically for the condition of the central city housing stock having any effect on urban population distribution at all. The coefficient of SUBSTD is less than its standard error in the DENGRA equation, only slightly larger in the CNTPOP equation and negligible in the LNAREA equation. In the first two, however, the coefficient is still large enough to be of some practical importance. During the 1950's the proportion of substandard central city dwellings fell from 0.20 to 0.11 in the cities studied here, mostly, I believe, because of the growth in income during the decade. Such a decline would tend to increase the density gradient by about 14 per cent and the central city population by about 8 per cent. Because of the dramatic increase in dwelling unit condition during the 1950's, one would have to argue that urban decentralization during the decade was a delayed response to previously existing poor-quality housing to try to salvage the "flight from blight" hypothesis.

A much better case can be made on purely statistical grounds for the hypothesis that decentralization has occurred because of the relative growth in central city's Negro population. POPNEG's coefficient was about twice its standard error in the DENGRA and LNAREA equations. I have not yet calculated the 1960 proportion of the central city's population which was Negro, but I doubt that the proportion could have increased more than 50 per cent or by 7 percentage points over the 1950 average of a little under 14 per cent. An increase of 7 percentage points would reduce the density gradient by approximately 20 per cent and increase land area by around 10 per cent. Thus, the effects of a changing racial composition of the central city population would certainly be small relative to those of increased automobile transportation. And, according to equation (19), relative increases in the Negro population of the central city cannot account at all for the suburbanization of population.

It would appear that the distribution of population between the central city and its suburbs and the land used by the urbanized area are largely governed by the same forces influencing population distribution within the central city. But two qualifications must be made to this statement. From my CNTPOP and LNAREA regressions, an influx of lower-income persons into the central city would tend to increase the proportion of the urbanized area's population which is suburban and also its total land area. The best explanation for this effect, I believe, is the increase in the tax burden on higher-income central city households and upon business firms which the inmigration of low-income persons would imply. Secondly, my results imply that the central city population and, to a lesser extent, the land area occupied by the central city and its suburbs tend to respond less than would be anticipated to factors that reduce the relative rate of population density decline within the central city. Such a result might follow from a long-run disequilibrium in 1950 in urbanized area population distribution, which could have resulted from the depression of the 1930's and the war and postwar adjustments of the 1940's. I hope to test this last hypothesis by repeating the analyses of CNTPOP and LNAREA for 1960. Some preliminary results seem to suggest that the regression coefficients of the more important variables were quite similar for 1950 and 1960. Another possible explanation for the discrepancy between the actual and predicted coefficients of equations (19) and (20) is that a greater fraction of total land area is held vacant in the suburbs in anticipation of more intensive future development. But, if anything, the apparent attenuation in the suburbs of forces making for decentralization is inconsistent with the statements one frequently hears that urban decentralization has been carried too far.

Finally, I would like to consider the total effects of all the changes during the 1950's on urban decentralization and examine their consistency with observed changes in central city populations and total land area used for urban purposes. Altogether the changes discussed above would imply a decline in density gradients of about 60 per cent, or from a 1950 average for the cities studied here of around 0.30 to 0.12. These same changes would imply an increase in central city populations of around 20 per cent according to the actual coefficients of equation (19), compared with an actual increase of about 9 per cent. However, a value for the coefficient of CAREGS only one standard error larger numerically than the actual coefficient in (19) would convert the expected increase to 4 per cent. Likewise, the coefficients of equation (21), together with the changes in the explanatory variables that took place during the 1950's, would imply an increase in land area of about 62 per cent, against about 82 per cent which was actually observed. Again, if CAREGS's coefficient were one standard error larger, the expected increase would be over 95 per cent. It would certainly appear, then, that my analysis of population distribution based upon differences among urbanized areas in 1950 is broadly consistent quantitatively with the urban decentralization observed during the past decade.