Urban Policy Effects on Carbon Mitigation

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Introduction

Suppose that your household was choosing between living in suburban Houston or center city San Francisco. In each case, what would your household's annual carbon footprint be? Glaeser and Kahn (2010) estimate that a standardized household would create 12.5 extra tons of carbon dioxide per year if it moved to Houston rather than moving to San Francisco. In Houston, the same household drives more, lives in a bigger home, uses more residential electricity – electricity that is generated by power plants with a higher emissions factor. Using data from 2006 for 74 major Chinese cities, Zheng, Wang, Glaeser and Kahn (2010) document that northern cities have the largest household carbon footprints due to coal burning for winter heat. This cross-sectional descriptive work creates a benchmark for comparing cities' household carbon emissions from transportation, electricity consumption and home heating, at a point in time and tracking city trends over time. In both studies, there is clear evidence that cities differ sharply with respect to their "greenness" on this important dimension. Given that greenhouse gas emissions are a global externality, households are unlikely to internalize this cost of moving to a city like Houston when they make their locational decisions.

Why is San Francisco "greener" than Houston? San Francisco is blessed with a temperate climate. Northern California's electric utilities emit less greenhouse gas emissions per unit of power generated than their Texas counterparts. In addition to these factors, San Francisco's urban form and public transit system encourage more households to live a walking, compact, "new urbanist" life relative to households living in sprawling Houston.

This discussion highlights that there are a number of urban policies that can affect a metropolitan area's per-capita carbon emissions. Rather than attempt to tease out the individual contributions of any one policy, I focus on estimating how much does a household's carbon footprint shrink by when it lives closer to the city center. Throughout this paper, I assume that urban areas can enact a range of policies including urban transit investments, to business incentives (such as urging major employers to remain downtown) and center city quality of life improvements. Such policies increase the demand for living and working in the center city. I seek to measure the carbon mitigation externality benefits of having a more vibrant center city that attracts households to live closer to the center.

To quantify the greenhouse gas emissions reductions benefits from living at higher population density, and closer to the city center, this paper uses recent micro data from the 2009

National Household Transportation Survey and unique 2008 data from a California electric utility to measure how a household's carbon footprint varies as a function of how close it lives to the city center, and proximity to rail transit. This paper's main finding is that a standardized household drives less and consumes less electricity when it lives closer to the city center than if it lived in the same metropolitan area's suburbs.

Is this a causal effect? A reasonable concern is residential self-selection; those with an unobserved taste for living a "low carbon" life cluster close to rail transit stops and close to city centers. My cross-sectional OLS estimates are likely to reflect a mixture of selection and treatment effects and thus to represent an upper bound on the policy induced benefits of moving a household chosen at random closer to the city center.

Urban Transportation

Miles Driven as a Function of Urban Form

The Department of Transportation has recently released the 2009 National Household Transportation Survey (NHTS).[2] This micro data set is distinctive because it reports household vehicle mileage for a large representative sample of households. I have been able to access a special version of the data set that has census tract identifiers. Using data from Baum-Snow and Kahn (2005), I restrict the sample to households living within 35 miles of a major city center. For each household, I observe which metropolitan area it lives in, its distance to the City Center and its distance to the closest rail transit station using data from Baum-Snow and Kahn (2005). I estimate ordinary least squares regressions using observations on 100,519 households based on equation (1):

$$\ln(1 + miles) = MSA + B_1 * Demographics + B_2 * Urban\ Form + U \qquad (1)$$

In this regression, the dependent variable is the log of 1 + total household miles driven. Controlling for metropolitan area fixed effects, dummy variables for the household's income category, the household head's age and the number of people in the household, the key coefficients of interest are urban form variables. This set of variables includes; the log of the household's distance to the city center, the log of population density in the census tract in which

[2] http://nhts.ornl.gov/download.shtml#2009

the household lives and a dummy variable that equals one if the household lives within one mile of a rail transit station.

As shown in Table One, I find that mileage elasticity with respect to distance from the city center equals .219. This means that a 10% increase in a household's distance from the city center is associated with driving 2.2% more miles per year. The dummy variable "close to rail transit station" has a coefficient of -.21 but it is statistically insignificant. This variable's coefficient indicates that households who live within one mile of a rail transit station drive 21% less than households who do not. The final urban form variable is the household's census tract's population density. Households who live in areas with more people per square mile drive less. The density elasticity of -.126 indicates that a 10% increase in tract population density is associated with a 1.3% reduction in miles driven. These three urban form variables are jointly statistically significant at the 1% level. I recognize that the dependent variable in equation (1) (log(1+miles)) represents a mixture of a discrete choice (vehicle ownership) and utilization. To study the relationship between urban form and vehicle ownership and vehicle usage conditional on owning a vehicle, I break out these variables separately in Table One's columns (2,3,5, and 6).

These correlations are suggestive about the role that urban policy plays in encouraging driving less. If households were randomly assigned to homes, then OLS estimates of equation (1) would be of immediate use to policy makers in determining how urban policies affect an important part of the household carbon footprint (miles driven). But, we know that households self select where they want to live. Liberal/environmentalists are likely to self-select and choose to live in the high density areas, close to center city and close to subway stations (Kahn and Morris 2009). This means that OLS estimates are likely to over-state the true causal effect of how a random household's transit behavior would change if it was randomly assigned to a "new urbanist" location. An active research agenda in urban planning examines the importance of attitudes, beliefs and preferences in determining residential location choice and travel behavior (e.g. Cao, Handy, and Mokhtarian, 2006; Cao, Mokhtarian, and Handy, 2007; Krizek, 2003).

Public Transit Use from 1970 to 2000

In previous research with Nate Baum-Snow, I have examined how worker public transit varies across cities and over time for cities that have expanded their rail transit systems (Baum-Snow and Kahn 2005). This work has public policy implications because rail transit construction is a favorite urban policy for encouraging center city growth and compact urban development.

Communities differ with respect to their distance to the CBD and their distance to rail transit stations. Rail transit is a fast means for commuting to the city center. As discussed in Glaeser and Kahn (2001 2004), a fundamental challenge for urban policy in battling climate change is that jobs continue to suburbanize. When people work in the suburbs, they do not use public transit to commute there. But, in cities such as New York City with a vibrant center city core, public transit remains an important commuting mode.

To examine how rail transit access affects commute mode choice, I use census tract level data for 42 major metropolitan areas. I examine how proximity to the CBD and proximity to rail transit correlates with public transit use. I use a geocoded census tract panel data set from 1970, 1980, 1990 and 2000 and observe public transit use by workers (the percent of the census tract who commute using public transit), while restricting the sample to tracts within 35 miles of a major city's CBD.

In Table Two, the dependent variable is a tract's public transit use share. Each column reports a separate regression. In columns 1-3, I include all metropolitan areas that are within 35 miles of a city center that has a rail transit system. Controlling for metropolitan area fixed effects, several facts emerge. Relative to the omitted category (1970), the propensity to commute by public transit has declined each decade. The probability of using public transit declines with distance from the city center and increases if a tract is close to public transit. These results are robust to controlling for tract demographics such as the share black and the share college graduate (see columns 2 and 5). Columns (3) and (6) mimic the identification strategy reported in Baum-Snow and Kahn (2005). I exploit the fact that 16 major cities (including Boston, Washington D.C) expanded their rail transit systems between 1970 and 2000. These expansions mean that there are census tracts that were more than one mile from the closest station before "treatment" and due to the transit expansion are now within one mile of the closest station. I use this within tract variation to estimate equation (2) while including census tract fixed effects. As shown in Table Two's columns (3) and (6), I find that the average tract that experiences access to public transit gains a 2.3 percentage point increase in the propensity to commute using public transit. As shown in column (6), for a smaller set of seven major metropolitan areas (Boston, Chicago, Dallas, Los Angeles, New York City, San Francisco and Washington D.C), I estimate a larger 3.5 percentage point increase.

2008 Electricity Consumption in Northern California

In this section, I use unique micro data to study household electricity consumption as a function of urban form from a utility in California. I use household level data from July 2008 for homeowners. The dependent variable will be the log of daily average electricity consumption in July. I model this consumption as a function of attributes of the home such as; size of home, year built, swimming pool, and basic attributes of the household; income, age of head, and number of people in the household. Controlling for these standard factors, I examine how electricity consumption varies with a household's distance from the City Center.

$$\ln(electricity) = c + B_1 * Demographics + B_2 * Urban\ Form + U \qquad (2)$$

Why would urban form matter? Standard urban economics teaches us that land prices decline with distance from the city center to compensate households for longer commutes. If land prices are lower, then homes will be larger further from the city center and will be more likely to have durables such as swimming pools.

Table Three reports the regression results. The table reports seven regressions. In columns (1-3), the dependent variable is the log of average electricity consumption in July for 140,482 homeowners in 2008. Richer households and larger households consume more electricity. Controlling for these demographics, the electricity consumption/distance from the City Center elasticity equals .17. A 10% increase in distance is associated with a 1.7% increase in consumption.

In column (2), I include extra housing attributes such as the size of the house, its year built and whether it as a swimming pool. These variables all have intuitive signs with regards to electricity consumption but to my surprise the distance coefficient only shrinks slightly down to .168. Households who live further from the city center may spend more time at home than the urbanites. Columns (4-6) of Table Three switch the dependent variable. Further from the city center, where land is cheaper, homes are larger, newer and more likely to have a swimming pool.

The data provide the opportunity to study the role of residential self selection. As shown in column (7), households who are registered as Democrats, Green Party, and Peace and Freedom Party members live closer to the city center than Republican communities. If Democrats, on average, choose to have a smaller consumption footprint then part of the distance/electricity consumption gradient may be explained by household sorting rather than by a true causal effect of density. To test this, I re-estimate equation (2) while controlling for the community's political party registration. As shown in column (3), controlling for a block group's politics shrinks the distance coefficient by 25% (down to .12).

Urban Policies that Encourage City Living

This paper's empirical work highlights that people who live closer to city centers have smaller carbon footprints. In part, this is selection but likely to also be a treatment effect. So, if we take this result seriously, how do we encourage more households to live downtown? Public transit expansions will help if the city has a vibrant downtown that people want to go to (Kahn 2005). The vibrancy of downtown can be spurred by fighting crime and by improving urban public schools (Berry-Cullen and Levitt 1998). While street safety, improving the quality of public schools, and using incentives to keep businesses located downtown do not appear to be "urban climate policy", they all indirectly strengthen the city's core.

While these policies directly and indirectly reduce a city's greenhouse gas emissions, there are other policies being pursued by many cities that actually unintentionally raise greenhouse gas emissions. New highways cause population and employment suburbanization (Baum-Snow 2007). Another example is center city land use regulation (Glaeser, Gyourko and Saks 2005, and Quigley and Raphael 2005). When center cities such as Boston and San Francisco and Manhattan make it difficult to build new housing, it pushes urban growth to the sprawling suburbs. Such a "deflection effect" has carbon consequences due to the results I documented in Tables 1-3. For example, if Santa Monica, a city with temperate climate and near the beach, blocks new housing construction, the housing development thus occurs in the desert climate of Riverside – requiring more electricity use in this hotter area that features lower home prices. As such sprawling suburban communities boom, they have the political clout to lobby for electricity and water subsidies that further increases the region's carbon footprint.

Conclusion

The low carbon city is a city that is compact and dense, and offers fast, frequent public transit that helps people commute to downtown. The city center is a vibrant hub featuring cultural opportunities, jobs, and entertainment. Ideally, it is located in a region whose electricity is generated by renewable power.

The "macro" debate about the costs and benefits of adopting carbon pricing has not discussed how carbon mitigation incentives will affect competition between center cities and their suburbs. The residents of low carbon cities will face less of the carbon tax burden. Previous incidence studies have focused on geography and income categories but not the center city/suburbs dimension (Hassett , Mathur, and Metcalf 2007). The introduction of a significant carbon tax may help to reverse a fifty year trend in the suburbanization of households and firms (Glaeser and Kahn 2004).

Such a tax could sharply reduce the current carbon gap between cities such as San Francisco and Houston. In the presence of such a tax, Houston would have an incentive to adopt various policies that San Francisco already has and some convergence would be achieved. Urban economists have tried to use the "natural experiment" of the OPEC Oil Shocks to examine whether high gas prices encourage densification (Muth 1984). These short run shocks did not increase the demand for center city living but the 1970s was a different era featuring high center city crime rates.

Urban policies that strengthen center city quality of life will encourage people to live at high density close to the city. In recent years, the population has suburbanized. The average person who lived in a metropolitan area lived 9.8 miles from the City Center in 1970 and this distance grew to 13.2 miles by the year 2000.

This 35% increase in average distance from the City Center has carbon implications. Based on the results presented in this paper, this increase in distance over time has increased our carbon footprint from driving and electricity consumption by 7%. A productive future line of research should use panel data to disentangle whether the observed correlation between center city living and the low carbon lifestyle represents a self selection effect or a true causal effect brought about by urban policies.[3]

[3] See Eid, Overman, Puga and Turner (2008) for a recent study that uses panel data to attempt to estimate the impact of urban form on obesity. By observing weight changes for migrants from center cities to suburbs (and vice-versa), the reject the claim that "sprawl is making us fat".

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Table One: Household Miles Driven in 2009 as a Function of Urban Form

	All Metropolitan Areas			Major Metropolitan Areas		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	ln(1+mile)	No Car	ln(mile)	ln(1+mile)	No Car	ln(mile)
Household Size	0.192	0.003	0.271	0.354	-0.009	0.317
	[0.031]***	[0.003]	[0.008]***	[0.054]***	[0.005]*	[0.020]***
Age of Head of Household	-0.001	-0.001	-0.009	0	0	-0.008
	[0.003]	[0.000]**	[0.001]***	[0.006]	[0.001]	[0.002]***
Log(Distance to City Center)	0.22	-0.02	0.04	0.406	-0.043	0.01
	[0.055]***	[0.006]***	[0.017]**	[0.145]***	[0.015]***	[0.043]
1(Within 1 Mile of Rail Transit)	-0.214	0.01	-0.152	-0.059	-0.007	-0.167
	[0.231]	[0.026]	[0.091]*	[0.291]	[0.032]	[0.104]
Log(Census Tract Density)	-0.126	0.007	-0.068	-0.174	0.009	-0.106
	[0.029]***	[0.003]**	[0.008]***	[0.071]**	[0.007]	[0.018]***
Constant	5.536	0.418	9.478	3.678	0.653	9.974
	[0.716]***	[0.075]***	[0.218]***	[1.907]*	[0.201]***	[0.546]***
Observations	100519	100519	84579	14424	14424	12135
R-squared	0.18	0.13	0.296	0.21	0.154	0.316
fixed effects	Metro	Metro	Metro	Metro	Metro	Metro
Household Income Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

The unit of analysis is the household. The dependent variable in columns (1) and (4) is the log(1+household annual mileage). In columns (2 and 5), the dependent variable is a dummy that equals one if the household does not own a car. In columns (3) and (6), the sample only includes households who drive more than zero miles. The sample in columns (1-3) includes all households in the 2009 NHTS who live in a census tract whose centroid is within 35 miles of a city center. In columns (4-6), the sample is the subset of households who live within 35 miles of the CBD of Boston, Chicago, Dallas, Los Angeles, New York City, San Francisco and Washington D.C. *** indicates statistical significance at the 1% level. Standard errors are reported in brackets. The standard errors are clustered by census tract. The omitted category is a household who lives more than a mile from the closest rail transit station. Dummy variables for the household's income category are included in the regressions but their coefficients are suppressed.

Table Two: Public Transit Use and Urban Form from 1970 to 2000

	Tract Share of Workers Commuting Using Public Transit					
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Tract Distance to CBD)	-0.119	-0.109		-0.15	-0.142	
	[0.001]***	[0.001]***		[0.001]***	[0.001]***	
1(Within 1 Mile of Rail Station)	0.043	0.038	0.023	0.032	0.025	0.035
	[0.002]***	[0.002]***	[0.001]***	[0.002]***	[0.002]***	[0.002]***
1980 Year Dummy	-0.024	-0.022	-0.011	-0.031	-0.029	-0.016
	[0.001]***	[0.001]***	[0.000]***	[0.002]***	[0.002]***	[0.001]***
1990 Year Dummy	-0.032	-0.033	-0.021	-0.037	-0.036	-0.026
	[0.001]***	[0.001]***	[0.000]***	[0.002]***	[0.002]***	[0.001]***
2000 Year Dummy	-0.032	-0.034	-0.021	-0.036	-0.036	-0.026
	[0.001]***	[0.001]***	[0.000]***	[0.002]***	[0.002]***	[0.001]***
Tract Share College Graduate		0			-0.002	
		[0.002]			[0.004]	
Tract Share Black		0.148			0.149	
		[0.002]***			[0.002]***	
Constant	1.329	1.204	0.154	1.682	1.585	0.214
	[0.006]***	[0.005]***	[0.000]***	[0.009]***	[0.008]***	[0.001]***
Observations	74076	74076	74076	40805	40805	40805
R-squared	0.665	0.701	0.969	0.654	0.686	0.97
fixed effects	metro	metro	tract	metro	metro	tract

This table reports six ordinary least squares regressions. The omitted category is a 1970 census tract whose centroid is more than one mile from the closest rail transit station. In columns (1-3), the sample includes all census tracts whose centroid is within 35 miles of a CBD in a city with a rail transit system. In columns (4-6), the sample is the set of census tracts within 35 miles of the CBD of Boston, Chicago, Dallas, Los Angeles, New York City, San Francisco and Washington D.C. *** indicates statistical significance at the 1% level. Standard errors are reported in brackets. The dependent variable has a mean of .16 and a standard deviation of .19.

Table Three: Urban Form and Residential Electricity Consumption in a California County

	log(Daily Average kWh in July)			log(feet)	Year Built	Pool	Block % Liberal
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log(household income)	0.167	0.052	0.094	0.255	6.303	0.112	-0.051
	[0.015]***	[0.011]***	[0.007]***	[0.014]***	[1.463]***	[0.012]***	[0.007]***
Age of Head of Household	-0.002	-0.003	-0.003	0.001	-0.228	0	
	[0.000]***	[0.000]***	[0.000]***	[0.000]*	[0.031]***	[0.000]**	
Household size	0.11	0.093	0.088	0.028	-0.038	0.019	
	[0.004]***	[0.003]***	[0.003]***	[0.003]***	[0.199]	[0.004]***	
log(distance to CBD)	0.17	0.168	0.121	0.067	13.999	0.049	-0.116
	[0.022]***	[0.022]***	[0.026]***	[0.018]***	[3.502]***	[0.012]***	[0.011]***
log(interior space)		0.377	0.414				
		[0.019]***	[0.020]***				
Year Built		-0.003	-0.003				
		[0.001]***	[0.001]***				
Swimming Pool		0.33	0.337				
		[0.008]***	[0.008]***				
Share of Block College Graduate			-0.42				
			[0.084]***				
Share of Block Liberal			-0.237				
			[0.130]*				
Constant	-0.121	3.866	4.217	3.861	1,785.70	-1.574	2.124
	[0.220]	[1.370]***	[1.358]***	[0.172]***	[27.914]***	[0.128]***	[0.134]***
Observations	140482	140482	140482	140482	140482	140482	140482
R-squared	0.174	0.266	0.272	0.308	0.324	0.062	0.652

This table reports seven ordinary least squares regressions. The unit of analysis is a homeowner. The omitted category is a home that does not have a swimming pool.*** indicates statistical significance at the 1% level. Standard errors are reported in brackets.