Urban Labor Markets And Commuting

by

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ABSTRACT

Urban employment locations in the United States have become increasingly decentralized in the postwar era, mirroring the residential suburbanization which has also occurred. This study analyzes this trend and links this spatial distribution of employment to wages and commuting times for metropolitan workers.

The study consists of four chapters. The first chapter uses data from the 1980 and 1990 U.S. censuses to document the suburbanization trend in large metropolitan areas during the 1980's. Employment was found to have become increasingly decentralized in all regions of the country and in all sectors of the economy. Commuting times for workers in suburban employment locations were also found to have increased more than those of central city workers.

The second chapter uses a simple linear programming model to show how differentials in commuting time between employment locations are capitalized into wages and rents. The shadow wage differential is shown to depend upon the commuting times of commuters from the marginal zone, implying that larger employment centers will have higher wages and longer average commuting times.

The third chapter uses data from the 1990 Public Use Microdata Sample to estimate the spatial variation in wages within five metropolitan areas. Wages are shown to vary significantly in each city. The wage variation is also significantly correlated with the average commuting times of workers in each employment zone, thereby supporting the theory of the wage capitalization of commuting time.

The final chapter examines changes in wages, commuting times, and employment levels between 1980 and 1990 in each of the five areas used in chapter 3. Employment growth is found to have been stronger in zones with lower initial wage levels. Wage levels are also found to have converged significantly during the decade, while evidence of commuting time convergence is weaker.

Thesis Supervisor: William C. Wheaton
Title: Professor of Economics

Acknowledgements

As with any doctoral dissertation, this work represents the culmination of many years of study and research. The process has not been one of steady and consistent progress, but rather resembles Dr. Stephen Gould's "punctuated equilibrium" theory of evolutionary development: long periods of head-scratching and equanimity interrupted by brief flashes of furious activity and progress. It is hoped that the final product is most reflective of these shorter periods.

I would like to thank those at M.I.T. who have assisted me in making it through my Ph.D. program. In particular, I am indebted to my thesis advisor, Bill Wheaton, for his encouragement, advice, and patience as my dissertation slowly iterated through numerous ideas and topics into its final form. Gary King and John Dippold provided valuable administrative and technical assistance. I would also like to thank the National Science Foundation and Don Pickrell of the Volpe National Transportation Systems Center for financial support.

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Chapter 1

Employment Decentralization in U. S. Cities: 1980-1990

I. Introduction

The increasing suburbanization of urban populations has been a constant feature of urban development in the United States since at least the late 19th Century,[1] the result of increasing real incomes and decreasing intracity transportation costs, as well as increasing urban populations. These underlying factors have been especially strong in the post-World War II era, as increasing household income, the Baby Boom, growing private automobile ownership, and improved urban highway systems enabled large tracts of land near established urban centers to be developed as residential communities. For example, the central city share of population in Mills' sample of 18 metropolitan areas declined from 57.3% to 39.9% between 1950 and 1980 (Mills 1972, Mills and Hamilton 1984). The implied population density gradient coefficient for those cities declined from .58 to .24 (Macauley 1985).[2]

This trend in household residential locations has been mirrored by the decentralization of urban employment locations. In Mills' sample, the central city share of metropolitan area employment declined from 70.1% to 49.5% over the period.[3] The same trend in employment continued during the 1980's, as the central city share of metropolitan population nationwide remained steady, increasing slightly from 40.1% to 40.4%, while the employment share decreased from 49.4% to 47.3%.[4]

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[1]See Meyer and Gomez-Ibanez (1981), Appendix, for data on Milwaukee, Philadelphia, and Chicago which support this.

[2]This coefficient is the slope parameter of a negative exponential density function; i.e., the rate at which density declines with distance from the city center.

[3]The average employment density gradient coefficients decline from a range of.68 (manufacturing) to 1.00 (wholesaling) in 1948 to a range of .30 (retailing) to .38 (services) in 1977.

[4]Population figures for 1980 and 1990 are from the Census Bureau (1980) and (1990); employment figures are from U.S. Dept. of Transportation (1992).

The decentralization of urban employment centers has been due primarily to technological factors which have reduced the incentive for employment concentration. Changes in the sectoral composition of the American economy, toward light manufacturing and services, have decreased the importance of centrally-located export facilities (Meyer and Gomez-Ibanez 1981). More recently, improvements in telecommunications technology and the expansion of the information production sector have decreased production economies of scale in employment.[5] Changes in manufacturing toward more land-intensive production processes have increased the importance of land costs in the cost function. This weakening of centripetal forces has increased the relative strength of the centrifugal forces of lower suburban land and labor costs.

This chapter uses data from the 1980 and 1990 decennial censuses to document the trend toward greater employment decentralization in 47 of the largest U.S. metropolitan areas during the decade of the 1980's. Changes in commuting times are also presented, and the link between suburbanization and commuting is addressed.

II. Data

The data used in this chapter were drawn from two sources: a) the *1980 Journey-to-Work Files*[6], and b) the *1990 Census Transportation Planning Package*[7]. The sample was limited to metropolitan areas with a minimum 1990 population of 750,000. In making comparisons across census years, several issues were addressed:

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[5]A growing segment of the workforce in this sector is becoming "completely decentralized", as workers are able to use computers and fax machines to "telecommute".

[6]9-track data tapes from the *Bureau of the Census*, distributed by the Inter-University Consortium for Political and Social Research. These contain totals of workers by industry, occupation, and means of transportation for all counties in the United States, and for Places with population greater than 25,000.

[7]CD-ROM files distributed by the *Bureau of Transportation Statistics*. These files contain extensive tabulations and cross-tabulations of commuting flows for places larger than 2,500 in population.

A. Comparability of the Data

The key census variables of interest in this chapter were place of work and travel times to work. The questions asked on the census were similar in the two years, though tabulations for 1980 were made using only one-half of the full sample (FHWA 1994). The key discrepancy between the two censuses, however, is in the way in which workers with unreported work locations are dealt with. In 1980, these were recorded under the separate category "Place of Work Not Reported". In 1990, however these workers were assigned a place of work based on travel time, means of transportation, and other demographic factors, and no tallies were given for the total number of allocated workers. To facilitate comparability, the non-reported workers from each place of residence with commuting flows to places of work within the selected metropolitan areas were allocated to each place of work based on that workplace's share of reported commuters from that place of residence.

B. Geographic Definitions

1) Metropolitan Areas. Metropolitan area boundaries are defined by the Office of Management and Budget as groups of counties, surrounding an urban core, which are economically and socially integrated.[8] The boundary definitions are adjusted after each census to reflect new patterns of residential and economic development. Early census reports from each census are generally based on the preceding redefinitions; thus, the 1980 census reports are based on the 1974 OMB definition, and 1990 census reports are based on the 1983 definitions. Later intra-decade reports (such as the *Statistical Abstract of the United States*) generally use the updated definitions. To ensure comparability of the data from two censuses

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[8]Metropolitan areas in the New England states are based on city and town boundaries. Cities and towns in this region fulfill many functions performed by counties in other regions, and are exhaustive within each state.

used in this chapter, the 1983 definitions were used, and the 1980 data was retabulated to reflect this.[9]

Metropolitan areas are also classified (after the 1983 redefinition) as either a) Consolidated Metropolitan Statistical Areas (CMSA's), comprised of two or more Primary Metropolitan Statistical Areas (PMSA's), or b) Metropolitan Statistical Areas (MSA's). The metropolitan area definitions used here are either CMSA's or MSA's, and are listed in Appendix A.

2) Central Places. The other important geographic issue concerns the definition of the "central place", as opposed to the "suburbs". The 1994 *Trends* report published by the Federal Highway Administration continues the practice in earlier such reports of using the central county, rather than the central city, to define the central place. This approach has the following advntages and disadvantages:

a) Many metropolitan areas have multiple central cities defined by the Census Bureau, leading to ambiguities in using this definition. Many of these so-called "central cities" (such as Mesa, Arizona, and Virginia Beach, Virginia) are clearly suburban in nature, while others (such as Long Beach, California or Akron, Ohio), are clearly minor centers relative to their larger counterparts. Using a central county definition, however, does not necessarily alleviate this problem, as many of these alternate central cities are also in other counties.

b) The central counties often account for a disproportionate share of total metropolitan residences and employment. Table 1.1 shows these proportions for the metropolitan areas used in the *Trends* report. While the table provides evidence of widespread employment

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[9] The notable exceptions are the metropolitan areas of Boston, Hartford, Providence, and New Haven. Definitions of metropolitan areas in New England are based on city and town boundaries, as opposed to county boundaries. Exact metropolitan definitions based on these minor civil divisions could not be obtained during the course of this research; thus, these cities are eliminated from the data and analysis which follow.

decentralization during the 1980's (as the central county share declines for almost every city), the central counties themselves encompass a large fraction of the workforce within most of the metro areas, with more than half having central counties with more than 45% of the workforce by residence. Among the ten cities whose central counties house less than 30% of metropolitan workers, however, eight of them are coextensive with their central cities.[10] Thus, the using the central city as the central place might better distinguish the center from the suburbs.

c) Much of the growth in "edge cities" during the 1980's took place in the inner suburbs, many along circumferential highways. Many of these suburbs fall within the central county, thus making their growth indistinguishable from that of the central city.

d) County boundaries do offer the advantage of being much more permanent than city boundaries, which can change due to annexation. Table 1.2 shows the land area of the largest central cities in metropolitan areas with populations greater than 750,000 in 1990. The table shows that, for most cities, changes in land area were very minor, amounting to less than 5%.[11] Annexation of new land was limited primarily to the newer, growing cities of the Sunbelt and West. Such growth would tend to dampen the magnitude of any measured decentralization during the time period.

e) The use of central cities has some of the same deficiencies as central counties. Many large cities incorporate large areas with densities and land use patterns that are clearly suburban in nature, thus obscuring the center city/suburb dichotomy. The 1980 Census additionally broke down central city employment into central business district (CBD)/non-CBD

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[10]Atlanta and New York City are the exceptions.

[11]The data were obtained from the 1983 and 1994 *County and City Data Books*, published by the Census Bureau. Since most cities experienced no boundary changes, it is unclear where the discrepancies in most cases may have come from.

employment, allowing a finer definition of centrality. Unfortunately, however, the 1990 Census did not, making comparisons across time impossible.

With all of the above arguments in mind, it was decided for the purposes of this chapter to use the central city as the unit of central place.[12] This approach should provide more insight into the American suburbanization experience of the 1980's than using central counties, while noting the caveats of additional central cities and boundary changes which make the analysis less clean than it might otherwise be.

The focus of this paper on examining first differences in employment growth and commuting times helps to mitigate a common problem of cross-sectional analyses of suburbanization. As noted above, central cities vary widely in the nature of the land use patterns which their political boundaries encompass. Thus, comparisons across urban areas using central city/suburban dichotomies to define the relevant variables become more difficult to interpret. Analyzing changes over time should help reduce these difficulties by focusing on dynamic (rather than static) variation within metropolitan areas.

III. Evidence of Employment Decentralization

A. Central City vs. Suburban Employment Growth

Table 1.3 shows how metropolitan employment growth during the 1980's was distributed between central cities and suburban locations. Suburban employment grew faster than central city employment in all but two of the metropolitan areas listed.[13] The suburbanization trend occurred across the board, in large, medium, and small metropolitan areas. The regional breakdowns show that this occurred in all regions of the country: the Northeast and Midwest

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[12]The one exception is New York City, which is comprised of multiple counties. Thus, the central city for this metropolitan area was defined to be New York County (Manhattan Borough).

[13]The two cities with faster-growing central cities, Charlotte and Greensboro, NC, were among those listed in Table 1.2 which had significant growth in the land area of their central cities.

had stagnant central cities, growing suburbs, and moderate growth overall, while the rapidly growing Sunbelt regions had moderate growth in their central cities (many of which were growing geographically as well), and extremely rapid growth in their suburbs. Table 1.4 displays the same data in terms of the central cities' share of total metropolitan employment.

Tables 1.5a and 1.5b break down employment suburbanization by industry and region. The table shows that decentralization crossed all sectors of the urban economy, as suburban growth was greater in the expanding service sectors, while job losses were smaller in the declining manufacturing sector. The trend was most pronounced in the wholesale, utility, and financial sectors, and was less pronounced in personal and professional services. The sectoral trends in decentralization were also common across regions.

B. Import Ratios

The import ratio for a region is defined as the number of workers employed in the region divided by the number of workers residing in the region. Thus, the import ratio for the central city in a metropolitan area represents a measure of employment decentralization relative to residential decentralization. Table 1.6 lists import ratios for the central cities of the metropolian areas for 1980 and 1990. Changes in import ratios for most cities were small, indicating that the employment suburbanization trend during the 1980's essentially followed the continued suburbanization of urban populations. Import ratios in some cities (especially Norfolk, Tampa, and Orlando) rose sharply during this period; understanding the exact reasons for this would require a more in-depth knowledge of local land use pattern and jurisdictional changes during the decade.

III. Decentralization and Commuting Time Changes

Table 1.7 lists the average commuting time by place of work for commuters in each metropolitan area.[14] Overall, commuting times rose slightly during the decade, particularly in the growing cities of the South and West. Figure 1.1 shows this correlation between metropolitan growth rates and commuting time changes. The bivariate regression coefficient suggests that a 10% increase in employment increases average metropolitan commuting times by approximately one-half minute.[15] The effect of decentralization can be seen by adding the change in the central city employment share to the regression: the coefficient implies that a 10 percentage point decrease in the central city share decreases commuting times by .7 minutes (Table 1.8a).[16]

The table also shows, however, that commuting time changes varied between central city and suburban employment locations, with central cities seeing a decrease in times overall, while suburban commuting journeys lengthened in time almost everywhere. Figure 1.2 and Table 1.8b show the relationship between employment growth and commuting time change for both cities and suburbs. Central city commuting times appear to be very responsive to employment growth, slightly more so than metropolitan areas in general. The same coefficient for suburban work locations, however, is much smaller, and the commuting time/employment growth correlation is not as strong.

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[14]This excludes individuals who worked at home, though these workers are included in the totals presented in Table 1.3.

[15]Commuting times could increase due to either longer average commuting journeys, as the urban area expands outward, or to increased congestion caused by more workers commuting within the same space.

[16]This result is essentially a simplified, first-differenced version of the approach used in Gordon, Kumar and Richardson (1989). They used the central city employment share as a measure of decentralization in a regression model of cross-section variation in average commuting times across large and small urbanized areas. Other regressors in their equations included density, land area, income and employment mix measures. They found a significantly positive coefficient on the central city employment share. While they gave no interpretation to the magnitude of the coefficient, they did see this as support for the view that more centralized cities would have longer commuting times.

Figures 1.3 and 1.4 plot the differentials in the central city/suburban commuting time change against the percentage employment growth differential (suburbs-city) and changes in the import ratio, respectively, with regression results summarized in Table 1.9. Most cities in Figure 1.3 appear in the northeast quadrant, reflecting the general trend of greater suburban employment growth combined with larger increases in average commuting times. The relationship is significantly positive, as greater suburban relative employment growth results in a greater differential in commuting time changes. Conversely, central city import ratio changes are strongly negatively correlated with commuting time change differentials: central cities which experienced larger expansions/smaller contractions of their employment base than of their population base had a smaller increase in suburban commuting times relative to the inner city.

V. Conclusions

The increasing suburbanization of employment was a nearly ubiquitous phenomenon in large metropolitan areas in the U. S. during the 1980's. The trend was not localized, but rather occurred in all regions and all sectors of the economy, both those which were expanding and those which were contracting, as the industrial mix shifted toward the service sector and migration from the Rustbelt to the Sunbelt continued.

Employment decentralization appears to have had a significant impact on commuting times, as it led to greater increases in commuting times for suburban-employed workers and smaller increases or even decreases in central city commuting times. Suburbanization seems to have had the effect of dampening increases in overall metropolitan commuting caused by general urban employment growth, as longer average commuting journeys (due to increased metropolitan size) were offset by the movement of jobs toward the decentralizing residential locations of the workforce. These dynamic effects of employment decentralization will be explored further in Chapter 4, where evidence of intraurban convergence in employment, commuting times, and wages will be presented.

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Appendix 1A
Metropolitan Areas and Abbreviations

Abbreviation	Metro Area
ALB	Albany-Schenectady-Troy, NY MSA
ATL	Atlanta, GA MSA
BAL	Baltimore, MD MSA
BIR	Birmingham, AL MSA
BUF	Buffalo-Niagara Falls, NY CMSA
CHL	Charlotte-Gastonia-Rock Hill, NC-SC MSA
CHI	Chicago-Gary-Lake County, IL-IN-WI CMSA
CIN	Cincinnati-Hamilton, OH-KY-IN CMSA
CLE	Cleveland-Akron-Lorain, OH CMSA
COL	Columbus, OH MSA
DAL	Dallas-Fort Worth, TX CMSA
DAY	Dayton-Springfield, OH MSA
DEN	Denver-Boulder, CO CMSA
DET	Detroit-Ann Arbor, MI CMSA
GSB	Greensboro--Winston-Salem--High Point, NC MSA
HON	Honolulu, HI MSA
HOU	Houston-Galveston-Brazoria, TX CMSA
IND	Indianapolis, IN MSA
JAC	Jacksonville, FL MSA
KCY	Kansas City, MO-KS MSA
LAN	Los Angeles-Anaheim-Riverside, CA CMSA
LOU	Louisville, KY-IN MSA
MEM	Memphis, TN-AR-MS MSA
MIA	Miami-Fort Lauderdale, FL CMSA
MIL	Milwaukee-Racine, WI CMSA
MIN	Minneapolis-St. Paul, MN-WI MSA
NAS	Nashville, TN MSA
NEO	New Orleans, LA MSA
NYC	New York-Northern New Jersey-Long Island CMSA
NOR	Norfolk-Virginia Beach-Newport News, VA MSA
OKC	Oklahoma City, OK MSA
ORL	Orlando, FL MSA
PHI	Philadelphia-Wilmington-Trenton, PA-NJ-DE-MD CMSA
PHX	Phoenix, AZ MSA
PIT	Pittsburgh-Beaver Valley, PA CMSA
POR	Portland-Vancouver, OR-WA CMSA
RIC	Richmond-Petersburg, VA MSA
ROC	Rochester, NY MSA
SAC	Sacramento, CA MSA
SLC	St. Louis, MO-IL MSA
SAT	Salt Lake City-Ogden, UT MSA
SDG	San Antonio, TX MSA
SFO	San Diego, CA MSA
SEA	San Francisco-Oakland-San Jose, CA CMSA
STL	Seattle-Tacoma, WA CMSA
TAM	Tampa-St. Petersburg-Clearwater, FL MSA
WAS	Washington, DC-MD-VA MSA

Table 1.1

Metro Area	Percent in Central County			
	Place of Work		Place of Residence	
	1980	1990	1980	1990
New York City	28.6	25.4	9.4	9.4
San Francisco	20.6	17.6	13.0	11.9
St. Louis	33.8	27.4	16.7	13.9
Washington	40.8	35.8	17.9	13.8
Atlanta	46.7	37.7	25.3	21.3
Philadelphia	33.5	28.1	25.5	22.9
Denver	48.6	38.8	30.2	24.0
Baltimore	47.1-	36.0	30.2	25.8
Portland	60.8	51.8	39.0	39.6
New Orleans	58.1	49.6	42.0	36.3
Kansas City	55.8	47.6	43.9	39.5
Detroit	49.2	41.5	44.7	39.6
Tampa	47.7	47.9	45.3	44.9
Dallas	62.9	58.5	45.4	47.7
Minneapolis	54.6	53.4	46.1	42.9
Cleveland	61.2	59.4	53.0	49.7
Milwaukee	68.5	62.9	60.7	56.9
Pittsburgh	72.9	70.4	62.4	62.3
Miami	67.0	64.7	63.2	60.2
Cincinnati	68.9	64.3	63.2	49.1
Seattle	70.2	69.5	63.8	61.6
Los Angeles	70.2	63.9	65.1	60.4
Chicago	71.2	66.9	65.2	61.7
Indianapolis	73.9	77.8	66.5	63.5
Columbus	86.4	81.3	72.0	71.9
Sacramento	80.9	73.0	72.3	70.3
Houston	85.0	84.2	79.6	77.1
Buffalo	82.4	83.7	81.6	81.5
San Antonio	94.6	93.5	92.2	90.8
Phoenix	100.0	100.0	100.0	100.0
San Diego	100.0	100.0	100.0	100.0

Table 1.2

City	Land Area (sq. mi.)			
	1980	1990	Chg	Pct Chg
Albany	21.6	21.4	-0.2	-0.9
Atlanta	131.0	131.8	0.8	0.6
Baltimore	80.3	80.8	0.5	0.6
Birmingham	98.5	148.5	50.0	41.1
Buffalo	41.8	40.6	-1.2	-2.9
Chicago	228.1	227.2	-0.9	-0.4
Charlotte	139.7	174.3	34.6	22.1
Cincinnati	78.1	77.2	-0.9	-1.2
Cleveland	79.0	77.0	-2.0	-2.6
Columbus	180.9	190.9	10.0	5.4
Dallas	333.0	342.4	9.4	2.8
Dayton	48.4	55.0	6.6	12.8
Denver	110.3	153.3	43.0	32.9
Detroit	135.6	138.7	3.1	2.3
Greensboro	60.3	79.8	19.5	28.0
Honolulu	87.0	82.8	-4.2	-4.9
Houston	556.4	539.9	-16.5	-3.0
Indianapolis	352.0	361.7	9.7	2.7
Jacksonville	759.7	758.7	-1.0	-0.1
Kansas City	316.3	311.5	-4.8	-1.5
Los Angeles	464.7	469.3	4.6	1.0
Louisville	60.0	62.1	2.1	3.4
Memphis	264.1	256.0	-8.1	-3.1
Miami	34.3	35.6	1.3	3.7
Milwaukee	95.8	96.1	0.3	0.3
Minneapolis	55.1	54.9	-0.2	-0.4
Nashville	479.5	473.3	-6.2	-1.3
New Orleans	199.4	180.6	-18.8	-9.9
Norfolk	53.0	53.8	0.8	1.5
New York City	22.2	28.4	6.2	24.6
Oklahoma City	603.6	608.2	4.6	0.8
Orlando	39.5	67.3	27.8	53.3
Philadelphia	136.0	135.1	-0.9	-0.7
Phoenix	324.0	419.9	95.9	25.9
Pittsburgh	55.4	55.6	0.2	0.4
Portland	103.3	124.7	21.4	18.8
Richmond	60.1	60.1	0.0	0.0
Rochester	34.2	35.8	1.6	4.6
Sacramento	96.1	96.3	0.2	0.2
San Antonio	262.7	333.0	70.3	23.7
San Diego	320.0	324.0	4.0	1.2
Seattle	83.6	83.9	0.3	0.4
San Francisco	43.4	46.7	3.3	7.3
Salt Lake City	75.2	109.0	33.8	37.1
St. Louis	61.4	61.9	0.5	0.8
Tampa	84.4	108.7	24.3	25.3
Washington	62.7	61.4	-1.3	-2.1

Table 1.3

Metro	City	Employment by Place of Work (1000's)								
		metro			city			suburb		
		1980	1990	Pct Chg	1980	1990	Pct Chg	1980	1990	Pct Chg
NYC	New York	7356	8586	15.5	1930	2071	7.1	5426	6515	18.3
LAN	Los Angeles	5136	6814	28.3	1556	1844	17.0	3580	4969	32.8
CHI	Chicago	3487	3875	10.5	1409	1386	-1.6	2078	2488	18.0
SFO	San Francisco	2543	3256	24.7	511	567	10.4	2031	2689	28.0
PHI	Philadelphia	2360	2788	16.7	758	761	0.5	1602	2027	23.5
WAS	Washington	1706	2363	32.6	654	730	11.1	1052	1632	43.9
DET	Detroit	1873	2092	11.0	463	366	-23.3	1410	1725	20.1
DAL	Dallas	1454	2010	32.4	660	726	9.5	794	1284	48.0
HOU	Houston	1501	1779	17.0	1032	1133	9.3	469	646	32.0
ATL	Atlanta	1006	1528	41.8	366	403	9.7	640	1125	56.4
MIA	Miami	1131	1475	26.5	354	343	-3.2	777	1132	37.6
MIN	Minneapolis	1067	1339	22.8	273	290	6.1	794	1049	27.9
SEA	Seattle	976	1326	30.7	385	439	13.1	590	886	40.6
CLE	Cleveland	1218	1272	4.3	369	332	-10.6	849	940	10.2
SDG	San Diego	812	1216	40.3	483	681	34.5	330	535	48.3
STL	St. Louis	1021	1174	14.0	343	317	-7.9	678	857	23.4
BAL	Baltimore	928	1135	20.2	428	396	-7.7	500	739	39.2
PHX	Phoenix	655	998	42.2	397	555	33.4	258	443	54.3
DEN	Denver	811	983	19.2	393	378	-3.9	418	604	36.9
PIT	Pittsburgh	974	965	-0.9	329	305	-7.5	645	660	2.4
TAM	Tampa	611	907	39.5	203	274	29.8	408	634	44.0
CIN	Cincinnati	698	828	17.1	277	278	0.5	422	550	26.6
KCY	Kansas City	667	788	16.7	305	317	4.0	362	471	26.2
MIL	Milwaukee	728	787	7.8	330	315	-4.7	398	472	17.0
POR	Portland	590	731	21.5	300	338	11.8	290	394	30.7
NOR	Norfolk	508	709	33.3	162	214	28.1	346	495	35.6
COL	Columbus	558	706	23.5	329	400	19.7	229	306	28.7
SAC	Sacramento	460	683	39.5	209	270	25.3	251	413	49.9
IND	Indianapolis	533	651	20.1	392	461	16.4	141	190	29.7
CHL	Charlotte	482	635	27.6	213	309	37.1	269	326	19.3
ORL	Orlando	318	591	61.9	129	217	52.2	189	374	68.1
SAT	San Antonio	453	582	25.2	378	477	23.3	75	105	34.2
BUF	Buffalo	502	535	6.3	199	192	-3.8	303	343	12.4
NEO	New Orleans	512	526	2.8	273	257	-5.7	239	269	11.7
NAS	Nashville	388	515	28.3	255	329	25.3	133	186	33.9
GSB	Greensboro	411	506	20.8	107	144	30.0	304	362	17.4
ROC	Rochester	432	495	13.6	206	197	-4.6	226	298	27.8
SLC	Salt Lake City	387	485	22.4	180	186	3.4	208	299	36.4
MEM	Memphis	382	470	20.7	311	355	13.3	72	115	47.8
DAY	Dayton	400	460	14.1	144	133	-7.5	256	327	24.4
LOU	Louisville	410	459	11.3	218	209	-4.5	192	251	26.7
OKC	Oklahoma City	400	459	13.9	275	300	8.8	125	159	24.2
RIC	Richmond	368	458	21.7	195	176	-10.6	173	282	48.8
JAC	Jacksonville	305	444	37.5	254	358	34.6	52	86	50.7
HON	Honolulu	356	438	20.7	249	281	12.2	108	157	37.9
ALB	Albany	359	429	17.7	108	123	12.5	251	306	19.9
BIR	Birmingham	358	411	13.6	194	205	5.4	164	206	22.5
	Total	50591	62662	21.4	19485	21341	9.1	31106	41321	28.4
	Northeast	14616	17297	16.8	4612	4776	3.5	10005	12521	22.4
	Midwest	12660	14430	13.1	4850	4806	-0.9	7809	9625	20.9
	South	10589	14005	28.0	5359	6220	14.9	5230	7786	39.8
	West	12726	16929	28.5	4663	5540	17.2	8062	11389	34.5

Table 1.4

Metro	City	Central City Share (by POW)		
		1980	1990	Chg
NYC	New York	26.2	24.1	-2.1
LAN	Los Angeles	30.3	27.1	-3.2
CHI	Chicago	40.4	35.8	-4.6
SFO	San Francisco	20.1	17.4	-2.7
PHI	Philadelphia	32.1	27.3	-4.8
WAS	Washington	38.3	30.9	-7.4
DET	Detroit	24.7	17.5	-7.2
DAL	Dallas	45.4	36.1	-9.3
HOU	Houston	68.8	63.7	-5.1
ATL	Atlanta	36.4	26.4	-10.0
MIA	Miami	31.3	23.3	-8.0
MIN	Minneapolis	25.6	21.7	-3.9
SEA	Seattle	39.5	33.1	-6.4
CLE	Cleveland	30.3	26.1	-4.2
SDG	San Diego	59.4	56.0	-3.4
STL	St. Louis	33.6	27.0	-6.6
BAL	Baltimore	46.2	34.9	-11.3
PHX	Phoenix	60.7	55.6	-5.1
DEN	Denver	48.5	38.5	-10.0
PIT	Pittsburgh	33.8	31.6	-2.2
TAM	Tampa	33.2	30.2	-3.1
CIN	Cincinnati	39.6	33.6	-6.1
KCY	Kansas City	45.7	40.3	-5.4
MIL	Milwaukee	45.3	40.0	-5.3
POR	Portland	50.9	46.2	-4.7
NOR	Norfolk	31.8	30.2	-1.6
COL	Columbus	58.9	56.7	-2.2
SAC	Sacramento	45.5	39.5	-6.0
IND	Indianapolis	73.5	70.8	-2.7
CHL	Charlotte	44.2	48.6	4.4
ORL	Orlando	40.5	36.7	-3.8
SAT	San Antonio	83.5	81.9	-1.6
BUF	Buffalo	39.7	35.9	-3.8
NEO	New Orleans	53.2	48.9	-4.3
NAS	Nashville	65.8	63.8	-2.0
GSB	Greensboro	26.0	28.5	2.5
ROC	Rochester	47.7	39.8	-8.0
SLC	Salt Lake City	46.4	38.4	-8.0
MEM	Memphis	81.3	75.5	-5.8
DAY	Dayton	35.9	28.9	-7.0
LOU	Louisville	53.2	45.4	-7.8
OKC	Oklahoma City	68.8	65.4	-3.4
RIC	Richmond	53.0	38.4	-14.6
JAC	Jacksonville	83.0	80.6	-2.4
HON	Honolulu	69.8	64.1	-5.7
ALB	Albany	30.1	28.6	-1.5
BIR	Birmingham	54.2	49.9	-4.3
	Total	38.5	34.1	-4.5
	Northeast	30.6	26.6	-4.0
	Midwest	42.6	36.7	-5.9
	South	48.2	44.6	-3.6
	West	57.1	51.5	-5.5

Table 1.5a
Percent Growth

Industry	Total			Northeast			Midwest			South			West		
	metro	city	suburb	metro	city	suburb	metro	city	suburb	metro	city	suburb	metro	city	suburb
Const	33.1	18.4	39.8	40.1	26.6	43.6	30.9	17.2	37.0	19.8	5.6	30.3	41.5	31.8	45.5
Mfg	-8.4	-24.5	-1.6	-29.6	-38.1	-26.8	-14.5	-39.8	-3.5	3.6	-14.0	15.3	11.0	-4.2	16.9
TCPU	19.0	3.0	30.9	12.6	-11.2	23.0	12.6	-1.7	24.3	27.1	9.3	48.5	24.7	11.7	34.8
Whole	23.4	-0.5	38.1	14.2	-13.9	24.7	20.0	-8.2	35.9	27.9	5.4	53.8	31.6	8.8	45.3
Retail	22.0	10.2	27.2	12.7	2.2	15.5	16.4	1.1	22.7	32.2	16.2	44.6	27.5	16.3	32.6
FIRE	32.7	18.2	45.2	29.5	16.8	39.9	28.4	13.4	40.9	39.6	24.5	57.6	34.4	18.0	46.7
Bus Rep Serv	30.4	16.0	39.7	13.8	0.3	20.2	30.0	13.4	40.4	44.7	25.5	65.1	37.4	22.3	46.7
Pers Serv	24.8	17.5	29.3	15.6	13.2	16.6	16.2	4.6	22.8	25.9	16.8	33.9	38.3	30.0	43.5
Prof Serv	34.2	28.6	37.7	29.8	28.1	30.5	27.8	19.8	33.1	42.5	33.1	51.5	39.6	33.6	43.1
Pub Admin	7.5	-1.4	15.3	1.5	-8.6	8.9	-0.4	-8.1	7.1	19.8	10.8	31.9	13.0	2.2	20.9
Other	34.6	27.9	37.6	29.8	22.3	32.2	35.4	42.0	33.3	30.9	20.5	38.6	40.3	33.6	43.1

Table 1.5b
Central City Employment Shares

Industry	Total			Northeast			Midwest			South			West		
	1980	1990	Chg	1980	1990	Chg	1980	1990	Chg	1980	1990	Chg	1980	1990	Chg
Const	33.4	28.8	-4.6	22.3	19.5	-2.8	32.9	28.7	-4.2	45.5	39.5	-6.0	30.9	28.1	-2.8
Mfg	32.3	27.5	-4.8	25.3	23.2	-2.1	34.1	26.4	-7.6	43.2	36.2	-7.0	30.2	26.0	-4.3
TCPU	46.2	39.4	-6.8	34.2	27.0	-7.2	48.2	41.8	-6.4	59.3	49.6	-9.7	46.6	40.9	-5.7
Whole	42.9	33.8	-9.1	31.1	23.5	-7.6	41.3	31.1	-10.1	59.4	47.4	-12.0	41.8	33.3	-8.5
Retail	32.7	29.0	-3.6	22.3	20.1	-2.2	31.4	26.9	-4.5	47.0	40.1	-7.0	32.9	29.4	-3.5
FIRE	49.9	43.2	-6.7	48.0	42.3	-5.7	48.9	42.1	-6.8	58.3	50.1	-8.2	46.4	39.4	-7.0
Bus Rep Serv	42.1	36.4	-5.7	34.5	30.2	-4.4	41.5	35.2	-6.4	56.5	46.6	-9.9	40.8	35.0	-5.7
Pers Serv	39.4	36.6	-2.8	30.2	29.5	-0.7	38.3	34.1	-4.2	48.7	44.5	-4.3	40.3	37.1	-3.2
Prof Serv	39.3	37.1	-2.2	31.7	31.2	-0.5	41.7	38.5	-3.2	51.3	46.7	-4.6	37.7	35.5	-2.2
Pub Admin	48.6	44.4	-4.2	44.4	40.1	-4.3	51.0	47.2	-3.8	60.0	54.8	-5.2	44.3	39.8	-4.5
Other	31.9	29.8	-2.1	25.1	23.3	-1.8	22.8	24.4	1.6	44.5	40.1	-4.4	30.4	28.4	-2.0

Table 1.6

Metro	City	Central City Import Ratio		
		1980	1990	Chg
NYC	New York	2.84	2.75	-0.09
LAN	Los Angeles	1.15	1.13	-0.01
CHI	Chicago	1.18	1.17	-0.01
SFO	San Francisco	1.53	1.48	-0.05
PHI	Philadelphia	1.25	1.19	-0.06
WAS	Washington	2.21	2.40	0.19
DET	Detroit	1.23	1.13	-0.11
DAL	Dallas	1.45	1.45	0.00
HOU	Houston	1.27	1.47	0.19
ATL	Atlanta	2.15	2.34	0.19
MIA	Miami	2.29	2.32	0.02
MIN	Minneapolis -	1.49	1.54	0.05
SEA	Seattle	1.57	1.57	0.00
CLE	Cleveland	1.79	1.87	0.08
SDG	San Diego	1.15	1.21	0.07
STL	St. Louis	2.02	2.00	-0.03
BAL	Baltimore	1.45	1.29	-0.16
PHX	Phoenix	1.10	1.17	0.07
DEN	Denver	1.62	1.59	-0.02
PIT	Pittsburgh	1.98	2.02	0.04
TAM	Tampa	1.76	2.09	0.33
CIN	Cincinnati	1.79	1.79	-0.00
KCY	Kansas City	1.47	1.52	0.05
MIL	Milwaukee	1.20	1.17	-0.03
POR	Portland	1.77	1.58	-0.19
NOR	Norfolk	1.26	1.64	0.38
COL	Columbus	1.30	1.26	-0.04
SAC	Sacramento	1.88	1.70	-0.19
IND	Indianapolis	1.24	1.27	0.03
CHL	Charlotte	1.35	1.45	0.10
ORL	Orlando	1.99	2.38	0.39
SAT	San Antonio	1.20	1.21	0.00
BUF	Buffalo	1.58	1.50	-0.08
NEO	New Orleans	1.27	1.38	0.11
NAS	Nashville	1.19	1.31	0.13
GSB	Greensboro	1.44	1.46	0.02
ROC	Rochester	2.09	1.98	-0.11
SLC	Salt Lake City	2.40	2.50	0.09
MEM	Memphis	1.18	1.35	0.16
DAY	Dayton	1.94	1.90	-0.03
LOU	Louisville	1.89	1.84	-0.05
OKC	Oklahoma City	1.47	1.43	-0.03
RIC	Richmond	1.98	1.86	-0.12
JAC	Jacksonville	1.07	1.15	0.07
HON	Honolulu	1.36	1.45	0.09
ALB	Albany	2.44	2.50	0.06
BIR	Birmingham	1.73	1.89	0.16
	Total	1.49	1.50	0.01
	Northeast	1.99	1.96	-0.03
	Midwest	1.38	1.36	-0.02
	South	1.42	1.52	0.10
	West	1.33	1.32	-0.01

Table 1.7

Metro	City	Average Commuting Time by Place of Work (in minutes)								
		metro			city			suburb		
		1980	1990	Chg	1980	1990	Chg	1980	1990	Chg
NYC	New York	31.4	30.9	-0.5	49.3	45.3	-4.0	25.1	26.3	1.1
LAN	Los Angeles	23.8	26.4	2.6	27.6	29.7	2.1	22.0	25.2	3.2
CHI	Chicago	27.6	28.3	0.6	35.5	35.0	-0.5	22.3	24.5	2.2
SFO	San Francisco	24.2	26.0	1.8	33.0	33.4	0.4	21.9	24.4	2.5
PHI	Philadelphia	24.4	24.0	-0.4	32.1	29.8	-2.3	20.7	21.8	1.1
WAS	Washington	29.6	30.8	1.2	35.7	35.4	-0.3	25.8	28.7	2.8
DET	Detroit	23.0	23.8	0.8	27.7	27.3	-0.4	21.4	23.1	1.6
DAL	Dallas	23.0	24.6	1.6	26.3	27.8	1.5	20.2	22.7	2.5
HOU	Houston	26.6	26.3	-0.3	28.6	28.2	-0.4	22.3	22.9	0.6
ATL	Atlanta	26.1	26.7	0.6	31.7	30.8	-0.9	22.9	25.2	2.3
MIA	Miami	23.1	24.1	1.0	26.6	27.2	0.6	21.5	23.1	1.6
MIN	Minneapolis	20.5	21.7	1.2	24.2	24.5	0.3	19.2	21.0	1.7
SEA	Seattle	23.0	24.7	1.7	26.6	28.2	1.6	20.6	22.9	2.4
CLE	Cleveland	22.4	22.4	- 0.0	28.3	27.1	-1.2	19.8	20.7	0.9
SDG	San Diego	19.7	21.9	2.2	20.6	23.0	2.4	18.5	20.4	1.9
STL	St. Louis	23.4	23.9	0.5	27.8	26.9	-0.9	21.2	22.8	1.6
BAL	Baltimore	25.5	24.8	-0.7	28.3	27.0	-1.3	22.9	23.6	0.6
PHX	Phoenix	21.6	23.1	1.5	22.3	24.8	2.5	20.2	21.0	0.8
DEN	Denver	22.2	22.9	0.7	24.8	25.4	0.6	19.7	21.3	1.6
PIT	Pittsburgh	23.2	22.9	-0.3	28.9	28.1	-0.8	20.3	20.4	0.2
TAM	Tampa	20.1	21.7	1.6	21.9	24.5	2.6	19.2	20.5	1.3
CIN	Cincinnati	22.4	22.8	0.4	24.9	24.8	-0.1	20.6	21.8	1.2
KCY	Kansas City	21.3	22.1	0.8	23.9	24.1	0.2	19.0	20.7	1.7
MIL	Milwaukee	19.2	20.2	1.0	21.7	21.8	0.1	17.1	19.1	2.0
POR	Portland	21.3	22.0	0.7	23.9	24.1	0.2	18.5	20.1	1.6
NOR	Norfolk	22.2	22.1	-0.1	24.0	25.1	1.1	21.2	20.9	-0.3
COL	Columbus	20.7	22.3	1.6	22.1	23.1	1.0	18.6	21.2	2.6
SAC	Sacramento	19.3	21.9	2.6	21.5	23.8	2.3	17.4	20.6	3.2
IND	Indianapolis	21.9	23.0	1.1	23.3	24.1	0.8	17.9	20.5	2.6
CHL	Charlotte	20.6	22.5	1.9	23.4	25.3	1.9	18.4	19.9	1.5
ORL	Orlando	20.7	23.9	3.2	21.1	24.5	3.4	20.4	23.5	3.1
SAT	San Antonio	20.8	22.4	1.6	21.2	23.0	1.8	18.3	19.5	1.2
BUF	Buffalo	19.7	19.5	-0.2	22.8	22.0	-0.8	17.6	18.1	0.5
NEO	New Orleans	26.1	25.3	-0.8	27.8	27.2	-0.6	24.2	23.5	-0.8
NAS	Nashville	22.7	23.8	1.1	24.3	25.1	0.8	19.4	21.5	2.1
GSB	Greensboro	18.9	19.4	0.5	18.9	20.0	1.1	18.9	19.2	0.3
ROC	Rochester	19.7	20.3	0.6	22.2	22.0	-0.2	17.4	19.1	1.7
SLC	Salt Lake City	20.1	20.0	-0.1	22.4	22.6	0.2	18.2	18.3	0.1
MEM	Memphis	22.6	22.7	0.1	23.5	23.3	-0.2	18.7	20.8	2.1
DAY	Dayton	19.6	20.2	0.6	22.2	22.1	-0.1	18.0	19.4	1.4
LOU	Louisville	23.3	22.2	-1.1	25.4	23.1	-2.3	20.8	21.4	0.6
OKC	Oklahoma City	20.6	20.8	0.2	22.4	22.3	-0.1	16.7	17.9	1.2
RIC	Richmond	22.9	22.7	-0.2	24.4	24.1	-0.3	21.3	21.8	0.5
JAC	Jacksonville	21.8	22.8	1.0	22.4	23.7	1.3	18.7	19.0	0.3
HON	Honolulu	22.9	24.9	2.0	24.5	27.2	2.7	19.1	20.6	1.5
ALB	Albany	20.1	21.0	0.9	24.0	24.3	0.3	18.4	19.6	1.3
BIR	Birmingham	24.4	23.9	-0.5	25.4	24.8	-0.6	23.2	23.0	-0.3
	Total	24.6	25.4	0.8	29.1	29.0	-0.2	21.7	23.5	1.7
	Northeast	28.1	28.0	-0.1	38.0	36.2	-1.8	23.5	24.8	1.4
	Midwest	23.4	24.1	0.7	28.0	27.6	-0.4	20.6	22.3	1.7
	South	23.2	23.9	0.7	25.5	25.9	0.4	20.9	22.4	1.5
	West	22.9	24.9	2.0	25.8	27.4	1.6	21.2	23.7	2.5

Table 1.8a

Dep. Variable: Δ Avg. Metropolitan Commuting Times		
	(1)	(2)
Pct. Δ Employment	5.52 (0.89)	5.47 (0.85)
Δ Cent City Share	----	6.78 (3.09)
Rbar²	.45	.49

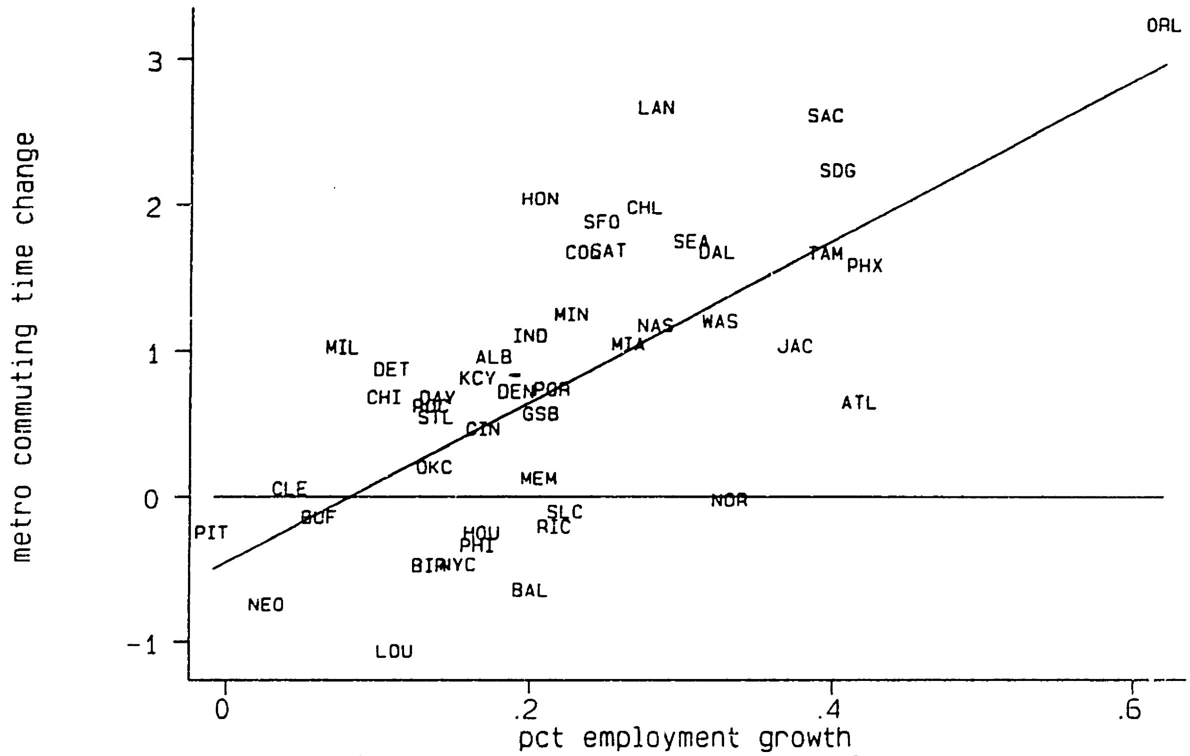
Table 1.8b

Dep. Variable: Δ Avg. Commuting Times		
	Central City	Suburbs
Pct. Δ Employment	6.46 (0.97)	2.70 (0.95)
Rbar²	.48	.15

Table 1.9

Dep. Variable: Commuting Time Change Differential			
	(1)	(2)	(3)
Pct. Employment Growth Differential	3.37 (1.39)	----	2.47 (1.35)
Import Ratio Change	----	-4.65 (1.49)	-3.96 (1.50)
Rbar²	.16	.10	.20

Std. Errors in Parentheses



Metro Employment & Commuting Changes

Figure 1.1

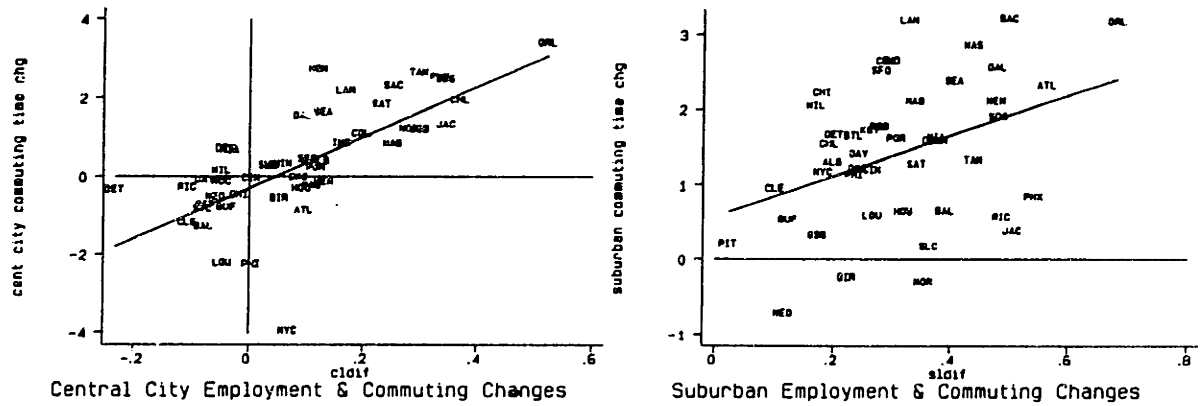
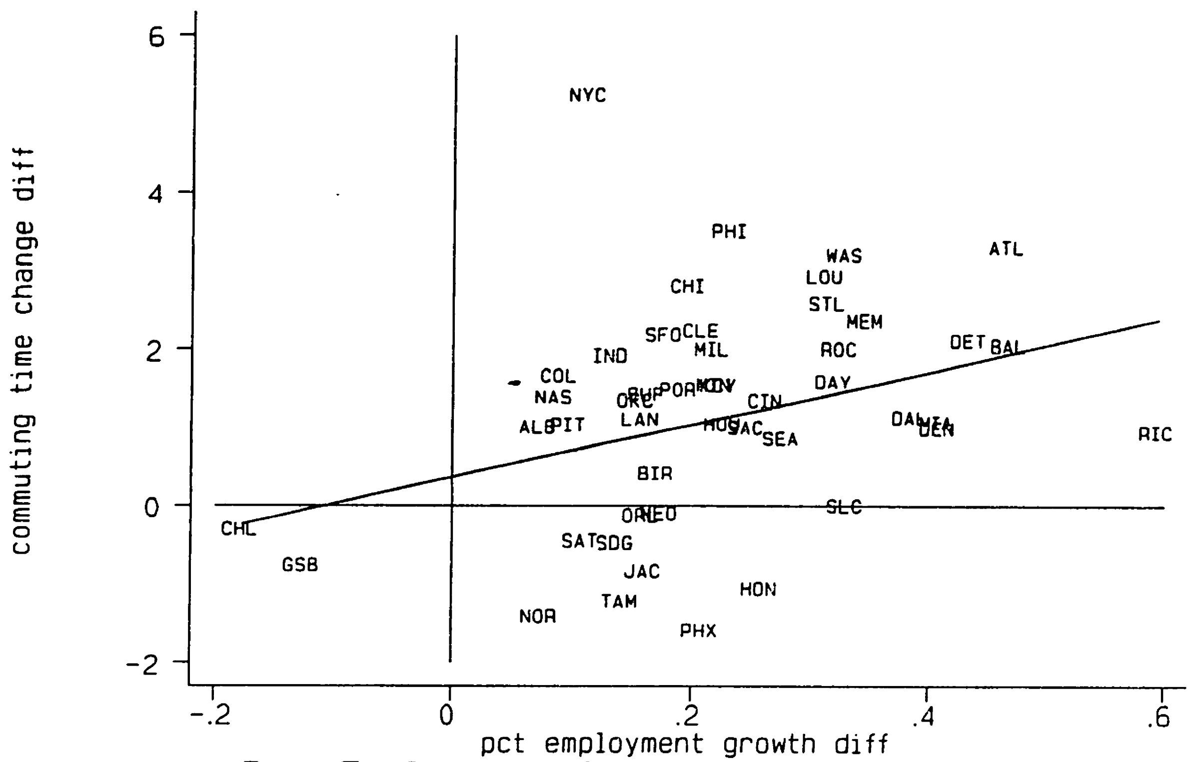
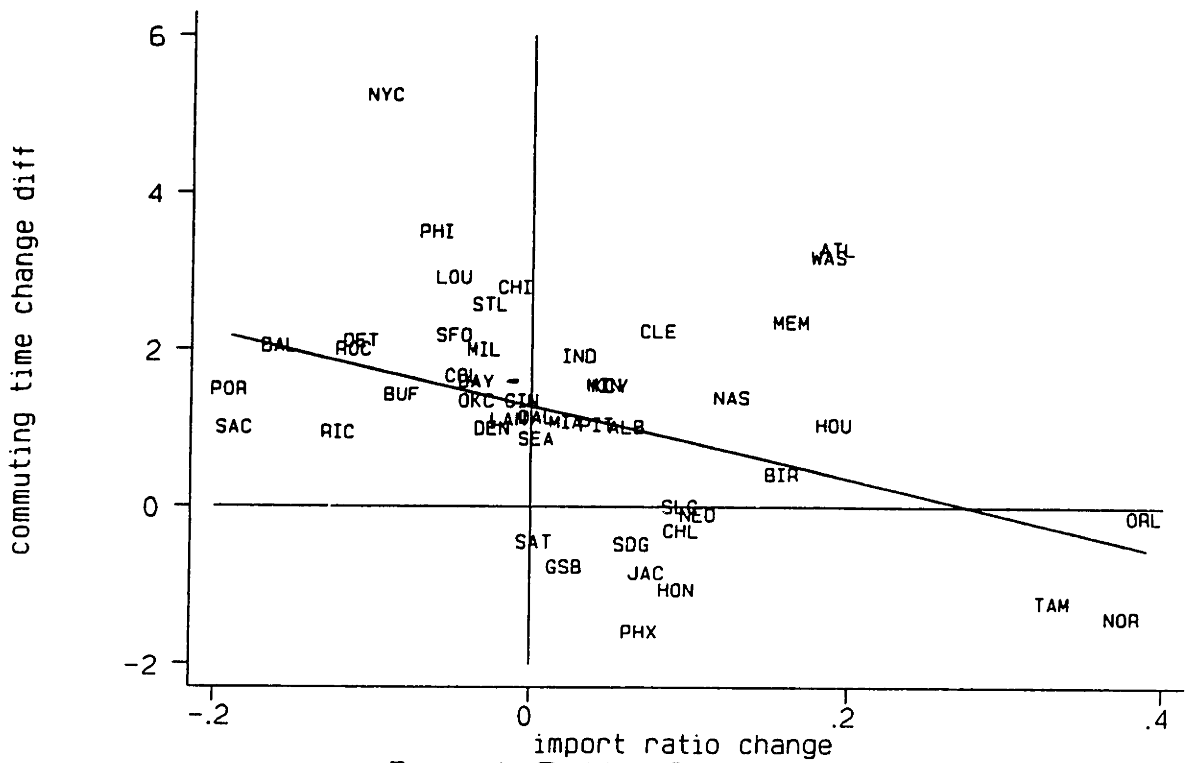

cent city commuting time chg
cldif
Central City Employment & Commuting Changes
suburban commuting time chg
sldif
Suburban Employment & Commuting Changes

Figure 1.2



Pct. Employment Growth Differential

Figure 1.3



Import Ratio Changes

Figure 1.4

Chapter 2

A Linear Programming Model of Wages, Rents, and Commuting in a Decentralized Metropolitan Area

I. Introduction

The capitalization of commuting costs and other spatial characteristics into land rents has long been a well-established feature of urban economic models. More recently, authors have noted that the mobility of workers and firms must also result in a second capitalization of transportation costs, into wages. As Moses (1962) pointed out, the imperfect mobility of workers within metropolitan areas may lead to differences in wage rates across intraurban regions.[1] At the same time, the contiguous nature of urban residential development will result in an arbitrage condition between competing employment centers, thereby establishing the relative pattern of wage variation.

While much of the early work in urban economic modelling focused on discrete spatial zones, this was soon superceded by models using a continuous spatial variation. In the vein of this earlier work, the purpose of this paper is to use a simple linear programming model to illustrate how wage differentials across employment centers must exist, due to differences in marginal commuting costs. The model generates shadow prices on the residence and work location constraints, which are interpreted as shadow land rents and wages. The model is used to simulate how wages must vary across different-sized employment zones, and how the decentralization of employment must lead to the convergence of wages and commuting times. The implications of these results for empirical work are also discussed.

II. Previous Literature

[1]Employment centers within an urban area may vary in their accessibility to locally employed workers. These differences in commuting costs, along with rent capitalization, make it possible for workers to achieve equal utility while receiving different incomes.

Urban spatial models are generally of two basic types: continous-space and discrete-space. The relevant contributions of both lines of research to the topic of employment decentralization are discussed here.

A. Continuous-Space Models

In the standard monocentric city model of Muth (1969) and Mills (1972), work locations are concentrated in a single core, around which households locate in concentric rings. In order for an equilibrium to exist in the housing market, a rent gradient must develop, characterized by the the condition

$$R'(t)q(t)=K'(t)$$

where t is distance from the employment center, $R(t)$ is rent per unit of land, $q(t)$ is land consumption, and $K(t)$ is the transportation cost function. This equation implies that the shape of the rent gradient will be determined by the transport cost function: the decline in total rent paid in moving further away from the city center is equal to the increase in commuting costs.

Muth (1969) also allowed for a locally employed sector in addition to the CBD-employed sector. These local workers face no transportation costs. Since both types of workers must achieve the same utility level in equlibrium, the rent gradient will still have the same slope. The wages of locally employed workers must therefore decline as a function of distance from the center:

$$W'(t)=R'(t)q(t)=K'(t)$$

Thus, a wage gradient must exist which is linked to commuting costs through the rent gradient.

White (1976) extended the Muth-Mills model to allow for an urban subcenter, based around a suburban export node. Because of labor scarcity in the suburban area, firms in the subcenter will be forced to offer a wage greater than that offered by the decentralized firms in the Muth model. The wage offerred must be sufficient to induce a sufficient number of workers to commute to the subcenter so as to fill the labor demand of firms located there. The wage rate will thus depend on the commuting costs of the marginal worker (located at a point between the two employment centers) who is indifferent about which center to commute to.

Ogawa and Fujita (1980) devloped a non-monocentric model of urban land use by explicitly modelling the equilibrium location choices of households and firms. Households have identical preferences over land and a composite commodity, while firms have a Leontief production function using land and labor as inputs. Firms also face transaction costs in dealing with other firms which are proportional to the distance between them. Land and labor markets are perfectly competitive. They showed that, under conditions of no cross-commuting,[2] The equilibrium wage profile will continue to be a linear function of distance[3], regardless of the direction of commuting.

White (1988) generalized her earlier model to allow for more broadly dispersed employment locations. She showed how households' wage- and rent-offer curves will vary by residential and employment location, again resulting in a negatively-sloped wage gradient. The resulting location pattern has households segregated by employment location. Households are indifferent among residential locations in the rings occupied by workers in their chosen workplace, rather than across the entire occupied residential region.

Wheaton and Sivitanidou (1992) adapted the two-center model to allow for land use by firms. They show that, under general conditions, differential accessibility between centers will

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[2]In their model, cross-commuting occurs when commuter A "leapfrogs" both commuter B's residential and employment location when commuting to work. Ogawa and Fujita prove that this will not occur when households have strict preferences over job locations, allowing them to disregard this case.

[3]Just as in the Muth model.

continue to be primarily capitalized into wages, rather than into the land rent paid by firms. This result may hold even when either or both centers are constrained in their land use.

B. Discrete-Space Models

The discrete analog to the Muth-Mills monocentric model is the bid-rent theory of Alonso (1964). In his framework, landowners auction off their lots to homeowners, accepting the highest bids, which are based on the net value of the parcel to the householder. He establishes three conditions for an equilibrium in such a market, namely that a) each household is allocated to a parcel of land, b) the supply of and the demand for land are balanced, and c) each parcel goes to the household offering the highest bid (obtaining the highest net return).

Concurrent with the development of the Alonso model, Herbert and Stevens (1960) developed a linear programming model which they hoped could generate an Alonso-type equilibrium. Their objective function sought to maximize the net return (bid rent minus cost) over different household types, housing unit types, and locations, subject to constraints on the land available in each zone and the number of individual households in each cohort. In this way they hoped to achieve an equilbrium location pattern.

Wheaton (1972) showed, however, that the Herbert-Stevens model could not guarantee an equilibrium, due to the exogeneity of the utility levels assumed by households in calculating their bids. By iteratively adjusting these household bid rents, he showed how an equilibrium could be guaranteed and computed.

Anderson (1982) took a different approach in refining the Herbert-Stevens model. He showed that under certain conditions (namely, that housing units vary only by location), the H-S model could indeed be guaranteed to reach an equilbrium. This simplification essentially eliminates one of the dimensions over which the H-S linear program is to be optimized, that of different housing types, which was at the root of Wheaton's proof that an equlibrium could not be guaranteed. In Anderson's framework, household bid rents are maximized relative to some reference alternative. Under the simplifying assumptions of his model, bid rent differences across housing unit types will be constant and equal to variations in travel and other spatial costs. Thus, the problem of bid rent maximization under these circumstances is equivalent to one in which spatially variable costs are minimized. He then demonstrated how the market clearing section of the NBER Urban Simulation Model (Kain, et al., 1973) meets these criteria.

III. Model

To illustrate the dual capitalization of commuting costs, consider the following simple linear programming model of intraurban location. The city consists of *P* identical households residing in *n* residential zones (*i*), and workplaces located in *m* employment zones (*j*). Each household has exactly one employed worker, who incurs commuting costs from residential zone *i* to work zone *j* equal to c_{ij}. In this simplified framework, with housing attributes varying solely by location, maximization of the bid-rent function R_{ij}-R_{i0j0}[4] is equivalent to the minimization of c_{ij}-c_{i0j0}. Normalizing the transportation cost of this last zone to *0* yields the following linear program:

[4]Where *i0* and *j0* are the reference residential and employment zones, respectively.

Minimize $\sum_i \sum_j c_{ij} x_{ij}$

subject to

$$\sum_j x_{ij} \geq N_i \qquad i=1,\ldots,n$$

$$\sum_i x_{ij} \leq E_j \qquad j=1,\ldots,m$$

$$x_{ij} \geq 0$$

$$\sum_i N_i = \sum_j E_j$$

where

x_{ij} = number of workers living in residential zone i and commuting to work zone j

N_i = total number of workers living in zone i

E_j = total employment in zone j

This formulation of the model is a pure transportation problem, minimizing the total cost of shipping a commodity (i.e., labor) from suppliers (households) to demanders (employers). The constraints ensure that the equilbrium flows from each residential zone will be no larger than the available supply of workers; that equilibrium flows to each employment zone will be no less than the total demand for workers there; that all commuting flows will be nonnegative; and that labor supply will equal labor demand.[5] The minimization problem will result in workers commuting to the least-cost (nearest) employment center.

[5]This last constraint will also imply that constraint equations ( ) and ( ) will hold with equality.

More interesting for the purposes of this paper is the dual of the above primal form.[6] The objective of the dual program is to

$$\text{maximize} \quad \sum_j w_j E_j + \sum_i r_i V_i$$

subject to

[illegible]

The variables r_i and w_j are shadow prices on the supply and demand constraints, respectively. In the traditional economic interpretation of transportation problems, these prices are thought of as the value of a commodity at its production source and its value to the user. The constraint on the shadow prices implies that this value to the user must be no greater than the value at the production source plus transportation costs. The shadow prices r_i represent the comparative locational advantage of the various production sites; the shadow prices w_j are delivered prices which correspond to an optimal resource allocation. Together, they define a spatial price equilibrium in an economy of competitive buyers and sellers (Dorfman, Samuelson, and Solow 1958).

Stevens (1961) gave a further interpretation of the dual shadow prices as location rents. For a given demand node, suppliers closer to the node will earn extra profits over suppliers located further away. The shadow prices thus represent these rents which advantageously located suppliers can obtain. The shadow prices on the demand constraints are interpreted as

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[6]The dual of the linear program (in matrix form) *min cx s.t.* $Ax \geq b$, $x \geq 0$ is *max yb s.t.* $yA \leq c$, $y \geq 0$.

the location rent which a supplier facing zero transportation costs to the consumption point would earn.

In the commuting model as formulated above, the r_i's and w_j's can be interpreted as shadow land rents and shadow wage levels, respectively. To motivate this interpretation, it is helpful to first recall the rules of complementary slackness, which stipulate that for the dual constraints:

$$x_{ij} > 0 \Rightarrow w_j - r_i = c_{ij}$$
$$x_{ij} = 0 \Rightarrow w_j - r_i < c_{ij}$$

Thus, for any flow x_{ij} which is in the basis vector, the difference in the shadow prices of the origin and destination nodes i and j will exactly equal the commuting costs between the two nodes. Thus, for a given origin (residential zone) i, the difference between the shadow prices at destinations (employment zones) j and k will be given by

$$w_j - w_k = c_{ij} - c_{ik}$$

Similarly, the difference for a destination j between the shadow prices of origins i and l will be

$$r_i - r_l = c_{ij} - c_{lj}$$

It can also be shown that for a pure transportation problem, there will be at most $m+n-1$ positive origin-destination flows in an optimal solution to the cost minimization problem. Thus, the system of constraints which hold with equality will have $m+n-1$ equations in $m+n$ unknowns (the r_i's and w_j's). Thus, one of the shadow prices can be normalized to zero, and all other shadow prices calculated relative to this anchor point. This result also implies that there will be at most $m-1$ origins which supply more than one destination.

To illustrate how these shadow prices might be considered as shadow wages and rents, consider first a city with a single work center *1* and *n* residential zones. The dual constraint equations thus become

$$\begin{aligned} w_1 - r_1 &= c_{11} \\ &\vdots \\ w_1 - r_n &= c_{n1} \end{aligned}$$

Since w_1 can be normalized to *0*, the shadow prices r will simply be the opposite of the transportation costs from each residential zone. The shadow prices represent the relative locational advantages in commuting cost savings of each zone, and can thus be thought of as location rents (as per Stevens (1961)), which fully capitalize these travel cost differences.

Consider next a city with two employment centers. The set of $n+1$ equality constraints in the dual will have the form

$$\begin{aligned} w_1 - r_1 &= c_{11} \\ &\vdots \\ w_1 - r_a &= c_{a1} \\ w_2 - r_a &= c_{a2} \\ &\vdots \\ w_2 - r_n &= c_{n2} \end{aligned}$$

with its $n+2$ unknowns. The residential zones will be partitioned between the two employment zones, and there will be at most one residential zone (here, zone a) which has positive flows to both employment centers. Thus, the differential between the shadow prices on the employment constraints will be uniquely determined by

$$w_d = w_2 - w_1 = c_{a2} - c_{a1}$$

Normalizing w_1 to zero yields the shadow rents

$$r_i = -c_{i1} \qquad i=1,\ldots,a$$

$$r_i = w_d - c_{i2} \qquad i=a,\ldots,n$$

The dual capitalization becomes readily apparent in these equations. Differences in shadow rents for residential zones serving the same employment center are fully determined by differences in commuting costs between those zones. The shadow wage differential, however, is determined the commuting cost differential to each employment zone from the marginal zone a, which provides workers to both zones.[7]

When there are multiple employment centers, the same framework will generally apply. The set of equality constraints will have $n+m-1$ equations, with residential zones partitioned among the m employment zones, and $m-1$ marginal, or "tie" zones. By normalizing the shadow wage at the first employment zone to zero, the remaining shadow wages can be determined recursively, and shadow rents also determined.

IV. Simulation Results

The role of the dual capitalization and its effect on shadow wage differentials can perhaps best be illustrated through some simple simulations using solved linear programs. The solutions were obtained using the *RELAX-IV* code for solving minimum-cost flow models developed by Dimitri Bertsekas and Paul Tseng (Bertsekas and Tseng 1994). The models used take on two basic forms:

Closed (Housing Market) Model. The city has a fixed number and spatial distribution of residential zones. As the distribution of employment shifts among work

[7]It is also possible that there will be less than $m+n-1$ positive flows in the optimal origin-destination system. Under this condition, known as *degeneracy*, there will be more than one free elements in the set of dual equality constraints, and the wage differential cannot be determined. This will generally occur when the supply from each residential zone and the demand at each employment zone are all proportional to some constant, resulting in a commuting flow pattern which is completely separated among the employment centers and thus has no marginal commuting zone. Adjusting the demands from one employment node to another by even one unit alleviate this problem, however. The simulations which follow in section IV take account of such periodic degeneracies in the calculation of the shadow wage differentials.

zones, the pattern of commuting simply shifts among employment centers from these fixed zones. The analog is to a city with a fixed stock of housing and fixed borders. Changes in employment distribution simply result in the exchange of housing units between workers employed at different centers. The stipulation of a housing stock in fixed locations replicates a short-run equilibrium.

Open (Land Market) Model. This framework allows for the spatial distribution of residences to shift as the employment distribution changes. Thus, some former residential zones may be abandoned when new residential zones are developed, in alignment with the new employment centers. The analog here is to a land market, or long run equilbrium, in which housing units can be spatially located in a optimal configuration relative to a given spatial distribution of employment.

The simulations for the two types of models will be presented in turn.

A. Housing Market Model

Consider initially a city consisting of 41 residential zones and a single employment center.[8] Each zone has 100 single-worker housing units. Commuting to the employment center takes place along a street grid. The minimum cost configuration for the residential zones, showing the commuting cost from each zone to the employment center, is found in Figure 2.1. This pattern mimics that for a city with 4 residential rings located at constant intervals from

[8]Firms use no land in any of the models presented here

the city center.[9] The shadow rent for each residential zone will be equal to the negative of the transportation costs from that zone. Aggregate commuting costs for the city are 12000.

Suppose next that a second employment center is located at the extreme right corner.[10] As this center grows, jobs are shifted from the original, primary center. At subcenter employment levels (E_2) less than 100, there are ample workers in the same zone to fill its labor demand while also providing some workers to the primary center. Thus, this rightmost zone will be the marginal zone. The shadow wage differential w_1 - w_2 will equal *4*, and the rent in this zone remains *-4*. Once E_2 rises above 100, however, workers must be drawn from an adjacent zone, of which there are three. One of these zones thus becomes the marginal zone, the shadow wage differential drops to 2, and shadow rent in the rightmost zone rises to -2. These shadow prices will hold until subcenter employment rises above 400, at which point a new zone, equidistant from the primary center and the subcenter, becomes marginal. At this point, the wage differential falls to *0*, and rent at the extreme right corner rises to *0*.

Figure 2.2a illustrates how the average aggregate commuting cost, average commuting cost differential between the two centers, and wage differential (≡ marginal commuting cost differential) change as the subcenter share of total employment increases. The following should be noted about this graph:

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[9]Under this arrangement, a ring located *a* units from the city center will have *4a* zones in it. Thus, the total number of residential zones for a city with maximum commuting distance *k* will be

$$\left(\sum_{i=1}^{k} 4i\right) + 1$$

[10]The shadow wage differential relative to the original center will be greatest at the extreme edge of the city, since the commuting cost differential is greatest there. Thus, the original firms which move out from the city center can minimize their labor costs there, and the subcenter will develop at an edge location initially. Although such optimizing firm behavior is not built in directly to the models and results presented here (which show how shadow wage levels must adjust as employment is exogenously relocated among exogenously-determined work zones), this underlies the choice of an edge zone for the suburban work center for these models. The movement of firms into lower-wage regions of the city will be explored empirically in Chapter 4.

a) Aggregate costs decline until the marginal commuting cost is equalized. Up until this point, each worker added to the subcenter is closer to the subcenter than to the primary center. Thus, the decentralization of employment results in lower aggregate commuting costs. Once these equidistant zones are fully allocated to the subcenter, however, additional subcenter growth must shift workers whose residences are closer to the primary center, thereby increasing aggregate costs.

b) The shadow wage differential is a non-increasing step function of the suburban employment share. Wage equality occurs relatively early, at a share between 0.1 and 0.22. This is due to the closed nature of the model: housing locations cannot adjust in response to the subcenter growth, forcing the shadow wages to equilbrate at an early stage of decentralization.

c) The average cost differential generally follows the wage differential downward.[11]

Figures 2.2b-2.2d replicate the single-subcenter results for 2, 3, and 4 symmetric subcenters located at each of the corners. As the number of subcenters increases, wage equilibration occurs at a larger suburban employment share. The average commuting cost differentials continue to track the wage differentials. Figure 2.3 shows how total commuting costs decline at all levels of suburbanization as the number of (symmetric) subcenters increases, up to the limiting case of complete suburbanization, which drives commuting costs to zero.[12]

B. Land Market Model

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[11]The average cost differential is uniquely determined only at points where a range of potential marginal zones are filled. These points are denoted by empty squares in the figures, and correspond to the points where the shadow wage differential changes. The exact relationship of average costs for intermediate values depends on which zones of the potential marginal zones are filled first. The possible values range between two extremes, in which the commuting shed of one employment center or the other is made as compact as possible.

[12]The continuous efficiency improvements of employment decentralization are an obvious result of the simple labor market presented here, which is characterized by perfect information and a homogeneous workforce.

As described above, the land market model allows housing locations to adjust in response to employment distribution changes. To simulate this in a linear programming context, the set of residential zones is greatly expanded beyond the 41 zones used in the housing market model (to 400). A hypothetical workzone is created which has zero commuting costs from each residential zone, thereby taking up any slack in labor demand which exists in the urban employment center(s), ensuring that total labor demand will always equal total labor supply.[13]

In this framework the monocentric city takes on a slightly different character. Consider a single employment center with 4101 workers.[14] The linear program minimizes the commuting cost of all workers (including those residing in non-commuting zones). The optimal configuration of residential zones supplying workers to the employment center is nearly identical to that in the closed model, with a single worker commuting from a distance of *5*, resulting in aggregate travel costs of *12005*. The presence of this marginal commuter and second employment zone allows us to calculate a wage differential (=5) between the urban employment center and the rural sector. This also pins down a schedule of shadow rents[15] ranging from *5* in the center to *1* at the edge of the city, with a rural shadow rent of *0*.[16] Figure 2.4 shows the spatial configuration of the urban (light) and "rural" (shaded) residential zones.

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[13]This extra workzone might be thought of as representing a local or agricultural sector, employing rural non-commuters (as opposed to urban commuters). This mimics the practice in other urban LP models, such as Wheaton (1974) and Anas (1975), of including an additional household sector whose bid rent is equal to the opportunity cost of land.

[14]The single additional worker is added to prevent degeneracy.

[15]The non-urban residential zones will always have a shadow rent equal to the shadow wage of the non-urban employment zone, which can be benchmarked at zero.

[16]When E_l = *4099*, the shadow wage differential is *4* and the shadow rent at the edge of the city equals the rural shadow rent, *0*.

Consider next a city with two employment centers, one located at the site of the original center, and one located at the edge of the monocentric city.[17] In this case there will be at most two marginal zones, which allow us to calculate wage differentials for both employment zones relative to the rural employment zone (whose shadow wage will always be normalized to zero). Note that this may occur when a) one urban employment zone shares a residential zone with the rural sector and one with the other urban center, or b) both urban centers share zones with the rural sector, and do not share a residential zone together. The shadow wage differential between urban centers can thus be calculated either directly or indirectly.

Figure 2.5a shows the path of average aggregate commuting costs, average cost differentials, and shadow wage differentials between the two urban centers. The results simulate the development of the subcenter at a constant overall urban employment level of 4101. The following points can be noted about this figure in contrast to the housing market model of Figure 2.2a:

a) The land market allows for a more efficient spatial allocation of residences, leading to lower minimum aggregate transportation costs as employment decentralizes.

b) Wage equilibration occurs later, centered around a median employment share.

c) The wage differential function has more discrete steps. This is due to the fact that additional workers for the growing subcenter may be obtained by relocating distant workers from the far side of the primary center, rather than removing them from an intermediate residential zone, allowing a more incremental change in commuting distances for marginal workers.

[17]See the discussion above for the rationale behind locating the second employment center at the initial edge of the monocentric city. Of course, in a model with dynamically optimizing firms and perfect foresight, decentralizing firms might want to locate in a currently "rural zone", beyond the original urban boundary.

d) The average cost differential continues to track the shadow wage differential, although the slope for the average differential is smaller than the slope of the wage differential.

Figure 2.5b shows similar results for the case of two symmetric subcenters. Wage equlibration/cost minimization is centered around a suburban employment share of *2/3*, reflecting a balanced employment distribution among the three centers. Figures 2.6a and 2.6b show the pattern of urban residential zones at wage equilibration.

C. Multipl Employment Levels

Another way in which the linear programming model can shed light on commuting costs and shadow wage levels is by considering a city with multiple employment centers of different sizes. With the capitalization of commuting costs into wages, larger employment centers will have to draw upon a large region to supply their labor demand. Thus, the marginal worker at the larger zone is likely to have a longer commute, leading to a higher wage premium in that zone relative to a smaller employment zone. Figure 2.7a illustrates this result for a city composed of 4 employment centers with 40, 30, 20, and 10 percent of total urban employment.[18] The figure shows how the shadow wage levels vary across centers at different overall urban employment levels, with employment shares held constant.[19] The centers display the expected hierarchy from larger to smaller employment centers, with wage differentials increasing as the size of the city increases. Figure 2.7b shows the average commuting costs

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[18]The centers are located at the same positions as the four centers used in the 3-subcenter housing market model:

40%	center
30%	right corner
20%	left corner
10%	top corner

[19]The wage in the rural employment zone is normalized to *0*.

for each employment center, which again show the same trend and hierarchy as the shadow wages.

V. Empirical Implications

The results of the linear programming theory and simulations in this paper provide an ample illustration of the dual capitalization which must occur in order for the land market in a multicentric city to reach an equilibrium. In particular, the results show how marginal commuting time differentials will be capitalized into the shadow price of increasing labor demand, or the shadow wage. To the extent that urban areas conform to the simple specifications of this model, then, we should expect to find higher wages and longer commutes for workers in larger employment centers within metropolitan areas. This will be the focus of **Chapter 3**, in which wage equations are estimated in order to determine the wage premia associated with different regions within cities, and to examine whether these premia are related to commuting times.

One important result from the above simulations is the extent to which average commuting costs track marginal commuting costs, the definition of shadow wages in this simple model. In the real world, commuting sheds for different employment areas overlap, making determination of the actual "marginal commuter" difficult. Average commuting times for different employment zones are more readily calculated. The simulations provide a basis for using them as a proxy for marginal commuting times in the empirical work which follows.

The simulations also lend some insight into the expected dynamics of employment decentralization. The existence of wage differentials provides a significant incentive for cost-minimizing firms to decrease their wage bill by moving away from existing employment concentrations and toward the residential locations of their employees. There is thus a strong centrifugal force at the margin counteracting the centripetal forces of agglomeration and/or export node access. In a stable equilbrium, these forces must equally balance each other. As these agglomerative forces weaken over time, urban employment will become increasingly decentralized. Empirically, as the simulations have shown, this should result in the convergence of wages and commuting times across employment regions within cities as decentralization occurs. Growth should also occur most rapidly, *ceterus paribus*, in regions with lower initial wage levels. These questions will be explored in **Chapter 4**.

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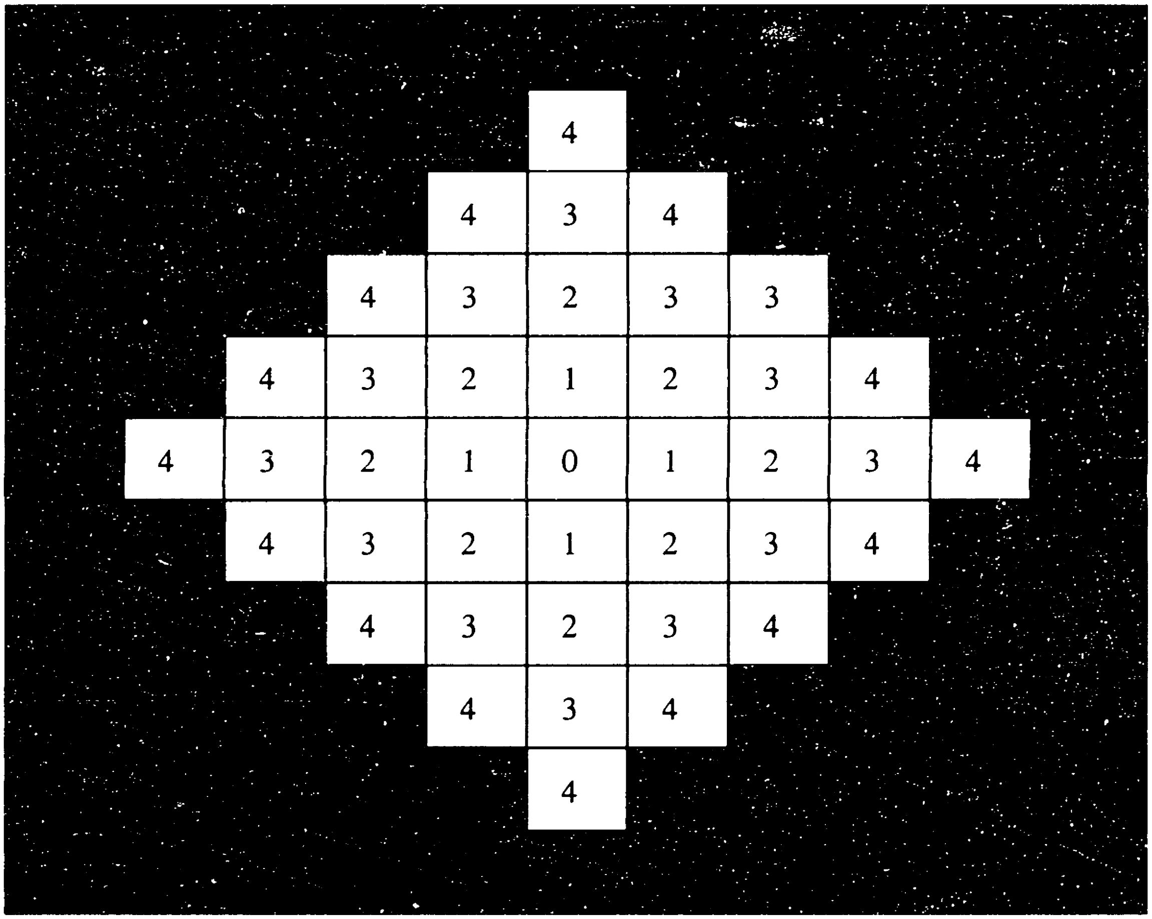


Figure 2.1

Figure 2.2a
Single Subcenter

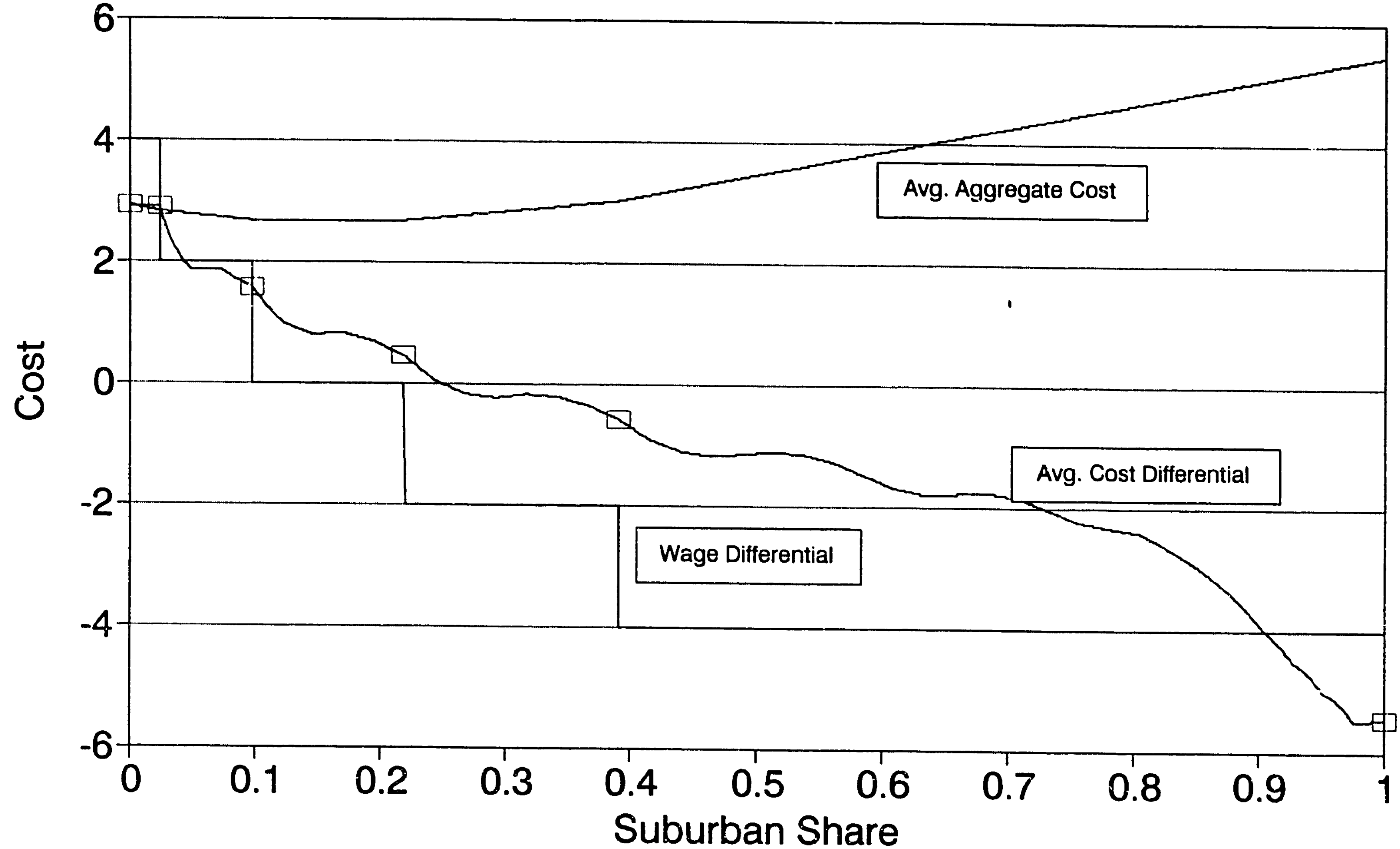


Figure 2.2b
Two Subcenters

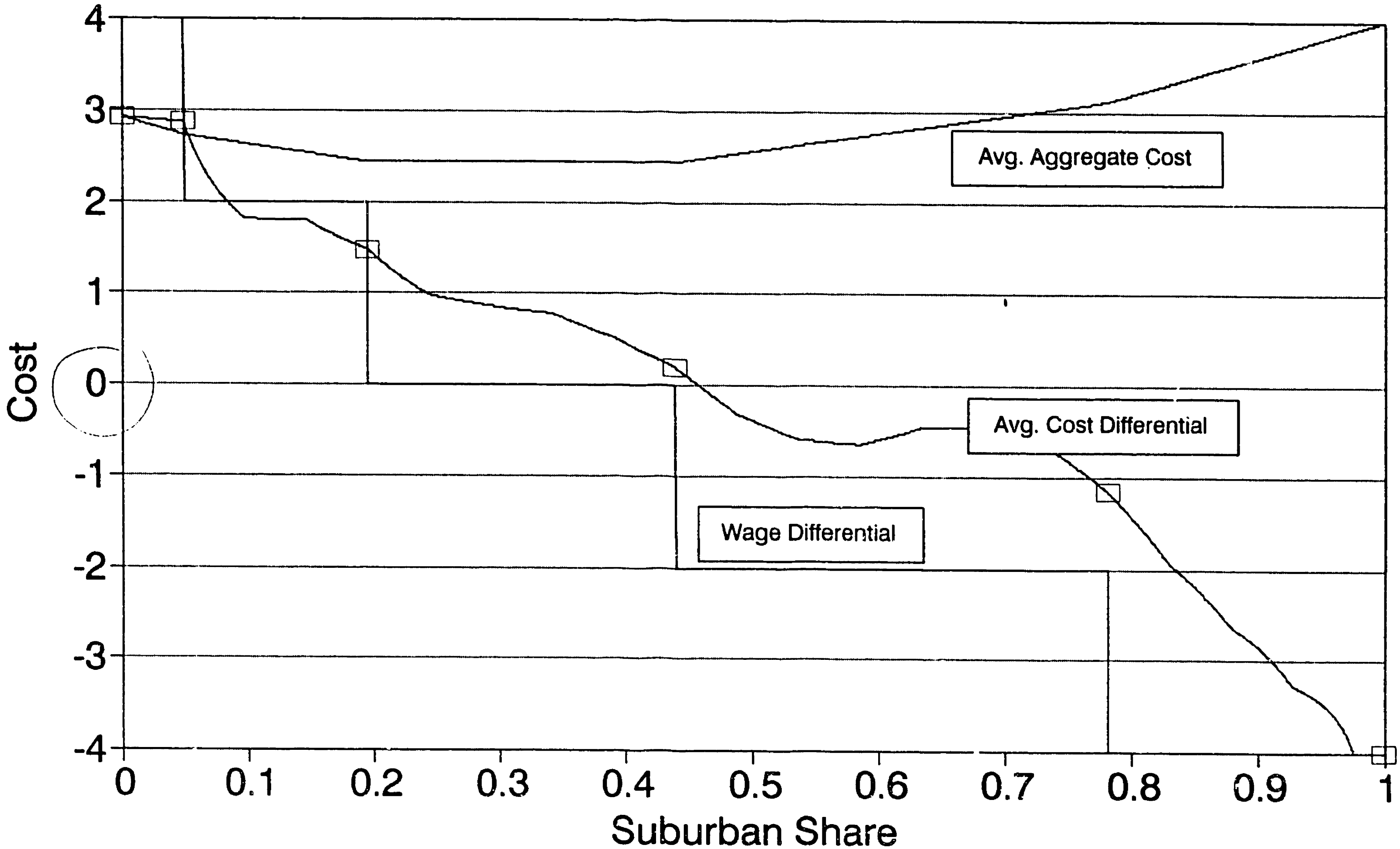


Figure 2.2c
3 Subcenters

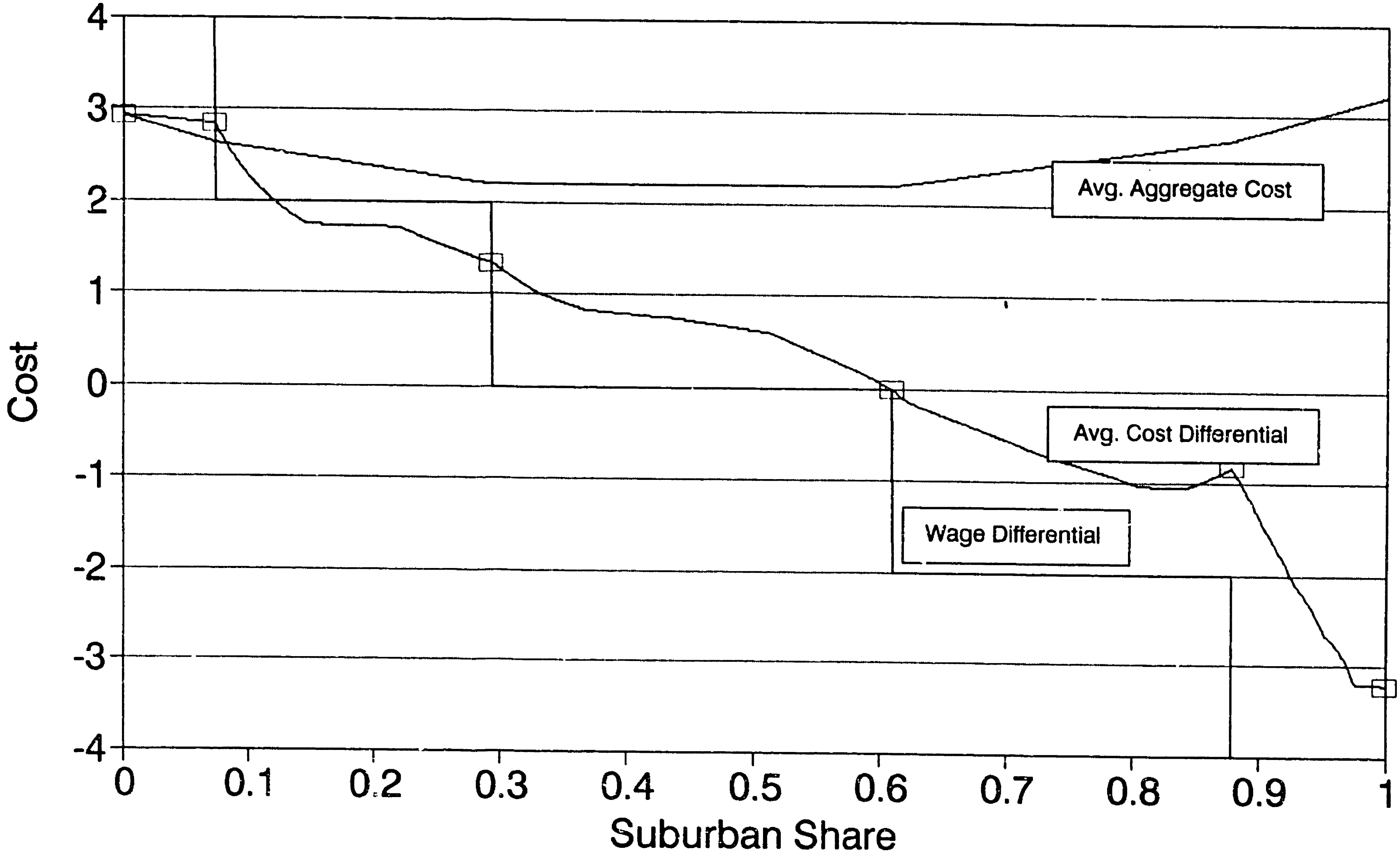


Figure 2.2d
4 Subcenters

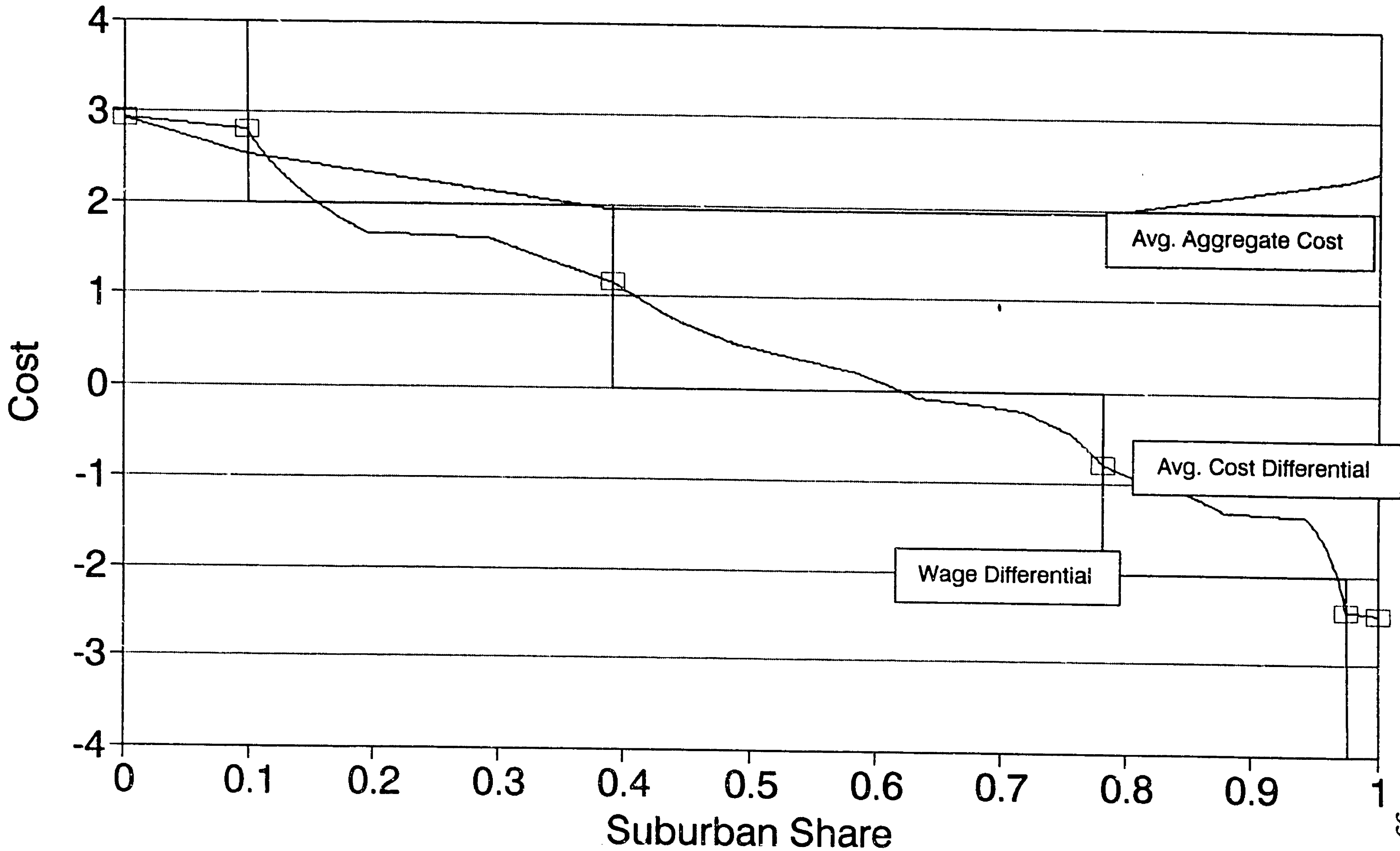


Figure 2.3
Total Commuting Costs

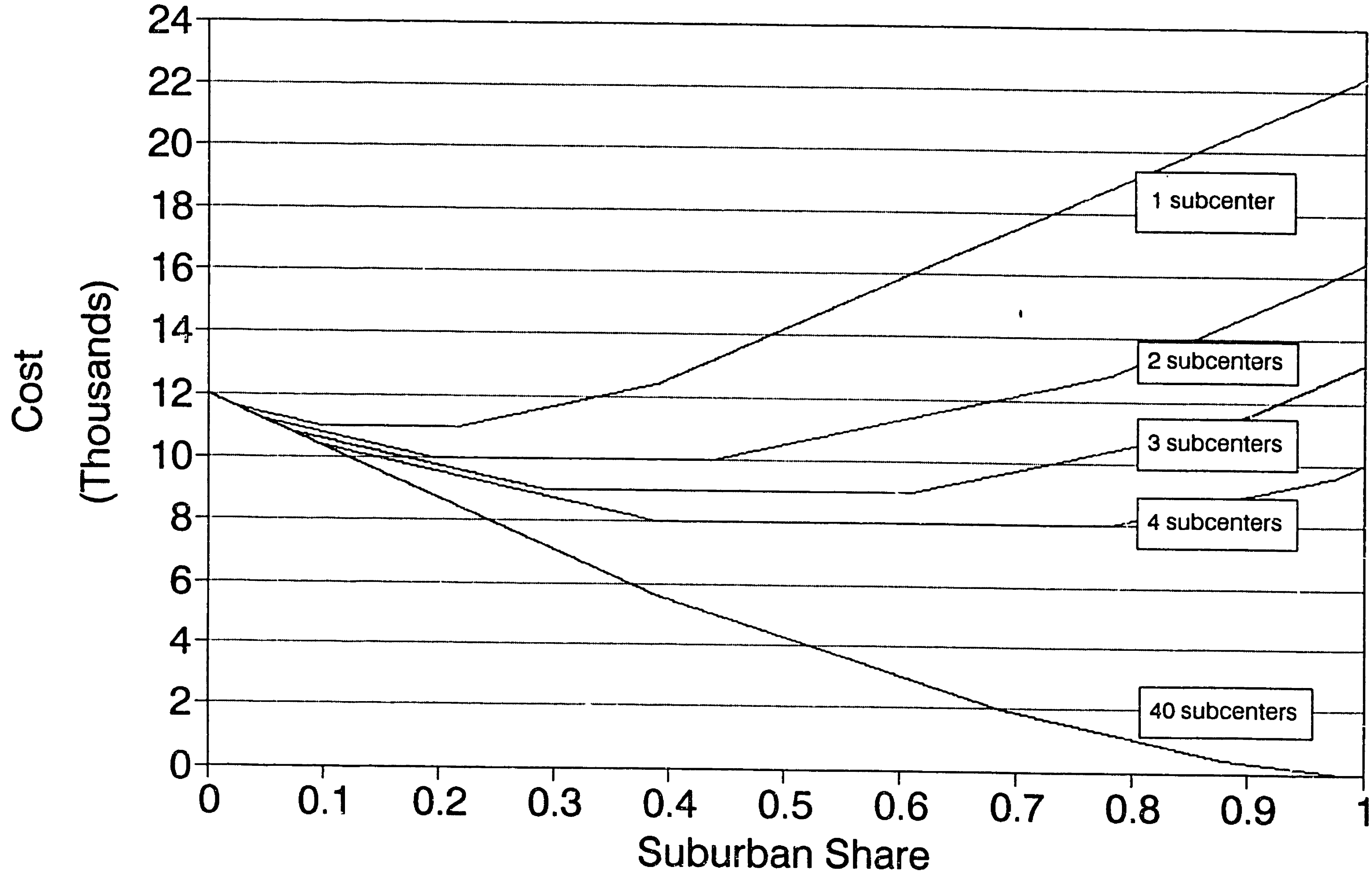


Figure 2.6a

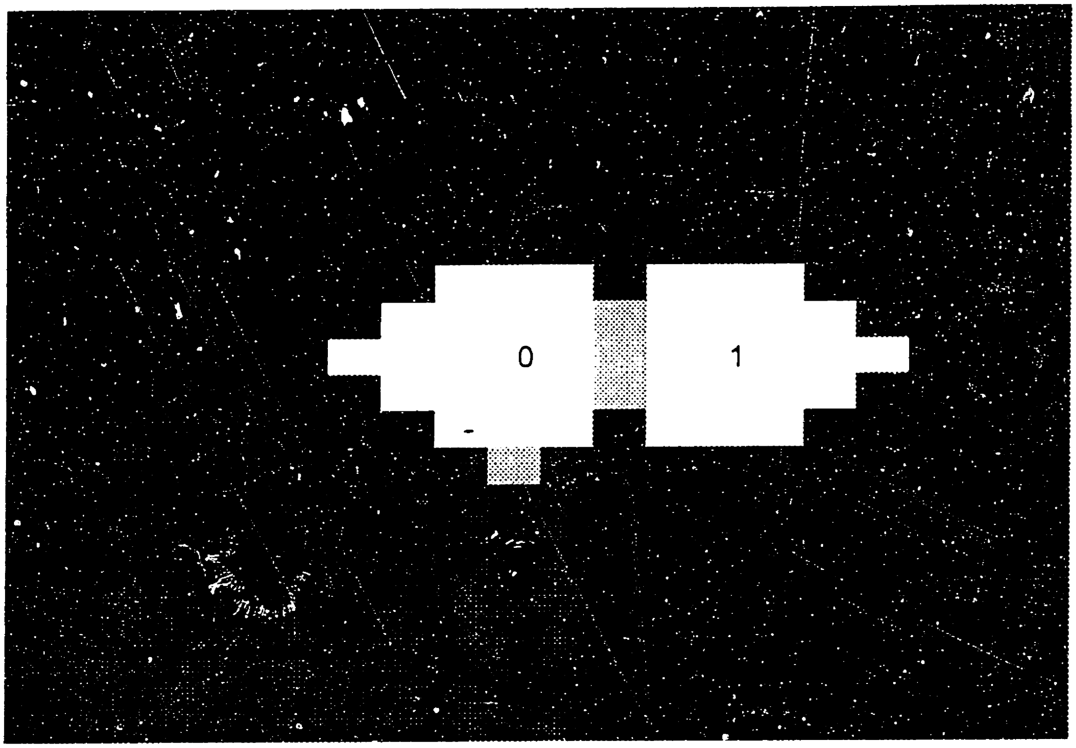


Figure 2.6b

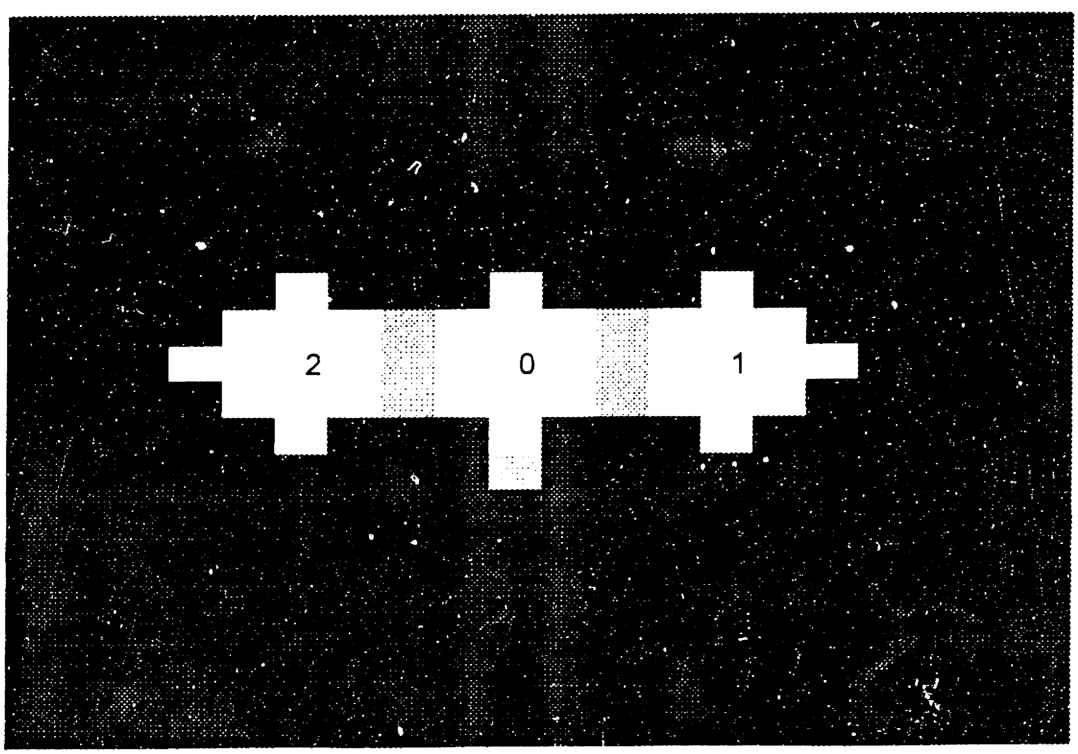


Figure 2.5a
Single Subcenter (Land Market)

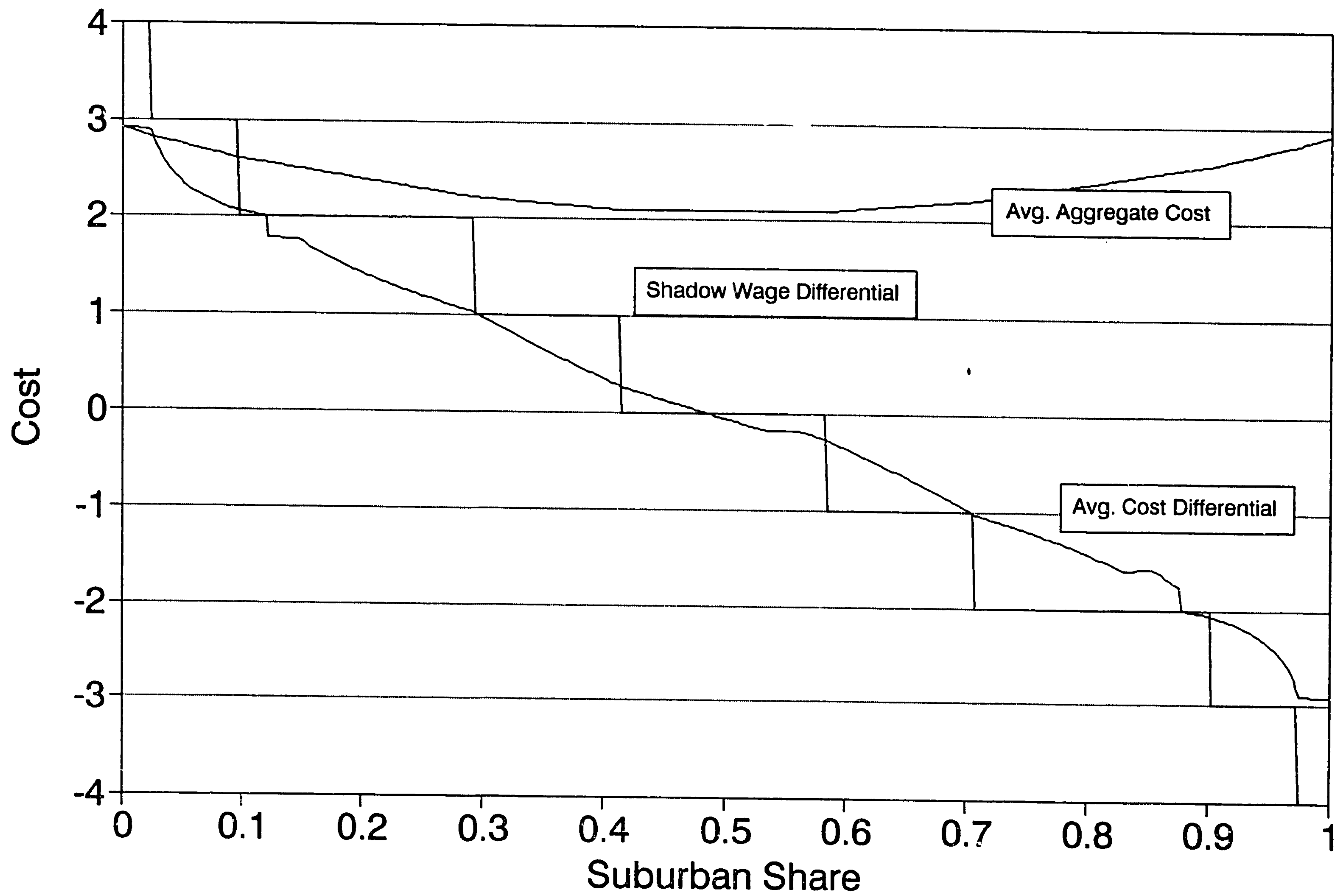
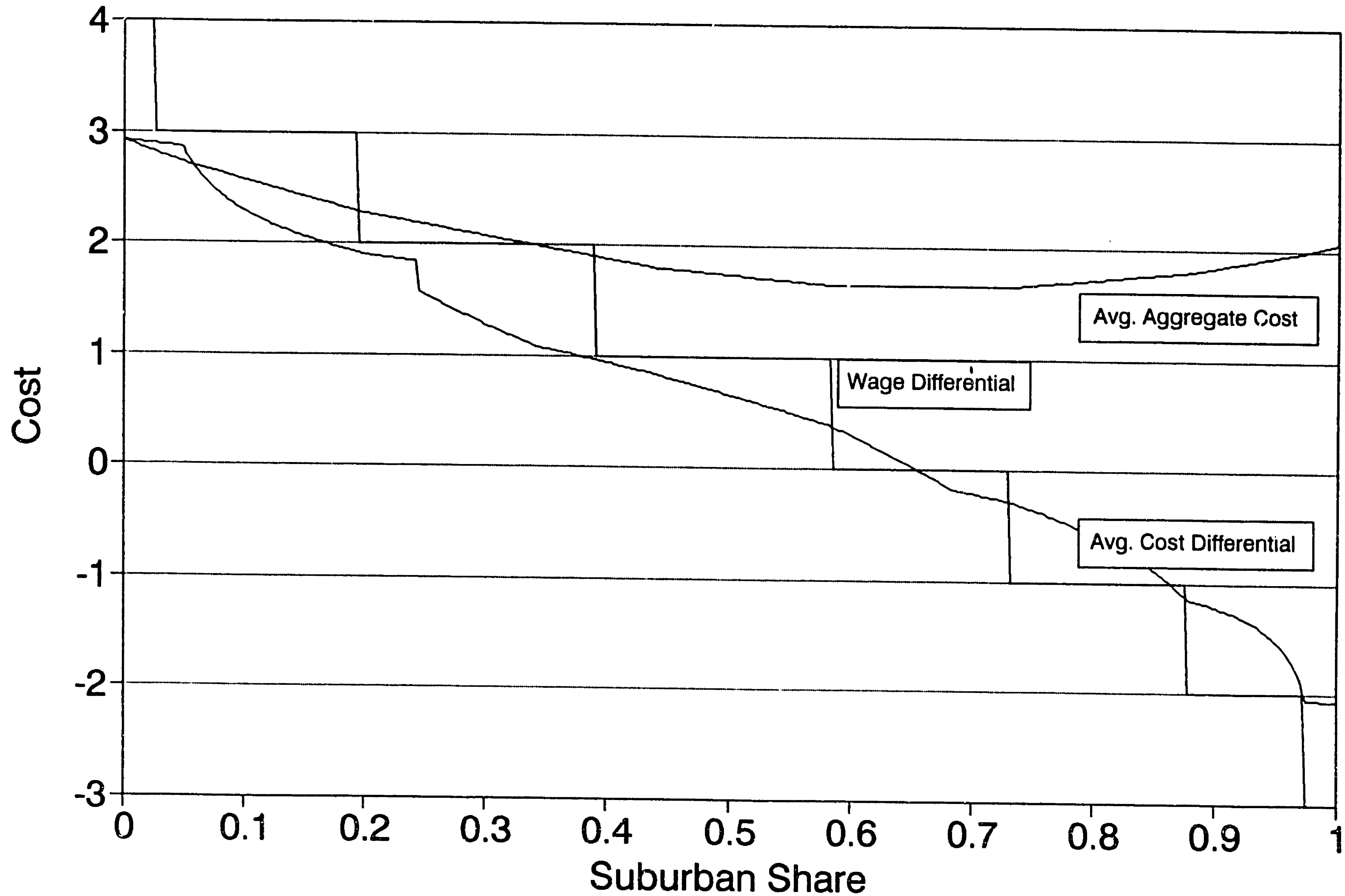


Figure 2.5b
Two Subcenters (Land Market)



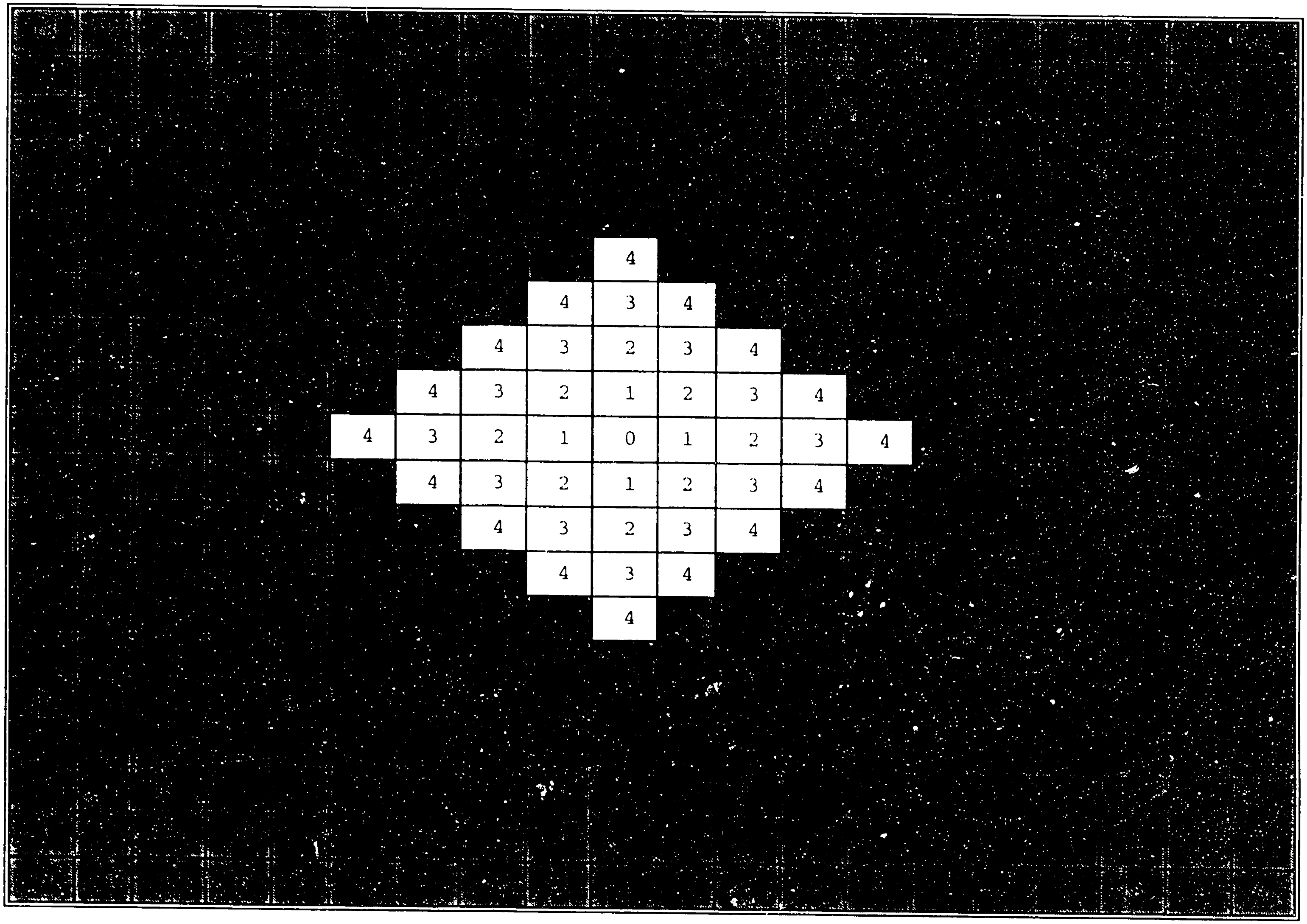


Figure 2.4

Figure 2.7a
Shadow Wage Levels

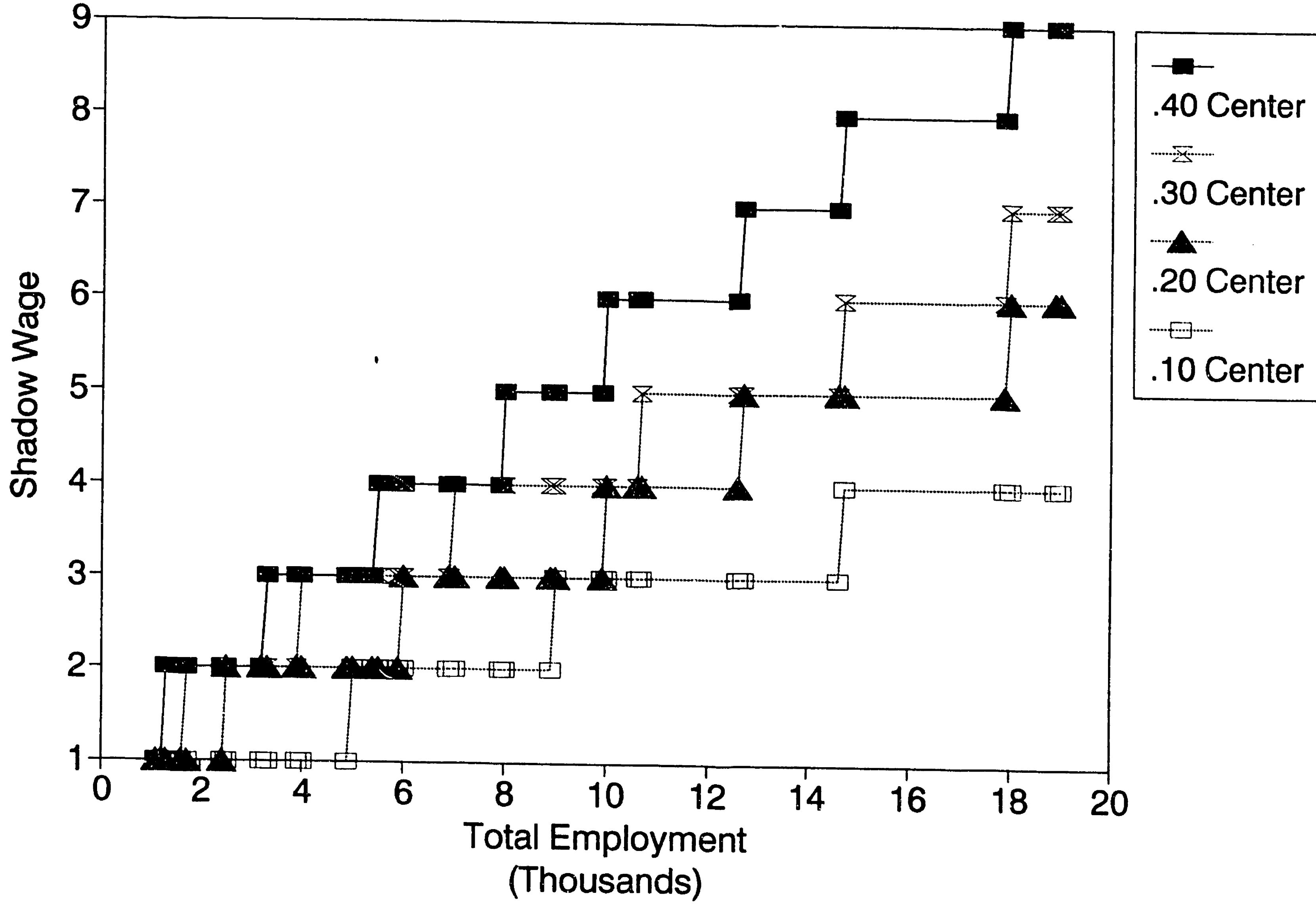
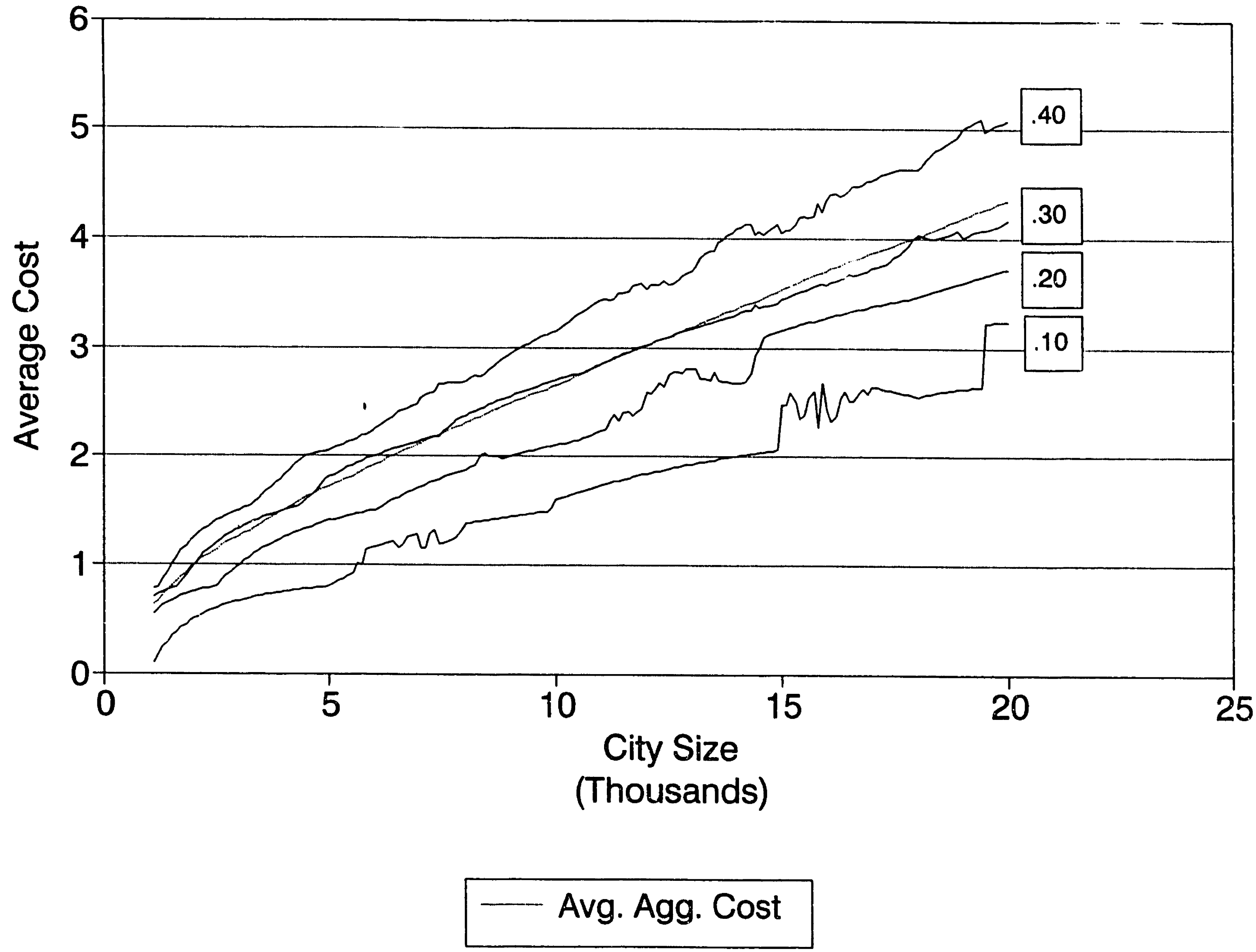


Figure 2.7b


6
5
4
3
2
1
0
Average Cost
0
5
10
15
20
25
City Size
(Thousands)
.40
.30
.20
.10
Avg. Agg. Cost

Chapter 3

Intraurban Wage Differentials and Commuting Time

I. Introduction

The previous chapter showed in a simple model how commuting costs (and other spatially varying costs) will be capitalized into both wages and market land rents. This chapter seeks to empirically analyze the wage capitalization side of the dual capitalization. Urban economic theory predicts that wage differentials between work zones within a city will result from differences in commuting times. This paper seeks to validate the conclusions of these models by focusing on three questions. First, do wages vary within metropolitan areas by workplace location? Second, is this variation correlated with commuting times? Third, do larger employment centers have longer average commutes?

II. Previous Empirical Work

Early studies of wage gradients were hampered by limited, often aggregated data. Segal (1960) computed average wages for several different types of workers in the New York City metropolitan area, and compared the wages of central city and suburban workers. He found wages to be lower in the suburbs for some kinds of workers, implying a negatively sloped wage gradient, while wages for other occupations were higher in the suburbs.

Rees and Schultz (1970) used a survey of individual workers at 74 firms in the Chicago area. They included dummy location variables for the north and south regions of the city, in addition to the downtown area. They found wages for blue-collar workers in the southern region to be significantly greater than those in the other two areas, implying a wage gradient which peaks in that area. They attributed this result to the concentration of heavy industry in that area.

Eberts (1981) used data on municipalities in the Chicago area to estimate wage gradients for municipal workers. His data consisted of average metropolitan salary and fringe benefits levels for five categories of workers. He estimated municipal wage gradients for each group, controlling for local government policies and socioeconomic characteristics of the cities. He found significant wage gradients for four of the five categories, with elasticities of wages with respect to distance of -.1 to -.4. He inferred the existence of a similar private wage gradient based on mobility between the public and private sectors.

DiMasi and Peddle (1986) used municipal level data on the wages of manufacturing production workers in the Boston SMSA, with municipal-level controls similar to those used by Eberts. They used a bivariate specification of the wage surface, which they find to be superior to a univariate measure. They find no local extrema in the surface, but do find a saddle point, with wage gradients of up to 1% per mile from this point.

More recent wage gradient studies have attempted to improve on these previous studies through the use of microdata. Madden (1985) used data from the Panel Study of Income Dynamics to test for the existence of a wage gradient. By looking at changes in wages and rents for individiuals who change jobs or housing locations, she finds evidence of a wage gradient, based on the finding that workers who change jobs to a more distant work location receive higher wages.

McMillan and Singell (1992) use microdata from the 1980 Public Use Microdata Sample (PUMS) to test for wage diffferentials between suburbs and central cities.[1] Using a pooled sample from seven midwestern cities, they first predict an individual's work location, then use that prediction in a wage regression. They find a significant differential, 9%, between suburb and central city.

Ihlanfeldt (1992) also used the 1980 PUMS to directly estimate wage gradients for Detroit, Philadelphia, and Boston. Using several alternative specifications of the functional form of the wage/distance relationship (of which he finds a log-log specification to be

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[1]This is essentially a methodologically improved version of the Segal approach.

superior), he estimates wage elasticities for six occupational categories. His estimated wage gradients imply a wage decline of between 5 and 19 percent at 10 miles from the CBD and from 6 to 24 percent at 20 miles.

These studies suffer from an overly simplified specification of intraurban wage variation, forcing it into a one-or-two-dimensional gradient measure. This oversimplification presents a problem in the presence of multiple, secondary and tertiary employment centers. If large secondary centers develop on the edge of the urban area, with smaller centers or dispersed employment between the primary and suburban centers, a single-dimension gradient may understate the degree of spatial variation in employment and wages. It also makes the estimation of a pure wage gradient in bimodal cities (such as Dallas-Fort Worth or Minneapolis-St. Paul) impossible. If wages are relatively stable within the metro area, however, but drop sharply at the urban fringe, the inclusion of these areas may lead to an overestimation of the wage gradient. Finally, precise estimation of a wage gradient requires individual-level wage and personal characteristic data as well as workplace location data at a highly disaggregated level. Given the level of disaggregation currently available in microdata for job location, the distance from the city center to employment locations can only be very coarsely measured, leaving the measurement of the wage gradient sensitive to the specification of the employment centroid within the area.

The studies which directly estimate wage gradients (Eberts, DiMasi and Peddle, Ihlanfeldt) implicitly or explicitly use the Muth's local employment sector model, implying a smooth rent gradient. The model used for this paper, however, is one of urban subcenters. Rather than estimating wages purely as a function of distance, then, this paper will simply attempt to illustrate the degree of spatial variation in metropolitan wages. More importantly, it will seek to investigate the underlying model which generates wage variation, namely, differential accessibility of worksites to employees from their residences.

III. Estimation

The subcenters-based model to be estimated here takes the following form:

$$C_i = F_1(E_i) \,,\quad F_1'>0 \tag{3.1}$$

$$W_i - W^0 = F_2(C_i) \,,\quad F_2'>0 \tag{3.2}$$

where

C_i = Commuting cost of workers in employment zone i

E_i = Employment in zone i

W_i = Wage rate in zone i

W^0 = Base metropolitan wage rate

Equation *(3.1)* states simply that larger employment centers will have marginal commuters who live further away, resulting in a positive correlation between center size and commuting times. Equation *(3.2)* represents the capitalization of commuting costs into wages, the primary focus of this paper.[2] To estimate equation *(3.2)*, a semi-log wage equation of the following form was used:

$$ln(W_j) = \alpha X_i + \beta' Z_j$$

where

W_j = Wage of individual j

X_i = A work zone-specific variable (or variables)

[2]The employment level here is taken to be exogenous. One might well suppose, however, that the employment level could also depend negatively on the relative wage rate: $E_i = F_3(W_i),\ F_3'<0\ (3.3)$. Employment levels would thus be endogenous, and equations (3.1) and (3.2) could not be consistently estimated. Suppose however, that the dynamic process underlying the equilibrium relationships of equations (3.1) and (3.2) are more or less instantaneous, while the feedback from wage rates into employment levels takes place over a longer horizon. In this case, the simultaneous-equations bias introduced by equation (3.3) will be small, and employment can be treated as an exogenous variable. The issue of dynamics will be explored more thoroughly in **Chapter 4**.

Z_j = A vector of individual characteristics

IV. Data

In examining wage variation and commuting within cities, two types of data are available, each of which has its own comparative advantages. Micro-level data, containing details on the demographic characteristics of individual workers, offer the advantage of being able to control for differences in the occupational, industrial, and human-capital mix of the workforces in various employment zones within the city. Aggregate data, on the other hand, while losing such detail, generally provides a more detailed geographic specification of workzones. In this analysis, both types of data were used.

A. Micro-Level Data

The data used in the estimation of the micro-level wage equations come from the 5% Public Use Microdata Sample (PUMS) of the 1990 U.S. Census. The Census Bureau provides both a 5% sample of households and a 1% sample, using data drawn from the 1990 Census of Population and Housing. This dataset provides information on both household and individual characteristics, including age, ethnicity, education, income, and employment. Especially relevant for this study is the geographic identification of residence and workplace locations, discussed below.

1. Covariates. The following individual characteristics were used as control variables (the Z matrix):

1) Age (entered as a quartic function)

2) Education (dummy variables for highest degree obtained)

3) Race (dummy variables for Black, Asian and Hispanic)

4) Gender dummy

5) Marital Status (also interacted with female)

6) Veteran Status dummy

7) English Ability (dummy variables for 4 different levels)

8) Disability (dummies for 3 types of disability)

9) Industry (see Appendix 3B)

10) Occupation (see Appendix 3B)

The individual's wage was obtained by dividing wage and salary income from 1989 by total weeks worked in that year.[3] Regressions were also run using income as the dependent variable on a more restricted sample of full-time workers.[4]

2. Geographic Identifiers. Residence and workplace locations for individuals in the 1990 PUMS are coded using Public Use Microdata Areas (PUMAs). These areas are state-specific and consist of groups of counties or portions of counties with a minimum population of 100,000.[5] The definition of the PUMAs is left to the individual state data centers, using guidelines set by the Census Bureau.[6] Residential PUMAs (RESPUMAs) and place-of-work PUMAs (POWPUMAs) are slightly differently defined, with respumas forming subsets of POWPUMAs.

According to the Census Bureau guidelines, PUMAs which are based on census tract boundaries, rather than municipal or state boundaries, cannot constitute an individual place-of-

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[3]Since the reported workplace and travel times are based on the current (April 1990) job location, while income and hours reported are for the previous year, the computed wages will not correspond to the correct work zone for individuals who change jobs between zones. To partially account for this, the sample was restricted to individuals who reported working at least 35 weeks during the previous year, based on the notion that year-round workers are less likely to have changed jobs than seasonal workers. The sample also excluded part-time workers (those who reported working less than 25 hours per week on average in 1989) for the same reason.

[4]Minimum 48 weeks worked, 35 hours per week. The results for this group are qualitatively and quantitatively similar to those obtained from the wage regressions, and are not reported here.

[5] These correspond the County Groups used in the 1980 PUMS

[6]The variation in effort across states in defining the pumas strongly affects the usablity of large metro areas within those states for this analysis, which determined the choice of cities used.

work PUMA.[7] Thus, subcounty POWPUMAs can consist of a city, a group of cities, or the remaining cities and unincorporated portions of the county, and correspond either to an individual RESPUMA or group of RESPUMAs.[8]

Given this geographic coding scheme, five metro areas were selected which have a sufficient number of identifiable work zones to provide meaningful spatial variation: Boston, Detroit, Minneapolis-St. Paul, Cleveland, and Dallas-Fort Worth.[9] Definitions of the PUMAs are given in Appendix 3A.

B. City and Town-Level Data

For the Boston metropolitan area, a separate data set was compiled. Data on mean earnings, average commuting time, and employment (all by place of work) were obtained for 156 cities and towns in eastern Massachusetts. The data on employment and commuting times for 1990 were drawn from the *1990 Census Transportation Planning Package*, cited in **Chapter 1**. Earnings and employment data were obtained from the Massachusetts Division of

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[7]The arbitrariness of this rule is illustrated by noting that the City of Los Angeles has 24 respumas and one powpuma, while Pasadena is both a respuma and a powpuma. This is hardly an effective method of dealing with confidentiality concerns, but it nevertheless is the one used by the Census Bureau.

[8] For example, Wayne County, Michigan has 5 powpumas: Detroit (with 8 respumas), Livonia (1 respuma), Garden City and 3 other cities (1 respuma), Lincoln Park and 4 other cities (1 respuma), and the remainder of the county (5 respumas).

[9]The metro area definitions roughly correspond the Consolidated Statistical Area boundaries. Thus, Detroit includes the Ann Arbor MSA, and Cleveland includes the Akron and Lorain MSAs. For Boston, the disaggregation of the work zone data permitted a metropolitan area defintion roughly encompassing the region bounded by the New Hampshire border and Interstate 495, thus including all or most of the Salem, Lowell-Lawrence, and Brockton MSAs. The metropolitan areas have the following PUMA totals:

	RESPUMAs	POWPUMAs
Boston	28	24
Detroit	35	16
Minneapolis	15	15
Cleveland	21	14
Dallas	32	13

Employment and Training through the Central Transportation Planning Staff in Boston.[10] This data set covers all of the municipalities included in the Boston metro area's 25 POWPUMAs for 1990, plus a few more communities. A list of the minor civil divisions in this sample appears in Appendix 3C.

As discussed above, this data set represents a tradeoff (relative the the PUMS) of greatly improved geographic detail against the loss of micro-level wage data. The Boston metropolitan area is particularly well-suited in this respect, due to the large number of minor civil divisions (cities and towns) for which aggregate data are available. The communities are also relatively small and close in geographic size, helping to avoid difficulties in interpretation which can occur with large and variable employment zone sizes.

To improve upon the earnings variable in this data, an attempt was made to partially control for differences in the occupational/industrial mix of different localities. To do this, the mean earnings for workers in 11 industrial sectors in the Boston area were tabulated using the 1990 PUMS. An industry-predicted earnings level for each municipality was then constructed using the formula

$$E_j = \sum s_{ij} E_i$$

where

s_{ij} = *Industry i's share of employment in locality j*

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[10]The employment figures for this second data set exclude the self-employed (who do not need to register with the DET), whereas the employment figures based on census data include all workers over the age of 16. Average commuting times are for workers who did not work at home.

A similar occupation-based predicted earnings level was then constructed using 9 occupational categories.[11] Earnings residuals for each community were then obtained by regressing the industry and wage-predicted earnings on actual average earnings.

V. Results

The wage equations were estimated separately for private sector and public sector employees in each city.[12] Within the public sector, the following characteristics are expected *a priori*:

1) Federal government salaries are set centrally, with some adjustment between metro areas to account for cost-of-living differences. Thus, wages for these workers are not expected to vary within metro areas (at least in a way that is systematically related to travel times).

2) Wages for employees of local governments, however, are free to differ across jurisdictions within the metro area. Since local governments must draw their workers from the local labor pool, municipalities with larger employment concentrations might need to draw their workers from further away, leading to higher wages and a positive correlation with commuting times.

3) For state employees, the expected relationship is unclear. If wages are fixed exogenously, as at the federal level, then there will be no correlation with commuting

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[11]The predicted earnings levels were normalized using the ratio of mean metropolitan earnings from the aggregate sample to mean metropolitan earnings from the PUMS. Ideally, a single predicted earnings level, based on both industry and occupation, would have been used. However, cross-tabulations of employment totals by industry/occupation for each town were not available.

[12]The self-employed were excluded due to the difficulty of interpreting "wage and salary income" for these individuals (48% of the full-time self-employed individuals in the sample reported no wage and salary income in 1989). The results for regressions run including the self-employed among private sector workers did not vary significantly from those associated with this more limited group.

times. If state salaries do vary within the city, however, there may exist some degree of correlation. Thus, the *a priori* expectation is that wages for these workers will have an intermediate commuting time correlation, between that for local and federal government employees.

The equations were also estimated separately for each of eight different occupational classes (government workers excluded). The sample was restricted to individuals who live and work within the metropolitan area.[13] Agricultural, mining, and active-duty military were also excluded.

A. Wage Variation

To determine the wage variation within each city, the wage equations were estimated allowing for different structural effects in each POWPUMA. The associated wage premia are presented in Table 3.1a, along with the adjusted r^2 from the wage regression. The coefficients represent the percentage difference in wages between the POWPUMA and the largest city in each metro area. A city-by-city examination of the table reveals the following:

Boston: Wages are found to vary up to 15% between Boston and the outlying workzones in Lawrence/Haverhill, located 25 miles to the north, and Foxboro, 25 miles to the southeast. All other zones have wage premia which are significantly smaller than in Boston.

Detroit: A wage differential of nearly 25% exists between Detroit and exurban Lapeer/Shiawassee counties, and of 15-18% in Livingston and St. Clair counties, also on the edge of the metro area. Wage variation within the core metropolitan area, however, is much smaller, up to only 8%. Five zones have wage premia insignificantly smaller than the central city, and one, Warren, is significantly greater than Detroit, at 2.3%.

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[13]For Boston, workers were also included who lived in regions adjacent to, and work in, the defined metro area. The definitions of the other areas were sufficiently broad as to realistically include all who work in the urban area.

Minneapolis: Wage differentials of up to 18% are found between Minneapolis and the exurban counties to the north. Wage variation within the rest of the metro area is on the order of 10%. Three zones are insignificantly smaller than Minneapolis, and one, suburban Plymouth/Edina/Minnetonka, is larger than the central city.

Cleveland: Wage variation of 12 to 15% is found between Cleveland and the outlying counties, and up to 11% within the core metro area. Again, one region, suburban Strongsville-Berea, is found to be significantly larger than Cleveland, at a 3.1% premium.

Dallas: Wages drop off sharply at the urban fringe, with a differential of 28% between Dallas and the fringe counties west of Fort Worth, and 17% with the edge counties to the south and east. No zones have premia larger than Dallas, but two, Plano and Irving, are not significantly smaller.

There thus appears to be significant wage variation within each of the five metropolitan areas. It is most pronounced at the extreme edge of the metropolitan areas. This might lead to the overestimation of a wage gradient when these areas are included. At the same time, however, these areas tend to be much larger geographically than others in the metro region, due to their lower population densities. Thus, the large wage differential may simply capture the fact that the centroids of employment in these areas are far removed from the center of the city. They are included in the analyses presented below, and their impact will be discussed later.

The coefficients of the other variables included in the regressions are shown in Table 3.1b.

Summary statistics for mean wages and for the estimated residuals from the 156-city Boston sample are presented in Table 3.1d.

B. Commuting Times

The average travel time for employees commuting to each Place-of-Work PUMA are listed in Table 3.1c.[14] As with the wage premia, there is significant variation across work zones. In Boston, average commuting times of workers employed in the central city are nearly double those of workers in Salem, with an overall range from 18.4 minutes to 34.3 minutes. In Detroit the range is 16.1-28.1 minutes; Minneapolis, 15.0-25.6; Cleveland, 17.6-27.6; and Dallas, 16.6-28.2. Unlike the wage premia, the central city in each metro area has the longest average commuting time of all the work zones. This may be ascribed to two effects: 1) as the largest employment center, the central city draws workers from the widest region, and (2) traffic congestion tends to be the highest there, lengthening trip times. Commuting time summary statistics for the larger Boston metro sample are shown in Table 3.1d.

In Figure 3.1, the wage premia for each POWPUMA are plotted against average POWPUMA travel times. The plot points are the POWPUMA numbers found in Appendix 3A. The lines in each graph represent the fitted values of a bivariate least squares regression of travel times on wage premia. As evidenced by these figures, the wage premia appear to be significantly and positively correlated with average POWPUMA travel time, as predicted by theory. In bivariate regressions of average POWPUMA travel times on the wage premia, the coefficients on travel time are significant and positive, with r^2's from .51 to .77.[15] Similar plots for the Boston CTPP/DET data, using both mean earnings and the estimated residuals, are shown in Figure 3.2. The examination of these graphs provides the impetus for the next phase: including travel time directly in the wage regressions.

C. Wages and Commuting Times

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[14]The 1990 PUMS provides individual sampling weights for each person. The average travel times reported in Table 1b are the individually-weighted averages for full-time workers in each employment zone.

[15]These $.^2$ values do not account for the fact that the wage premia are estimated values. Thus, they overstate the true goodness-of-fit of these bivariate regressions.

The wage equations were next estimated using the average travel time of all commuters to the work zone of the individual worker, in place of POWPUMA structural effects.[16] Note that this is **not** the travel time of the individual worker. The theory links wages to the travel time of the marginal worker in the zone, not the individual. If residences are located contiguously around their respective employment centers, the average commuting time is a sufficient statistic for the commuting time of the marginal worker. The linear programming simulations produced in **Chapter 2** also showed how average commuting times track marginal commuting times in a discrete environment. Additionally, it is felt that in the context of the real world, in which workers are not contiguously distributed, the average better captures the competition between centers than the marginal. Thus the primary focus in this analysis will be on results based on average commuting times, although some results using marginal commuters will also be reported.

1. Private/Public Sector Workers. Table 3.2 shows the results for private and public sector workers. Heteroscedasticity-robust standard errors are in parentheses underneath each coefficient. The coefficients on the average work zone travel time variable range from .008 (Boston) to .016 (Dallas). This coefficient represents the semi-elasiticity of the hourly wage with respect to two additional minutes of commuting time. Thus, for an average eight-hour workday, the embedded value of commuting time would be 240 times the estimated coefficient, or from two to four times the

wage rate. This figure is considerably higher than most of those reported in the value-of-time studies cited in Miller (1989) and Small (1992), which rarely find values greater than one. Two sources readily come to mind which might help explain this discrepancy:

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1) The wage rate variation incorporates out-of-pocket commuting expenses (such as gasoline, parking, and depreciation) as well as the inherent value of commuting time. Thus, estimates over state the pure time value.

2) The coefficient estimates are inflated by the inclusion of the exurban regions, which have wage premia well below the trend line for the metropolitan areas as a whole.

Even with both of the considerations, however, the coefficients do appear to reflect an extremely high value of time.

The results for government workers are shown for each of the three levels.[17] The coefficients exhibit the expected pattern in Boston and Dallas, with an insignificant correlation for federal workers, an intermediate effect for state workers, and a strong, positive effect for local government employees. In Minneapolis, both state and federal wages are insignificantly related to commuting times, while in Cleveland the effect is strongest for state workers. Detroit presents the biggest puzzle. All three levels show a strong relationship between wages and travel times, and in fact are statistically indistinguishable from each other. A closer examination is required to determine the source of this observed correlation. For the other cities, however, the hypothesis of no correlation for federal workers and a strong correlation for local workers is supported.

2. Gender and Racial Differences. To examine whether differences in the responsiveness of wages to commuting time differentials might exist based on gender or race two types of specifications were used. In the case of gender, if women value their time spent in commuting more (due to their having a greater share in household responsibilities, for example), then the wages of female workers must adjust even more strongly than those of men

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[17]Wage equations for government workers were estimated jointly, allowing for a different slope coefficient on average travel times for each group. The industry and occupation dummies used are shown in Appendix 2.

to compensate for commuting time differences. In Table 3.2a, the results from separate wage regresssions for each gender are shown. In the first specification, using the travel time of all workers in the POWPUMA, women's wages clearly show a much stronger response to commuting time differences than those of men, with coefficients 1.5 to 2.5 times as high. Specifications using the travel times of workers of the same gender in the POWPUMA show a lesser differential between men and women.[18] Thus, there is support for a gender differential in the wage/commuting time relationship.

In the case of race, a plausible story for differences rests on the spatial mismatch hypothesis. If black workers are constrained in their housing choices to more central locations, then the decentralization of employment will lead to longer average commutes for them. Table 3.2b provides weak support for this hypothesis. For white workers, their wages are significantly and positively correlated with the average travel times of workers in their POWPUMA. For black workers, their wages show a negative or negligible correlation with the travel times of all workers in the zone, and a positive or zero correlation with the average travel times of black workers in their place of work.

3. Marginal Commuters. An attempt to compare marginal commuters with average commuters was made by using the commuting times of the 75th percentile and the 90th percentile workers in each POWPUMA in place of average commuting times. The results for each city are shown in Table 3.2c. The travel time coefficients are quite similar in each city to the results using averages, though slightly smaller in magnitude. This lends further support to the use of average commuting times.

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[18]The appropriate specification depends on the marginal rate of substitution in production of male for female workers. If men and women are perfectly substitutable, then the commuting times of all workers are relevant for both genders. If jobs are gender-specific, then only the travel times of workers in the same gender should affect wages.

4. Aggregate Data. Results using the Boston community-level sample are shown in Table 3.2d. The strong correlation between commuting times and wages is observed here as well. The higher slope coefficient using mean earnings (as opposed to estimated wage premia) reflects the fact that the occupational, industrial, and human capital structure of local labor forces has not been controlled for. Since individuals with higher incomes have longer individual commutes on average, this is reflected in a stronger correlation between earnings and commuting.

5. Occupational Differences. Table 3.3a presents the estimated travel time coefficients for each occupational class, estimated separately. The following points can be noted from this table:

1) The coefficients are not stable within each city across occupational categories.

2) Managerial wages are significantly correlated with travel times, and the value is greater than that for the coefficients estimated with the full sample in each city.

3) Professionals also show a strong wage correlation with travel time.

4) Wages for technicians have the most inconsistent commuting time correlation across cities, with no correlation for Boston and Minneapolis and a strong correlation for Detroit.

5) Coefficients for workers in sales-related occupations and for administrative support occupations are approximately the same as those for managers.

6) Travel time coefficients for Service Workers, Craftsmen, and Laborers are close to the city-wide values.

In Table 3.3b, the results for the same regressions using average POWPUMA travel times of workers in the same occupation are presented. The results are qualitatively similar to those in Table 3.3a. One notable exception is in the wage regressions for administrative support workers, where the values are approximately one-third lower than those using average travel times of all workers.

6. 1980 Results. The stability of the wage-commuting time relationship over time can be examined by comparing the results using 1990 data with those using 1980 data. Some of these are presented in Tables 3.4a, 3.4b, and 3.4c. The coefficients are remarkably similar between the two censuses for each city, and exhibit the same general pattern with respect to public/private sector workers and for individual occupations.

D. Commuting Times and Employment Size

To test the employment/travel time linkage, POWPUMA employment was regressed on average POWPUMA travel times.[19] As the exact nature of the relationship is unknown, POWPUMA employment was entered both linearly and in log form. Simply using total employment in the zone, however, obviously suffers from the problem of arbitrariness in the spatial definition of the workzones.[20] For this reason, a second measure of employment concentration, the import ratio, was also used. The import ratio (calculated as the ratio of workers employed in the PUMA to workers residing in the PUMA) should influence commuting times in two ways. First, there is a rather mechanical relationship, as it measures the average availabilty of an adjacent workforce. Second, it also serves as a measure of employment concentration, as it controls for the geographic size of the employment zone

[19]The employment levels of each POWPUMA are listed in Appendix 3D. The numbers are tabulations based on the sampling weights for each observation in the sample, not the actual numbers in the sample.

[20]For the Boston city-and-town sample, this problem is lessened by the relatively homogeneous geographic size distribution of the municipalities in the region.

(which may also be correlated with population size). The results (reported in Table 3.5) indicate that travel times are significantly correlated with the concentration of employment in each work zone.

VI. Discussion

The key factor underlying the results presented here is that the observed wage variation within metropolitan areas is systematically correlated with commuting times to the various zones of employment. Alternative explanations of this effect must rely on finding additional sources of interzonal wage variation which are also correlated with commuting. One set of explanations might be based upon the theory that individuals tend to segregate themselves in the housing market to congregate with others of similar, unmeasured abilities. Thus, some of the wage variation attributed to workplace location might actually be the result of household residential location decisions. If firms which want high-ability workers choose to locate in areas with high-ability workers, however, this would lead to high-wage areas having lower travel times, thereby depressing the amount of wage variation attributed to travel time differences. To account for this effect, the equations were also estimated using structural dummies for the residence PUMAs in each city. The results from these regressions are reported in Tables 3.6a and 3.6b. The results are comparable to those found without the residential effects, though in general the travel time coefficients are slightly larger. Thus, it is doubtful that heterogeneity among residential locations accounts for the perceived travel time/wage premium connection.

Another hypothesis, which might alternately explain these results, is an efficiency wage story. If firms wish to attract high-ability employees, they must broaden the labor pool from which to draw potential applicants. In order to broaden this pool, they must offer a higher wage. Thus, the probability of finding a worker residing at a greater distance is increased, and the average travel times for workers at this firm will be above those of other firms, which choose to employ low-ability workers at lower wages.

Such a scenario does not explain, however, why firms which employ similar strategies would tend to cluster within the metropolitan area, thereby generating a correlation between wages and average zonal commuting times. Under this hypothesis, there should also be no systematic correlation between the size of the workforce in the zone and the wage paid in the zone, since the wage is based on strategic firm-level decisions. In the model used in this paper, the size of the employment center (combined with the transportation system) generates average commuting times, which in turn lead to wages paid at the center. Finally, this hypothesis relies on continuous disequilibrium. Since the worker is being compensated for commuting distance only and not for his "ability premium", he does not receive the marginal revenue product of his labor, and the firm enjoys a rent. In order for the firm to maintain such a strategy, it must be continually searching for new workers.

These observations suggest three means of testing this hypothesis:

1) Observe whether the relative industry concentrations of the work zones might explain wage variation. If firms in an industry tend to employ similar wage strategies, and the industry is concentrated in certain regions of the city, this would induce a spurious correlation of wages with travel times.
2) Examine the relationship between work zone employment levels and average commuting times.
3) Determine whether workers in zones with higher wages also have higher turnover.

Unfortunately, the length of service in the present job for each individual is not available, making the third test impossible. The second test was already performed earlier: the results shown in Table 3.5 indicate a strong correlation between employment concentration and commuting times. To examine the first question, a measure of industry concentration was included directly in the wage regressions.[21] The coefficients on average travel times, shown in Table 3.7, are virtually unchanged from the results in Tables 3.2 and 3.6. Thus, industry concentration does not seem to explain the travel time/wage correlation. These two simple tests support a rejection of the hypothesis that the wage/travel time correlation is generated by firm-level wage strategies.

VII. Conclusion

As employment decentralizes and subcenters develop, there can be large variations in commuting time between subcenters and between subcenters and downtown work locations. This paper has attempted to test for the presence of an important equilibrium condition due to this variation, namely a positive correlation between wages and average commuting times across different work zones within metro areas. Wages are found to vary significantly (up to 15%) within metro areas, but decline most precipitously at the urban fringe, where wages can be as much as 25% lower than those in the central city. This variation is significantly related to travel times for workers in the various zones. The implied value of travel time is between 25 and 50% of the wage rate.

The next step in this research is to examine the dynamics of employment decentralization, by analyzing changes in wage differentials, commuting times, and employment levels between 1980 and 1990. This follows in **Chapter 4**. Of particular interest are the hypotheses that the wage gradient should flatten over time, as employment becomes more decentralized, and that employment growth should be greater in work zones with lower initial wages.

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[21]Concentration was measured as the percentage of POWPUMA employment in the industry relative to the percentage of total urban employment in the industry. For example, suppose the manufacturing share of total employment in a city is 20%. A POWPUMA with 40% of its workforce in manufacturing would have a concentration ratio of 2, while a POWPUMA with 10% in manufacturing would have a concentration ratio of .5. In the regressions, each individual worker was assigned the concentration of her industry in her work zone.

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Appendix 3A: PUMA Definitions

Boston

	PUMA	Largest Cities
1	1400	Lowell
2	1500	Chelmsford-Tewksbury-Dracut
3	1600	Lawrence-Haverhill
4	1700	Methuen-North Andover-Newburyport
5	1800	Salem-Beverly-Marblehead
6	1900	Peabody-Danvers-Gloucester
7	2000	Boston
8	2100	Revere-Everett-Chelsea
9	2200	Malden-Medford
10	2300	Cambridge-Somerville
11	2400	Waltham-Belmont-Lexington-Arlington
12	2500	Newton-Brookline
13	2600	Quincy-Milton
14	2700	Lynn-Saugus-Lynnfield
15	2800	Woburn-Melrose-Stoneham-Winchester
16	2900	Burlington-Reading-Wakefield
17	3000	Acton-Maynard-Concord
18	3100	Natick-Needham-Wellesley
19	3200	Framingham-Marlboro-Sudbury
20	3300	Milford-Franklin-Foxboro
21	3400	Dedham-Norwood-Westwood
22	3500	Braintree-Randolph-Stoughton
23	3600	Weymouth-Hingham-Hanover
24	3700	Brockton-Whitman

Detroit

1	2200	Lapeer Co.-Shiawassee Co.
2	3000	Monroe Co.
3	3100	Ann Arbor
4	3200	Washtenaw Co.(part)
5	3300	Detroit
6	3400	Wayne Co.(part)
7	3500	Livonia
8	3600	Westland-Garden City-Inkster
9	3700	Lincoln Park-Wyandotte-Allen Park
10	3800	Warren
11	3900	Macomb Co.(part)
12	4000	Sterling Heights
13	4100	Oakland Co.(part)
14	4200	Royal Oak-Madison Heights-Clawson
15	4300	Livingston Co.
16	4400	St. Clair Co.

Minneapolis-St. Paul

1	900	Chisago-Isanti-Wright-Benton-Sherburn Cos.
2	1100	Carver Co.-Scott Co.
3	1200	Coon Rapids-Fridley-Columbia Hts
4	1300	Anoka Co.(part)
5	1400	Washington Co.
6	1500	Minneapolis
7	1600	Bloomington-Richfield
8	1700	Plymouth-Minnetonka-Edina-Eden Prairie
9	1800	Brooklyn Park-Brooklyn Center-Champlin
10	1900	St. Louis Park-Crystal-New Hope
11	2000	Hennepin Co.(part)
12	2100	St. Paul
13	2200	Ramsey Co.(part)
14	2300	Burnsville-Eagan-Apple Valley
15	2400	Dakota Co.(part)

Cleveland-Akron-Lorain

1	400	Geauga Co.-Ashtabula Co.
2	800	Medina Co.
3	900	Portage Co.
4	3700	Lorain-Elyria
5	3800	Lorain Co.(part)
6	3900	Cleveland
7	4000	Lakewood-North Olmsted-Westlake
8	4100	Strongsville-Brook Park-Berea
9	4200	Parma-Parma Hts-Seven Hills
10	4300	Garfield Hts-Maple Hts-Solon
11	4400	Cleveland Hts-East Cleveland-Shaker Hts
12	4500	Euclid-South Euclid-Mayfield Hts
13	4600	Lake Co.
14	4700	Summit Co.(Akron)

Dallas-Fort Worth

1	1500	Ellis-Kaufman-Rockwall Cos.
2	1800	Johnson-Parker-Hood-Wise Cos.
3	1900	Fort Worth
4	2000	Arlington
5	2100	Tarrant Co.(part)
6	2200	Denton Co.
7	2300	Collin Co.(part)
8	2400	Plano
9	2500	Dallas
10	2600	Garland
11	2700	Irving
12	2800	Mesquite
13	2900	Dallas Co.(part)

Appendix 3B: Industries and Occupations

Private Sector

Occupations

1	Managers
2	Management Related
3	Engineers & Scientists
4	Doctors
5	Nurses & Therapists
6	Teachers
7	Social Scientists
8	Lawyers
9	Artists, etc.
10	Technicians
11	Sales Representatives
12	Sales Workers
13	Clerical
14	Secretaries & Receptionists
15	Other Service Workers
16	Mechanics & Repairers
17	Craftsmen
18	Precision Production
19	Operators
20	Fabricators
21	Transportation & Material Movers
22	Laborers

Industries

1 Construction
2 Manufacturing
3 Transportation, Communications, and Public Utilities
4 Wholesale
5 Retail
6 Finance, Insurance, and Real Estate
7 Business and Repair Services
8 Personal Services
9 Professional Services

<u>Government</u>

Industries

1 Postal Service
2 Other Transp, Comm, Pub Utilities
4 Health Services
5 Education
6 Executive, Legislative, & Public Finance
7 General Administration
8 Justice
9 N.E.C.

Occupations

1 Managers
2 Engineers & Scientists
3 Other Professionals
4 Elementary School Teachers
5 Secondary School Teachers
6 Technicians
7 Clerks
8 Secretaries & Receptionists
9 Protective Service Workers
10 Other Service Workers
11 Craftsmen and Laborers

Appendix 3C

Boston Metro Area Cities and Towns

1 ABINGTON
2 ACTON
3 AMESBURY
4 ANDOVER
5 ARLINGTON
6 ASHLAND
7 AVON
8 AYER
9 BEDFORD
10 BELLINGHAM
11 BELMONT
12 BERLIN
13 BEVERLY
14 BILLERICA
15 BLACKSTONE
16 BOLTON
17 BOSTON
18 BOXBOROUGH
19 BOXFORD
20 BRAINTREE
21 BRIDGEWATER
22 BROCKTON
23 BROOKLINE
24 BURLINGTON
25 CAMBRIDGE
26 CANTON
27 CARLISLE
28 CHELMSFORD
29 CHELSEA
30 CLINTON
31 COHASSET
32 CONCORD
33 DANVERS
34 DEDHAM
35 DOVER
36 DRACUT
37 DUNSTABLE
38 DUXBURY
39 EAST BRIDGEWATER
40 EASTON
41 ESSEX
42 EVERETT
43 FOXBOROUGH
44 FRAMINGHAM
45 FRANKLIN
46 GEORGETOWN
47 GLOUCESTER
48 GROTON
49 GROVELAND
50 HALIFAX
51 HAMILTON
52 HANOVER
53 HANSON
54 HARVARD
55 HAVERHILL
56 HINGHAM
57 HOLBROOK
58 HOLLISTON
59 HOPEDALE
60 HOPKINTON
61 HUDSON
62 HULL
63 IPSWICH
64 KINGSTON
65 LANCASTER
66 LAWRENCE
67 LEXINGTON
68 LINCOLN
69 LITTLETON
70 LOWELL
71 LYNN
72 LYNNFIELD
73 MALDEN
74 MANCHESTER
75 MANSFIELD
76 MARBLEHEAD
77 MARLBOROUGH
78 MARSHFIELD
79 MAYNARD
80 MEDFIELD
81 MEDFORD
82 MEDWAY
83 MELROSE
84 MENDON
85 MERRIMAC
86 METHUEN
87 MIDDLETON
88 MILFORD
89 MILLIS
90 MILLVILLE
91 MILTON
92 NAHANT
93 NATICK
94 NEEDHAM
95 NEWBURY
96 NEWBURYPORT
97 NEWTON
98 NORFOLK
99 NORTH ANDOVER
100 NORTH READING
101 NORTHBOROUGH
102 NORTHBRIDGE
103 NORWELL
104 NORWOOD
105 PEABODY
106 PEMBROKE
107 PEPPERELL
108 PLAINVILLE
109 PLYMOUTH
110 QUINCY
111 RANDOLPH
112 RAYNHAM
113 READING
114 REVERE
115 ROCKLAND
116 ROCKPORT
117 ROWLEY
118 SALEM
119 SALISBURY
120 SAUGUS
121 SCITUATE
122 SHARON
123 SHERBORN
124 SHIRLEY
125 SOMERVILLE
126 SOUTHBOROUGH
127 STONEHAM
128 STOUGHTON
129 STOW
130 SUDBURY
131 SWAMPSCOTT
132 TEWKSBURY
133 TOPSFIELD
134 TYNGSBOROUGH
135 UPTON
136 UXBRIDGE
137 WAKEFIELD
138 WALPOLE
139 WALTHAM
140 WATERTOWN
141 WAYLAND
142 WELLESLEY
143 WENHAM
144 WEST BRIDGEWATER
145 WEST NEWBURY
146 WESTBOROUGH
147 WESTFORD
148 WESTON
149 WESTWOOD
150 WEYMOUTH
151 WHITMAN
152 WILMINGTON
153 WINCHESTER
154 WINTHROP
155 WOBURN
156 WRENTHAM

Appendix 3D: Full-Time Employment Levels by POWPUMA--1990

puma	Boston	Detroit	Minneap	Cleve	Dallas
1	29691	21194	32250	37693	30381
2	53832	25838	26947	24152	34457
3	31372	60997	44879	30495	224527
4	62197	56525	16977	40084	71843
5	33624	274431	28127	27791	129840
6	47495	241120	224095	259133	53366
7	362963	60173	83159	41926	26155
8	26448	32060	112800	37778	44967
9	24102	33125	23409	82244	543665
10	95853	84357	73179	60935	43278
11	88301	108704	22938	20835	83111
12	44377	40222	136707	58924	21691
13	34881	408335	84375	66683	195750
14	33556	44017	45317	163517	
15	36438	20725	35274		
16	59599	30945			
17	55935				
18	53189				
19	70333				
20	28061				
21	44991				
22	53675				
23	43276				
24	25539				
Total	1439728	1542768	990433	952190	1503031

Table 3.1a
Wage Premia for Each Work Zone
Full-Time, Private Sector Employees

powpuma	Boston	Detroit	Minneap	Cleve	Dallas
1	**-.073**	**-.247**	**-.176**	**-.151**	**-.168**
2	**-.040**	**-.080**	**-.053**	**-.148**	**-.271**
3	**-.149**	**-.070**	-.009	**-.124**	**-.080**
4	**-.057**	-.012	**-.089**	**-.061**	**-.094**
5	**-.130**		-.038	**-.087**	**-.079**
6	**-.119**	.007			**-.137**
7		-.014	.013	**-.034**	**-.089**
8	**-.101**	-.011	**.026**	**.031**	-.018
9	**-.084**	-.013	-.038	-.016	
10	**-.045**	**.023**	-.006	-.019	**-.073**
11	-.013	**-.060**	**-.063**	-.030	-.010
12	**-.060**	.001	-.015	.001	**-.079**
13	**-.080**	.010	**-.025**	**-.077**	**-.013**
14	**-.066**	**-.044**	**-.031**	**-.080**	
15	**-.045**	**-.153**	**-.070**		
16	**-.027**	**-.184**			
17	**-.028**				
18	**-.034**				
19	**-.029**				
20	**-.146**				
21	**-.060**				
22	**-.051**				
23	**-.114**				
24	**-.104**				
Adj-R2	.419	.475	.443	.463	.446
obs	53979	48783	27831	35461	56545

Values in **bold** are significantly different from zero at the 5% level

Table 3.1b
Coefficient Estimates of the Covariates

	Boston	Detroit	Minneap	Cleve	Dallas
age	**.1328**	**.1602**	**.2377**	**.1324**	**.1600**
age^2	**-.0030**	**-.0037**	**-.0065**	**-.0029**	**-.0039**
age^3	**3.1-5**	**4.0-5**	**8.2-5**	**3.0-5**	**4.4-5**
age^4	**-1.3-7**	**-1.8-7**	**-4.1-7**	**-1.4-7**	**-2.1-7**
hsch	**.1119**	**.0912**	**.0887**	**.0984**	**.1244**
postsec	**.1599**	**.1766**	**.1279**	**.1733**	**.1995**
assoc	**.2139**	**.2183**	**.1520**	**.2181**	**.2397**
bach	**.3034**	**.3504**	**.2769**	**.3747**	**.4094**
mast	**.4285**	**.4639**	**.3915**	**.4891**	**.5054**
prof	**.3827**	**.4759**	**.3078**	**.4360**	**.5859**
doct	**.4708**	**.5777**	**.4608**	**.5559**	**.5777**
female	**-.0847**	**-.1375**	**-.0801**	**-.1340**	**-.1108**
married	**.1944**	**.2074**	**.2166**	**.2220**	**.1685**
marr*fem	**-.2052**	**-.2214**	**-.2355**	**-.2451**	**-.1579**
black	**-.0921**	**-.0503**	**-.1258**	**-.0405**	**-.1247**
asian	**-.1139**	**-.0378**	**-.0595**	**-.0676**	**-.0422**
hisp	**-.0600**	.0124	-.0111	**.0547**	-.0172
military	**-.0294**	**-.0108**	**-.0185**	**-.0177**	**-.0120**
english2	**.0627**	.0412	.0010	.0712	**.0862**
english3	**.1302**	**.1040**	.0614	**.0765**	**.1521**
english4	**.1660**	**.1320**	**.1104**	**.1175**	**.2260**
dis1	**-.1144**	**-.1017**	**-.1495**	**-.0954**	**-.1572**
dis2	-.0822	.0207	-.0984	-.0324	-.0816
dis3	-.0238	-.0064	-.0001	-.0359	-.0089

Values in **bold** are significantly different from zero at the 5%

Table 3.1b, cont'd

ind2	**-.0513**	**.1112**	.0219	**.0535**	**.0966**
ind3	-.0166	**.0730**	**.0599**	**.0933**	**.1423**
ind4	**-.0636**	-.0099	**-.0439**	-.0201	**.0500**
ind5	**-.2088**	**-.2064**	**-.1908**	**-.2072**	**-.0971**
ind6	**-.0592**	**-.0473**	-.0299	**-.0351**	.0226
ind7	**-.1101**	**-.1002**	**-.1443**	**-.1165**	-.0214
ind8	**-.2622**	**-.2682**	**-.2334**	**-.2055**	**-.1435**
ind9	**-.1576**	**-.0991**	**-.1407**	**-.0854**	**-.0923**
occ1	**.3524**	**.2887**	**.3541**	**.3254**	**.4073**
occ2	**.2527**	**.2335**	**.2137**	**.2284**	**.3109**
occ3	**.3333**	**.2907**	**.3514**	**.3037**	**.4239**
occ4	**.4282**	**.3880**	**.7262**	**.4308**	**.4687**
occ5	**.4356**	**.4049**	**.4369**	**.4970**	**.5020**
occ6	-.0151	**.1323**	**.1132**	**.0862**	**.1514**
occ7	.0199	**-.0958**	-.0570	**-.1372**	**.0741**
occ8	**.5347**	**.4930**	**.5640**	**.5373**	**.7612**
occ9	**.1620**	**.2130**	**.1841**	**.1409**	**.2030**
occ10	**.2211**	**.1847**	**.2479**	**.2322**	**.3134**
occ11	**.2583**	**.1846**	**.2326**	**.2237**	**.3032**
occ12	**.0394**	.0318	.0292	.0359	**.0770**
occ13	**.0594**	**.0544**	**.0563**	**.0681**	**.1387**
occ14	**.0728**	**.0544**	.0516	**.0687**	**.1610**
occ15	**-.0551**	**-.1150**	**-.0592**	**-.1044**	**-.0294**
occ16	**.1637**	**.1848**	**.1937**	**.1912**	**.2[illegible]67**
occ17	**.1772**	**.2128**	**.2005**	**.2109**	**.2076**
occ18	**.0972**	**.1345**	**.1044**	**.0885**	**.1734**
occ19	.0081	.0310	.0405	**.0471**	**.0469**
occ20	.0183	**.1214**	-.0065	**.1029**	**.0888**
occ21	.0101	.0262	.0080	**.0565**	.0210
constant	.1269	**-.4358**	**-1.1068**	-.1041	**-.6504**

Values in **bold** are significantly different from zero at the 5% level

Table 3.1c
Average Commuting Times for Workers in Each Zone

powpuma	Boston	Detroit	Minneap	Cleve	Dallas
1	22.8	16.1	15.0	17.6	16.7
2	25.3	16.7	17.8	18.1	16.6
3	19.3	21.2	22.4	18.1	23.7
4	22.8	21.2	19.9	17.8	21.1
5	18.4	28.1	18.0	18.6	22.4
6	20.4	23.8	25.6	27.6	19.5
7	34.3	23.1	22.8	19.2	20.4
8	22.7	20.5	24.1	20.5	22.2
9	21.9	21.0	21.5	23.2	28.2
10	29.1	25.7	23.4	23.7	21.9
11	27.6	22.2	19.9	21.8	27.0
12	26.3	25.4	22.9	22.6	20.8
13	25.6	25.3	21.0	19.7	25.1
14	21.1	23.6	20.7	19.3	
15	24.1	20.1	17.8		
16	27.2	17.1			
17	28.6				
18	27.1				
19	25.6				
20	20.7				
21	24.4				
22	25.0				
23	20.6				
24	19.4				
Mean	26.9	24.2	22.5	22.3	24.8
Std. Dev	5.0	2.9	2.8	3.8	3.4

Table 3.1d
Boston Metropolitan Area Sample
Summary Statistics

	Mean Earnings	Earnings Residuals	Mean Commuting Times
Mean	28238	.0572	25.7
Std. Dev.	4509	.0844	5.0
Max	41051	.3571	32.3
Min	17380	-.1761	16.3
R-bar^2	-----	.62	----

Table 3.2
Travel Time Coefficients
Public and Private Sectors

Private Sector

	Boston	Detroit	Minneap	Cleve	Dallas
	.0079 (.0005)	.0126 (.0009)	.0120 (.0012)	.0106 (.0008)	.0164 (.0007)
Adj-R^2	.418	.473	.442	.461	.445
obs	53979	48783	27831	35461	56545

Public Sector

	Boston	Detroit	Minneap	Cleve	Dallas
Federal	.0010 (.0015)	.0096 (.0043)	-.0018 (.0065)	.0047 (.0038)	.0020 (.0032)
State	.0072 (.0022)	.0096 (.0054)	-.0006 (.0077)	.0147 (.0051)	.0089 (.0042)
Local	.0117 (.0020)	.0106 (.0047)	.0141 (.0072)	.0116 (.0042)	.0163 (.0037)
Adj-R^2	.345	.419	.392	.404	.389
obs	9751	7210	4388	5469	8622

Standard errors in parentheses

Table 3.2a
Separate Regressions for Men and Women

	Boston		Detroit		Minneapolis	
	(1)	(2)	(1)	(2)	(1)	(2)
Males	.0060 (.0007)	.0072 (.0007)	.0089 (.0012)	.0107 (.0013)	.0066 (.0017)	.0090 (.0020)
Females	.0095 (.0006)	.0078 (.0005)	.0150 (.0012)	.0121 (.0011)	.0178 (.0016)	.0134 (.0012)

	Cleveland		Dallas	
	(1)	(2)	(1)	(2)
Males	.0065 (.0010)	.0082 (.0012)	.0106 (.0010)	.0137 (.0013)
Females	.0153 (.0011)	.0125 (.0009)	.0229 (.0010)	.0180 (.0008)

Heteroscedasticity-robust Standard Errors in parentheses

Column (1) uses the average commuting time of all workers in the same POWPUMA
Column (2) uses the average commuting time of workers in the same POWPUMA and Gender

Table 3.2b
Separate Regressions for Black and White Workers

	Detroit	Cleveland	Dallas
Whites	.0117 (.0007)	.0111 (.0008)	.0167 (.0008)
Blacks(1)	-.0064 (.0029)	.0014 (.0027)	.0017 (.0023)
Blacks(2)	.0003 (.0028)	.0066 (.0028)	.0039 (.0024)

Blacks(1) uses average travel time of all workers in the puma
Blacks(2) uses average travel time of black workers in the puma

Table 3.2c
Travel Time Coefficients
75th and 90th Percentiles

	Boston	Detroit	Minneap	Cleve	Dallas
75th Pctile	.0058 (.0003)	.0100 (.0008)	.0138 (.0013)	.0084 (.0038)	.0148 (.0007)
90th Pctile	.0045 (.0003)	.0119 (.0008)	.0083 (.0008)	.0060 (.0005)	.0143 (.0009)

Table 3.2d
Boston Metropolitan Area

Dep Variable: Mean Earnings

Indep Variables	(1)	(2)
Mean Commuting Time	.0384 (.0031)	.0183 (.0034)
Industry-Predicted Earnings	----	1.61 (.23)
Occupation-Predicted Earnings	----	1.35 (.29)
$rbar^2$ obs	.50 156	.68 156

Standard errors in parentheses

Table 3.3a
Travel Time Coefficients by Occupation*

	Boston	Detroit	Minneap	Cleve	Dallas
Managers	.0098 (.0011)	.0164 (.0024)	.0160 (.0036)	.0146 (.0020)	.0228 (.0021)
Professionals	.0069 (.0011)	.0125 (.0026)	.0215 (.0035)	.0053 (.0022)	.0170 (.0020)
Technicians	.0014 (.0017)	.0156 (.0055)	-.0070 (.0053)	.0092 (.0031)	.0086 (.0031)
Sales	.0114 (.0015)	.0165 (.0029)	.0156 (.0037)	.0180 (.0027)	.0217 (.0022)
Admin Support	.0091 (.0009)	.0179 (.0017)	.0127 (.0022)	.0171 (.0015)	.0213 (.0015)
Service	.0088 (.0015)	.0077 (.0028)	.0073 (.0039)	.0121 (.0030)	.0176 (.0024)
PPCR	.0071 (.0013)	.0075 (.0020)	.0109 (.0028)	.0098 (.0019)	.0107 (.0021)
OFL	.0068 (.0015)	.0078 (.0019)	.0090 (.0027)	.0009 (.0017)	.0060 (.0018)

Standard Errors in Parentheses
*Using Average Travel Time of All Workers in the POWPUMA

PPCR=Precision Production, Craft, and Repair
OFL=Operators, Fabricators, and Laborers

Table 3.3b
Travel Time Coefficients by Occupation*

	Boston	Detroit	Minneap	Cleve	Dallas
Managers	.0085 (.0010)	.0091 (.0016)	.0130 (.0031)	.0114 (.0016)	.0185 (.0018)
Professionals	.0087 (.0013)	.0145 (.0021)	.0206 (.0038)	.0051 (.0023)	.0163 (.0020)
Technicians	.0031 (.0017)	.0140 (.0051)	-.0040 (.0051)	.0092 (.0030)	.0061 (.0024)
Sales	.0111 (.0015)	.0134 (.0024)	.0142 (.0032)	.0146 (.0024)	.0212 (.0021)
Admin Support	.0077 (.0008)	.0128 (.0013)	.0087 (.0016)	.0125 (.0011)	.0153 (.0010)
Service	.0111 (.0018)	.0041 (.0032)	.0074 (.0045)	.0144 (.0034)	.0192 (.0027)
PPCR	.0073 (.0014)	.0076 (.0021)	.0092 (.0024)	.0126 (.0023)	.0131 (.0026)
OFL	.0072 (.0016)	.0066 (.0020)	.0080 (.0025)	.0040 (.0026)	.0091 (.0024)

Standard Errors in Parentheses
*Using Average Travel Time for Workers in the same POWPUMA and Occupation

Table 3.4a
Travel Time Coefficients
1980

Private

	Boston	Detroit	Minneap	Cleve	Dallas
	.0073 (.0007)	.0102 (.0010)	.0100 (.0016)	.0071 (.0009)	.0150 (.0012)
Adj-R2 obs	.374 21294	.392 26498	.383 14232	.378 17502	.353 20102

Government

Federal	.0042 (.0024)	.0001 (.0050)	.0009 (.0082)	-.0037 (.0044)	.0097 (.0058)
State	.0090 (.0033)	.0110 (.0061)	.0165 (.0101)	.0050 (.0066)	.0044 (.0082)
Local	.0095 (.0029)	.0149 (.0053)	.0151 (.0091)	.0105 (.0049)	.0148 (.0065)
Adj-R2 obs	.314 4983	.363 5091	.375 2790	.344 3074	.344 3324

Table 3.4b
Travel Time Coefficients by Occupation
1980

	Boston	Detroit	Minneap	Cleve	Dallas
Managers	.0088 (.0018)	.0144 (.0027)	.0139 (.0041)	.0130 (.0026)	.0136 (.0032)
Professionals	.0113 (.0019)	.0125 (.0032)	.0032 (.0056)	.0094 (.0028)	.0157 (.0044)
Technicians	.0042 (.0035)	.0091 (.0050)	-.0073 (.0075)	.0067 (.0053)	.0229 (.0054)
Sales	.0044 (.0025)	.0043 (.0034)	.0265 (.0066)	.0100 (.0043)	.0188 (.0038)
Admin Support	.0129 (.0013)	.0134 (.0019)	.0103 (.0030)	.0085 (.0017)	.0156 (.0023)
Service	.044 (.005)	.0123 (.0036)	.0040 (.0061)	.0130 (.0036)	.0169 (.0047)
PPCR	.0062 (.0019)	.0081 (.0020)	.0082 (.0043)	.0057 (.0020)	.0125 (.0028)
OFL	.0017 (.0019)	.0083 (.0023)	.0086 (.0038)	.0017 (.0020)	.0132 (.0029)

Standard errors in parentheses
Using the average travel time of all workers in the POWPUMA

Table 3.4c
Boston Metropolitan Area
1980

Dep Variable: Mean Earnings

Indep Variables	(1)	(2)
Mean Commuting Time	.0345 (.0033)	.0297 (.0033)
Industry-Predicted Earnings	----	1.28 (.18)
Occupation-Predicted Earnings	----	-.023 (.29)
rbar^2 obs	.42 156	.55 156

Standard errors in parentheses

Table 3.5
PUMA Employment and Commuting Times

Dep Var: Mean Commuting Times

Indep Var	Boston	Detroit	Minneap	Cleve	Dallas	Boston-156
emp($x10^4$)	.399	.186	.368	.292	.172	.295
	(.084)	(.064)	(.095)	(.095)	(.051)	(.065)
r^2	.51	.37	.52	.44	.51	.12
log(emp)	5.36	2.74	2.76	2.54	2.79	1.59
	(.79)	(.66)	(.71)	(.91)	(.69)	(.197)
r^2	.65	.52	.51	.39	.59	.30
import ratio	9.86	5.10	5.20	5.88	7.27	4.95
	(1.35)	(2.18)	(1.15)	(1.23)	(1.44)	(.44)
r^2	.71	.28	.61	.66	.70	.45
log(imp rat)	9.90	5.33	4.36	5.37	6.71	4.76
	(1.52)	(2.09)	(1.09)	(1.48)	(1.22)	(.41)
r^2	.66	.32	.55	.52	.73	.46

Standard errors in parentheses

Table 3.6a
Travel Time Coefficients with Residence Zone-Specific Effects

Private Sector

	Boston	Detroit	Minneap	Cleve	Dallas
	.0101 (.0005)	.0112 (.0011)	.0138 (.0013)	.0129 (.0009)	.0162 (.0009)
Adj-R^2	.424	.480	.450	.466	.450

Public Sector

	Boston	Detroit	Minneap	Cleve	Dallas
Federal	.0035 (.0016)	.0095 (.0045)	.0040 (.0067)	.0054 (.0040)	.0033 (.0035)
State	.0094 (.0021)	.0036 (.0054)	.0033 (.0078)	.0142 (.0051)	.0082 (.0043)
Local	.0148 (.0020)	.0097 (.0047)	.0184 (.0072)	.0128 (.0042)	.0175 (.0038)
Adj-R^2	.353	.424	.399	.410	.395

Table 3.6b
Travel Time Coefficients by Occupation
Residence Zone-Specific Effects

	Boston		Detroit		Minneapolis	
	(1)	(2)	(1)	(2)	(1)	(2)
Managers	.0100	.0091	.0124	.0078	.0136	.0127
	(.0012)	(.0010)	(.0028)	(.0018)	(.0038)	(.0032)
Profess	.0086	.0097	.0092	.0138	.0213	.0206
	(.0012)	(.0014)	(.0029)	(.0024)	(.0038)	(.0041)
Technical	.0050	.0062	.0143	.0135	-.0031	-.0018
	(.0020)	(.0019)	(.0077)	(.0072)	(.0058)	(.0056)
Sales	.0130	.0132	.0098	.0079	.0136	.0128
	(.0017)	(.0016)	(.0038)	(.0030)	(.0043)	(.0037)
Admin Support	.0122	.0104	.0167	.0110	.0151	.0104
	(.0010)	(.0009)	(.0022)	(.0016)	(.0026)	(.0013)
Service	.0120	.0146	.0055	.0014	.0074	.0076
	(.0020)	(.0025)	(.0037)	(.0039)	(.0054)	(.0054)
PPCR	.0086	.0092	.0081	.0060	.0141	.0117
	(.0014)	(.0016)	(.0023)	(.0025)	(.0031)	(.0026)
OFL	.0105	.0115	.0089	.0074	.0144	.0114
	(.0018)	(.0020)	(.0023)	(.0024)	(.0029)	(.0027)

Standard Errors in Parentheses

Column (1) uses Average Travel Times of all workers in the same POWPUMA
Column (2) uses Average Travel Times of workers in the same POWPUMA and Occupation

Table 3.6b, Continued

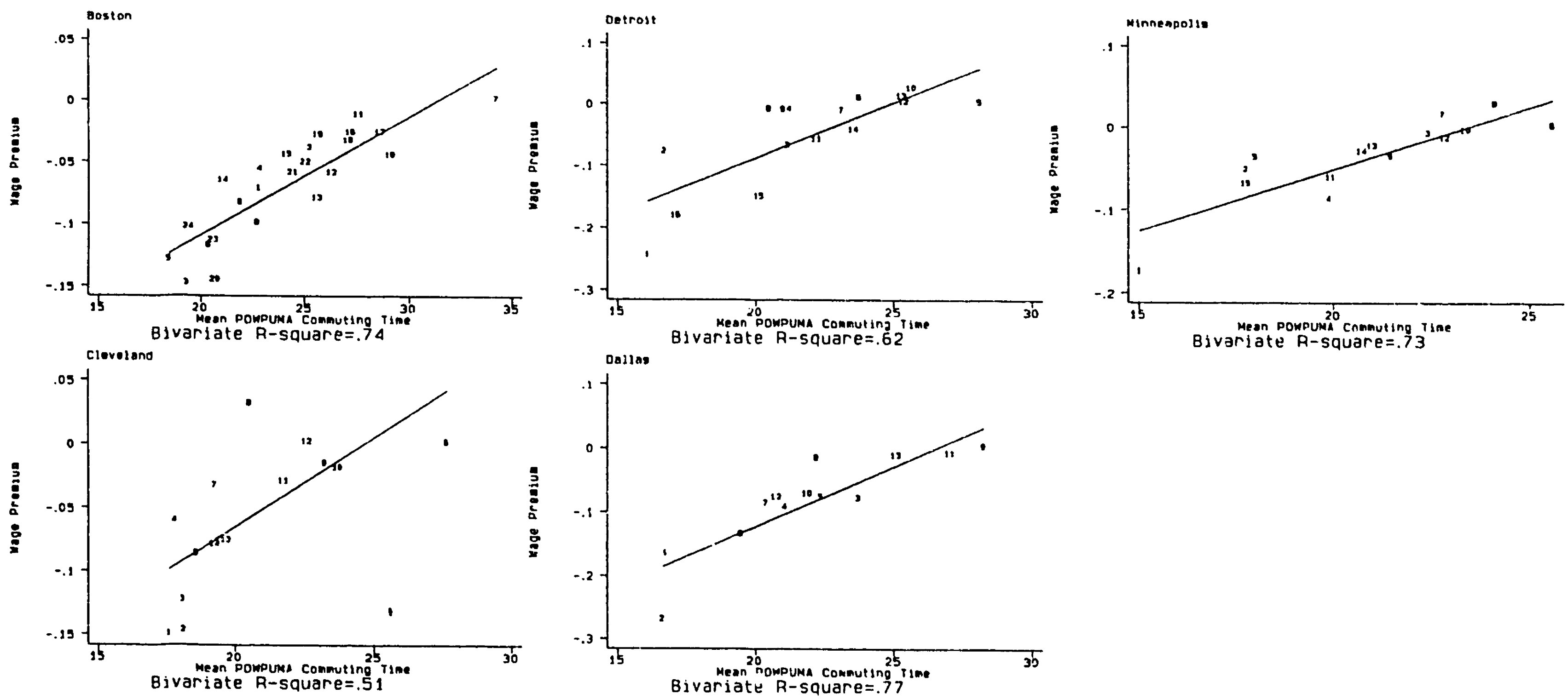
	Cleveland		Dallas	
	(1)	(2)	(1)	(2)
Managers	.0180 (.0023)	.0137 (.0018)	.0205 (.0022)	.0170 (.0019)
Professionals	.0071 (.0027)	.0065 (.0027)	.0167 (.0022)	.0159 (.0022)
Technicians	.0081 (.0035)	.0073 (.0036)	.0089 (.0036)	.0065 (.0027)
Sales	.0191 (.0032)	.0151 (.0029)	.0180 (.0025)	.0182 (.0024)
Admin Support	.0194 (.0019)	.0134 (.0014)	.0201 (.0018)	.0143 (.0013)
Service	.0139 (.0041)	.0191 (.0049)	.0186 (.0035)	.0183 (.0038)
PPCR	.0100 (.0023)	.0129 (.0028)	.0125 (.0026)	.0151 (.0034)
OFL	.0042 (.0022)	.0133 (.0033)	.0080 (.0023)	.0114 (.0030)

Table 3.7
Travel Time Coefficients
Industry Concentration Ratios Included

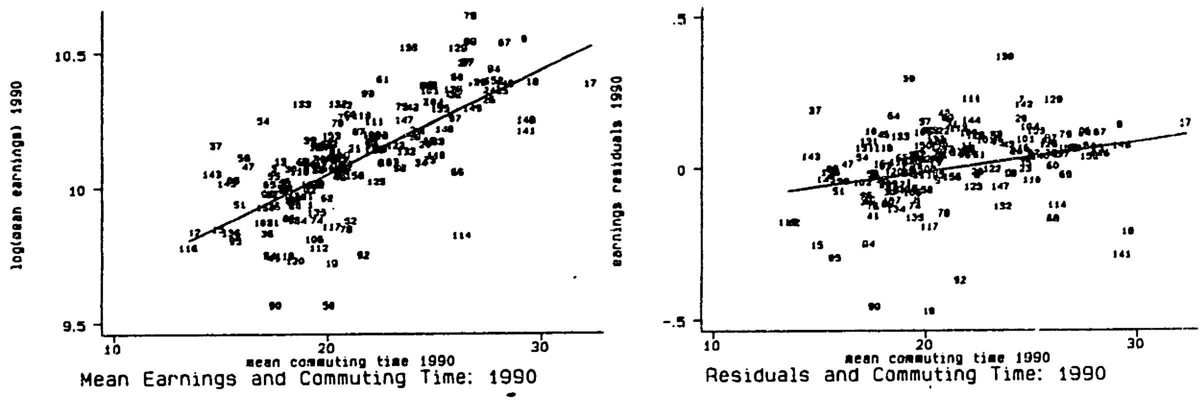
	Boston	Detroit	Minneap	Cleve	Dallas
(1)	.0079 (.0004)	.0133 (.0008)	.0123 (.0011)	.0106 (.0007)	.0177 (.0007)
(2)	.0100 (.0005)	.0117 (.0010)	.0142 (.0012)	.0132 (.0009)	.0177 (.0008)

Standard errors in parentheses

Specification (2) includes residential PUMA dummies



Wage Premia and Travel Time
Figure 3.1



Earnings and Travel Time--Boston

Figure 3.2

Chapter 4

Intraurban Wage, Employment, and Commuting Time Dynamics

I. Introduction

In **Chapter 3**, the variation of wage premia within metropolitan areas was documented, along with the link between this wage variation and variation in average commuting times across different intrauraban employment zones. The existence of such wage differentials provides a significant incentive for cost-minimizing firms to decrease their wage bill by moving away from existing employment concentrations and toward the residential locations of their employees. Thus, there is a strong centrifugal force at the margin, counteracting the centripetal forces of agglomeration and/or export node access. In a stable equilibrium, these forces must equally balance each other. Over time, however, technological change may weaken these agglomerative forces, be it through improvements in telecommunications (decreasing the need for face- to-face contact), manufacturing processes (requiring more land and fewer nearby suppliers), or the sectoral composition of the economy (toward industries with decreased scale economies). As these forces weaken over time, urban employment will become increasingly decentralized, as firms find it more profitable to produce in less centralized locations.

This paper extends the static analysis of the previous chapter to a dynamic context. By examining changes in wages, employment levels, and commuting times in the 5 cities used in the earlier analysis, we hope to gain insight into the evolution of metropolitan spatial structure over time. The first question to be addressed is one of structural adjustment: does employment grow faster in zones which have lower initial wage levels? Secondly, does employment become less concentrated over time? Finally, does this result in the convergence of wages, commuting times, and employment levels across the metropolitan area?

II. Previous Literature

The urban economics literature is relatively devoid of dynamic models of urban employment growth. One of the first papers to attempt to specifically model intraurban employment location dynamically was Helsley and Sullivan (1991). Their model solves the planner's problem of allocating workers to different employment sites, subject to the prior installation of public capital, production technologies, and transportation costs. They show how subcenter formation results from a tradeoff between scale economies in production and diseconomies in transportation. Urban development initially occurs only in the central employment zone, followed by periods of exclusive subcenter development and ending with simultaneously growing centers. Their planner, however, is myopic, and does not exercise foresight in the allocation of employment to the two centers. Their model also does not account for economic agents (especially households and firms) participating in urban land and labor markets. Thus, there are no specific results on the resulting pattern of rents and wages.

Di Xu (1995) examined the dynamic formation of suburban office centers. In her model, external scale economies arise from information exchange among firms, resulting in tight, interactive employment clusters. Subcenter forms when the central business district reaches a critical size, beyond which wage and office rent costs exceed the external benefits of clustering. The subcenter will form at the edge of the metropolitan area, as the atomistic firms go there to take advantage of the minimal rents and wages which prevail there.

A related strand of literature, coming from the regional economics field, models wage and employment growth across regions within the economy. They typically show how the migration of workers acts as an arbitrage tool to force the convergence of wages, resulting in variations in regional population and employment growth. Topel (1986) looked at the determinants of local wage levels in a dynamic setting. He showed that short-term shocks to regional labor demand positively affect wages (due to the costs of migration), while anticipated changes in labor demand have a smaller effect, due to increased migration in expectation of increased demand. He also showed that the wages of immobile workers are most sensitive to local demand shocks.

Farber and Newman (1989) sought to disentangle the structural variation in wages across regions (due to differences in the demographic composition of labor markets) from the compensating variation (due to differences in pecuniary and nonpecuniary costs). Their structural equality tests found that the prices of human capital characteristics do not generally vary across regions of the economy. This supports an empirical approach which controls for such human capital attributes in accounting for regional wage variation.

Treyz, et. al. (1993) estimated a dynamic model of regional migration. They showed that population movement is responsive to interregional differentials in employment opportunities and wages. Zandi and Basel (1994) estimated a cross-sectional model of state- level employment growth differentials, based on the initial industry mix, business costs (labor, energy, taxes), and other region-specific factors. They found employment growth to be highly responsive to relative costs, particularly labor costs, over the period studied (1984-93). These studies of regional employment dynamics find that labor costs are an important factor in determining interregional variation in growth rates. The mobility of production factors through migration (labor) and firm relocation (capital) ensures a decrease over time in the spatial variation of input prices. The purpose of this research is to determine whether such an equilibrating mechanism appears to function at the intraurban level as well.

III. Analytical Approach

The empirical issues to be addressed in this paper involve extending the static model of Chapter 3 to a dynamic framework. The equilibrium analysis of that chapter showed that wage differentials exist within cities which capitalize commuting time differentials between zones. As technological factors change which reduce efficiencies associated with the centralization of employment, firms will tend to spread out and suburbanize, leading to the dispersal of urban employment. If firms are decentralizing in order to reduce their labor costs, then employment should increase most significantly in those zones which have the lowest relative wages. Over time, this decentralization should also result in decreasing wage differentials and commuting time differentials across employment centers.

The first empirical question to be answered, then, involves employment decentralization itself: do we observe diminishing concentration of employment within urban areas over time? In earlier chapters the terms *employment decentralization* and *employment suburbanization* were essentially used synonymously, as simply to avoid prosaic monotony. At a more refined semantic level, however, the two terms can have slightly different meanings. *Employment suburbanization* refers to the movement of employment locations from their historical concentrations in primary, central cities out into the historically residential areas surrounding the urban core. The occurrence of this process during the 1980's in large American metropolitan areas was documented in Chapter 1. *Employment decentralization*, however, refers to the declining spatial concentration of workplaces in general, regardless of the actual location of such concentrations relative to the center of the metropolitan area. This paper will focus on this latter, more general question, by looking at a) the convergence of employment levels across intraurban zones, and b) changes in measures of employment concentration.

A natural measure of such concentration is the Herfindahl index, generally used to characterize the firm or plant-level concentration of an industry, and computed as the sum of the squared shares of total industry output produced by each firm. The geographic analog would be the sum of the squared shares of total metropolitan employment located in each employment zone. A metropolitan area with more of its employment concentrated into larger employment regions would thus have a higher "Employment Herfindahl". Such a measure obviously depends highly on just how disaggregated the intraburban regions are, making cross-sectional comparisons impossible. However, by comparing index values for the same metro area and identical subregions, the dispersion of employment through the metropolitan area can be measured.

This geographically-based Herfindahl index can also be modified to measure the extent to which employment concentration within the metropolitan area differs from residential concentration.[1] Such an index could be calculated as the sum of the squared deviations between the employment share and the residential share of each subregion, normalized by the residential Herfindahl. Ellison and Glejser (1994) use such an index to measure industrial concentration, where a region's share of the output of a particular industry is normalized by the population of that region .[2] By comparing values of this modified Herfindahl, we can measure whether employment is becoming less decentralized relative to the residential distribution of the workforce.

The second issue is a straightforward question of structural adjustment: does employment decentralization occur in a manner consistent with the hypothesis that decentralizing firms will move into employment zones with lower wage levels? This question will be addressed via a simple regression analysis of employment growth on initial wage levels.

The third question involves the dynamic relationship of employment levels, wages, and commuting times within metropolitan areas. In **Chapter 3**, the static relationship between these variables equations in *(3.1)* and *(3.2)* was estimated, and it was demonstrated that employment concentration is positively correlated. The question then becomes, do these relationships hold

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[1]This "residential concentration' could be due to either 1) greater densities in certain regions or 2) larger geographic boundaries around certain regions. Thus, a modified measure would, to a certain extent, account for boundary arbitrariness.

[2]2Ellison and Glejser refer to this normalized measure as the "raw geographic concentration of the industry".

in first differences: does relative employment growth cause commuting times to increase, thereby increasing relative wage levels? Thus, the dynamic equivalents of *(3.1)* and *(3.2)* are

$\Delta C_i = G_1\ (\Delta Ei)\ ,\ G_1'>0$ (4.1) $\Delta(W_i - W_0) = G_2\ (\Delta Ci)\ ,\ G_2'>0$

(4.2)

If commuting times and wages adjust instantaneously, then the equilibrium relationships of *(3.1)* and *(3.2)* will hold at every point in time, and the dynamic coefficients in *(4.1)* and *(4.2)* will be equivalent to their static counterparts. These equations of first differences can therefore be estimated, and the results compared to their static counterparts. The difficulty arises, however, in the dynamic counterpart of equation *(3.3)*:

$$\Delta Ei = G_3(\Delta Wi)\ ,\ G_3'<0 \qquad (4.3)$$

In **Chapter 3**, the claim was made that the process inducing negative correlation between employment levels and wages would not attain an equlibrium as rapidly as the first two would; thus, employment levels were taken to be exogenous. In a dynamic model, however, this would clearly not be the case: over time, there should be feedback from wage growth into employment growth, thereby dampening the dynamic relationships in *(4.1)* and *(4.2)*. In the absence of instruments, the resulting feedback loop makes estimation of the dynamic structural coefficients in each linkage stage impossible. Nevertheless, reduced forms of the linkage relationships can be estimated, and the implications of the results discussed.

Finally, however, the dynamic behavior of wages and commuting times can be addressed, despite the lack of structural coefficient estimates. Specifically, do technological shocks to the production processes of urban firms, which decrease agglomeration economies, cause the metropolitan area to move toward a more even spatial distribution of relative wages and average commuting times? Stated simply, do we observe convergence in these economic variables? As with employment convergence, this can be tested through the regression of changes on levels.

IV. Data

This chapter uses both household-level and place-level data to examine the dynamic issues at hand. These two sources are briefly described below.

A. Micro-Level Data

As this chapter extends the static analysis of **Chapter 3** to a differences/growth framework, it is desirable to use the same cities and data set used in that chapter.[3] This requires the ability to match the employment regions in each metropolitan area between the two census years. Unfortunately, the criteria for and the geographic definitions of the PUMAs[4] changed between the two editions of the PUMS, making an exact matching impossible. To work around this, the PUMAs and COGs of each year's PUMS were aggregated into *Conformable Employment Zones* (CEZ's) for each city, resulting in a slight loss of geographic detail. This was done for Detroit, Minneapolis, Cleveland, and Dallas. Unfortunately, the extent of the discrepancies between the two years made it impossible to match employment regions from the PUMS for Boston. The same wage equations used in Chapter 3 were then estimated using CEZ's in place of PUMAs/COGs, and the associated wage premia calculated. Employment totals and average commuting times were also tabulated.[5] A description of the CEZ's appears in Appendix 4A.

B. City and Town-Level Data

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[3]This was a leading factor in the selection of these particular cities.

[4]Referred to as County Groups (COGs) in the 1980 PUMS.

[5]The 1990 PUMS includes inverse probablity weights for each individual in the sample, while the 1980 PUMS does not. Employment levels and commuting times for 1990 were calculated using these weights.

For the Boston metropolitan area, the 156-city data set referred to in **Chapter 3** was used. 1990 data on employment and commuting times were drawn from the *1990 Census Transportation Planning Package*. Data for 1980 were obtained from the Central Transportation Planning Staff in Boston, based on the *1980 Urban Transportation Planning Package*, which was provided to metropolitan planning organizations by the Census Bureau. Earnings and employment data for the years 1970-75-80-85-90 were obtained from the Massachusetts Division of Employment and Training through the CTPS. The data set covers all of the municipalities included in the Boston metro area's 23 COGs for 1980 and 25 POWPUMAs for 1990.[6] A list of the 156 cities and towns is found in Appendix 3C.

V. Results

The analytical results fall into three primary categories: decentralization, structural adjustment, and convergence. In the Four-City PUMS-based sample, the limited number (7-16) of CEZ's in each city makes the precise estimation of the dynamic coefficients hazardous at best. The large number of data points in the CTPPbased Boston sample, meanwhile, provides a much better fit, under the caveat of a more poorly measured wage variable. In both cases, however, the associated graphs and slope coefficients can be instructive in assessing the existence and sign of the expected changes in wages, commuting time, and employment. Graphs of the bivariate data plots appear as Figures 4.1-4.8 (*a* and *b*), while the associated slope coefficients, standard errors, and adjusted-R^2's appear in Tables 4.2a and 4.2b.

A. Decentralization

1) Employment convergence. Employment convergence is measured by regressing employment growth on log(1980 employment levels). If convergence is occurring, zones with lower initial employment levels should exhibit more rapid growth. Graphs of these values for

[6] There were no boundary changes for minor civil divisions during this time period.

the Four-city sample and for Boston are shown in Figures 4.la and 4.lb. The results imply that convergence does appear to be occurring in each city, as smaller employment centers experienced more rapid employment growth. The primary source of the negative slopes in each of the PUMS cities, however, is the relatively low growth rates of center city employment. This measure also suffers from the same geographic arbitrariness discussed in **Chapter 3**. In order to form the CEZ's, several PUMAS and COGs had to be aggregated. This creates a problem in large suburban counties, which had large employment bases initially, yet still experienced rapid growth. Thus, some of these counties (Oakland Co., MI, Hennepin Co.,MN (minus Minneapolis), and Cuyahoga Co., OH (minus Cleveland)) appear as outliers in three of the cities. Both of these results (given the limited disaggregation available in the data) imply that suburbanization, rather than pure decentralization, was the primary process at work in the 1980's. In Boston, the greater level of disaggregation allows for a clearer picture of decentralization. Here the convergence result appears to more noticeably reflect decentralization in each of the two employment series, as the overall trend is clearly negative, with the central city (*zone 17* on the graph) actually pulling the regression line upwards. The arbitrary geography issue is also lessened with greater disaggregation, as the cities and towns of the region more closely resemble each other in geographic size. To partially overcome the geography problem, we can compare employment growth with the initial import ratios for each zone, shown in Figures 4.2a and 4.2b. Here the results are more consistent with widespread decentralization, as each city shows a strong negative correlation between initial employment concentration and growth. The greater employment concentration associated with higher import ratios does appear to be correlated with greatly diminished employment growth.

2) Concentration Measures. Tables 4.1a and 4.1b show the values of different measures of employment concentration for 1980 and 1990 in each of the four cities. These will be discussed in turn:

a) The first measure, central city employment share, declines for each metropolitan area, reflecting the overall suburbanization trend documented in **Chapter 1**.[7]

b) The next measure, the employment Herfindahl index, is given for the metropolitan area as a whole and also broken down into its urban/suburban components.[8] By this measure, employment concentration decreased overall in each city, due to the sharp declines in central city employment shares, which offset the increased employment concentration of suburban locations. This perceived concentration increase, however, may be due to the coarseness of the geographic specification, which aggregates much of the suburban growth together. Indeed, the more detailed Boston data show a slight decrease in suburban employment concentration during the decade, coupled with a sharp decrease in the central city's employment share.

c) Values for the residential Herfindahl generally reflect the same pattern, with the concentration decline less pronounced in most of the cities.[9] For the detailed sample of Boston, the residential Herfindahl was essentially unchanged, declining only slightly

[7] Values in this table are also given for the secondary central cities of St. Paul and Fort Worth in those two bimodal metro areas, rather than including them with other suburban locations.

[8] The values computed here are based on percentages, rather than fractions. Thus, a Herfindahl value of 10000 would represent complete concentration.

[9] Cleveland being the exception. In Detroit, the decline in concentration of worker residences in the city was matched by an increase in the "concentration" in the suburbs.

in both the city and suburbs, indicating that the residential decentralization process may have played itself out in that mature city.

d)The modified Herfindahl is based on the difference between the employment and residential shares in each zone. This measure also declined in each city, primarily due once again to the declining employment share of the central cities. Only in Cleveland did the modified Herfindahl also decline markedly in the suburbs, indicating widespread, diminished concentration in that city.

e) Using the longer DET employment series, Table 4.1c shows that decentralization was also a phenomenon of the 1970's. The central city's share of employment declined steadily throughout both decades, and accounted for most of the measured decline in employment concentration.

On the whole, the concentration measures once again support the notion that simple suburbanization, as opposed to true decentralization, was the predominant process during the 1980's affecting the five urban areas studied here.

B. Adjustment

Figure 4.3a illustrates the structural adjustment of employment growth, as it plots employment growth against the initial wage premia in 1980. The results here are mixed. Minneapolis and Cleveland show a strong negative correlation between wage levels and employment growth, while the result is much weaker for Detroit and Dallas. In both of those cities, the slope is strongly pulled down by exurban counties which had extremely low relative wages in 1980 but relatively slow employment growth. For Boston, four plots (for both employment series against both mean earnings and the earnings residuals) are shown in Figure 4.3b. The results there are consistent using either employment series and both means and residuals, as employment growth exhibits a strong negative correlation with wages. Although this simple analysis obviously omits several important factors affecting employment growth, it does provide weak evidence that wage levels affect employment growth.

C. Dynamic Linkages

The employment growth/commuting time change link (equation 4.1) is illustrated by Figures 4.4a and 4.4b. The slope coefficients represent the elasticity of average commuting times with respect to employment growth. The slopes are positive in each city, indicating that the expected relationship holds in this link.

The link from commuting time changes to wage differential changes (equation 4.2) is shown in Figures 4.5a and 4.5b. The link here appears to be very weak, as only one of the four PUMS cities displays even a mildly positive relationship. In Boston, a significantly positive relationship appears using mean earnings, but not when using the estimated earnings residuals.

The net effect of wage growth on employment growth (Figures 4.6a and 4.6b) appears to be positive for each city, except when using the Census employment series and the earnings residuals. This result would seem to indicate that the indirect positive effect of employment growth on wage growth (through commuting time changes) dominates the direct, negative feedback from wage growth to employment growth.

D. Convergence

As discussed above, while the structural effects of the linkages between growth in employment, commuting times, and wages cannot be determined, the convergence of the latter two variables can be measured. The convergence of wages and commuting times is a measure of the extent to which the different regions of the metropolitan area are becoming more homogeneous in terms of their locational advantages and in the breadth of the labor market which they draw from.

1) Wage Convergence. The evidence on wage and earnings convergence, depicted in Figure 4.5a, is generally quite strong, with each of the PUMS cities displaying the expected negative correlation between changes and levels. Once again, the exurban counties of Dallas and Detroit appear to diminish the apparent degree of convergence, as their estimated wage premia failed to increase significantly despite their low levels in 1980. In Boston (Figure 4.5b), convergence was especially strong in the earnings residuals of each community.

2) Commuting Time Convergence. Evidence for the convergence of commuting times within the metropolitan areas is mixed (Figures 4.6a and 4.6b). In Detroit, the estimated slope is positive, and it is small and insignificant for Minneapolis and Dallas. Among the PUMS cities, only Cleveland exhibits convergence, due solely to the lack of growth in central city commuting times. In Boston, commuting times appear to converge significantly, in either levels or in logs. An import factor influencing changes in commuting times, omitted here, would be improvements in transportation infrastructure. Such supply-side factors are also likely to be endogenous, as funds for infrastructure investment are allocated in regions with the greatest congestion.

V. Conclusions

This chapter has presented evidence that metropolitan spatial structure does appear to be evolving in a manner consistent with urban economic theory, as employment growth is strongest in regions with lower wage levels. The result is an increasing level of suburbanization of metropolitan workforces, and slightly diminished spatial employment concentration overall. There is strong evidence that the differences in locational wage premia are declining over time, coupled with weaker evidence on the convergence of travel times for commuters to different employment zones.

The tradeoff between geographic detail and improved wage premia estimates appears to favor the former approach (at least in studying dynamics), as the results are much stronger and more consistent for the analysis using Boston. The lack of convergence between exurban employment locations and the remainder of the intraurban zones, combined with the excessively low wage premia for these outlying counties found in **Chapter 3**, suggests that the local labor markets in these areas may not be well-integrated with the remainder of the urban region. An updated analysis, focusing on the central city and its inner and middle suburbs, might better reveal the extent of the wage capitalization of commuting time and the evolution of wages, employment, and commuting times within each metro area.

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Appendix 4A
Conformable Employment Zones

	COGs (1980)	POWPUMAs (1990)	CEZs
Detroit	27	16	16
Minneapolis	12	15	8
Cleveland	16	14	7
Dallas	12	13	11

Detroit

1 Detroit
2 Wayne Co.(part)
3 Livonia
4 Westland-Garden City-Inkster
5 Lincoln Park-Wyandotte-Allen Park
6 Warren
7 Macomb Co.(part)
8 Sterling Heights
9 Oakland Co.(part)
10 Royal Oak-Madison Heights-Clawson
11 Ann Arbor
12 Washtenaw Co.(part)
13 Livingston Co.
14 St. Clair Co.
15 Monroe Co.
16 Lapeer Co.-Shiawassee Co.

Minneapolis

1 Minneapolis
2 Hennepin Co.(part)
3 St. Paul
4 Ramsey Co.(part)
5 Chisago-Isanti-Wright-Sherburne-Carver-Scott Cos.
6 Anoka Co.
7 Washington Co.
8 Dakota Co.

Cleveland

1 Cleveland
2 Cuyahoga Co.(part)
3 Lorain Co.
4 Summit Co.
5 Portage Co.
6 Medina Co.
7 Geauga-Lake-Ashtabula Cos.

Dallas

1 Dallas
2 Garland
3 Irving
4 Dallas Co.(part)
5 Fort Worth
6 Arlington
7 Tarrant Co.(part)
8 Denton Co.
9 Collin Co.
10 Ellis-Kaufman-Rockwall Cos.
11 Johnson-Parker-Hood-Wise Cos.

Table 4.1a

	Detroit			Minneapolis-St. Paul			Cleveland			Dallas-Fort Worth		
	1980	1990	Chg	1980	1990	Chg	1980	1990	Chg	1980	1990	Chg
Central City Share	24.4	17.0	-7.3	26.0	21.9	-4.1	29.7	25.7	-3.9	45.8	35.4	-10.4
(1)				18.5	13.7	-4.8				16.1	14.8	-1.3
Emp Herfindahl	1423.2	1388.8	-34.4	2010.5	1890.7	-119.8	2246.2	2200.1	-46.1	2577.9	1868.9	-709.0
cc	592.9	289.7	-303.2	676.5	480.5	-196.0	879.7	661.0	-218.7	2100.4	1255.3	-845.1
cc2				343.0	188.2	-154.8				260.5	220.2	-40.3
sub	830.3	1099.1	268.8	991.0	1222.0	231.0	1366.5	1539.1	172.6	217.0	393.4	176.4
Res Herfindahl	1231.2	1232.6	1.4	1655.3	1587.1	-68.2	2150.4	2090.8	-59.6	1611.4	1247.3	-364.0
cc	361.7	212.4	-149.4	295.4	201.6	-93.8	255.2	181.7	-73.5	1023.1	543.4	-479.7
cc2				142.8	103.6	-39.1				152.6	101.4	-51.2
sub	869.5	1020.2	150.7	1217.1	1281.9	64.7	1895.2	1909.1	13.9	435.7	602.6	166.9
Modified Herf	57.5	41.8	-15.7	201.0	149.4	-51.6	307.0	228.2	-78.8	303.1	248.9	-54.2
cc	32.4	6.8	-25.6	93.3	70.8	-22.4	238.6	189.1	-49.1	228.5	167.8	-66.7
cc2				51.8	14.9	-37.6				17.1	26.0	12.5
sub	25.1	35.0	9.9	56.0	63.6	8.4	68.4	39.1	-29.7	57.5	55.0	-0.1

Table 4.1b

Boston Metro Area
Census-CTPP Data

	1980	1990	Chg
Central City Share	26.4	23.3	-3.0
Emp Herfindahl	794.7	639.2	-155.5
Cent City	694.5	543.3	-151.3
Suburbs	100.2	96.0	-4.2
Res Herfindahl	292.4	289.4	-3.0
Cent City	201.5	200.8	-0.7
Suburbs	90.9	88.6	-2.3
Modified Herf	172.0	103.7	-68.2
Cent City	152.9	85.5	-67.4
Suburbs	19.0	18.2	-0.8

Table 4.1c

Boston Metro Area
DET Employment Data

	1970	1975	1980	1985	1990
Central City Share	30.7	28.5	27.3	25.6	25.2
Emp Herfindahl	1051.6	922.0	842.1	748.5	725.1
Cent City	944.2	812.5	744.7	653.3	633.4
Suburbs	107.4	109.5	97.3	95.2	91.7

Table 4.2a

Graph	Dep Var	Indep Var	Detroit	Minneapolis	Cleveland	Dallas
4.1a	% Emp Growth	Log(1980 Emp)	-0.06	-0.18	-0.08	-0.13
			0.05	0.07	0.03	0.08
			0.09	*0.54*	*0.52*	*0.23*
4.2a	% Emp Growth	1980 Import Ratio	-0.27	-0.51	-0.23	-0.51
			0.19	0.07	0.07	0.23
			0.13	*0.89*	*0.71*	*0.35*
4.3a	% Emp Growth	1980 Wage Premium	-0.51	-1.83	-1.43	-0.01
			0.61	1.23	0.46	1.06
			0.05	*0.27*	*0.66*	*0.00*
4.4a	% Chg in Commuting Time	% Emp Growth	0.08	0.10	0.45	0.13
			0.07	0.06	0.25	0.09
			0.07	*0.29*	*0.39*	*0.18*
4.5a	Chg in Wage Premium	Chg in Commuting Time	-0.01	0.01	-0.00	-0.00
			0.01	0.02	0.01	0.01
			0.08	*0.09*	*0.01*	*0.02*
4.6a	% Emp Growth	Chg in Wage Premium	2.25	2.86	2.69	2.75
			1.66	2.63	1.70	2.04
			0.12	*0.17*	*0.33*	*0.17*
4.7a	Chg. in Wage Premium	1980 Wage Premium	-0.16	-0.45	-0.23	-0.18
			0.08	0.09	0.13	0.15
			0.20	*0.81*	*0.36*	*0.14*
4.8a	Chg. in Commuting Time	1980 Mean Commuting Time	0.11	-0.07	-0.26	-0.07
			0.13	0.09	0.08	0.14
			0.05	*0.08*	*0.66*	*0.02*

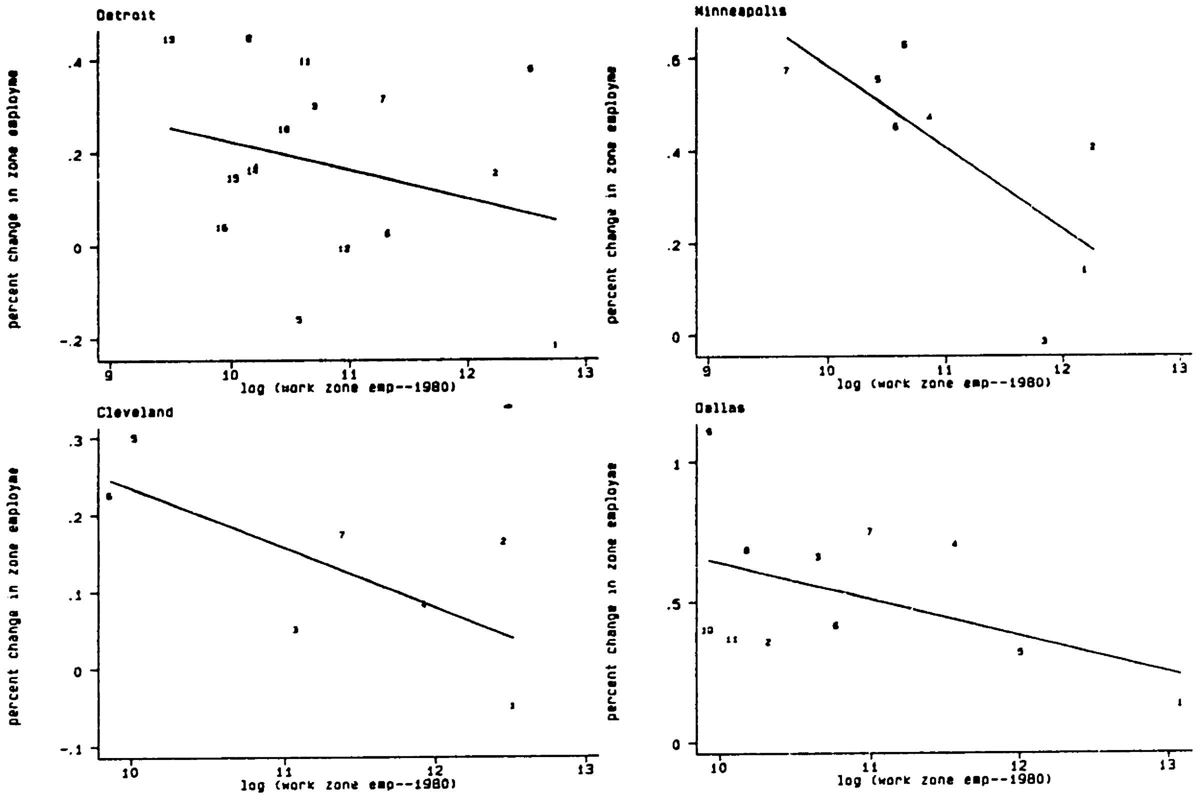
1st Row in each cell: Slope Coefficient
2nd Row in each cell: Standard Error
3rd Row in each cell: R-square

Table 4.2b

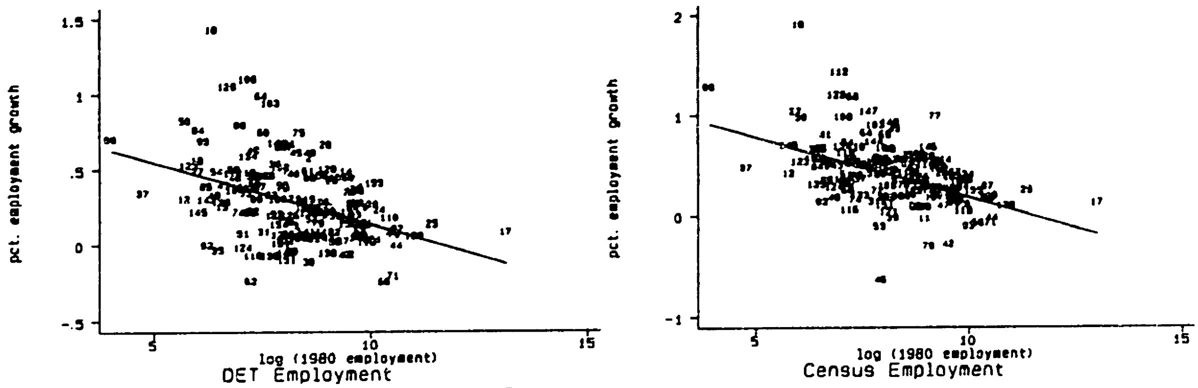
Graph	Dep Var	Indep Var	Boston
4.1b	Pct. Emp Growth (DET)	Log(1980 Employment)	-0.083 0.014 *0.17*
	Pct. Emp Growth (Census)	Log(1980 Employment)	-0.12 0.016 *0.25*
4.2b	Pct. Emp Growth (DET)	1980 Import Ratio	-0.134 0.048 *0.04*
	Pct. Emp Growth (Census)	1980 Import Ratio	-0.298 0.053 *0.16*
4.3b	Pct. Emp Growth (DET)	Log (1980 Mean Earnings)	-0.408 0.111 *0.07*
	Pct. Emp Growth (Census)	Log (1980 Mean Earnings)	-0.436 0.133 *0.06*
	Pct. Emp Growth (DET)	1980 Earnings Residuals	-0.519 0.134 *0.08*
	Pct. Emp Growth (Census)	1980 Earnings Residuals	-0.432 0.164 *0.04*
4.4b	Pct. Commuting Time Change	Pct. Emp Growth (DET)	0.132 0.036 *0.08*
	Pct. Commuting Time Change	Pct. Emp Growth (Census)	0.122 0.031 *0.09*

Graph	Dep Var	Indep Var	Boston
4.5b	Pct. Earnings Growth	Pct. Commuting Time Change	0.488 0.083 *0.18*
	Chg. in Earnings Residuals	Pct. Commuting Time Change	0.322 0.095 *0.07*
	Pct. Earnings Growth	Chg. in Commuting Time	0.028 0.005 0.19
	Chg. in Earnings Residuals	Chg. in Commuting Time	0.007 0.005 *0.01*
4.6b	Pct. Emp Growth (DET)	Pct. Earnings Growth	0.609 0.142 *0.11*
	Pct. Emp Growth (Census)	Pct. Earnings Growth	0.541 0.174 *0.06*
	Pct. Emp Growth (DET)	Chg. in Earnings Residuals	0.341 0.137 *0.04*
	Pct. Emp Growth (Census)	Chg. in Earnings Residuals	0.049 0.167 *0.01*
4.7b	Pct. Earnings Growth	Log (1980 Mean Earnings)	-0.208 0.059 *0.07*
	Chg. in Earnings Residuals	1980 Earnings Residuals	-0.682 0.059 *0.46*
4.8b	Pct. Commuting Time Change	Log (1980 Commuting Time)	-0.332 0.041 *0.29*
	Chg. in Commuting Time	1980 Commuting Time	-0.137 0.051 *0.04*

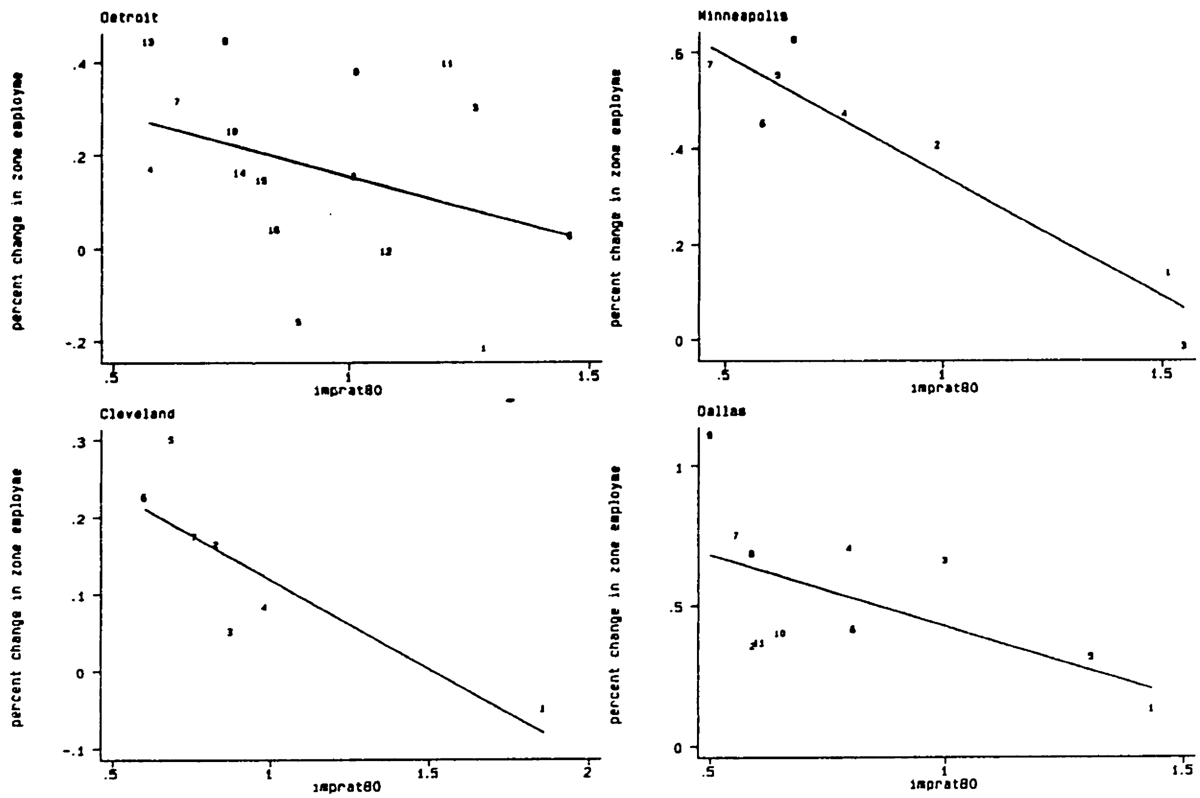
1st Row in each cell: Slope Coefficient
2nd Row in each cell: Standard Error
3rd Row in each cell: R-square



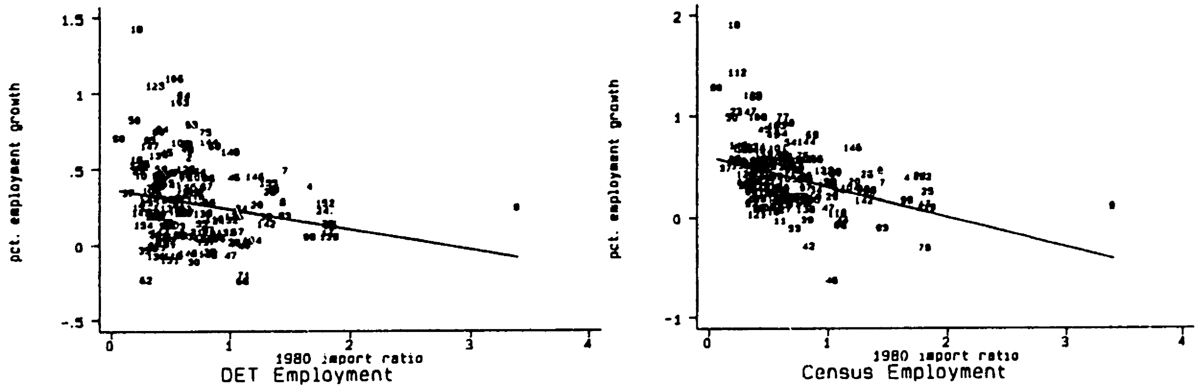
Employment Convergence
Figure 4.1a



Employment Convergence
Figure 4.1b

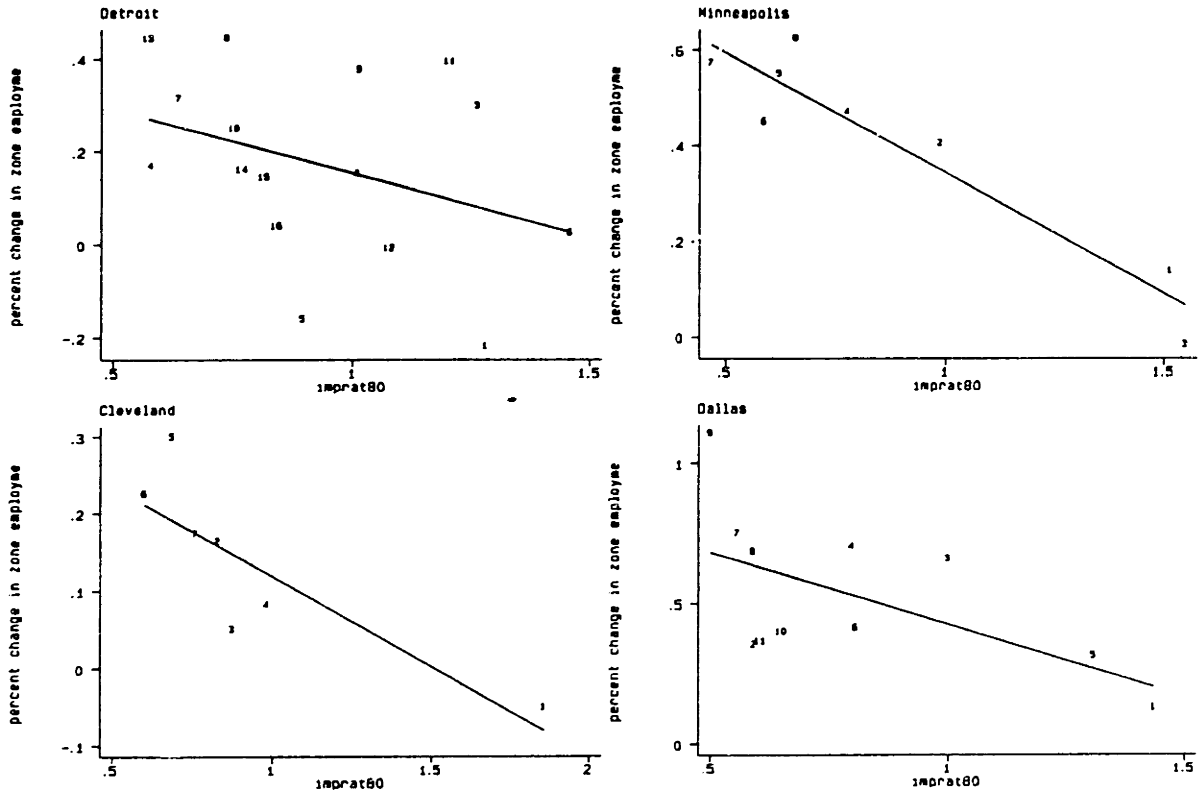


Employment Growth and 1980 Import Ratios
Figure 4.2a

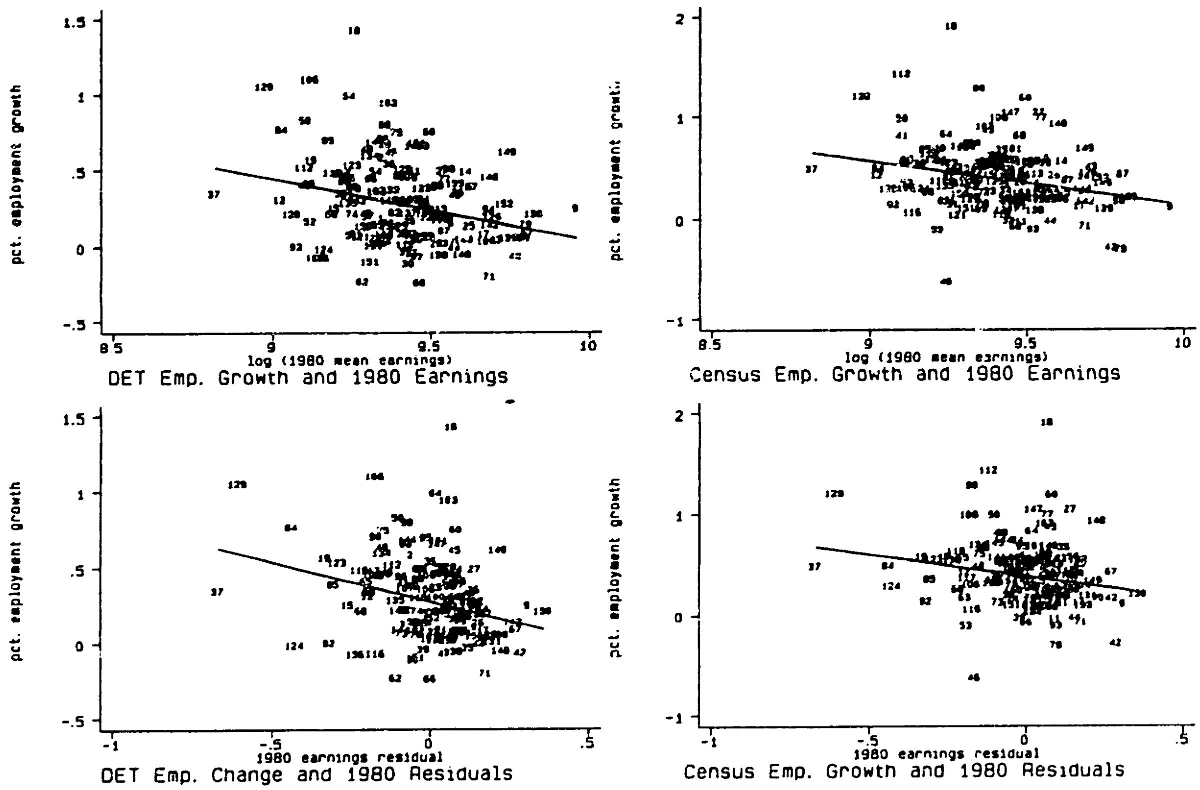


Employment Growth and 1980 Import Ratios

Figure 4.2b

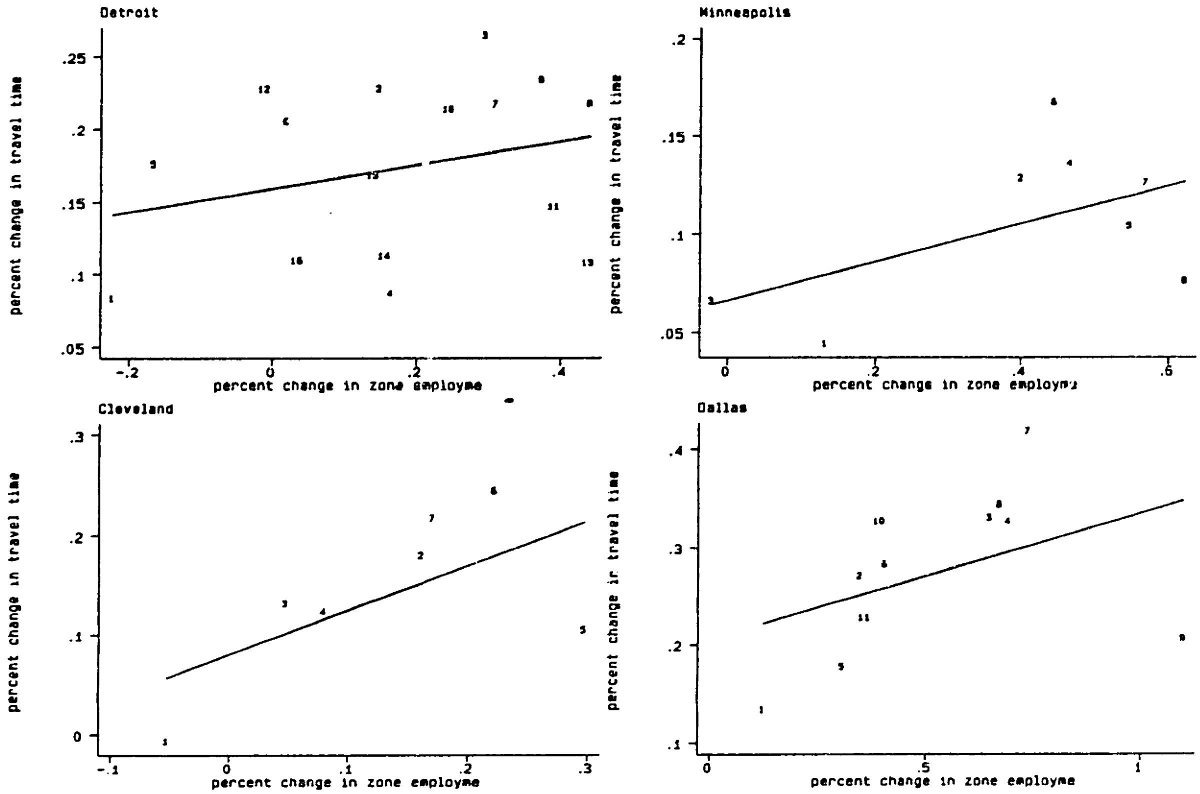


Employment Growth and 1980 Import Ratios
Figure 4.3a



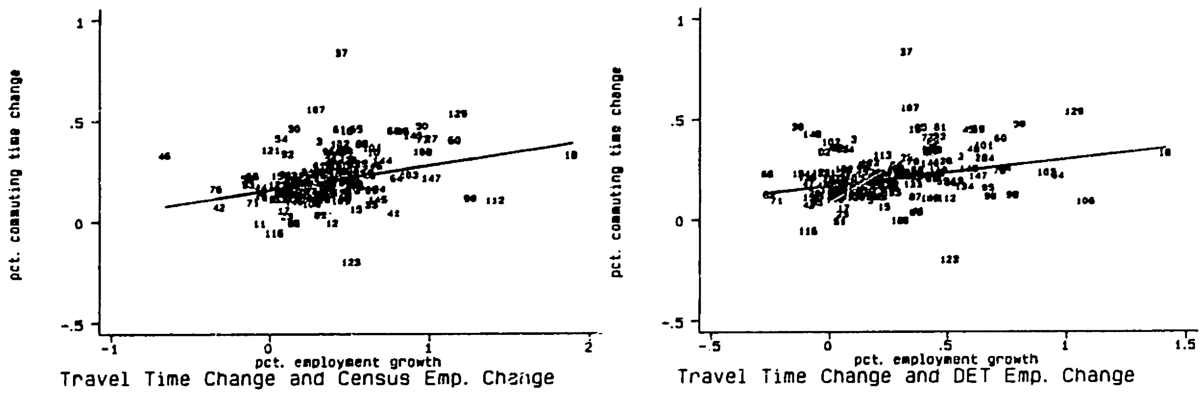
Employment Growth and 1980 Earnings

Figure 4.3b



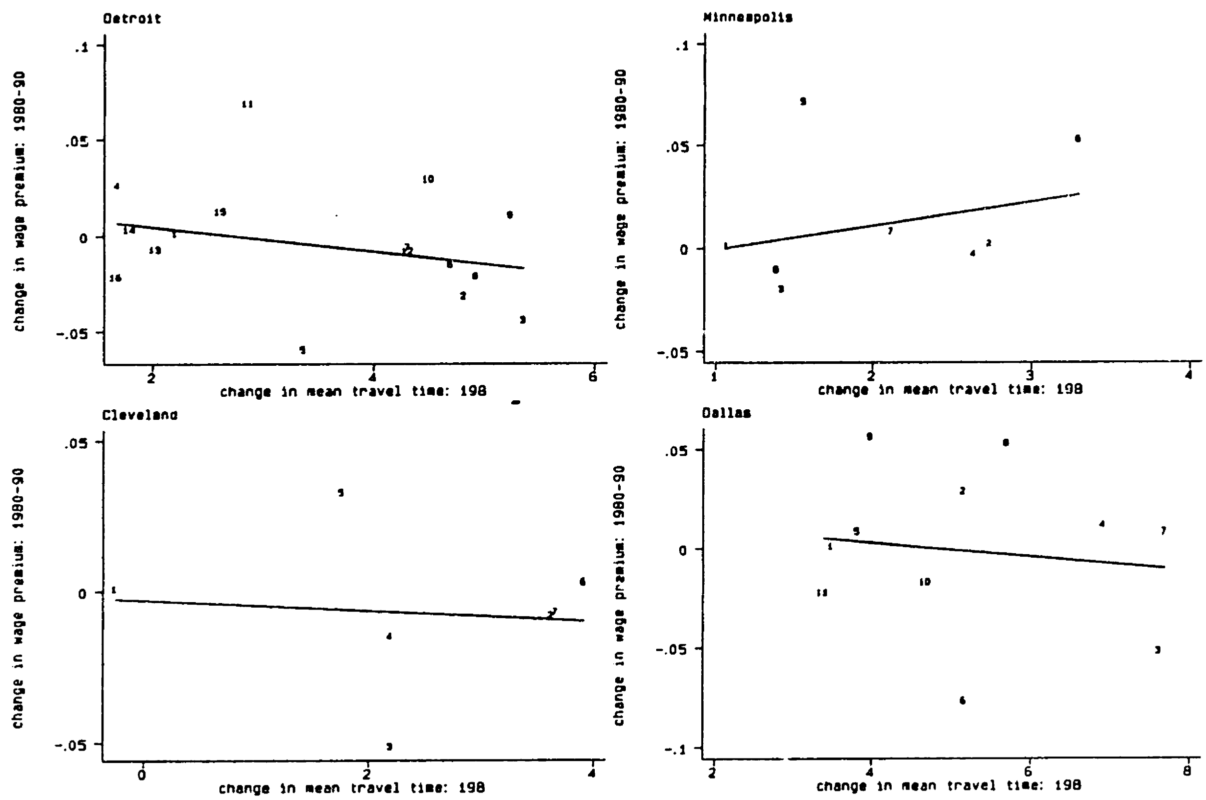
Travel Time Changes and Pct. Employment Growth

Figure 4.4a

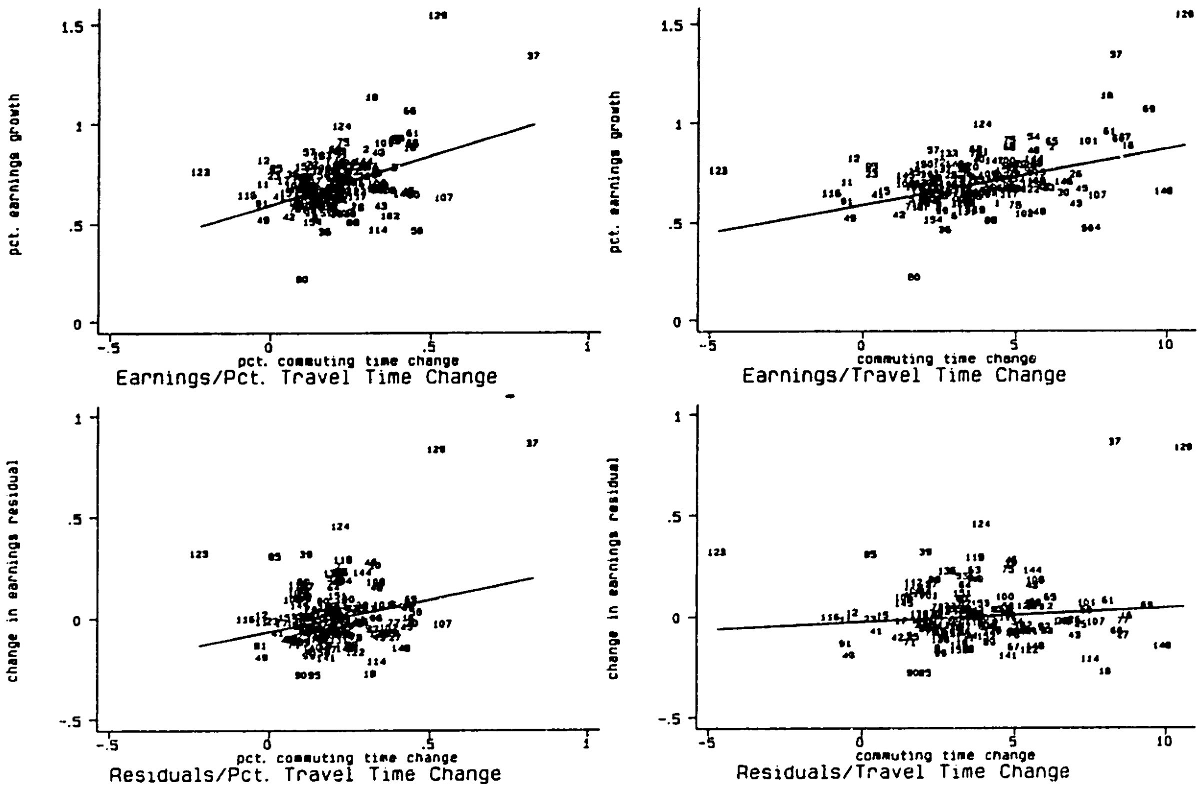


Commuting Time Change and Employment Growth

Figure 4.4b

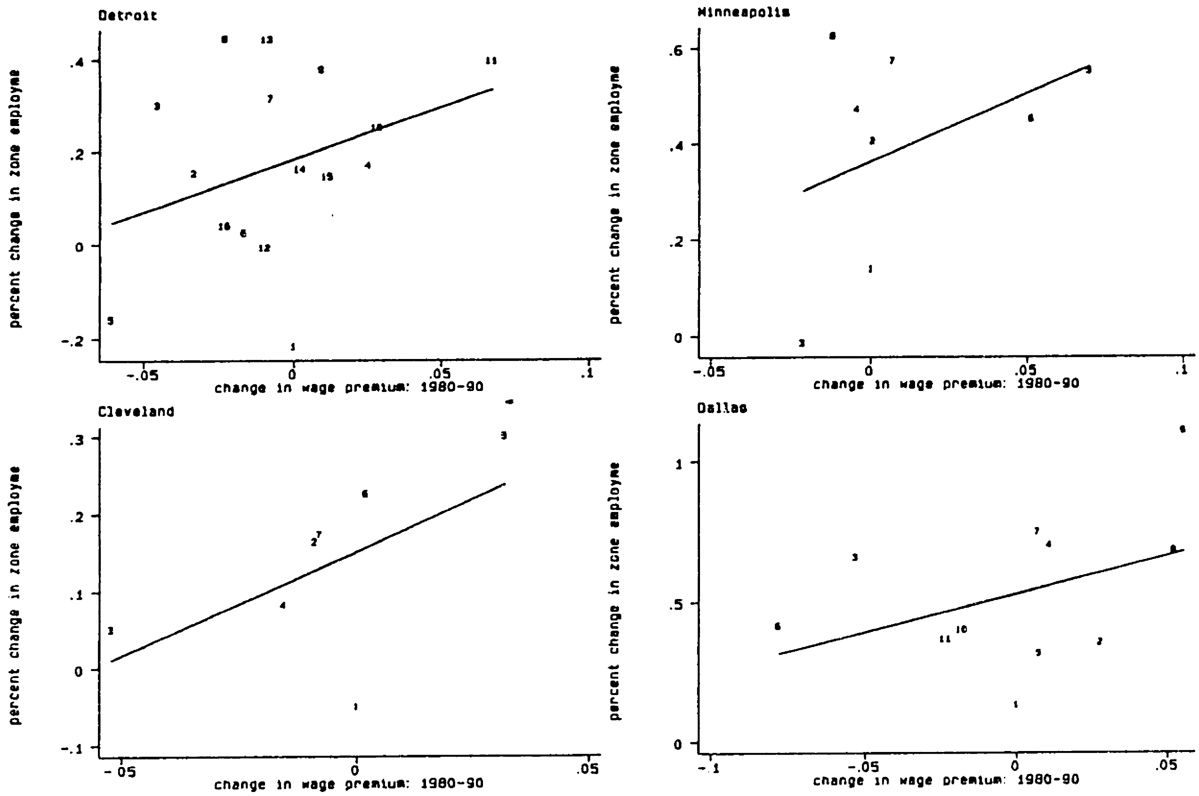


Wage Premia Changes and Travel Time Changes
Figure 4.5a

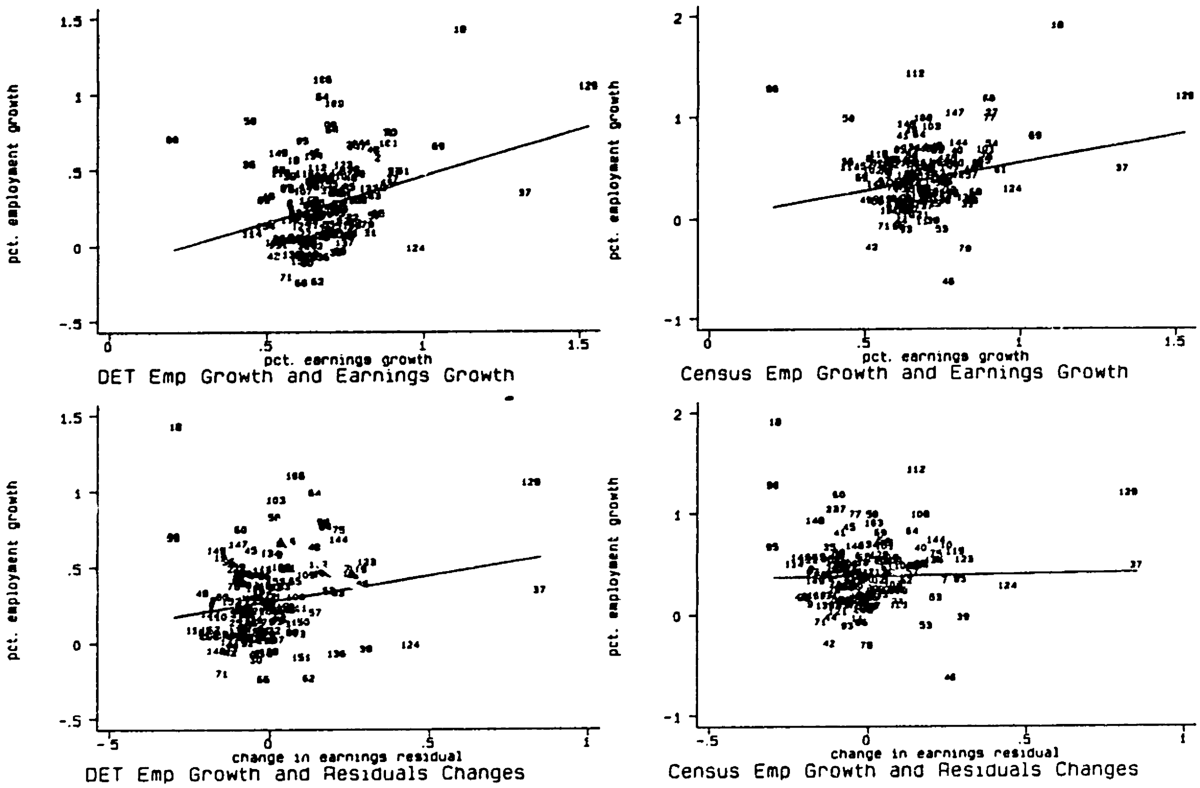


Earnings and Travel Time Changes

Figure 4.5b

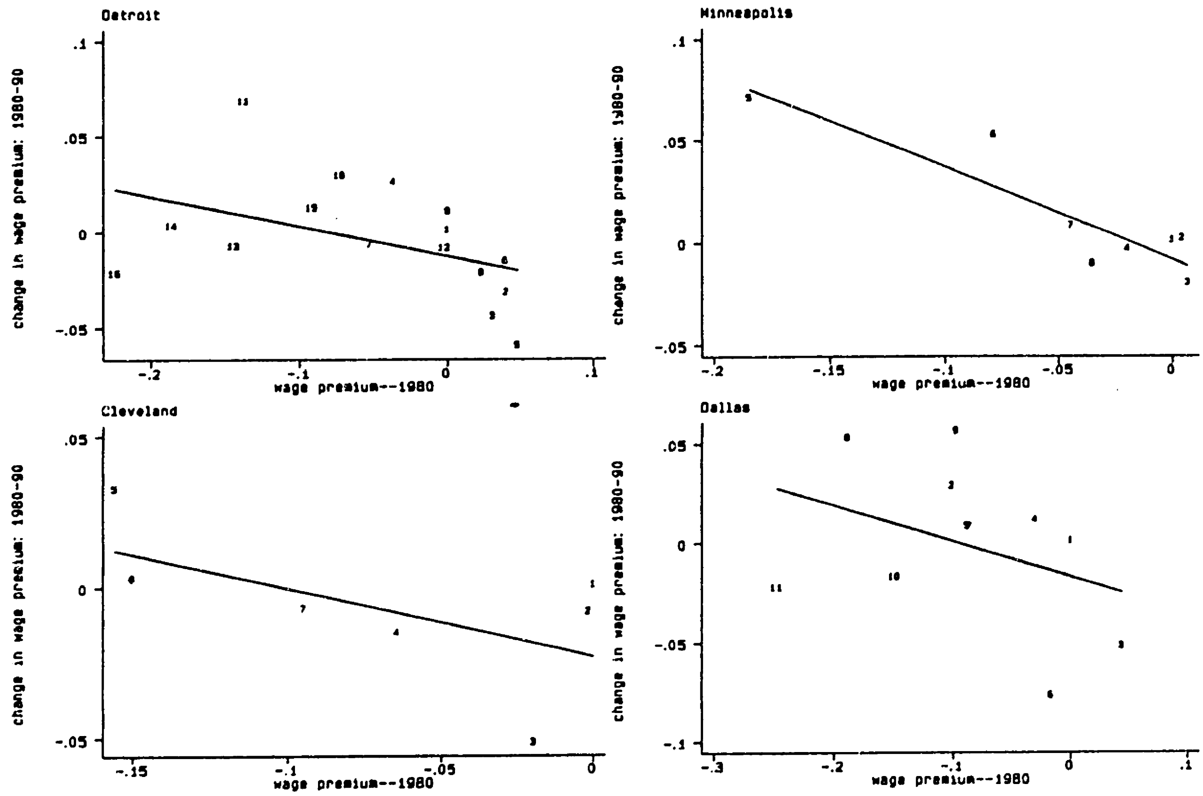


Pct. Employment Changes and Wage Premia Changes
Figure 4.6a

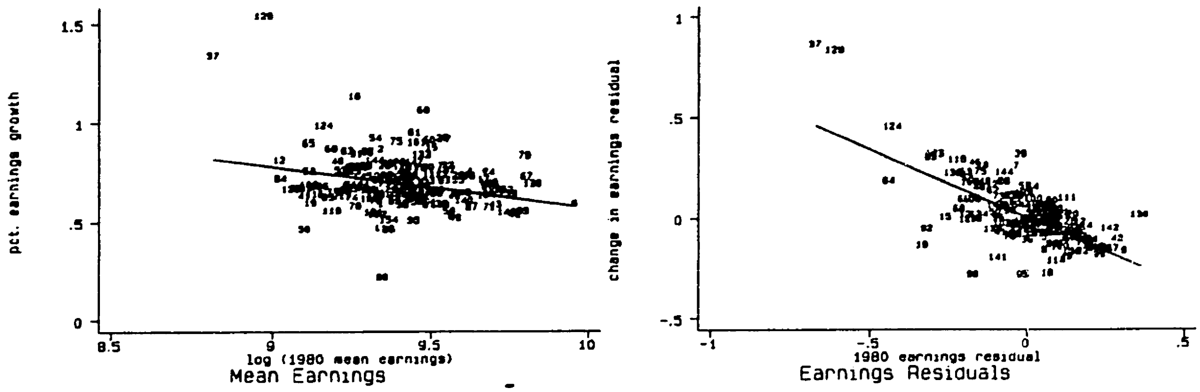


Earnings Growth and Employment Growth

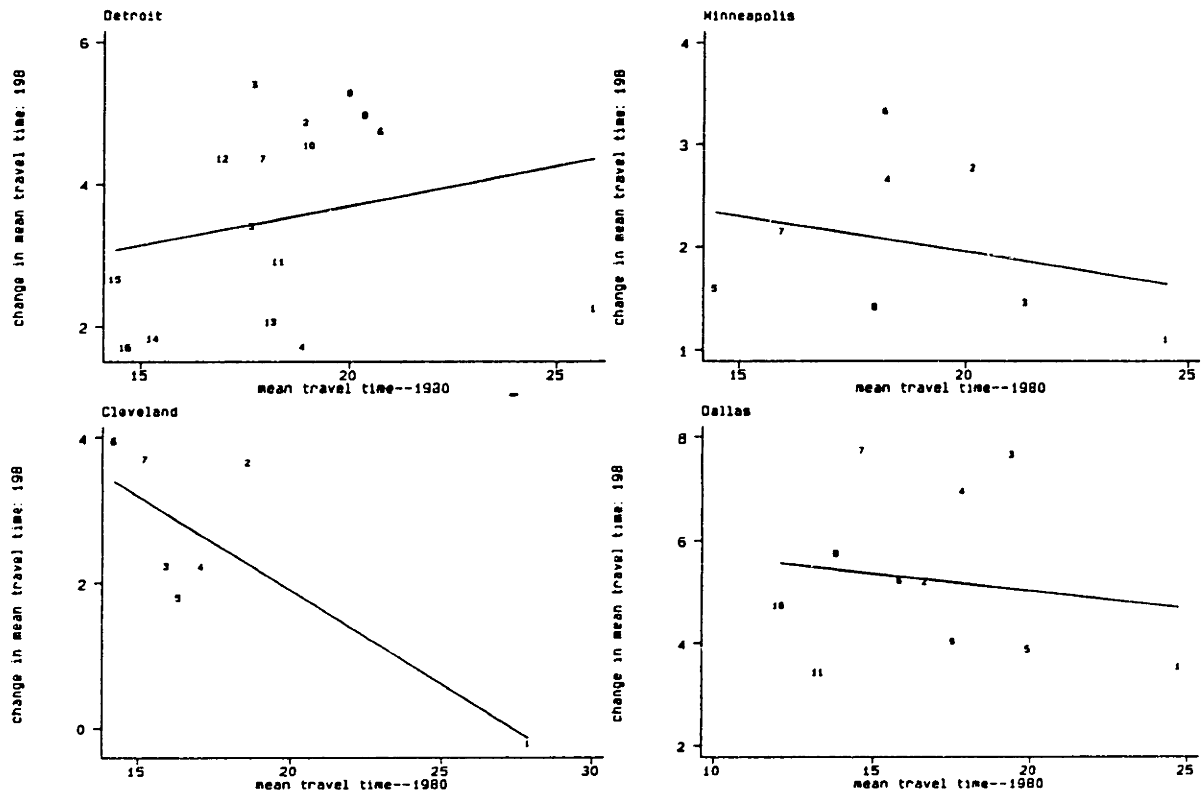
Figure 4.6b



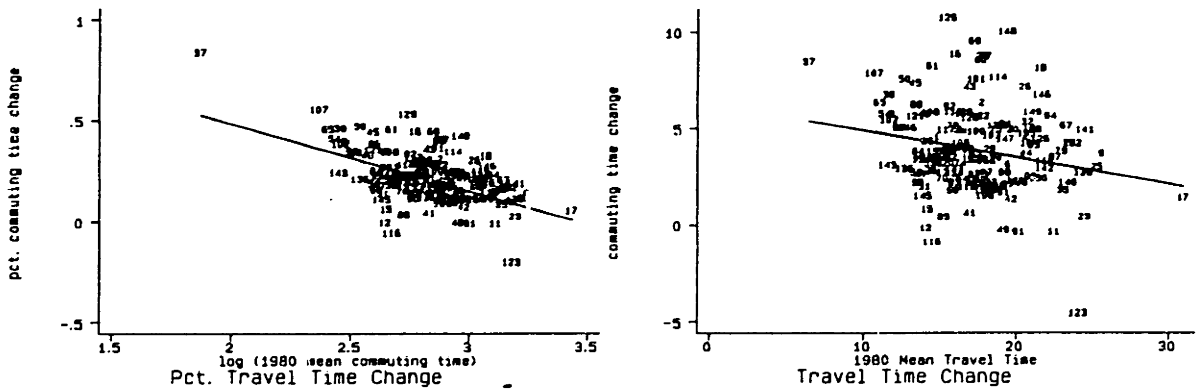
Wage Premia Convergence
Figure 4.7a



Earnings Convergence
Figure 4.7b



Commuting Time Convergence
Figure 4.8a



Commuting Time Convergence
Figure 4.8b