# The Service Sector in Urban Revitalization: Sectoral Composition, Employment Density Gradients, and Central City Fiscal Capacity

Aaron S. Gurwitz

Rand

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# The Service Sector in Urban Revitalization: Sectoral Composition, Employment Density Gradients, and Central City Fiscal Capacity

Aaron S. Gurwitz

June 1982

Prepared for
The Department of Housing and Urban Development

Rand
SANTA MONICA, CA. 90406

## PREFACE

This report was prepared for the Office of Policy Development and Research, U.S. Department of Housing and Urban Development. It is part of a series of publications on the causes and consequences of expanded service employment in metropolitan economies.

Other forthcoming reports in this series include: Anthony H. Pascal and Aaron S. Gurwitz, *Systematic Planning for Local Economic Development*, R-2932-HUD; and Aaron S. Gurwitz and Sheila Nataraj-Kirby, *The Sectoral Composition of Metropolitan Economies: Effects on the Structure of Labor Demand and Opportunities for Occupational Mobility*, R-2756-HUD.

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## SUMMARY

This report is one of a series developed under The Rand Corporation's project on the role of the service sector in urban revitalization, which analyzes the relationships between the composition of urban economies and several desirable outcomes of urban development, such as increased employment and reduced structural unemployment. This report analyzes the differences in the sectoral composition of metropolitan economies in terms of the economic health of the central city compared to that of its suburbs and the fiscal capacity of local governments in the central county of the metropolitan area to contribute to urban revitalization. Section II of this report presents initial empirical estimates of these relationships. The results are discussed, followed by presentation of an economic model of sectoral composition, employment density, and fiscal capacity. The model suggests a more refined specification for the empirical work presented in Sec. II.

The economic health of the central city compared to that of its suburbs is represented by the constant elasticity of employment density with distance from the central business district (Eq. 8). This parameter was computed for a sample of U.S. Standard Metropolitan Statistical Areas (SMSAs) using annual data from the *County Business Patterns* (U.S. Bureau of the Census, 1980) series and was regressed on variables representing the relative sizes of various economic sectors, a series of dummy variables representing sample cities, and a number of other determinants of economic geography. The results indicated that the relative sizes of certain sectors exert a significant and quantitatively important effect on the value of this constant elasticity of employment density.

To determine the effect of sectoral composition on tax bases, we regressed total local tax revenues on a series of sectoral composition terms, a set of dummy variables representing sample cities, and a number of variables believed to reflect differences in the demand for tax revenues. This regression indicated that the relative sizes of some sectors exerted a statistically significant but quantitatively small effect on the aggregate size of central county tax bases.

The results of the two sets of regressions are presented in the following table.

SUMMARY OF INDUSTRIAL COMPOSITION EFFECTS

| Industry | Distance Elasticity of Employment Density ($\delta$) | Estimated Elasticity Tax[a] |
|---|---|---|
| Cultural | .25 | .268[b] |
| Durable manufacturing | .06 | -.04 |
| Nondurable manufacturing | .21 | -.07[b] |
| Wholesale sales | .42 | .03 |
| Finance, insurance, & real estate | .53[b] | .08 |
| Hotels | -.13 | .12[b] |
| Health services | -.41[b] | .13 |
| Recreational services | -.01 | -.03 |
| Retail sales | -.87[b] | .10 |
| Legal services | .36[b] | .08 |

SOURCE: U.S. Bureau of the Census (1978), (1980).

[a] $\frac{\partial \delta}{\partial S} \frac{\bar{S}}{\bar{\delta}}$ or $\frac{\partial Tax}{\partial S} \frac{\bar{S}}{Tax}$, where S is the share of SMSA employment in the sector.

[b] Significant at the 10 percent level or above.

The model developed in the second half of this report suggests the following about an improved specification of regressions that correlates these variables.

- The effect of the relative size of a given sector on the distance elasticity of employment density depends on the sizes of sectors that lie closer to the central business district. In other words, the coefficient on each sectoral term is variable and its variance is explained by the sizes of certain specific sectors.

- The effect of the relative size of a given sector on the tax base of a city or county varies with the wage rate in the city.
- The relationship between the sizes of sectors and the tax base of a city is nonlinear. If all sectoral composition terms and all variables reflecting demand for tax revenues are interacted, it is possible to distinguish a sector's separate effects on the demand for and supply of revenues.

## ACKNOWLEDGMENTS

Special thanks go to Tony Pascal, project leader, who made valuable contributions to this report; to Susan Marquis and Richard Fernandez, who reviewed an earlier draft and offered helpful suggestions for its improvement; and to Susanne Farmer, who prepared the draft copy. The helpful comments and encouragement of Susan Jacobs, of the Office of Management and Budget, and Michael Schneider, of the Department of Housing and Urban Development, are gratefully acknowledged.

CONTENTS

PREFACE ..... iii

SUMMARY ..... v

ACKNOWLEDGMENTS ..... ix

FIGURES ..... xiii

TABLES ..... xiii

Section
I. INTRODUCTION ..... 1

II. INITIAL EMPIRICAL WORK ..... 4
Econometric Considerations ..... 7

III. A MODEL OF INDUSTRIAL COMPOSITION, EMPLOYMENT DENSITY, AND FISCAL CAPACITY ..... 16
The Basic Model ..... 16
Sectoral Employment Density ..... 17
Spatial Structure ..... 20
Aggregate Land Rents ..... 25

BIBLIOGRAPHY ..... 29

## FIGURES

1. Employment Density Gradient for a Single Industry ..... 19

2. Bid Rent Gradients for Three Sectors and Their Upper Envelope ..... 21

3. Derivation of the Equilibrium Employment Density Function .... 22

## TABLES

1. Regression Results: Determinants of Distance Elasticity of Employment Density ($\delta$) ..... 9

2. Regression Results: Determinants of Tax Revenues ..... 11

3. Summary of Industrial Composition Effects ..... 13

# I. INTRODUCTION

As part of an effort to determine the special role of service industries in the economies of U.S. cities, the Rand project team developed a series of models that compared the industrial composition of metropolitan economies with several dimensions of urban economic health (Gurwitz and Kirby, 1982; Pascal and Gurwitz, 1982). These models were then linked to form a larger simulation model designed to project the effects of alternative interventions in a local economy on a number of regional outcomes (Pascal and Gurwitz, 1981).

Two aspects of metropolitan economic conditions are treated here: the health of the central city economy compared to that of its suburbs and the financial soundness of urban governments. The evidence suggests that both the economic well-being of the central city and the financial well-being of its government are likely to be influenced by the industrial composition of the metropolitan economy. Industrial composition, in turn, may be partly controlled by policymakers through the allocation of scarce investment funds through Urban Development Action Grants (UDAGs) and other urban development programs. One useful indicator of the economic health of a central city compared to that of its suburbs is the employment density gradient.* One objective of this analysis is to assess the spatial distribution of jobs created by various sectoral outcomes of different development policies.

The fiscal capacity of a jurisdiction is largely determined by its aggregate land rents. Although local governments rely heavily on property taxes (a trend that seems to be decreasing), the contribution of land rents to short-run fiscal capacity is obvious. It has been argued that in the long-run, since all factors that contribute to fiscal capacity (with the exception of land) are mobile, the burden of

*Employment density gradient is defined here as the function D(k), where k measures distance from the central business district (CBD) and D(k) is employment density at distance k from the CBD.

all differential local taxation will fall on landowners (DeTray et al., 1981). In that case, aggregate land rents exactly measure fiscal capacity. The second objective of this analysis is to assess the effects of different industrial composition on the size of a city's tax base.

This report has two purposes. The first is to present initial empirical findings concerning the effects of the industrial composition of a metropolitan area on the spatial distribution of its economic activity and tax base. The numbers presented here have been used to create a computational model intended to assist urban planners in evaluating alternative urban development strategies (Pascal and Gurwitz, 1981). To generate these empirical findings, a large data base was assembled and new techniques for characterizing the economic geography of a metropolitan area were used. The data, techniques, and results are reported in Sec. II.

The second purpose of this report is to prepare a more accurate set of estimates on the relationship between industrial composition and the economic geography and fiscal condition of metropolitan areas. Section III develops a model of an urban economy that compares industrial composition to spatial structure and aggregate land rents. This model suggests several areas of future econometric work on those relationships.

Compared to the close attention paid in the literature to population and housing density gradients, relatively little has been reported on the determinants of employment density. The reason for that lack of attention should become clear as we present our theoretical model.

Because households or firms in a single sector such as housing differ in only a few dimensions (income, for example), simple theoretical models can yield insightful analytical findings. Once we attempt to model the simultaneous behavior of firms in different sectors, however, the dimensions increase considerably, resulting in less obvious analytical results.

The lack of empirical findings on employment density is due to the difficulty of assembling comprehensive data sets on the determinants of spatial patterns of employment. To derive the results reported here, we assembled and merged variables from several large and complex data

sets. We also accounted for variation in the geographical structure of a sample of metropolitan areas. As our work progressed, it became evident why the task had not been undertaken before.

We have identified in the literature only one cross-sectional analysis of sectoral employment density patterns, reported by Edwin Mills (1972a). Mills attempted to explain differences in employment across broadly defined sectors in central cities and suburbs of large metropolitan areas. He was unable to identify a set of factors that explained this variation. This analysis takes a different approach. Here, with data bases that allow for a more detailed sectoral breakdown than Mills', the sectoral composition itself is used to explain aggregate employment density. Mills' failure to identify determinants of sectoral density gradients probably results from an overaggregation of sectors. The model presented here, which is only an extension of Mills' theory of urban spatial structure, suggests that each well-defined sector will locate in only a narrow annulus of the entire metropolitan area.

## II. INITIAL EMPIRICAL WORK

The simplest single measure of the economic health of a central city compared to that of its suburbs is a constant distance elasticity of employment density. In other words, we assume that the density gradient takes the form

$$D_i(k) = D_{oi}e^{-\delta_i k} \tag{1}$$

where $D_i(k)$ = employment density k miles from the CBD of city i,

$D_{oi}$ = density at the CBD of i,

$\delta_i$ = constant distance elasticity of density in city i.*

We assume that one objective of urban development policy is to increase $\delta_i$, that is, to create relatively more jobs in the central city than in the suburbs.

The initial problem in developing an empirical methodology is in obtaining estimates of $\delta_i$ for a sample of cities. For this study I took annual data on employment for the central county and entire Standard Metropolitan Statistical Area (SMSA) for a sample of SMSAs from the annual *County Business Patterns* (U.S. Bureau of the Census, 1980) series.

Moving on to examine two dimensions, I assumed that employment density in each SMSA is given by

$$D(x,y) = D_o e^{-\delta\sqrt{x^2 + y^2}}, \tag{2}$$

which indicates that densities are equal along the circumference of any circle around the CBD. I then expanded the technique adopted by

*Fallis (1979) shows that under reasonable assumptions, D(k) will decrease at a diminishing rate in k. The negative exponential functional form is one of several that has this property.

Mills (1972a), which resulted in two integral equations in the two unknowns $D_o$ and $\bar{\delta}$, namely,

$$E_{CC} = \int_{x \epsilon cc} \int_{y \epsilon cc} D_o e^{-\bar{\delta}\sqrt{x^2 + y^2}} \, dy \, dx \tag{3}$$

and

$$E_{SMSA} = \int_{x \epsilon SMSA} \int_{y \epsilon SMSA} D_o e^{-\bar{\delta}\sqrt{x^2 + y^2}} \, dy \, dx \tag{4}$$

The maps of the SMSAs and counties were approximated on cartesian coordinates, and the metropolitan and county borders were taken as the limits of integration for the two equations. The equations are then solved for $D_o$ and $\bar{\delta}$, using numerical techniques of approximation.

The CBP series, therefore, allows us to compute density parameters for each SMSA in the sample for most years from 1963 through 1977.* These constitute the dependent variables for a pooled time series cross-sectional estimate.

The independent variables included the following categories:

- Proportions of SMSA employment in each of a number of industries
- Total SMSA employment
- Determinants of location and magnitude of residents' demand for land (population, income, percent in poverty, population density)
- Dummy variables for most cities

The estimating equation was

$$\bar{\delta}_{it} = \beta_o + \sum_{j=1}^{j} \beta_j S_{jit} + \sigma_o E_{it} + \sum_{k=1}^{k} \sigma_k X_{kit} + U_{it} \tag{5}$$

where $\bar{\delta}_{it}$ = distance elasticity of employment density in SMSA i at time t,

*The years 1965, 1967, and 1972 were missing from this series. This data set, an invaluable one for analysis of regional economies in the United States, had never been assembled in consistent, machine readable form.

$S_{jit}$ = share of employment in sector j in SMSA i at time t,
$E_{it}$ = total employment in i at time t,
$X_{kit}$ = value of the kth characteristic in i at time t,
$U_{it}$ = normally distributed random variable in the mean zero and variance $\sigma_{it}$ (see below).

Total employment and sectoral proportions were also drawn from the CBP series. Other data for this equation were drawn from the *City and County Data Book* (U.S. Bureau of the Census, 1978).

To estimate effects of industrial composition on the tax base, a measure of that base is needed. Cross-sectional data on property tax bases for cities are notoriously dissimilar and cannot be compared. Consequently, I took tax revenues as the dependent variable for a sample of central counties* and controlled for determinants of revenues other than the size of the tax base by entering the following as independent variables:

- Determinants of demand for public service (population, population density, school age population, percent of population below poverty level, crime rate),
- Size of residential property tax base (value of housing),
- Size of sales and income tax base (total annual wages),
- Dummy variables for most cities.

The equation was

$$T_{it} = \alpha_o + \sum_{j=1}^{j} \alpha_i S_{ijt} + \eta_o E_{it} + \sum_{k=1}^{k} \eta_i X_{ikt} + U_{it}, \qquad (6)$$

where $T_{it}$ = total local tax revenues in central county i at time t.

Other elements of Eq. (6) are defined the same as above except that the list of $X_{ik}$s will differ between the two equations.

---

*Our objective was to analyze central city fiscal capacity; however, there is apparently no data set that includes annual observations on employment in a wide variety of sectors for central cities. A central county analysis was adopted as a next best alternative.

The magnitude and industrial composition of employment and wage variables used reflect annual figures drawn from the CBP series. Other variables were taken from the *City and County Data Book* (U.S. Bureau of the Census, 1978) and were interpolated for years between the decenial censuses. The tax revenue variable was taken from the series *Local Government Finances in Selected Metropolitan Areas and Large Counties* (U.S. Bureau of Census, 1977). All monetary variables were converted to constant 1967 dollars.

## ECONOMETRIC CONSIDERATIONS

The ideal econometric technique for these models would be the maximum likelihood estimator described by Mundlak (1978). With that technique, the structure of the data may include two components of variance in the residual term, cross-sectional and time series, and, as the model presented in the next section indicates is likely, the coefficients on the sectoral terms can vary systematically across observations and over time. Unfortunately, application of Mundlak's techniques requires the development of new computer software, a task beyond the scope of this project. Available software packages designed for pooled data could not generate variance components estimates with missing observations, nor could they accommodate as many dummy variables as the number of cities in the sample. Therefore, the following ad hoc estimator was used.

First, I estimated the correlations between dummy variables for each SMSA in the sample and all of the other variables in the two equations. (The results of these estimates are reported in Tables 1 and 2, and the findings on the effects of industrial composition are summarized in Table 3.) Dummy variables for any city for which the correlation between that dummy and one or more of the other variables exceeded 0.30 were included in the final regression equation.* Thus, all dummy variables that, if omitted, would be most likely to bias the estimates of other coefficients, were included.

Second, I assumed that variance across observations was constant at any point in time, but that serial correlation within individual time

*The value 0.3 was selected because that level eliminated enough SMSAs to accommodate the capacity of the software package.

series was possible.* Accordingly, I estimated each equation using ordinary least squares and computed the mean Durbin-Watson Statistic for the set of time series (see Johnston, 1972). This test indicated that strong positive autocorrelation was present in the density gradient equation (DW = 0.313). The test was inconclusive (DW = 1.39) for the tax equation. Minimizing computational error suggested acceptance of the ordinary least squares results for the tax equation, but efficient estimation of the density equation required generalized least squares.

The generalized estimator followed the procedure suggested by Johnston (1972). An equation identical to Eq. (5), but including a lagged dependent variable and lagged independent variables on the right hand side and excluding the city dummies, was estimated. The (significant) coefficient of 0.80 on the lagged dependent variable was taken as an estimate of the autoregressive term. Then a series of matrices were constructed to form

$$\Omega_j = \begin{bmatrix} \rho^{t_0} & \rho^{t_1} & \rho^{t_2} & \cdots & \rho^{t_n} \\ \rho^{t_1} & & & & \\ \rho^{t_2} & & & & \\ \vdots & & & & \\ \rho^{t_n} & \rho^{t_{n-1}} & \rho^{t_{n-2}} & \cdots & \rho^{t_0} \end{bmatrix} \qquad (7)$$

where $t_1, \ldots, t_n$ are associated with the n years of the time series available for city j.

*There are several reasons to suspect autocorrelation. The most important of these has to do with the effects of exogenous economic development projects in the city or suburbs. If planners "force" a sector that would ordinarily locate in the fringe into the central city, the result would be a disturbance that is sustained through time.

Table 1

REGRESSION RESULTS: DETERMINANTS OF DISTANCE ELASTICITY OF EMPLOYMENT DENSITY ($\delta$)

| Variables | Parameter Estimate | $t$-Ratio |
|---|---|---|
| Independent Variables | | |
| Intercept | 0.010371 | 2.1586 |
| Density | 0.00006386108 | 5.0520 |
| Income | 0.00000125492 | 0.3326 |
| Time | -0.00122627 | -1.0168 |
| Total Employment | -2.90633E-07 | -4.6482 |
| Percent Cultural Employment | 0.427459 | 1.5295 |
| Durable Manufacturing | 0.025314 | 0.5051 |
| Nondurable Manufacturing | 0.102444 | 1.3450 |
| Wholesale Sales | 0.336608 | 1.4435 |
| Finance, Insurance, & Real Estate | 0.622545 | 2.3984 |
| Hotels | -0.587013 | -1.1045 |
| Health | -0.413148 | -1.8527 |
| Recreation | -0.042332 | -0.0573 |
| Retail Sales | -0.249778 | -1.7390 |
| Legal Services | 5.471415 | 1.6328 |
| Dummy Variables for Sample Cities | | |
| Akron, OH | -0.057110 | -1.8683 |
| Albany, GA | 0.152254 | 4.7420 |
| Albuquerque, NM | 0.0003631669 | 0.0120 |
| Alexandria, AL | -0.00433327 | -0.1386 |
| Amarillo, TX | 0.195936 | 5.8149 |
| Atlanta, GA | 0.020901 | 0.6129 |
| Austin, TX | -0.031930 | -0.9860 |
| Battle Creek, MI | -0.023152 | -0.7425 |
| Birmingham, AL | -0.025662 | -0.8798 |
| Canton, OH | -0.024934 | -0.8493 |
| Chattanooga, TN | -0.011176 | -0.3655 |
| Colorado Springs, CO | 0.058510 | 1.6612 |
| Eau Claire, WI | 0.017798 | 0.5568 |
| Evansville, IL | -0.015627 | -0.5469 |
| Flint, MI | -0.022173 | -0.6827 |
| Florence, AL | -0.027778 | -0.8939 |
| Harrisburg, PA | -0.027714 | -0.4125 |
| Houston, TX | 0.049675 | 1.3535 |
| Huntsville, AL | -0.017377 | -0.5758 |
| Jackson, MS | 0.424878 | 13.3350 |
| Johnstown, PA | 0.011217 | 0.3858 |

Table 1 (cont.)

| Dummy Variables for Sample Cities | Parameter Estimate | $t$-ratio |
|---|---|---|
| Lynchburg, VA | 0.297514 | 7.9538 |
| Memphis, TN | 0.060452 | 1.9568 |
| Philadelphia, PA | -0.613623 | -4.4589 |
| Pittsburgh, PA | 0.015499 | 0.4327 |
| Richmond, VA | -0.199149 | -3.8623 |
| Roanoke, VA | -0.125250 | -2.6080 |
| Rockford, IL | -0.020132 | -0.6552 |
| St. Cloud, MN | -0.00227529 | -0.0696 |
| St. Louis, MO | -0.459179 | -4.5512 |
| Salem, OR | -0.038945 | -1.3870 |
| San Antonio, TX | -0.035246 | -1.1780 |
| Shreveport, LA | 0.026488 | 0.7027 |
| South Bend, IN | -0.057265 | -2.0832 |
| Springfield, IL | -0.020337 | -0.6300 |
| Terre Haute, IN | -0.025568 | -0.8621 |
| Topeka, KN | -0.027807 | -0.8955 |
| Wheeling, WV | -0.047632 | -1.6134 |
| Wichita Falls, TX | 0.050716 | 1.6583 |
| York, PA | -0.036919 | -1.1802 |

SOURCE: U.S. Bureau of the Census (1977), (1978), (1980).

Table 2

REGRESSION RESULTS: DETERMINANTS OF TAX REVENUES

| Variables | Parameter Estimate | $t$-Ratio |
|---|---|---|
| Independent Variables | | |
| Intercept | -796.451128 | -2.9668 |
| Density | 0.012463 | 1.2713 |
| Income | 0.050574 | 3.5803 |
| Time | -1.510971 | -1.2756 |
| Percent Poor | 8.706957 | 2.8067 |
| Crime Rate | -2393.58 | -1.7884 |
| School Age Population | 1119.823 | 1.2669 |
| Value of Housing | 0.101668 | 1.0301 |
| Wages | 0.021074 | 4.0337 |
| Total Employment | 0.0001000699 | 2.3384 |
| Percent Cultural Employment | 1194.078 | 2.9790 |
| Durable Manufacturing | -35.537211 | -0.4287 |
| Nondurable Manufacturing | -204.851996 | -2.0053 |
| Wholesale Sales | 63.850424 | 0.2337 |
| Finance, Insurance, & Real Estate | 253.756623 | 0.7628 |
| Hotels | 1413.893 | 2.0442 |
| Health | 330.278257 | 0.8331 |
| Recreation | -613.304577 | -0.4754 |
| Retail Sales | 77.097107 | 0.3441 |
| Legal Services | 3466.219 | 0.8532 |
| Dummy Variables for Sample Cities | | |
| Akron, OH | 3.784174 | 0.2038 |
| Atlanta, GA | -30.082412 | -1.5125 |
| Birmingham, AL | -30.750756 | -1.6099 |
| Flint, MI | 11.907003 | 0.5573 |
| Houston, TX | -21.410520 | -1.2149 |
| Memphis, TN | 25.536814 | 1.4425 |
| Philadelphia, PA | -152.405288 | -1.4398 |
| Pittsburgh, PA | -36.794000 | -1.4560 |
| Richmond, VA | 85.829422 | 2.0004 |

SOURCE: U.S. Bureau of the Census (1977), (1978), (1980).

For the cities with the most complete time series, $(t_0)$, = 0,1,3,5,7,8, 9,11,12,13,14. For cities with less complete time series, the relevant rows and columns were deleted from the complete matrix. I then computed the inverse dispersion matrix for the sample as a whole.

$$\Omega^{-1} = \begin{bmatrix} \Omega_1^{-1} & 0 & \cdots & 0 \\ 0 & \Omega_2^{-1} & \cdots & 0 \\ \vdots & & & \\ 0 & \cdots & & \Omega_j^{-1} \end{bmatrix} \qquad (8)$$

This matrix was used to weight the observations for the generalized least squares estimate of Eq. (1).

Besides obtaining parameter estimates for use in a simulation model, our objective in estimating these equations was to determine whether industrial composition exerts a significant and quantitatively important effect on the spatial distribution of employment. Table 3 indicates that some of these effects are indeed significant. The effects are also quantitatively important. To see this, observe the percentile distribution of $\delta$.

| Percentile | Value of $\delta$ |
|---|---|
| 100 | .558 |
| 75 | .043 |
| 50 | .019 |
| 25 | .0089 |
| 0 | ~0 |

Total employment averaged 173,492 in the sample SMSAs over the 1963-77 period. The average proportion of employment in, say, finance, insurance, and real estate was 0.049 or 8,501 jobs. If this proportion decreased to 0.033, a loss of about 2,776 jobs in the sector,* the effect over the

*With a prorata increase in all other sectors.

Table 3

SUMMARY OF INDUSTRIAL COMPOSITION EFFECTS

| Industry | Distance Elasticity of Employment Density ($\delta$) | Estimated Elasticity Tax[a] |
|---|---|---|
| Cultural | .25 | .268[b] |
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| Hotels | -.13 | .12[b] |
| Health services | -.41[b] | .13 |
| Recreational services | -.01 | -.03 |
| Retail sales | -.87[b] | .10 |
| Legal services | .36[b] | .08 |

SOURCE: U.S. Bureau of the Census (1977), (1978), (1980).

[a] $\frac{\partial \delta}{\partial S} \frac{\bar{S}}{\bar{\delta}}$ or $\frac{\partial Tax}{\partial S} \frac{\bar{S}}{Tax}$, where S is the share of SMSA employment in the sector.

[b] Significant at the 10 percent level or above.

long-run would be enough to change $\delta$ for the city from the median to the lowest quartile. A decrease of 2,776 jobs in a sector such as finance insurance and real estate is substantial, but not unprecedented in metropolitan areas. An asymmetry in the distribution of $\delta$ indicates that a much larger change in employment would be necessary to shift a city's employment distribution from the median to 75th percentile. In the average city, such a shift would require, for example, an increase of 761 jobs in the legal services sector,* more than a doubling of the average employment in that sector for the sample cities. Nevertheless, the magnitude of the coefficients indicates that the degree to which a metropolitan area's employment is concentrated near the center, compared to that of other areas, is at least moderately sensitive to the relative sizes of certain industries in the regional economy.

* With a prorata decrease in all other sectors.

The same is true of the effects of sector size on tax revenues. To understand those effects, consider what differences in tax revenues would be associated with a shift of 1,000 jobs from nondurable goods manufacturing to hotels in the average city, everything else being equal. That difference would represent a million dollar increase in tax revenues, or about a 0.6 percent increase in the average of $149.65 million for the sample cities over the 1963-77 period. A shift of 1,000 jobs would result in only about a 9 percent decrease in employment in nondurable manufacturing, but about a 50 percent increase in hotel employment. The latter figure, however, is not out of the question if the "average" city could expect to attract a moderate amount of new convention business.

We may conclude that moderate differences in industrial composition are associated with small but significant differences in tax revenues. Those findings indicate that the effects of different sectoral strategies can have significantly different effects on at least two outcomes of urban development that may be of interest to policymakers. If a city were choosing between two development strategies, one aimed at growth in nondurable manufacturing and the other at growth in the hotel industry, the difference in tax revenues generated is potentially large enough for planners to take into account, making more refined and narrowly focused analysis of these relationships worthwhile.

Indeed, further analysis is required to ensure reliable results for city planning and policymaking. The results presented here are adequate only for a preliminary specification of a simulation model for several reasons. First, for computational convenience, I have assumed that sectoral coefficients are constant across metropolitan areas. As we shall see, this is probably not the case.

Second, the model estimated here is a long-run equilibrium model. The estimates do not account for the short-run effects of existing physical structures, except through the dummy variables, which cannot represent certain specific disequilibrium effects. Nor can the model tell us anything about the dynamics of change in tax revenues or spatial structure for a specific, induced change in industrial composition. The coefficient estimates indicate average effects of relative industry size on, say, spatial composition. However, if a certain industry could be

induced, by zoning or subsidy, to locate somewhere other than it would in an unperturbed equilibrium, the immediate and long-run effects of industrial growth may be very different.

Third, in the tax equation specified here, the degree to which any estimated industrial effect reflects changes in the demand for or supply of revenues is unknown. The large, positive coefficient for hotel employment could reflect either that industry's contribution to the local tax base or the additional police protection required to attract tourists and convention goers.

All of the caveats having been stated and the case for a better designed analytical effort having been made, it should be pointed out that the estimates presented here can be used in an initial simulation model. The estimated coefficients are unbiased estimates of the relative average effects of different industries on the estimated variables. They can be used to predict long-run equilibrium effects of changes in industrial composition on employment concentration and government expenditures. If we further assume that industrial composition has a stronger effect on the supply of tax revenues than on the demand for them, we can identify the estimates in Table 2 that will affect the tax base. In other words, the results can be used to indicate the general direction of different industrial development strategies and to compare one strategy with another to determine their effect on the two outcomes. Without further refinement, however, they cannot be used to compare the values of these effects with the values of other outcomes of urban development such as aggregate employment or minority employment.

## III. A MODEL OF INDUSTRIAL COMPOSITION, EMPLOYMENT DENSITY, AND FISCAL CAPACITY

The estimates presented in Sec. II may be satisfactory for the initial specification of an urban development simulation model. However, improving that model will require more appropriate statistical techniques. In this section we develop a model that shows the relationships between industrial composition, density gradients, and tax bases, and suggest some of the complexities that a good estimator should take into account. For example, the model suggests that the coefficients for the industrial composition terms are likely to vary systematically across cities and that the correct specification of the tax base equation is nonlinear.

We must acknowledge, however, that this is not the only possible model that generates useful insights into these relationships, nor does this approach account for all possible complexities. The model is static, the modeled city is monocentric, and the sectoral production functions are very restrictive. The model presented here, however, is useful because it suggests a few empirical departures.

### THE BASIC MODEL

We begin with the following assumptions:

1. That perfectly competitive firms in industry ($i = 1, \ldots, I$) produce output $X_i$ using land, labor, and capital inputs.
2. That capital and labor are used in a fixed proportion in each sector (the proportion of labor in the fixed labor capital combination in sector $i$ is $a_i$).
3. That land and capital-labor are combined to produce $X_i$ under a constant returns to scale Cobb-Douglas production function.
4. That all output is sold at the CBD at a price per unit, and that a unit of the output of a firm can be transported to the CBD from a distance $k$ miles from the CBD at a cost that absorbs a proportion $\tau_i(k)$ of the value of the units ($\tau_i'(k) > 0$).*

*This assumption renders the model more appropriate for some sectors (e.g., legal services) than for others (e.g., retail sales).

5. That some proportion of the land k miles from the CBD, $\emptyset$, is available for use by firms. $\emptyset$ is determined by geography and (exogenous) zoning ordinances. $(0 < \emptyset < 2\pi)$.

Given these assumptions, we can define a unit of output in such a way that

$$X_i(k) = (\emptyset k)^{\alpha_i} N(k)^{1-\alpha_i} \tag{9}$$

where $X_i(k)$ = quantity of $X_i$, which would be produced k miles from the CBD,
$N(k)$ = number of units of the labor-capital input used,
$\emptyset k$ = amount of land available k miles from the CBD,
$\alpha_i$ = a production function parameter.

6. Firms maximize profits given the prices of inputs and output.
7. The price of a unit of the labor-capital input is invariant with distance from the CBD.*

The profit function is therefore

$$\Pi = P_i(\emptyset k)^{\alpha_i} N(k)^{1-\alpha_i} \left[1 - \tau_i(k)\right] - \emptyset k\, r(k) - w\, N(k), \tag{10}$$

where $r(k)$ = rental price of a unit of land k miles from the CBD,
$w$ = price of a unit of labor-capital.

SECTORAL EMPLOYMENT DENSITY

The only choice variable for the firms in sector i located k miles from the CBD is the quantity of capital-labor they will use. Maximizing Eq. (2) with respect to N(k) gives us:

*It is interesting to note that, to my knowledge, the empirical regularity that wages decline with distance from the CBD has always been explained by transportation costs, never by changes in the industrial composition of employment at different distances from the CBD.

$$\frac{d\Pi(k)}{dN(k)} = (1 - \alpha_i)P_i(\emptyset k)^{\alpha_i} N(k)^{-\alpha_i} \left[1 - \tau_i(k)\right] - w = 0. \qquad (11)$$

Therefore,

$$N_i(k) = \left[\frac{(1 - \alpha_i)P_i[1 - \tau_i(k)]}{w}\right]^{\frac{1}{\alpha_i}} \emptyset k. \qquad (12)$$

So that if only firms in sector i locate at distance k, employment density at k will be

$$D_i(k) = \left[\frac{a_i(1 - \alpha_i)P_i[1 - \tau_i(k)]}{w}\right]^{\frac{1}{\alpha_i}}, \qquad (13)$$

where $a_i$ represents the number of units of labor in one unit of labor-capital, and

$$D_i'(k) = \frac{-1}{\alpha_i}\left[\frac{a_i(1 - \alpha_i)P_i[1 - \tau_i(k)]}{w}\right]^{\frac{1-\alpha_i}{\alpha_i}} \frac{a_i(1 - \alpha_i)P_i\ \tau_i'(k)}{w}, \qquad (14)$$

so that $D_i'(k) < 0$. It can also be shown that $D''(k) \geq 0$ if $t''(k) \leq 0$.

$$D''(k) = \frac{1}{\alpha_i}\left[\frac{a_i(1-\alpha_i)\ P_i[1 - t_i(k)]}{w}\right]^{\frac{1-\alpha_i}{\alpha_i}} \frac{a_i(1-\alpha_i)P_i}{w}\left[\frac{1-\alpha_i}{\alpha_i}\frac{[t_i'(k)]^2}{1-t_i(k)} - t_i''(k)\right].$$

Furthermore, it is reasonable to believe that $\tau''(k) < 0$, because traffic congestion will be lower at greater distances from the central city. It is, therefore, not inconsistent to assume

8. That $D_i(k)$ can be closely approximated by $D_{oi}e^{-\delta_i k}$ where $D_{oi}$ is what employment density at the CBD would be if firms in sector i located there and $\delta_i$ is a constant parameter.

Given assumption 8, we see that

$$\frac{D_i'(k)}{D_i(k)} = \delta_i. \qquad (15)$$

So that, from Eqs. (13) and (14),

$$\delta_i = \frac{\tau_i(k)}{\alpha_i[1 - \tau_i(k)]} \cdot \tag{16}$$

In other words, if the entire local economy consisted of firms in sector i, the observed employment density gradient would take the form $D(k) = D_{oi}e^{-\delta_i k}$ and would look like the curve in Fig. 1.

However, since firms of type i will not typically locate throughout urban areas, but only within some annulus, say $(\underline{k}_i, \bar{k}_i)$, only the arc of $D_{oi}e^{-\delta_i k}$ between $\underline{k}_i$ and $\bar{k}_i$ will eventually form a part of the observed density gradient. The shape of the actual density gradient, therefore, depends both on the gradient parameters for each sector and on the spatial structure of the entire metropolitan area.

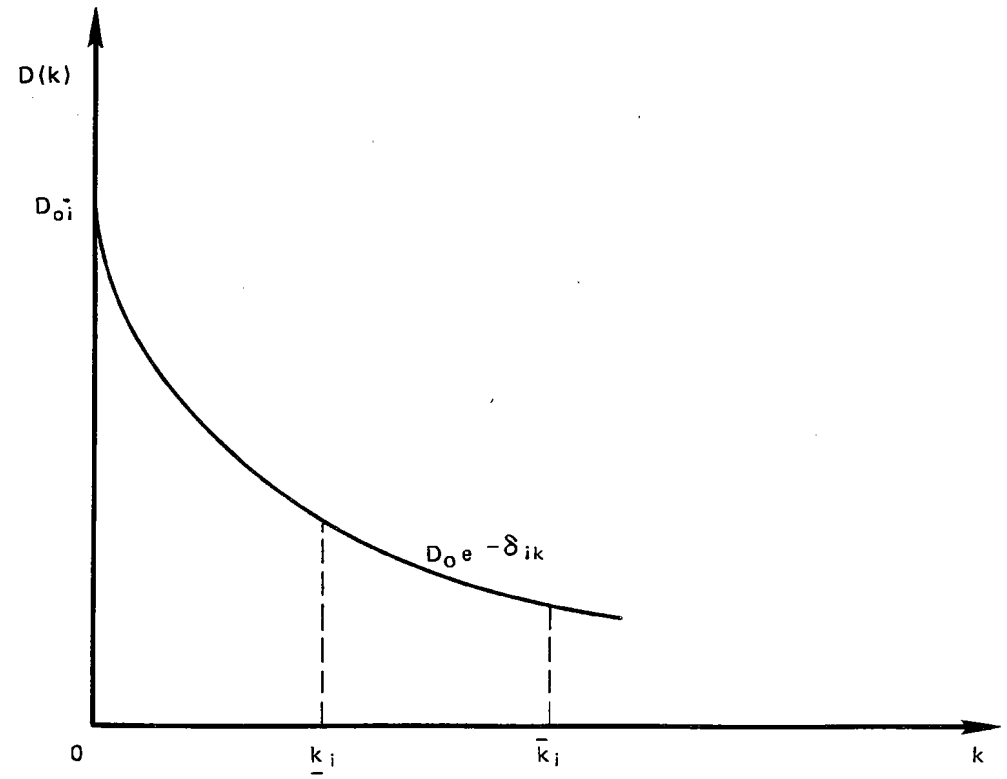


Fig. 1 — Employment density gradient for a single industry

SPATIAL STRUCTURE

Now we assume

9. That competition drives profits to zero, that is, all differential profits are absorbed by land rents.

This means that the bid rent at distance k offered by firms in sector i will be:

$$r_i(k) = \frac{P_i(\emptyset k)^{\alpha_i} N(k)^{1-\alpha_i} \left[ 1 - \tau_i(k) \right] - w\, N(k)}{\emptyset k} . \qquad (17)$$

One final assumption completes a model of the spatial structure of production in the urban area:

10. Landowners rent their land to the sector offering the highest bid rent per acre at that bid rent.

Equation (17) defines a downward sloping bid rent gradient for each sector. Three of these gradients are illustrated in Fig. 2.* The rental rate for agricultural land is $r_a$. The observed rent gradient is represented by the cross hatched upper envelope and the $\bar{k}_i$s and $\underline{k}_i$s depict the spatial distribution of economic activities in the urban area. If we knew all of the output prices, transportation cost functions, production function parameters and the price of labor-capital we could compute for each i

$$[\underline{k}_i, \bar{k}_i) \text{ s.t. } r_i(k) > r_j(k) \forall_j,\ k \in [\underline{k}_i, \bar{k}_i) . \qquad (18)$$

Given the assumed strict convexity of the functional forms and the large number of parameters that influence the bid rents of each sector, it is likely that the region $[\underline{k}_i, \bar{k}_i)$ will be well-defined, unique, and exclusive. This would give us a complete spatial description of economic activity within the urban area, which would allow the comparative static of

*In general these curves will be nonlinear, but have been made linear for ease of illustrating these gradients.

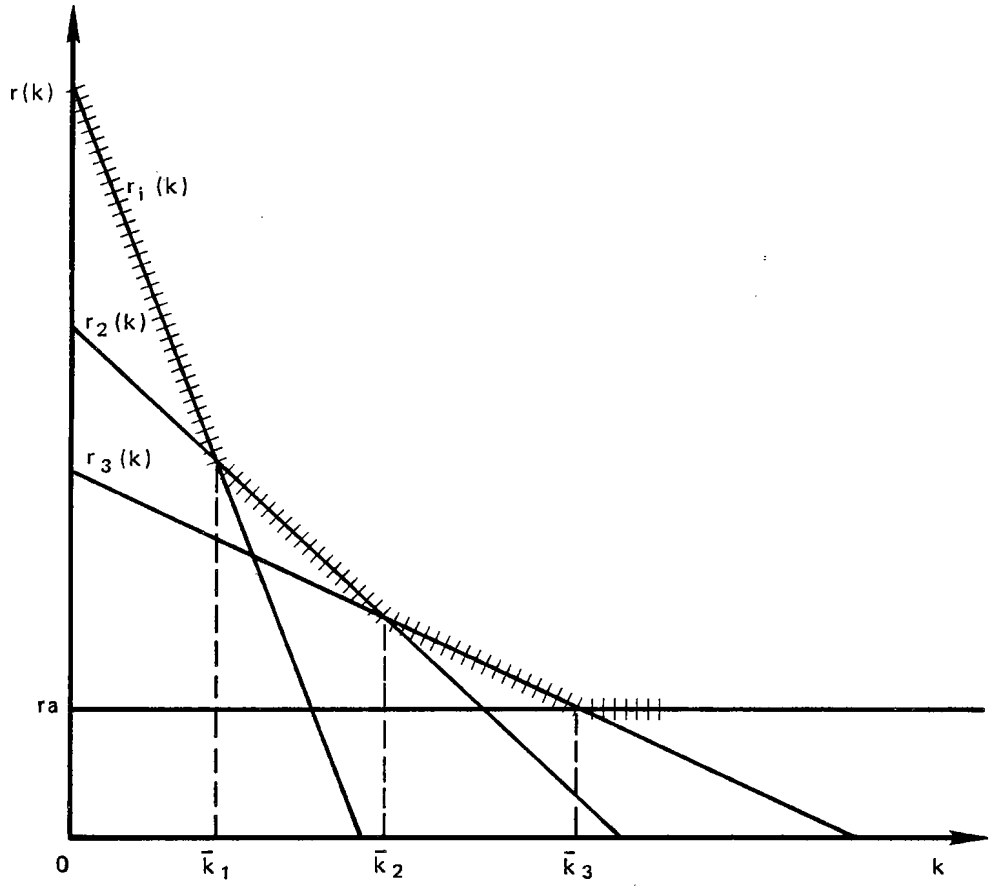


**Fig. 2 — Bid rent gradients for three sectors and their upper envelope**

alternative parameter configurations to be analyzed. Unfortunately, we do not know, nor are we likely to be able to discover in the near future, the values of all of the relevant parameters. We can, however, use this framework to show how different sectors contribute to the steepness of the average employment density gradient.

Consider the sectoral employment density gradients of the three sectors illustrated in Fig. 3. Our objective is to determine how much any given sector contributes to the steepness of the average density function.

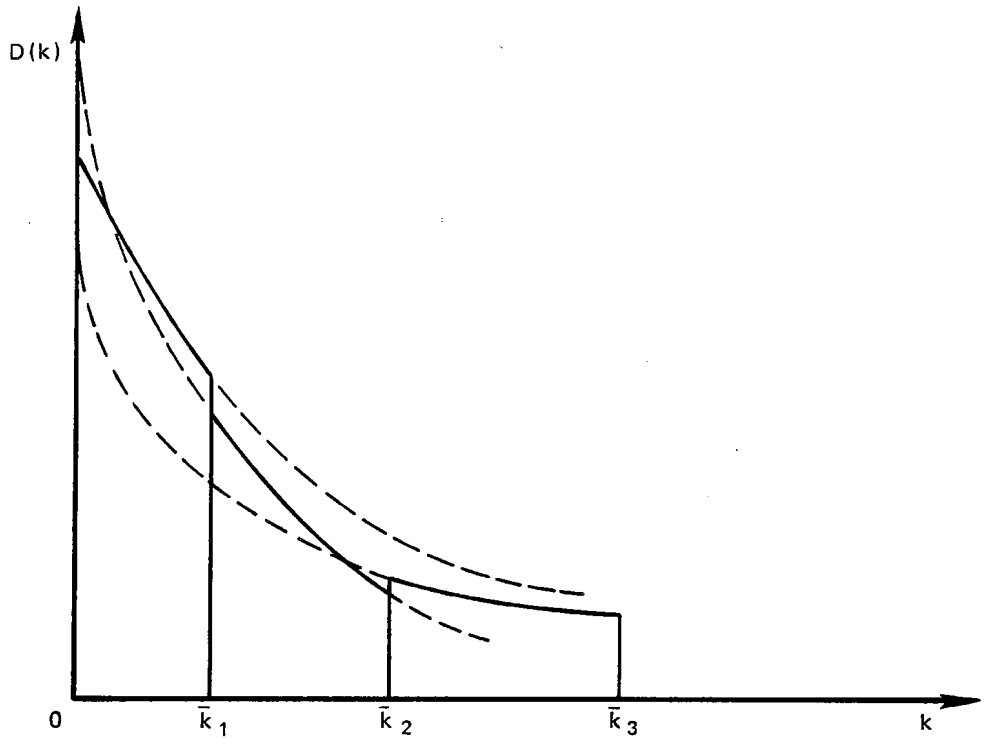


Fig. 3 — Derivation of the equilibrium employment density function

$$D_o e^{-\bar{\delta}k} \tag{19}$$

To determine this, consider a city with a large number of sectors, so that each sector covers only a very small annulus, effectively one point for each sector in a figure like Fig. 3. Each sector would then be represented by a point.

$$(k_i, D_{oi} e^{-\delta_i k_i}) \tag{20}$$

The average density function is defined by the $\bar{\delta}$ and $D_o$ that minimize the sum of the squared differences between

$$(k_i, D_{oi}e^{-\delta_i k_i}) \tag{20}$$

and

$$(k_i, D_o e^{-\bar{\delta} k_i}) \quad , \tag{21}$$

and we already know that $D_o$ is the $D_{oi}$, where 1 is the index of the sector that lies closest to the CBD. The solution to this problem does not change if we treat the natural logarithmic transform of $D_o e^{-\bar{\delta} k_i}$. The solution to this problem, which is equivalent to finding an OLS coefficient, is

$$\bar{\delta} = (1/\Sigma k_i^2) \sum_i (k_i \log D_{oi} - \delta_i k_i^2) \tag{22}$$

The right-hand side of this equation uses two different types of information: 1) information about sectors because

$$\delta_i = t_i'(k)/\alpha_i[1 - t_i(k)] \tag{23}$$

and

$$D_{oi} = \lim_{k \to o} D(k) = \left[\frac{\alpha_i(1 - \alpha_i)P_i}{w}\right]^{1/\alpha_i} ; \tag{24}$$

and 2) information about the city because the $k_i$s represent the distance from the ring in which sector i locates to the CBD.

Furthermore, we see that the specific spatial structure of economic activity is the city (the $k_i$s), which influences the way in which the size of a specific industry affects the city's $\delta$. That is, the relative and absolute weights of $\delta_i$ and $D_{oi}$ in determining $\bar{\delta}$ for a specific city differ, depending on how far sector i locates from the center of that city.

This conclusion, along with one more assumption, suggests a variable coefficients specification for the relationship we are examining.

11. Assume that the order in which sectors rank themselves in distance from the CBD is constant across SMSAs.

In other words, we assume that a certain sector always lies closest to the CBD, another is always the next closest, and so on. Whether or not this assumption is precisely true depends on the characteristics of the urban spatial-equilibrium problem discussed earlier. The assumption is, however, true to the spirit of the Von Thunen approach on which this general model is based (see Mills, 1972, p. 41). (Von Thunen tried to explain the regularity in the ranking of crops in the distance from the market they were grown.)

If Assumption 11 holds, the distance any sector lies from the CBD depends on the sizes (e.g., levels of employment) of the sectors that lie closer to the CBD. The effect of an increase in employment in a sector on relative economic conditions in the central city and suburbs of a given metropolitan area depends on the sizes of sectors with a lower rank.

We can, therefore, specify a variable coefficients estimation of $\delta$ in the following form.

$$\bar{\delta}_i = \sum_i \beta_{ij} L_{ij} + u_j \tag{25}$$

$$\beta_{ij} = \gamma_{ki} \sum_{k<i} L_{kj} + v_{ji} \tag{26}$$

where $L_{ij}$ = employment in sector i in city j,
$\beta_{ij}$ = a variable coefficient,
k = indexing of sectors in the rank of their distances from the central city,
$u_j$, $v_{ji}$ = random variables.

The ranking of the sectors used in this model could be obtained from the estimates presented in Table 1. If we rank the sectors according to the magnitude of their coefficients in the determination of $\bar{\delta}$ in this simple specification, we have: Rank 1 = closest to CBD or greatest contribution to $\bar{\delta}$. Using this ranking method, the sectors are ordered as follows:

1. Legal services
2. Finance, insurance, and real estate
3. Cultural services
4. Wholesale sales
5. Nondurable manufacturing
6. Durable manufacturing
7. Recreation
8. Retail sales
9. Health
10. Hotels

Other methods of ranking these sectors might include taking surveys of the location of the firm in a sample of metropolitan areas.

One addition to Eq. (20) is probably advisable. Note that all sectoral effects in a city are weighted by $1/\Sigma k_i^2$. This figure will reflect the size of the metropolitan area (i.e., if total employment is large, the figure will be large), and will also reflect the degree to which the annuli in the outermost sectors are narrow (i.e., many radii are almost as large as the largest). This factor might be corrected for by including terms for total employment and the proportion of employment in sectors, say, 8, 9, and 10 in total employment in each of the $\beta_{ij}$ equations.

Finally, we must include a variety of other exogenous determinants of economic geography (housing density, etc.) in Eq. (19). Many of these factors can be subsumed into a dummy variable for each city.

This part of the analysis concludes that the correct econometric specification of the relationship between the size of individual sectors and the concentration of employment close to the CBD must take into account differences in sectoral effects across cities. These differences are determined by the size of sectors that lie closer to the CBD, to total employment, and to the relative sizes of the outermost sectors.

AGGREGATE LAND RENTS

Land rents generated by a sector are equal to revenues left over once capital and labor are paid. Aggregate rents are the sum of sectoral rents:

$$R = \sum_i (P_i X_i - wN_i) - \sum_i P_i X_i - (w + m) \ , \qquad (27)$$

where R = aggregate land rents,

w = aggregate wages,

m = aggregate payments to capital.

Given competition, the labor-capital input will be paid the value of its marginal product, and with the Cobb-Douglas production function, we have:

$$wN_i = (1 - \alpha_i)P_i X_i$$

or

$$P_i X_i = \left(\frac{w}{1 - \alpha_i}\right) N_i - \alpha_i \left(\frac{w}{1 - \alpha_i}\right) L_i \ , \qquad (28)$$

where $\alpha_i$, again, is the number of units of labor in a unit of labor capital. Hence

$$R = \sum_i \left\{ \alpha_i \left(\frac{1 - \alpha_i}{w}\right) \right\} L_i - (w + m) \ . \qquad (29)$$

Note now that the price of labor-capital enters into the coefficient of $L_i$ in the summation in Eq. (24). It may be reasonable to assume away differences in the price of capital across metropolitan areas, but the prices of labor certainly do vary across metropolitan areas and over time. This suggests a variable coefficients estimate of a stochastic form of this equation with the coefficient varying systematically with metropolitan wage rate. (I merely state this conclusion here to focus on other potential complexities that should be taken into account in future econometric work on this problem.) For notational convenience, then, assume

12. That the term inside (i) in Eq. (24) is constant across cities and across time.

We can now write Eq. (24) as

$$R = \sum_i \mu_i L_i - (w + m) \ . \qquad (30)$$

To translate aggregate rents into the property tax base we assume

13. That at any time the property tax base is equal to aggregate land rents paid by firms, plus aggregate payments to capital by firms, plus the aggregate (imputed rental) value of housing;*

14. That the proportion of total government revenues raised by property taxes is exogenously determined and equal to $\Psi_j$ in city j;

and

15. The rate at which the property tax base is taxed is determined by the demand for government services which, in turn, is a linear function of a vector of city characteristics, $Y_\ell \ell = 1, \ldots, L$.**

Assumption 13 tells us that the property tax base is given by

$$\beta = \sum_i \mu_i N_i - W + H \quad , \tag{31}$$

where H = interest rate multiplied by the aggregate value of (land and capital) used in housing.

Assumption 14 tells us that total property tax revenues will be a proportion, $\Psi$, of total revenues. Demand for total revenues may be given by $\sum_{\ell=1}^{L} \nu_\ell Y_\ell$. This linear function may be normalized so that

$$\rho = \Psi \sum_{\ell=1}^{L} \nu_\ell Y_\ell \quad , \tag{32}$$

where $\rho$ is the property tax rate. Total property tax revenues are therefore:

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*The contents of factory buildings as well as the buildings themselves are usually subject to property taxation.

**The list of Ys may include levels of proportions of employment in different sectors, i.e., some of the Ls in Eq. (23). In other words, the methodology being developed here can distinguish the effects of sectoral employment on the demand for and supply of tax revenues.

$$T_{jt} = \Psi \left[ \sum_{\ell=1}^{L} \nu_\ell Y_{\ell jt} \right] \left[ \sum_{i=1}^{I} \mu_i N_{ijt} \right] + \Psi(H_j - W_j) \sum_{\ell=1}^{L} \nu_\ell Y_{\ell jt} + V_{jt} , \quad (27)$$

where j = indexing of cities,

t = indexing of time,

$V_{jt}$ = a stochastic disturbance.

Estimates of Eq. (27) could be used to identify the $\mu_i$s, relative degrees to which activity in any given sector, as measured by employment in that sector, contributes to aggregate land rents and therefore to fiscal capacity.

Our discussion here leads to two conclusions about the econometric specification of the relationship between industrial composition and size of the tax base. First, the effects of a single sector on the size of a metropolitan area's tax base vary across metropolitan areas according to wage rate. Second, even though we have no reliable, direct observations on the size of the tax base, we can identify the tax base effects of industrial composition by estimating a nonlinear model of tax revenue determination.

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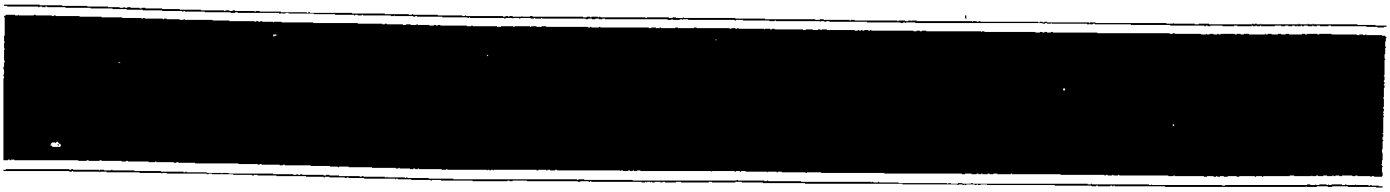
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