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New Evidence on Trends in the Cost of Urban Agglomeration

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I. Introduction

The benefits of urban agglomeration cannot take place if city living exposes the population to deadly levels of ambient air pollution and raises the risk of experiencing infectious diseases such as cholera, diarrhea, and dysentery (Melosi 2000). At the turn of the 20th century, the average white urbanite in the United States paid a ten year “mortality penalty” for not living in the countryside (Haines 2001). By 1940, big city investments in water treatment and sanitation significantly reduced the threat of water pollution (Cutler and Miller 2004, Haines 2001).

Over the 20th century, U.S big cities have experienced rising and then declining levels of crime and pollution. Ambient air pollution grew sharply over the 20th century, peaking in the early 1970s, and declining over the last 30 years. Urban crime rates have been documented to have risen during the 1970s and 1980s and to have declined sharply since the early 1990s (Levitt 2004, Reyes 2007).

At a point in time, big cities feature more congestion, pollution and crime than smaller cities (Glaeser 1998, Glaeser and Sacerdote 1999). These non-market local public bads can significantly reduce big city quality of life (Tolley 1974, Blomquist, Berger and Hoehn 1988, Gyourko and Tracy 1991). In contrast, larger cities offer greater cultural amenities and variety of shopping and cuisine options than smaller cities (Waldfogel 2008). Big cities offer greater possibilities for good matches in the marriage market and labor market. This suggests that big cities offer a quality of life tradeoff. They offer a greater variety of market goods than small cities but suffer from worse levels of non-market local public goods.

This paper examines how the population elasticity of producing local public bads such as crime, pollution and commute times has changed over time and how it varies across U.S census regions. In a nutshell, I find that the commute time/population elasticity is relatively small but stable over time. I document a sharp negative time trends in ambient pollution and violent crime in big cities.

In addition to exploring time trends in key determinants of quality of life, this paper also documents significant geographical variation in the ambient air pollution/population size relationship and crime/population size relationship at a point in time. Relative to cities in other regions, the metropolitan areas in the Northeast suffer the highest “big city premium” with respect to pollution and crime. This paper also documents that employment suburbanization in major cities has sharply reduced suburban commute times.

Big city quality of life progress along the crime and pollution dimensions means that these cities will have an easier time attracting and retaining the skilled to live there (Glaeser, Kolko and Saiz 2001). This in turn raises their prospects for future growth.

II. Urban Quality of Life Dynamics

The cross-city quality of life literature has used hedonic techniques to compare city quality of life at a point in time. Leading studies such as Blomquist, Berger and Hoehn (1988) and Gyourko and Tracy (1991) have estimated cross-city wage and rental hedonic regressions to parse out how much of the cross-city differences in quality standardized

wages and rents is due to tied locational amenities such as climate, street safety and other amenities.

While climate is a crucial non-market public good, in this paper I focus on city attributes that evolve over time. New York City today bears little resemblance to bankrupt, unsafe New York City of the 1970s. Similar urban rejuvenations can be found in a range of cities such as Boston, Los Angeles and San Francisco.

Recent cross-city hedonic wage and real estate research documents overall recent quality of life progress in big cities relative to small cities (Glaeser and Gottlieb 2006). They contrast the 1970 and 2000 wage and rent premium data in big and small cities. In 1970, workers with observationally identical demographics were paid higher wages in big cities relative to small cities but by the year 2000 this cross-city pattern had reversed such that quality adjusted wages were *lower* in big cities relative to small cities. Between 1970 and 2000, home prices increased more in big cities relative to smaller cities. These findings are consistent with the claim that big city quality of life has improved.

While metropolitan areas differ along several dimensions, in this paper I focus on three major disamenities namely commute times, urban air pollution and crime. Throughout this paper, I will present new estimates of the cross-sectional relationship between these city attributes and city population size.

Estimates of the relationship between commute times, pollution, crime and city population size represent important inputs in determining whether the observed dynamics in big city/small overall compensating differentials (as documented by Glaeser and Gottlieb (2006)) can be explained by big city progress with respect to three classic challenges that these cities face.

To link this paper's empirical work to the hedonic quality of life dynamics literature, suppose that we know the marginal willingness to pay to avoid a small change in commute time, pollution and crime and make the strong assumption that utility is linear in these non-market public bads. Define these valuation weights as respectively $b_{commute}$, $b_{pollution}$, b_{crime} . At a point in time t , the marginal quality of life damage caused by living in a bigger city relative to a smaller city equals $b_{commute} * \partial Commute_t / \partial Pop_t + b_{pollution} * \partial Pollution_t / \partial Pop_t + b_{crime} * \partial Crime_t / \partial Pop_t$. While the estimates of these valuation weights remains contentious, this simple equation highlight this paper's key empirical goals. I will provide new estimates of these marginal effects at several points in time and I will estimate how these marginal effects vary across regions.

III. The Commute Time vs. City Size Relationship Over Time

To document the commute time/city size relationship and how it has changed over time, I use IPUMS Census micro data from the 1% 1980, 1990 and 2000 samples. For person l living in city j at time t , I estimate;

$$\text{Log(Commute Time}_{jlt}) = c_t + b_t * \log(\text{Pop}_{jt}) + b_t * X_{jlt} + U_{jlt} \quad (1)$$

The regression results are reported in Table One. In this regression, I control for a vector of household level demographic variables included the head's age, sex and socio-economic status. My sample includes all workers who report positive commute times and who live in a metropolitan area that I could identify in all three of these Census data sets. I am able to identify 100 metropolitan areas that are geocoded in each of these

census years. This sample includes all of the major metropolitan areas. The five smallest metropolitan areas in this sample includes ;Boise City, ID, Sarasota, FL, Modesto, CA, Melbourne, FL, and Pensacola, FL. Table One presents two OLS estimates of this pooled cross-sectional regression. Two key findings emerge. In 1980, the elasticity of commute time with respect to metropolitan area population size was .13. In 1990 and 2000, this elasticity did not change. In the right column of Table One, I report the same regression but this time for the subset of workers who commute by private vehicle. In this case, the city size elasticity shrinks to .09.

Public transit is a relatively slow commuting mode and it is more likely to be used in major cities.¹ In 1980, the average worker in New York City, Chicago and Los Angeles had a one way commute time that was 5.9 minutes longer than the 100 MSA average commute time (29.9 to 24 minutes). In 2000, this differential had not changed with an average commute time of 32.3 minutes in these three major cities relative to a national average of 26.4 minutes for the 100 MSA sample. It is important to note that across this 100 metropolitan area sample in the year 2000, the average one way commute time using public transit was 44 minutes while the average one way commute time by private vehicle was 25 minutes. In addition, in New York City, Chicago and Los Angeles, public transit usage is much higher. In the year 2000, 4.1% of workers in the 100 MSAs commuted by public transit while 20% of workers in New York City, Chicago and Los Angeles commuted by public transit.

¹ These results are roughly in line with cross-city estimates reported in Glaeser (1998). Using 1990 city level data for the fifty largest cities, he estimates that a doubling of a city's population size is associated with a 1.9 minute increase in the one way commute.

To provide some evidence on how commute speeds are affected by city size, public transit use and location within the metropolitan area, I use micro data from the 2001 National Household Transportation Survey. An attractive feature of this data is that it is possible to obtain residential zipcode identifiers. I use this information to calculate each metropolitan area resident's distance to the Central Business District (CBD). Using information on each respondent's distance to work and commute time allows me to estimate their speed that they commute to work. Table Two reports three regressions based on equation (2). The dependent variable is the speed that workers commute at measured in miles per hour. The unit of analysis is person l in metropolitan area j in 2001.

$$\text{Speed}_{lj} = \text{constant} + b \cdot \log(\text{MSA Population}_j) + b \cdot (\text{Distance to CBD}_{lj}) + b \cdot 1(\text{Commute using Public Transit}_{lj}) + U_{lj} \quad (2)$$

The standard errors are clustered by metro area. In column (1), I only include the metropolitan area's population as the explanatory variable. A doubling of a metro area's population is associated with a reduction of speed of 1.6 miles per hour. In column (2), I control for a worker's residential distance to the CBD. For every extra mile that a household lives from the CBD, its commuting speed increases by .45 miles per hour. The third specification reported in Table Two demonstrates how slow public transit is. People in big cities are more likely to commute using public transit and this increases their commute times. All else equal, a worker who commutes using public transit travels 10.5 miles per hour slower than a worker who commutes by car. Note that controlling

for whether a worker commutes using public transit shrinks the city size coefficient from -2.46 to -1.81. Public transit use in big cities is an important explanation for long commute times.

Population suburbanization and reduced use of public transit in big cities have both helped to increase urbanite's commute speeds. Based on census tract level data, the average person who lived in a metropolitan area in 1970 lived 8.72 miles from the CBD while the average person who lived in a metropolitan area in the year 2000 lived 11.44 miles from the CBD. Over this same time period the share of urbanites who commuted using public transit decreased by ten percentage points. Based on the estimate reported in Table Two's column (3), these two trends would increase commute speeds by $(11.44 - 8.72) * .3847 - 10.55 * (.059 - .121)$ or 1.7 miles per hour.

IV. Within Major City Commute Time Differentials

In the past, when metropolitan area employment was concentrated in the Central Business District, urban growth would translate into rising commute times both because the marginal growth took place at the urban fringe and because the commuters would exacerbate congestion bottlenecks as they sought to get downtown. The ongoing decentralization of employment has helped to alleviate some of these congestion effects (Glaeser and Kahn 2001).

To study within city trends over time in commuting, I use census tract data from 1980 and 2000 (for details on the data see Baum-Snow and Kahn 2005). Figure One presents results from 1980 and 2000. For all people who live within 30 miles of a CBD, I

calculate the share of workers who have a commute over 45 minutes long by mileage distance to the CBD of the metro area they live in. The Figure's lines are roughly parallel. Very few commuters who live close to a CBD have a long commute in 1980 or 2000. The share with long commutes increases out to about 10 miles from the CBD and then in both years, the slope flattens. It is important to note that in the year 2000, a larger share of commuters do have long commutes relative to in the year 1980. This gap equals roughly 2 percentage points.

Figure Two is identical to Figure One but now I focus on just Chicago, Los Angeles and New York City. This cut of the data allows me to investigate changes in commuting patterns in the very biggest cities. The first point to note is that the figure does not look like Figure One. From zero miles to eight miles from the CBD, the share with a long commute increases but in the eight to twenty mile range it declines sharply. In these major cities, these commute times reject the claim that these are monocentric cities.

Figure Three examines the share of workers whose commute is less than 25 minutes long in the year 2000 by distance from the CBD. The facts for the major metropolitan areas of Chicago, Los Angeles and New York City echo those presented in Figure Two. Starting at zero miles from the CBD, the share of workers with a short commute declines sharply with distance but at roughly 8 miles out this function reaches its minimum and turns around such that workers who live 12 miles from the CBD are much more likely to have a short commute than workers who live 8 miles from the CBD. One simple explanation for this pattern is that in these cities suburban residents work at suburban jobs and are avoiding big city urban bottlenecks. In contrast, the average MSA

worker's probability of having a short commute declines monotonically with distance from the CBD.

Using year 2000 Census data on average commute times by census tract, in Figure Four I report average commute times for metropolitan area workers by mile of distance from their CBD. The Figure displays three different lines. One is for all urban workers, one is for workers who live in metropolitan areas with four or more million people and one is for workers who live in metropolitan areas with less than four million people. The figure highlights that average commute times rise with distance from the CBD. Commute times in big cities take longer on average but note the non-monotonic shape. Commute times in big cities decline sharply from seven miles to the CBD out to twenty miles from the CBD. In contrast, average commute times rise in smaller cities over this same mileage interval. This figure highlights the role that employment decentralization in major cities has played in helping suburbanites to enjoy shorter commutes.

V. Urban Pollution Progress

Today, major cities such as Los Angeles and New York City compete to be "Green Cities".² Such cities seek to enhance their environmental quality to improve public health and to retain the footloose skilled.

A city's pollution level at a point in time is a function of scale, composition and technique effects. Scale represents a city's population size. While urban economists have emphasized the role of the sheer scale of activity in imposing social costs,

² For example see New York City's Plan (<http://www.nyc.gov/html/planyc2030/html/greenyc/greenyc.shtml>), and Los Angeles' plan http://www.lacity.org/ead/EADWeb-AQD/GreenLA_CAP_2007.pdf

environmental economists have countered that composition and technique effects can offset the externality costs of population growth (Kahn and Schwartz 2008).

Composition effects focus on what are the major industries clustered in a city at a point in time. Technique effects are defined as the emissions per unit of activity from various forms of capital such as cars, power plants and factories. A city could have many steel mills (a brown composition) but if the steel mills released few emissions per dollar of output (a green technique) then the city may not be polluted.

Composition effects have played an important role in “greening” U.S cities. The rise and decline of urban manufacturing was an important factor driving urban pollution levels in the 20th century. In the 20th century, the rise of Pittsburgh as a steel capital had the unintended consequence of sharply increasing particulate levels. An unintended silver lining of the U.S Rust Belt’s decline in the 1960s and 1970s has been to sharply improve environmental quality in heavy industrial cities such as Pittsburgh and Gary, Indiana (Kahn 1999). Between 1969 and 2000, the number of manufacturing jobs in New York County (Manhattan) declined from 451,330 to 146,291. Similar declines in manufacturing have taken place in London, England. There are large public health gains from removing older polluting manufacturing plants from heavily populated areas. As shown in Figure Five, metropolitan areas in the United States have experienced a composition shift as the share of workers in urban manufacturing has declined and as the service sector’s share has grown.

Technique is the final key determinant of urban pollution levels. Technique refers to the emissions rates of different technologies used within the cities. Electric utilities are more likely to be located in counties with a larger population (Kahn 2009). Coal fired

power plants are major polluters. Many of these are located in the Midwest in states such as Ohio. Newer cohorts of electric utilities feature emissions factors (emissions per unit of power generation) that are 50% lower than older power plants (Burtraw and Evans 2003).

Vehicle emissions progress offers another example of a greening of urban technique. Cars cluster where people cluster. The rise of private vehicle use contributed to rising levels of ambient smog in cities. Under the Clean Air Act, new vehicles only faced stringent emissions standards starting in the early 1970s. As pre-1975 built vehicles have been scrapped, the average vehicle on the roads has become so much cleaner that many major cities such as Los Angeles have experienced significant smog progress despite ongoing growth in population and miles driven (Kahn and Schwartz 2008). Between 1980 and 2000, Los Angeles County's population grew by 29 percent between 1980 and 2000, while total automobile mileage grew by 70 percent. Yet, the number of days per year exceeding the federal one-hour ozone standard declined from about 150 days per year at the worst monitoring stations in this metropolitan area during the early 1980s, down to 20 to 30 days per year today (Kahn and Schwartz 2008).

I now present some new estimates of the time trend in urban ambient pollution levels. Using county/year level data, in Table Three I estimate five pollution production regressions. I use the U.S. Environmental Protection Agency's Annual Summary Table Query database to examine the relationship between urban population size and ambient pollution levels between 1973 and 2000.³ The sample includes counties in metropolitan

³ See U.S. Environmental Protection Agency, "Monitor Data Queries: Annual Summary Table Query" (www.epa.gov/aqspubl1/annual_summary.html).

areas that have at least one monitoring station operating. The estimation equation for county j in year t is:

$$\text{Log}(\text{Ambient Pollutant}_{jt}) = c + b_1 * \text{log}(\text{Population}_{jt}) + b_2 * \text{log}(\text{Population}_{jt}) * \text{Region}_j + b_3 * \text{Trend}_t + U_{jt} \quad (3)$$

The time trend results document the overall progress. Ambient carbon monoxide has declined by 4.2% per year. Particulate matter has improved by over 2.1% per year and ambient urban PM10 levels have fallen by 3.2%. I find no evidence supporting the claim that bigger cities have experienced a differential time trend than smaller counties. For carbon monoxide, total suspended particulates and smaller particulate matter (PM10) I find the largest county population elasticity effects. The regressions indicate that the pollution/population elasticity is consistently largest in North East relative to other regions.

VI. Urban Crime Progress

Crime is a key urban disamenity. Big city crime rates are higher than smaller cities (Glaeser and Sacerdote 1999). Crime has declined in big cities starting in the early 1990s. An empirical literature continues to debate what role has abortion, lead, crack cocaine, police hires, and incapacitation played in explaining this trend (Levitt 2004, Reyes 2007).

In this section, I present new estimates of crime trend rates over the time period 1994 to 2002, for counties located in metropolitan areas. I report results on the murder count and the violent crime count. The unit of analysis is county j in year t . I estimate equation (4).

$$\text{Crime Per-Capita}_{jt} = c + b_1 * \log(\text{Pop}_{jt}) + b_2 * \log(\text{Pop}_{jt}) * \text{Region}_j + b_3 * \text{trend}_t * \log(\text{Pop}_{jt}) * \text{Region}_j + U_{jt} \quad (4)$$

The data source is the FBI's county crime data base (<http://fisher.lib.virginia.edu/collections/stats/crime/>).

The results reconfirm the well known fact that per-capita crime victimization is higher in more populated areas. In terms of quality of life in big cities, the good news is that this effect is sharply declining over time. The North East is the region with the steepest crime/population relationship.

The estimates reported in Table Four provide insights into big city/small city quality of life convergence. I use the OLS estimates reported in column (1) to conduct a difference in difference thought experiment. Consider two different counties that are located in a metropolitan area. The first has a population of 200,000 and the second has a population of 1 million. Based on the estimates reported in Table Four's column (1), between 1994 and 2002 the murder rate per 1000 people between these two counties declined by .018 ($.0148 * \log(5) - (.0148 - .0014 * 8) * \log(5)$). Given the standard estimate of a \$6 million value of a statistical life, each person in the million person county would be willing to pay \$108 for this reduction in risk. A family of four would be willing to pay \$432 in after tax income for this reduction in risk. While sizable, this calculation reveals that even crime reductions by themselves cannot explain the large overall convergence in wages and divergence in home prices that Glaeser and Gottlieb (2006) document have taken place over the last 30 years. In Table Three, I documented significant negative

time trends in urban air pollution. While households certainly value such reductions, the overall gains in big cities versus small cities in pollution are unlikely to exceed the total willingness to pay for the crime risk reduction.

VII. Conclusion

Congestion, pollution and crime represent three important factors that discourage urban agglomeration. Unlike other spatial amenities such as climate, these local public bads change over time. This paper has used a variety of data sets to examine their time trends in major cities in the United States. This paper has used a production function approach to estimate how city size is associated with local public bads at different points in time and across U.S regions.

Big cities have enjoyed sharp recent reductions in ambient pollution and crime. This paper has documented that the commute time/city size relationship is small (an elasticity of .13) and stable over time.

This paper's results complement a recent revealed preference literature has used cross-city hedonic approaches to infer city quality of life (Glaeser and Gottlieb (2006) and Albouy (2008)). While I have documented crime and pollution progress, it is not clear whether these gains are large enough to fully explain the big city quality of life progress documented by these other authors.

One possible reconciliation of these findings is that a social multiplier effect is at work. Consider New York City during the 1990s. As crime fell, the city made a sharp comeback. Street safety and rising incomes may work synergistically to encourage more upscale stores, restaurants and night life to open. Put simply, market goods and city

quality of life are complements in providing consumer utility. A hedonic approach that solely focuses on conducting a separable decomposition teasing out each of these effects individually is likely to under-estimate the overall impact of these factors on urban quality of life. The net effect of crime and pollution reductions is that cities are stronger. This reduction in the cost of “city bigness” means that cities can grow and enjoy the beneficial effects of agglomeration.

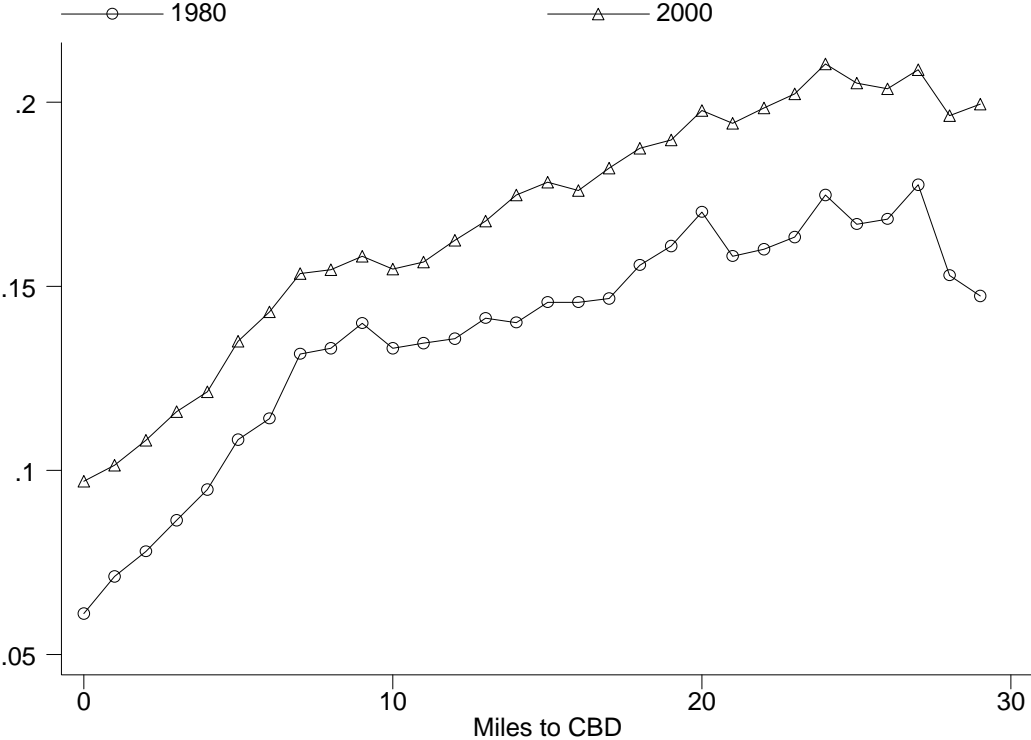
This study has focused solely on U.S cities. In developing countries where government regulation may be ineffective, is the marginal social cost of mega-city size at a point in time growth much larger?

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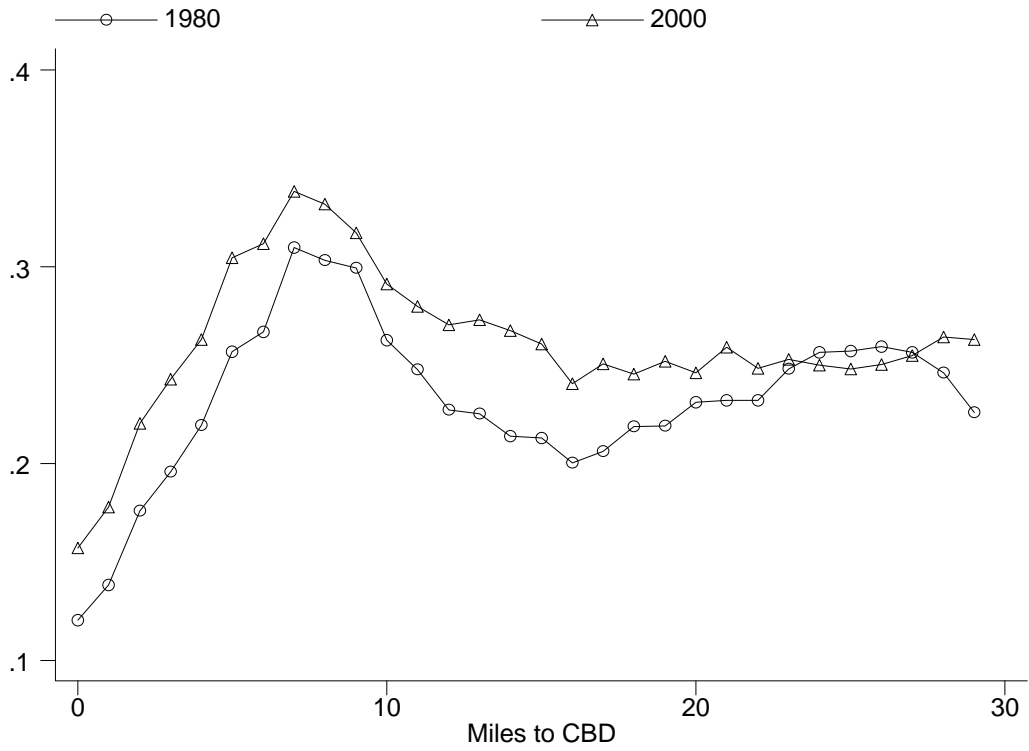
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Figure One



Share of Workers Whose One-Way Commute Time is Over 45 Minutes, All Metro Areas

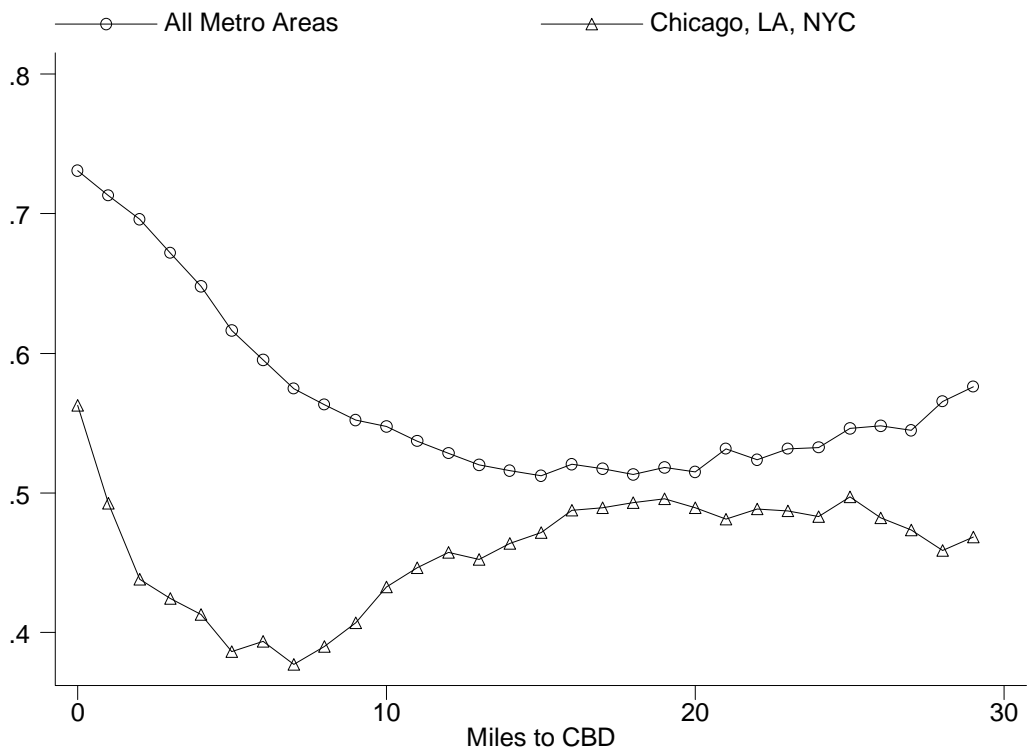
Figure Two



Share of Workers Whose One-Way Commute Time is Over 45 Minutes

Sample Includes Chicago, Los Angeles and New York City

Figure Three



Year 2000 Share of Commuters with One Way Commute Less than 25 Minutes

Figure Four

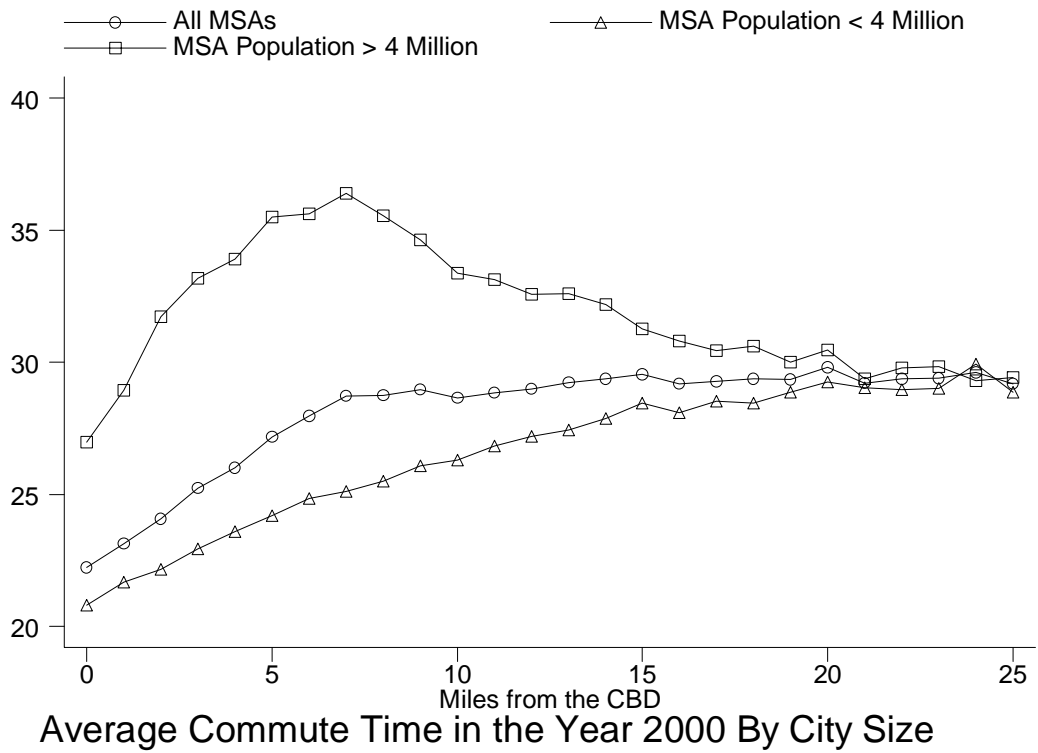


Figure Five

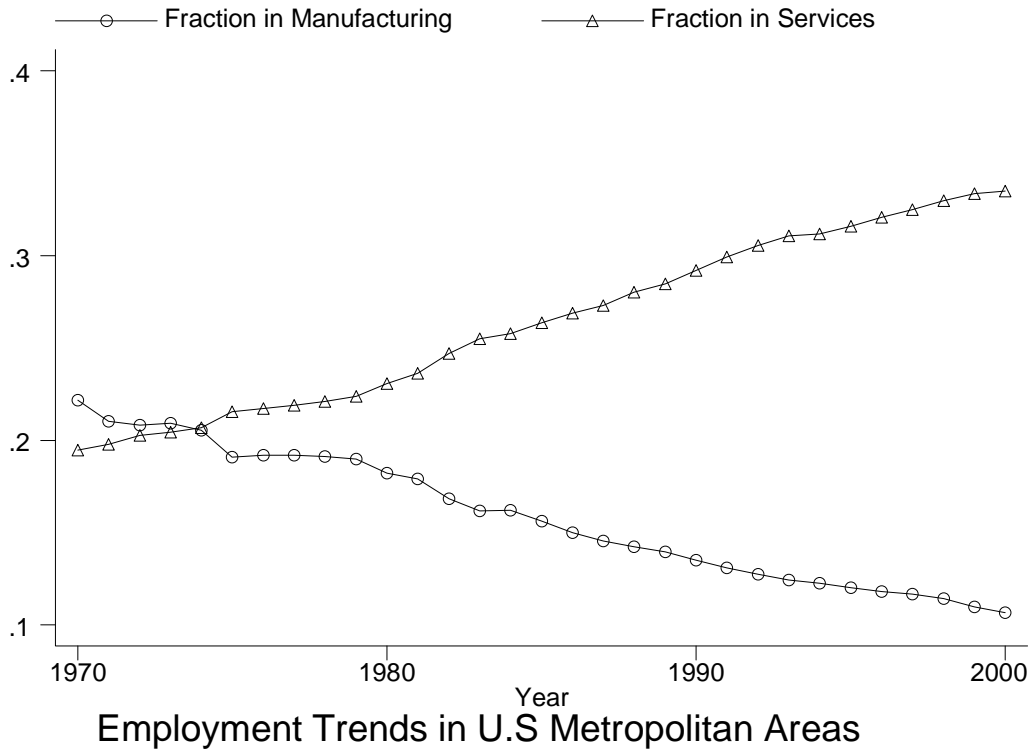


Table One: One Way Commute Time Elasticities by City Size

	All		Private Vehicle	
	beta	s.e	beta	s.e
Log(MSA Population)	0.1379	0.0271	0.0906	0.0087
Log(MSA Population)*1990 Dummy	-0.0018	0.0059	0.0071	0.0051
Log(MSA Population)*2000 Dummy	-0.0052	0.0064	0.0120	0.0048
Age	0.0018	0.0001	0.0018	0.0001
Male	0.1239	0.0092	0.1503	0.0080
Duncan SEI Index	0.0014	0.0002	0.0013	0.0001
Constant	0.8081	0.3348	1.2950	0.1363
Observations	1400363		1197907	
R2	0.038		0.032	
Year Dummies	Yes		Yes	

The dependent variable is the log of the one way commute time. The data set is the 1% IPUMS Sample From the 1980, 1990 and 2000 Censuses. The sample includes all workers who live in one of the hundred metropolitan areas that are identified in the 1980, 1990 and 2000 Census 1% samples. The omitted category is a female worker in the year 1980.

Table Two: Commuting Speeds in Cities Based on 2001 NHTS Micro Data

Column	Speed Measured in Miles Per Hour					
	(1)		(2)		(3)	
	beta	s.e	beta	s.e	beta	s.e
Log(Metropolitan Area Population Size)	-2.2870	0.4227	-2.4625	0.2774	-1.8149	0.2067
Distance to CBD			0.4472	0.0363	0.3847	0.0306
Commute Using Public Transit					-10.5490	0.7344
constant	62.5491	6.1644	59.9064	3.8177	51.6993	2.9003
observations	25778		25778		25778	
R2	0.023		0.0680		0.1010	

This table reports three OLS regressions. The unit of observation is a commuter. Standard errors are clustered by metropolitan area. In column (3), the omitted category is a worker who commutes by private vehicle.

Table Three: Time Trends in U.S Ambient Pollution Levels in Metropolitan Areas

	Log(Carbon Monoxide)		Log(Ozone)		Log(Nitrogen Oxide)		Log(TSP)		Log(PM10)	
	beta	s.e	beta	s.e	beta	s.e	beta	s.e	beta	s.e
time trend	-0.0424	0.0007	0.0024	0.0003	-0.0206	0.0006	-0.0206	0.0004	-0.0315	0.0007
log(county population)	0.2547	0.0152	-0.0138	0.0052	0.3272	0.0133	0.1142	0.0064	0.1245	0.0088
log(county population)*Mid West Dummy	-0.2072	0.0200	-0.0242	0.0067	-0.0623	0.0166	-0.0476	0.0082	-0.0681	0.0114
log(county population)*South Dummy	-0.1460	0.0192	-0.0128	0.0061	-0.1960	0.0152	-0.0928	0.0076	-0.1126	0.0103
log(county population)*West Dummy	-0.1684	0.0188	0.0330	0.0074	-0.0609	0.0171	0.0128	0.0086	-0.0049	0.0112
constant	-0.8979	0.0815	4.0750	0.0274	0.2322	0.0630	3.4027	0.0318	3.0604	0.0456
Fixed Effects	Region		Region		Region		Region		Region	
Observations	6366		9695		6540		10709		5653	
R2	0.4160		0.0630		0.3720		0.2770		0.3220	

The unit of analysis is a county/year for counties that are part of a metropolitan statistical area. The dependent variable is the log of a specific ambient pollutant. The data are from the years 1973 to 2000. The omitted category is a county in the Northeast.

Table Four: Metropolitan Area Crime Trends from 1994 to 2002

	Murders per 1000 People		Murders per 1000 People		Violent Crime per 1000 People		Violent Crime per 1000 People	
	beta	s.e	beta	s.e	beta	s.e	beta	s.e
Log(Population)	0.0148	0.0029	0.0212	0.0039	0.4862	0.0582	0.8585	0.1365
Log(Population)*Mid West			0.0070	0.0075			-0.2354	0.1564
Log(Population)*South			-0.0057	0.0050			-0.5379	0.1468
Log(Population)*West			-0.0045	0.0048			-0.1387	0.1966
Log(Population)*Time Trend	-0.0014	0.0004	-0.0015	0.0004	-0.0280	0.0056	-0.0305	0.0056
Constant	-0.0614	0.0250	-0.1605	0.0417	-2.5825	0.5445	-7.3409	1.5321
Observations	6338		6338		6338		6338	
R2	.043		.108		.097		.183	
Year Fixed Effects	Yes		Yes		Yes		Yes	
Region Fixed Effects	No		Yes		No		Yes	

The sample includes all counties that are located in a metropolitan area. In columns (2) and (4), the omitted category is a county in the Northeast. Murders per 1000 people has a mean and standard deviation of .047 and .071. Violent crimes per 1000 people has a mean and standard deviation of 1.86 and 1.63.

