Causes of Urban Sprawl in the United States: Auto Reliance as Compared to Natural Evolution, Flight from Blight, and Local Revenue Reliance

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Abstract

This paper describes a statistical study of the contribution of theories previously offered by economists to explain differences in the degree of urban decentralization in the U.S. The focus is on a relative comparison of the influence of auto reliance. A regression analysis reveals that a 10 percent reduction in the percentage of households owning one or more autos would reduce the square mile size of an urban area by only 0.5 percent and raise its population density by only 0.7 percent. Factors falling under the categories of "natural evolution" and "flight from blight" exert a far greater magnitude of influence. For instance, a 10 percent reduction in per capita income would reduce the square mile size of an urban area by 11.4 percent and raise its population density by 10.1 percent, while a 10 percent decrease in the percentage central place(s) population poor would reduce the square mile size of an urban area by 2.6 percent and raise its population density by 1.7 percent. A significant increase in urban decentralization will require more than just reduced auto reliance. *© 2008 by the Association for Public Policy Analysis and Management.*

INTRODUCTION

"Urban sprawl"—or what is characterized here as urban decentralization—is a contentious and widely debated topic among academics, urban planners, and the general public. The term is now a catch phrase that regular Americans use to label the underlying factor they believe responsible for many of the undesirable outcomes occurring in metropolitan areas: increased automobile travel and congestion, lack of functional open space, air and water pollution, loss of farmland, tax dollars spent on duplicative infrastructure, lack of employment accessibility, concentrated poverty, and racial and economic segregation (see Ewing, 1994, 1997; Sierra Club, 1998; Downs, 1999; Wasserman, 2000). Others point to the desirable metropolitan outcomes that decentralization can yield, including the increased satisfaction of housing preferences, the accommodation of automobile travel, the benefits of later filling in of "leapfrogged" land, and the generation of an increased number of suburban local governments, of which many are likely to have lower crime rates and better public schools (see Siegel, 1999; Burchell et al., 2000; Conte, 2000; Gordon & Richardson, 2000; and Glaeser & Kahn, 2003). If the undesirables of decentralization outweigh the desirables (as many urban planners believe), then it is appropriate to consider the adoption of public policies designed to reduce sprawl.

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Small (2000) believes it is difficult to evaluate the effectiveness of policies designed to reduce sprawl if we do not better understand the causes of sprawl. The purpose of this paper is to offer an empirical investigation of the validity of causal factors previously proposed as generators of urban sprawl. These results are produced in response to the reasonable criticism of Small and others that not enough is known about the factors that generate sprawl to be able to develop effective (often labeled "smart growth") policies to slow it. Many believe as Salingaros (2006, p. 114) that: "Sprawl exists only because it is an outgrowth of car activities." Thus, the focus here is on how auto reliance as a generator of sprawl in the U.S. compares in magnitude to other causal factors previously put forth by urban economists.

Since this is an empirical investigation of differences in the degree of sprawl across urban areas, the next section offers a review of previous views on defining urban sprawl and one way to quantify differences in the degree of its occurrence across U.S. urban areas. Following that is a summary of the general factors previously proposed as causing sprawl. I describe the theory behind the regression analysis and the data used to represent the chosen dependent and explanatory variables in the fourth section. The fifth section contains the regression results. The conclusion offers a summary of the findings and their implications for crafting policy to reduce the amount of sprawl in U.S. urban areas.

Measuring Sprawl

The economic and planning literature was examined for guidance on an appropriate empirical measure of differences in the degree of sprawl across a sample of urban areas. As demonstrated in the writings of Gordon and Richardson (1997), Mills (1999), and Brueckner (2000), economists associate the degree of sprawl in an urban area with "excessive" decentralization. Decentralization is considered excessive when it imposes greater net costs upon society than would have been generated if the corresponding urban development had instead occurred in the area's central places(s) and/or at a higher overall density. Urban planners often identify sprawl through the description of specific types of undesirable urban land uses. Ewing (1994) notes that the characteristics of sprawl's occurrence that have widely appeared in the planning literature include: (1) low-density, scattered, and/or dispersed development, (2) separation of where people live from where they work, and (3) a lack of functional open space.

To turn these concepts into a quantifiable measure of the degree of sprawl in a U.S. urban area, I rely upon the "density" portion of the definition offered by Galster et al. (2001, p. 685):

> Sprawl (n.) is a pattern of land use in an urbanized area that exhibits low levels of some combinations of eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity.

Glaeser and Kahn (2003) and Nechyba and Walsh (2004) also believe that the observable characteristics of low density and decentralization best capture what Americans view as sprawl. Based upon this consensus, along with available census data, a greater degree of sprawl in a U.S. urbanized area (UA) is accounted for here if (1) it uses a larger number of square miles to contain the same number of residents, or, alternatively, if (2) overall population density is lower.[1]

As noted by Wolman et al. (2005), disagreement exists on how to measure sprawl in a quantifiable manner that allows for the statistical testing of cause and effect relationships related to the concept. There is debate over both the appropriate geographical unit to measure sprawl by and whether it is best measured as a one-dimensional or multidimensional concept. The county-based geographic measure of a metropolitan statistical area is likely an "overbound" of the appropriate geographical unit, while the density-based measure of a UA can yield an "underbound." Perhaps the most appropriate geographic unit by which to measure sprawl is along the lines of Wolman et al.'s measure of an "extended urban area" that adds additional census blocks to the UA that contain 60 or more dwelling units, and in which 30 percent or more of the workers in the added blocks commute to the UA. Such a measure captures the low-density, leapfrogged development patterns at the edge of urbanized areas that many contend are the essence of sprawl and a pure UA definition can miss. The difficulty in using the geographic unit of an extended urban area is that it needs to be calculated by hand, not only for the chosen way of measuring sprawl, but also for the causal variables expected to influence sprawl.

I recognize the possibility that the use of the UA as the geographic unit by which to account for sprawl can result in an underbound measurement, but I make this realistic compromise given the appropriate data being widely collected for this geographic unit. In addition, the one-dimensional use of two forms of population density to characterize differences in the degree of sprawl across U.S. UAs needs to be noted. Before attributing the causal results described here to a multidimensional concept of sprawl, the analyses should be repeated for the four other measures of sprawl proposed by Galster et al. (2001).[2]

Figure 1 demonstrates the strong nonlinear relationship between population and square miles in the 452 urbanized areas in the U.S. in year 2000. The dashed line in the figure is a fitted linear regression that exhibits an R-squared of nearly 0.9. But Figure 1 also illustrates that for a given population there are differences in the land used in U.S. urbanized areas to contain it. Urbanized areas above the fitted line use more land area for a given population (for example, Columbus, MO, and Philadelphia, PA) than the typical U.S. UA, while others (for example, Watsonville, CA, and Chicago, IL) use less. For example, consider the urbanized areas of Kailua, HI, and Duluth, MN, both with populations very near the median population of all U.S.

[1] See Appendix A of the U.S. Census Bureau's PHC-3-A publication, retrieved December 21, 2007, from www.census.gov/prod/cen2000/phc-3-a.pdf, for a full description of the year 2000 method of choosing U.S. urbanized areas (UAs) and the designated central place(s) within them. It is important to note that census designated UAs prior to 2000 are not comparable. In 1990 the census designation of a UA focused on the inclusion of whole places wherever possible, and UAs were crafted to generally include all territory from previous census UA delineations; that is, grandfathering was used extensively and the square miles of a UA rarely shrank. Also, incorporated place territories that had 100 people per square mile were automatically fully included in the UA. In year 2000, the census switched its inclusion emphasis to a minimum population density of 1,000 without regard to incorporated area boundaries. Thus, I am restricted to the use of one year of data from U.S. UAs.

[2] In an empirical test of whether using the urbanized area or the extended urban area makes a difference in the population density calculated for six large U.S. urban areas, Wolman et al. (2005, p. 99) find the correlation between the two densities to be 0.95. For the one-dimensional measurement of sprawl by population density, the choice of either of these two geographic units makes little difference, though they also demonstrate that this cannot be said for the other four dimensions of sprawl suggested by Galster et al. (2001).

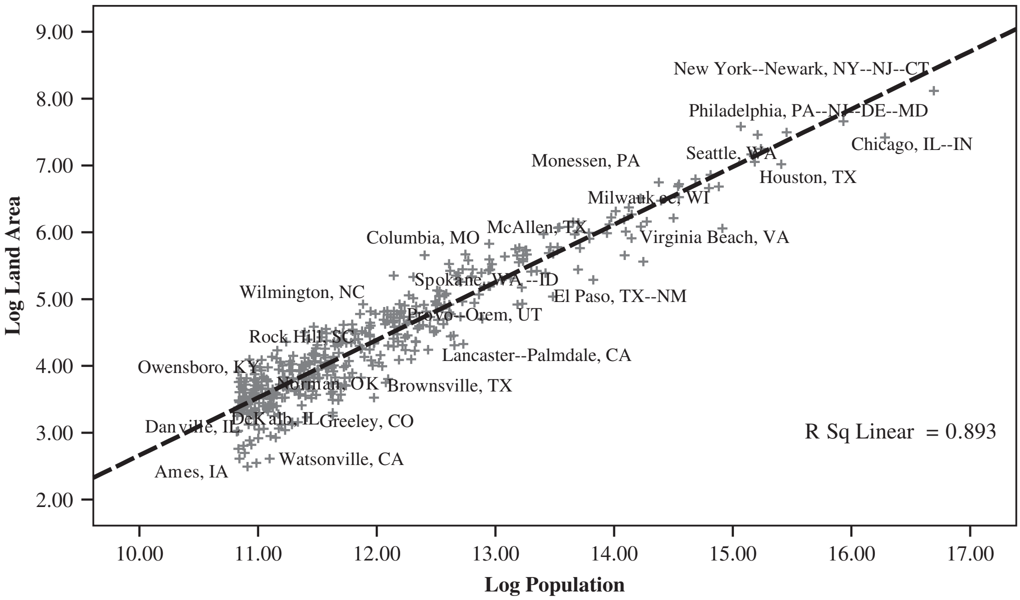

Figure 1. Log of Land Area and Log of Population for 452 U.S. Urbanized Areas in 2000.

urbanized areas of 118,000, but with respective urbanized land areas of 32.6 and 66.3 square miles, respectively.[3] Most would judge Duluth more sprawled than Kailua.

Causes of Sprawl

The earliest motivation for this study is the work of Brueckner and Fansler (1983). They use the traditional monocentric urban model of Alonso (1964), Mills (1967), and Muth (1969) to structure a regression analysis that explains differences in the 1970 square-mile size of 40 U.S. urbanized areas. This model requires that the area's total population fits inside its square miles and land rent at the radius of the urban area equals the rent paid to land in agricultural use. In this model, the size of the urban area is positively related to household income and negatively related to commuting costs. The Alonso, Mills, and Muth model does not account for other household characteristics due to the assumption that, with the exception of income, households are identical in the characteristics that influence their land use preferences.

Employing this simple urban model, the explanatory variables used in Brueckner and Fansler's regression include population, agricultural land price, income, and one of two proxies for commuting cost (percentage of commuters using public transit or percentage of households owning one or more autos). Based upon the explanatory power of their regression results and the statistical significance of regression coefficients, they suitably conclude that urban decentralization is not the result of a market system out of control, but that it generally follows an orderly process. Mieszkowski and Mills (1993) label the causal factors included in Brueckner and Fansler's study as making up the "natural evolution" theory of what causes

[3] This example illustrates the benefit of using the urbanized area as opposed to the metropolitan statistical area as the appropriate geographic unit to measure sprawl in places like Duluth, MN, and Kailua, HI. Duluth is located in St. Louis County, which is 6,226 square miles in size. Kailua is in Honolulu County, which is 600 square miles in size. As discussed in Wolman et al. (2005), the use of the entire county to measure population density for the Duluth urban area would clearly result in an overbound measure of sprawl.

greater suburbanization. Gordon and Richardson (2000) also write about the natural economic factors that have generated the greater dispersion observed in U.S. urban areas over the last 50 years. McGrath (2005) and Song and Zenou (2006) expand upon Brueckner and Fansler's study and further confirm the robustness of the Alonso, Mills, and Muth model through their regression findings.

Mieszkowski and Mills describe "flight from blight" as another important theory for the increased suburbanization of U.S. metropolitan areas. This theory proposes that greater decentralization observed in U.S. urban areas is in part driven by the repellant factors of higher tax rates, higher crime rates, crumbling infrastructures, low-performing public schools, and a greater presence of the poor and lower class that is often observed in America's central cities and inner-ring suburbs. Flight from blight looks beyond the natural forces that increase the footprint of an urban area and decrease population density, seeking a further explanation for urban decentralization based upon the desire to avoid the real and perceived blight of more centralized locations.

Mieszkowski and Mills (1993) conclude that both the natural evolution and flight from blight theories of urban decentralization are important to explaining differences in the degree of decentralization observed across U.S. urban areas in the late 20th century. They note that empirical research has already provided strong documentation in support of natural evolution, but suggest that more empirical work needs to be done on the significance of flight from blight factors.

A third theory of what can cause greater decentralization in U.S. urban areas is local revenue reliance regarding property or sales taxation. Land use decisions are fiscalized when they are influenced to a large degree by the local fiscal surplus that a particular land use generates for a community, and subsequently influenced to a lesser degree by what residents of the community need for consumption and employment purposes. Ladd (1998) concludes that fiscal impact analysis has been a local planning tool in the U.S. since at least the 1940s. Misczynski (1986), Brunori (2004), and Pagano (2003) have all pointed out that local fiscal impact analysis has increased in importance in states whose local governments have enacted statewide property tax limitations. As Lewis (2001) notes, there has been much discussion regarding the pervasiveness of fiscalized land use decisions, but few empirical studies have tried to isolate fiscal considerations from other influences on urban land use outcomes.

The amount of overall retail activity in an entire urban area is determined by factors such as population, income, age distribution, etc., in the region and is unlikely to change due to local government influence; however, local land use decisions can shape the distribution and form of overall retail development in an urban area. Local governments with undeveloped land—which are more likely to exist at the fringe of an urbanized area—are also more likely to zone this land for a low-density retail use such as an auto mall, big-box store, or regional shopping mall if local sales taxation is present, because of the local fiscal surplus that such forms of retail generates for them. Also, the placement of retail centers at the edge of a jurisdiction (or an urbanized area) serves the purpose of generating sales tax revenue for a jurisdiction from outside the jurisdiction. Concentrated retail activity at the edge of an urbanized area has the effect of pulling population beyond the edge (because it shortens shopping trips for those living beyond the edge) and generating sprawl. With the addition of local sales tax revenue, cities on the edge of an urbanized area can better use their powers of annexation to expand their jurisdictional boundaries, and this can also aid in the generation of greater sprawl.

There exists some evidence for the theory that greater local sales tax reliance yields greater urban decentralization. Lewis (2001) surveyed land use officials in 471 California cities, asking them to rank 18 listed motivations for evaluating the desirability of new and redevelopment projects. "New sales tax revenues generated" ranked first for new development and was tied for first with "city council support for the project" for redevelopment projects. In support of the argument just presented, non-central city officials were more likely to rank sales tax revenue higher than their central city colleagues. Wassmer (2002, 2003) finds that overall and big-box retail sales at the fringe of urban areas in the western U.S. are positively related to the fraction of statewide own-source municipal revenue gained from sales taxation.

Regarding local property tax reliance and urban decentralization, Brueckner and Kim (2003) demonstrate that the expected influence of a property tax on urban land use can be a reduction in the intensity of land development, a subsequent decrease in population density, and an increase in the spatial size of an urban area. As Pagano (2003) describes, an additional avenue in which property tax reliance may encourage sprawl is that a capital tax can discourage urban infill development. Taxing capital reduces the cost of holding inner city vacant land and reduces the incentive for owners of these vacant lands to develop. This can drive metropolitan development farther out. However, as noted by Brueckner and Kim (2003), the negative influence that property taxation has on housing prices also causes the quantity of overall housing capital demanded in an urban area to fall. Holding population and improvements per acre constant, if dwelling sizes decrease in response to the decrease in demand for housing capital, population density increases and the land required to house a fixed population decreases (or, as measured here, less sprawl). The theoretical effect of local property taxation on the size of an urban area is therefore ambiguous under general assumptions. Using a specific form of an individual preference function, Song and Zenou (2006) derive the theoretical effect that greater reliance on local property taxation results in urban areas that use less land. They confirm this prediction with a detailed empirical investigation of the size of U.S. urbanized areas.

Burchfield et al. (2006) use remote-sensing data taken from outer space to measure sprawl in the U.S. as the percentage of open space in each of the square kilometers that make up 275 urban areas in 1992. These percentages are aggregated for an urban area and regressed against measures that proxy for factors expected to cause differences in them. They find that measures of the lagged percentage of the types of the area's employment that is more likely for economic reasons to desire centralized locations, lagged streetcar passengers per capita, lagged percentage of the urban fringe incorporated, and the presence of surrounding mountains are all associated with less open space, while population growth, the presence of large aquifers, and intergovernmental transfers lead to more open space.

Regression Model and Data

The previous review of the literature resulted in the identification of three broad causal factors expected to influence differences in the size of U.S. urbanized areas: natural evolution, flight from blight, and local revenue choices. Based on one aspect of the natural evolution theory, increased auto reliance in an urban area is expected to lower personal commuting costs and increase sprawl. The regression model described in Equations (1) through (5) is an attempt to isolate the independent effects of explanatory variables that account for each of these three broad causal factors (including auto reliance) after controlling for any institutional or regulatory factors unique to the state in which the urbanized area is primarily located.[4]

[4] The use of statewide institutional controls is appropriate when using the urbanized area as the geographic unit of measurement for sprawl because, by definition, the square mile size is expandable and can never be considered "built out." Census blocks can be added to the UA if they meet the criteria for addition. This is not the case if using the county-based metropolitan statistical area as the geographic unit of measurement. For highly urbanized states (such as New Jersey or Connecticut), many counties are entirely built out.

Square Miles$_i$ or Population Density$_i$^ = f(Natural Evolution$_i$, Flight from Blight$_i$, Local Revenue Choices$_i$, State Institutions and Land Use Regulations$_i$); (1)

where

Natural Evolution$_i$ = f(Population^$_i$, Agricultural Land Price Per Acre$_i$, Per Capita Income$_i$, Percent Households Earning Greater \$100,000$_i$, Percent Households Owning One or More Autos$_i$, Percent Households Married$_i$, Percent Population Less Than 18 Years Old$_i$, Percent Population Greater Than 65 Years Old$_i$, Percent Employed in Wholesale/Warehousing$_i$, Percent Employed in Management/Finance/Insurance/Real Estate$_i$, Percent Employed in Public Administration$_i$); (2)

Flight from Blight$_i$ = f(Percent Central Place(s) Population Poor$_i$, Central Place(s) Crime Rate$_i$, Percent Central Place(s) Housing Two or Less Rooms$_i$, Central Place(s) Median Age of Housing$_i$, Percent Central Place(s) Population African American$_i$, Percent Central Place(s) Population Asian$_i$, Percent Central Place(s) Population Latino$_i$); (3)

Local Revenue Choices$_i$ = f(Number of Counties in Urban Area$_i$, Percent State's Municipal Own-Source Revenue from Property Taxes$_i$, Percent State's Own-Source County Revenue from Property Taxes$_i$, Percent State's Municipal Own-Source Revenue from General Sales/Gross Receipts Taxes$_i$, Percent State's Own-Source County Revenue from General Sales/Gross Receipts Taxes$_i$); (4)

State Institutions and Land Use Regulations$_i$ = f(a set of 49 Dummy variables representing each state except California), (5)

i = 1, 2, 3, ..., 452 census defined U.S. Urbanized Areas in 2000;

^ population removed as a natural evolution explanatory variable when population density replaces square miles as the dependent variable.

Table 1 offers a complete description of all variables used in the regression analysis. Dependent variables are designated (1) and (2). The explanatory variables numbered (3) through (13) are meant to control for natural evolution factors that are expected to influence the size of one urbanized area relative to another. Variables (3) through (7) closely parallel explanatory factors included in the Brueckner and Fansler (1983) and McGrath (2005) studies and are derived from the basic urban model of a typical consumer choosing a spatial location in a monocentric urban area. Like Brueckner and Fansler, I include a measure of the percentage of households in the urbanized area owning one or more autos. This represents a negative proxy for the commuting cost a typical household is expected to experience in the area. The urban models of Alonso, Mills, and Muth indicate that the larger this commuting cost, the smaller should be the size of urbanized area. To measure commuting cost, McGrath (2005) chose to include a regionally adjusted transportation price index, while Song and Zenou (2006) use an aggregate measure of state and local transportation expenditures in the region.

All measures of commuting cost are likely to be endogenously determined with land area or population density in an urban area. While a decrease in commuting costs causes an area to be more decentralized, a more decentralized area is also

Table 1. Variable descriptions (except where noted, year 2000 data drawn from 452 U.S. urbanized areas).

Name	Source	Mean (Stand. Dev.)	Maximum (Minimum)
(1) Square Miles	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	159.34 (301.93)	3,352.60 (12.10)
(2) Population Density	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	2,168.81 (880.91)	7,068.56 (851.54)
(3) Population	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	425,495.19 (1,245,603.43)	17,799,861.00 (50,058.00)
(4) Agricultural Land Price Per Acre (1997)[a]	Weighted average value per acre of farmland. U.S. Department of Agriculture: *1997 census of Agriculture Volume 1: National, State, and County Tables,* http://www.nass.usda.gov/census/census97/volume1/vol1pubs.htm.	635.45 (794.97)	6,390.05 (1.72)
(5) Per capita Income (1999)	U.S. Census Bureau, *2000 census of Population and Housing: U.S. Summary Social, Economic, and Housing Characteristics*, PHC-2-1 (Sample Data), http://www.census.gov/prod/cen2000.	19,346.97 (3,954.65)	43,596.00 (9,772.00)
(6) Percent Households Owning One or More Autos	U.S. Census Bureau, American Fact Finder: Census 2000 Summary File 3 (SF 3) Sample Data, http://factfinder.census.gov.	90.86 (4.87)	96.70 (56.70)
(7) Percent Households Earning Greater Than $100,000 (1999)	U.S. Census Bureau, *2000 Census of Population and Housing: U.S. Summary Social, Economic, and Housing Characteristics*, PHC-2-1 (Sample Data), http://www.census.gov/prod/cen2000.	10.36 (5.62)	36.7 (3.30)
(8) Percent Households Married	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	49.44 (6.31)	68.94 (30.57)
(9) Percent Population Less Than 18 Years Old	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	25.22 (3.81)	35.60 (11.80)
(10) Percent Population Greater Than 65 Years Old	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	12.80 (4.53)	41.10 (2.30)

(11) Percent Employed in Wholesale/Warehousing	U.S. Census Bureau, *2000 census of Population and Housing: U.S. Summary Social, Economic, and Housing Characteristics*, PHC-2-1 (Sample Data), http://www.census.gov/prod/cen2000.	7.93 (2.04)	18.44 (1.77)
(12) Percent Employed in Management/Finance/Insurance/Real Estate	U.S. Census Bureau, *2000 census of Population and Housing: U.S. Summary Social, Economic, and Housing Characteristics*, PHC-2-1 (Sample Data), http://www.census.gov/prod/cen2000.	14.61 (4.05)	32.17 (7.50)
(13) Percent Employed in Public Administration	U.S. Census Bureau, *2000 census of Population and Housing: U.S. Summary Social, Economic, and Housing Characteristics*, PHC-2-1 (Sample Data), http://www.census.gov/prod/cen2000.	5.09 (2.97)	24.41 (1.72)
(14) Percent Central Place(s) Population Poor (1999)	U.S. Census Bureau, *2000 census of Population and Housing: U.S. Summary Social, Economic, and Housing Characteristics*, PHC-2-1 (Sample Data), http://www.census.gov/prod/cen2000.	16.15 (6.38)	46.90 (4.10)
(15) Central Place(s) Crime Rate[b]	Weighted Average Uniform Crime Rates Per 100 of Central Place(s) Population FBI Uniform Crime Rate. U.S. Department of Justice, Office of Justice Programs, Bureau of Justice Statistics, http://bjsdata.oijp.usdoj.gov.	5.94 (2.60)	22.06 (0.05)
(16) Percent Central Places(s) Housing Two or Less Rooms	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	7.79 (3.84)	32.41 (1.27)
(17) Central Place(s) Median Age of Housing	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	33.71 (12.40)	60.00 (5.00)
(18) Percent Central Place(s) Population African American	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	15.61 (15.82)	70.77 (0.22)
(19) Percent Central Place(s) Population Asian	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	2.95 (4.25)	55.76 (0.23)
(20) Percent Central Place(s) Population Latino	U.S. Census Bureau, *2000 census of Population and Housing: Summary Population and Housing Characteristics*, PHC-1-1 (100% Data), http://www.census.gov/prod/cen2000.	11.97 (14.96)	94.19 (0.54)
(21) Number of Counties in Urbanized Area	U.S. Census Bureau, American Fact Finder: Census 2000 Summary File 1 (SF 1) 100% Data, http://factfinder.census.gov.	2.39 (2.32)	27.00 (1.00)
(22) Percent State's Municipal Own-Source Revenue from Property Taxes (1997)[c]	U.S. Census Bureau, 1997 census of Governments: *Finances of Municipal and Township Governments Volume 4, Government Finances,* http://www.census.gov/prod/gc97/gc974-4.pdf.	28.61 (15.68)	80.40 (3.31)

(23) Percent State's County Own-Source Revenue from Property Taxes (1997)	U.S. Census Bureau, 1997 census of Governments: *Finances of County Governments Volume 4, Government Finances*, http://www.census.gov/prod/gc97/gc974-3.pdf.	40.12 (12.21)	93.54 (15.94)
(24) Percent State's Municipal Own-Source Revenue from General Sales/Gross Receipts Taxes (1997)	U.S. Census Bureau, 1997 census of Governments: *Finances of Municipal and Township Governments Volume 4, Government Finances*, http://www.census.gov/prod/gc97/gc974-4.pdf.	9.47 (10.45)	36.79 (0.00)
(25) Percent State's County Own-Source Revenue from General Sales/Gross Receipts Taxes (1997)	U.S. Census Bureau, 1997 census of Governments: *Finances of County Governments Volume 4, Government Finances*, http://www.census.gov/prod/gc97/gc974-3.pdf.	9.12 (10.32)	44.46 (0.00)

[a] Calculated as weighted average of UA market value of agricultural products sold per acre;

$\sum_{i=1}^{n} x_i$ where x_i = {(county market value of agricultural products sold per acre) (county percent of UA land area)}, and n = number of counties included in the UA.

[b] Calculated as weighted average crimes per 100 of the population in UA central places;

$\sum_{i=1}^{n} x_i$ where x_i = {(central place crimes per 100 of the population) (central place percentage of UA total central place population)}, and n = number of central places in the UA.

[c] All tax data calculated as state total municipal or county own-source revenue/state total municipal or county revenue from the associated tax for each state. A state's municipal or county average was used for all of the UAs in that state. For interstate UAs, a weighted value was calculated;

$\sum_{i=1}^{n} x_i$ where x_i = {(state average municipal own-source revenue from associated tax) (state percent of UA land area)}, and n = number of states included in the UA.

likely to cause an increase in commuting cost. Brueckner and Fansler, McGrath, and Song and Zenou did not account for this possibility. If policy prescriptions are to be derived from the magnitude of an auto reliance regression coefficient, it is important to produce an unbiased estimate using two-stage least squares appropriately applied. This is done here.

Some may question the use of the percentage of households in an urbanized area that do not own an automobile as the best way to measure differences in the "automobile culture" across U.S. urbanized areas. Because they are collected by the census for urbanized areas, alternative measures that could also be used include the percentage of households that use various means to commute to work. I tried the percentage of households that use public transit (like Brueckner and Fansler, 1983) and the percentage of households that drive alone to work. Neither of these was used in the final analyses because an unbiased two-stage least squares estimation could not be accomplished with them. For a household in an urbanized area to abandon the use of automobiles entirely, viable non-auto transportation options must exist in the area. Continuing this line of reasoning, differences in the percentage of households owning one or more autos offers a reasonable metric of differences in the degree that an automobile-centric transportation culture exists across U.S. urbanized areas.

Variables (8) through (10) are also natural evolution factors; they are included to control for the fact that residents in U.S. urbanized areas differ in other important ways that influence their taste for types and location of housing and ultimately the size of urbanized areas. The expectation is that married households, households with children, and households with older adults are more likely to prefer a housing style and location on the urban fringe and thus increase the footprint of urbanized area, or decrease its density. In addition, as Bogart (2006, p. 60) points out in a book-length examination of sprawl, a lower percentage of children and/or a higher percentage of the aged in an urbanized area will naturally reduce density because households will be composed of a smaller number of people.

Explanatory variables (11) through (13) are included to control for the independent influences that variation in different forms of nonresidential activity has on the square mile size of a region. Burchfield et al. (2006) have empirically found that the extent of urban decentralization in the U.S. depends on the industry sectors in which the area specializes. Bogart's (2006) book develops this theory further and illustrates how the pattern and types of "trading places" in an urban area influence its geographic nature.

Variables (14) through (20) in Table 1 are included to measure various flight from blight factors that can also influence differences in the square mile size of U.S. urbanized areas. Unlike the earlier natural evolution factors, whose values were calculated for the entire urbanized area, these variables are only derived for an urbanized area's central place(s).[5] The expectation is that the greater the magnitude of occurrences in an urbanized area's central place(s) that residents are likely to view as negatives, the greater the flight from blight that is expected to occur, and the greater the size of an urbanized area or the lower its population density. Thus the greater the percentage of the central place(s) population that is poor, the greater

[5] The census defines a central place as the incorporated place or census designated place with the greatest population in an urbanized area. Additional central places are included if there are places that are two-thirds as large as the first central place and contain at least 50,000 people. Central place designations are used here to represent the economic hub(s) or trading places in an urban area that are more likely to contain the mixed use and high density development favored in most sprawl reducing or smart growth strategies. Since there can be multiple central places designated for an urbanized area, and many of the U.S. urban areas are no longer best considered monocentric in their economic focus, the central place designation is favored by most analysts over the single central city designation the census uses for metropolitan areas. Other specifics on how the census classifies central places and urbanized areas are in the *Federal Register* (2001).

the central place(s) crime rate, and the greater portion of the central place(s) housing made up of structures with less than two rooms, the greater should be the urban area's square miles. The expectation of the influence of a greater minority concentration in central places on land area is also positive if residents of U.S. urban areas use a certain race/ethnicity as a screening criterion for blight from lower class residents in central place(s). The expected influence that the median age of housing in an urban area's central place(s) should have on its land area or density is uncertain.

Variables (21) through (22), described in Table 1, represent attributes that are expected to denote the relative importance of local revenue choices on sprawl. The greater the number of local governments in an urban area, the more likely the generation of competition among them for new development, fueling land use decisions at the fringe of an urban area with a greater focus on the fiscal bottom line. Other variables measure the degree of statewide own-source revenue reliance by municipal or county governments on property taxation or sales/gross receipts in the urbanized area's state. These variables are purposefully measured at the statewide level to eliminate the simultaneity present if they were instead calculated for a specific urban area.[6]

Last, each of the regressions includes a set of 49 dummy variables representing all states except California. These dummy variables control for any statewide differences in the regulatory and/or institutional environment in which urban land use decisions are made. Nelson, Dawkins, and Sanchez (2007) document the diversity of statewide and local growth controls that exist in the U.S. and the impact they have on land use in its urban areas.

Note that the regression analysis is accomplished by first taking the log of the dependent variable and the logs of all but a few of the explanatory variables that contain zero values. As shown earlier in Figure 1, this functional form accounts for the likely nonlinear relationships that exist between explanatory variables and the footprint or density of an urbanized area.[7]

Regression Results

To account for the fact that differences in auto reliance in an urban area are concurrently determined with the size or population density of an urbanized area, the regression method used is two-stage least squares. This section starts with a description of precautions taken to ensure unbiased two-stage estimation, and then offers the appropriate statistical results that verify that this has been done. The second-stage regression results appear in a table with both land area and population density as dependent variables.

Stock and Watson (2007, Ch. 12), Murray (2006), and Angrist and Krueger (2001) all emphasize the fact that an unbiased regression coefficient for an endogenous variable will only result if great care is taken to ensure that the chosen instrument(s) are both relevant and exogenous. Relevant instruments are often found in natural experiments in which a policy was undertaken, unrelated to the dependent variable, which has resulted in observed differences in the endogenous dependent variable. The challenge, of course, is to find such "relevant" natural experiments that are both intuitively sound and statistically relevant.

[6] Song and Zenou (2006) chose to calculate a specific rate of local property taxation for each urban area in their sample. As they point out, these measures are endogenously determined with the size of the area and they appropriately use two-stage least squares to correct for it.

[7] A regression coefficient calculated using logged dependent and explanatory variables represents the expected percentage change in the dependent variable given a 1 percent change in the respective explanatory variable (elasticity). A regression coefficient calculated for a non-logged explanatory variable, when multiplied by the mean of the explanatory variable, represents the percentage change in square miles given a percentage change in the respective explanatory variable at the mean value.

Two proposed instruments are the 1997 rate of auto property taxation in the state in which the urban area is primarily located, and a dummy variable representing whether in 1997 there existed a state law that prohibited "below cost" motor fuel sales. An intuitively sound argument exists for why both of these instruments should influence auto ownership. First, a higher rate of statewide property taxation applied to autos is expected to raise the cost of auto ownership and hence reduce its prevalence. The adoption of such a tax should be unrelated to the size or density of a specific urban area in the state. Second, others (see Skidmore, Peltier, & Alm, 2005, and Anderson & Johnson, 1999) have shown that a state law that prohibits motor fuel sales below the cost to produce it affects the price of gasoline in a state, and these price variations should influence the decision to own an auto in an urban area where they are in effect. It would be hard to argue why the adoption of such laws in a state would be related to the size or population density of a specific urban area in the state adopting them.

As suggested by Wooldridge (2000, p. 484), before conducting two-stage regression analysis, it is important to test whether auto ownership is indeed endogenous. This is accomplished by regressing auto ownership on all exogenous variables in the system, including the two instruments just proposed, retrieving the residuals from this first-stage estimation, and then using these residuals as an additional explanatory variable in the structural equations, using population density and land area as alternate dependent variables. In both cases, the residual explanatory variable was significant at the greater than 99 percent confidence level, indicating that auto usage is indeed endogenously determined.

A second relevant test involves the strength of the chosen instruments. As described in Stock and Watson (2007, p. 441), this is accomplished by checking the F statistic produced from the first-stage regression. An F statistic less than 10 is an indicator of "weak" instruments. The F statistics when both instruments are included in the first-stage estimation, and when only the fuel sale law dummy or the auto property tax rate is included, are respectively 14.4, 13.9, and 12.0.

Given that there is only one endogenous variable in each regression, and two instruments, it is also possible to use the overidentifying restrictions test (J-statistic) to check whether both the chosen instruments are exogenous to both of the dependent variables used (see Stock and Watson, 2007, p. 444). Using land area as a dependent variable, the calculated J-statistic of 10.6 is large enough to reject the null hypothesis that both instruments are exogenous. But using population density as a dependent variable, the calculated J-statistic of 0.16 is not large enough to reject this null hypothesis. The first-stage regression used for the two-stage population density regression therefore includes both valid exogenous instruments. The first-stage regression used for the two-stage land area regression only includes the auto property tax rate because a stronger case can be made that more recently adopted laws requiring that gas prices in a state not fall below production cost are possibly related to auto reliance in an urban area in that state.

The second-stage regression results using both square miles and population density as dependent variables are recorded in Table 2. Most of the regression coefficients are statistically significant and conform to *a priori* expectations.[8] As appropriate, the statistically significant signs on the regression coefficients included in the square miles regression are opposite to those on the population density regression. Next, I describe only the regression results using square miles as the dependent variable.

[8] Throughout this paper, statistical significance is defined at the standard 90 percent confidence level in a two-tailed test.

Table 2. Second-stage regression results using year 2000 log square miles in 452 U.S. urbanized areas as dependent variable.

Explanatory Variable	Log Square Miles Coefficient (Standard Error)	Log Pop. Density Coefficient (Standard Error)
Constant	−21.489***(2.380)	20.747***(2.556)
Log Population	0.879***(0.015)	Not Used
Log Agricultural Land Price Per Acre (1997)	−0.052***(0.014)	0.073***(0.016)
Log Per Capita Income (1999)	1.139***(0.231)	−1.010***(0.241)
Log Percent Households Owning One or More Autos	0.052***(0.014)	−0.073***(0.016)
Log Percent Households Earning Greater Than $100,000 (1999)	−0.372***(0.101)	0.445***(0.111)
Log Percent Households Married	0.959***(0.198)	−1.134***(0.210)
Log Percent Population Less Than 18 Years Old	0.164(0.126)	0.078(0.131)
Log Percent Population Greater Than 65 Years Old	0.132**(0.058)	−0.115*(0.066)
Percent Employed in Wholesale/Warehousing	−0.110**(0.052)	0.120*(0.061)
Percent Employed in Management/Finance/ Insurance/Real Estate	−0.116*(0.064)	0.229***(0.068)
Percent Employed in Public Administration	−0.043*(0.025)	0.047(0.030)
Log Percent Central Place(s) Population Poor (1999)	0.260***(0.060)	−0.173***(0.066)
Log Central Place(s) Crime Rate	0.027(0.022)	−0.023(0.025)
Log Percent Central Place(s) Housing Two or Less Rooms	0.003(0.035)	0.012(0.040)
Central Place(s) Median Age of Housing	−0.084*(0.049)	0.094*(0.051)
Log Percent Central Place(s) Population African American	0.024(0.016)	−0.016(0.016)
Log Percent Central Place(s) Population Asian	−0.010(0.019)	0.000(0.022)
Log Percent Central Place(s) Population Latino	−0.036**(0.015)	0.043***(0.016)
Log Number of Counties in Urbanized Area	0.044**(0.020)	0.030(0.022)
Log Percent State's Municipal Own-Source Revenue from Property Taxes (1997)	0.075(0.071)	−0.137^(0.085)
Log Percent State's County Own-Source Revenue from Property Taxes (1997)	0.015(0.074)	0.004(0.078)
Percent State's Municipal Own-Source Revenue from General Sales/Gross Receipts Taxes (1997)	0.002(0.002)	0.003(0.004)
Percent State's County Own-Source Revenue from General Sales/Gross Receipts Taxes (1997)	0.002(0.002)	−0.002(0.003)
R-Squared	0.963	0.663
F-Statistic	140.51***	10.71***

White's heteroskedasticity robust weighted least squares used. Results are calculated with the inclusion of a set of 49 state dummy variables that represent the state the urbanized area is primarily located in. As a whole, this set of dummy variables exerted a statistically significant influence.

*** Indicates statistical significance in a two-tailed test at greater than 99 percent confidence, ** indicates greater than 95 to 99 percent confidence, * indicates 90 to 95 percent confidence, and ^ indicates 89 percent confidence.

Starting with the natural evolution factors that are similar to what Brueckner and Fansler (1983) included, a 1 percent increase in population yields about a 0.9 increase in square miles, while a 1 percent increase in agricultural land price only yields a 0.05 decrease. A 1 percent increase in per capita income results in just over a unitary elastic increase in land area. The population, agricultural land price, and income elasticities of urban size calculated here are lower than Brueckner and Fansler's respective findings of 1.1, −0.2, and 1.5. Additionally, a 1 percent increase in the percentage of households in the urban area owning one or more autos results in the very inelastic response of only a 0.05 percent increase in land area. When not accounting for its endogenous determination, it is worth noting that the auto ownership elasticity of urbanized land area is calculated as 1.2. As expected, not controlling for the simultaneous determination of this explanatory factor biases its value upward. Perhaps not expected was the magnitude of this bias. Observing such a large "uncorrected" elasticity (or even the simple correlation between auto usage and sprawl) may explain why many have prescribed a reduction in auto reliance as a surefire way to reduce urban sprawl.

For the additional natural evolution factors that I include, but Brueckner and Fansler did not, a 1 percent increase in percent of households married and percent of population greater than age 65, respectively, results in about 1.0 and 0.1 increases in an urbanized area's square miles. I also include an explanatory measure to account for the percentage of households earning greater than $100,000. Distinct from per capita income, this variable exerts a negative influence on the square mile size of U.S. urban areas. I suspect that it may be picking up the increased opportunity cost of long commutes for very affluent households and hence a greater preference of the affluent to live closer to where they work and shop, and thus the result of producing more compact urban areas. The regression coefficients calculated for types of nonresidential activity that are conducted more efficiently in an area with more dense land use match the expectations of urban economists. An urbanized area with greater percentages of its residents working in industries classified as wholesale/warehousing, management/finance/insurance/real estate, or public administration is smaller in square miles.

This regression study offers compelling evidence that flight from blight exerts a distinct influence on the degree of sprawl observed in a U.S. urban area. The largest flight from blight response calculated is that a 1 percent increase in the central place(s) poverty rate generates nearly a 0.3 percent increase in the total area's footprint. Only the race/ethnicity concentration of Latinos in an urbanized area's central place(s) exerts a significant influence on its overall footprint, and this effect is negative. The greater presence of Latinos could be retardant of flight from blight, but it may also be proxying for urban areas in the southwest U.S. that, for reasons of more rugged terrain and lack of water, are more compact in their development (as noted by Burchfield et al., 2006). The −0.1 median age home elasticity of an urban area's footprint may in fact be picking up the vintage of land development in the urban area. Urban areas with older homes in their central place(s) developed during a period when auto use was less prevalent and land development was subsequently more compact.

Fiscalization of land use has, at least in part, helped to determine the degree of sprawl observed across U.S. urban areas. The greater the number of counties in an urbanized area in 2000, holding other causal factors constant, the greater the urban area's size. Since more counties are likely to generate greater competition among local governments, this is a necessary finding if one argues that fiscalization of land use has a greater impact on urban form the greater the degree of competition between local governments. Examining the second set of regression results that used population density as an explanatory variable, a 1 percent increase in the percentage of own-source municipal revenue gathered statewide from property taxation yielded about a 0.1 decrease in the population density of urban areas. According to Brueckner and Kim's (2003) general theory of how property reliance influences land development in an urban area, this is confirmation of property taxes working to reduce the intensity of land development and consequently decrease population density. This study produced no regression results that support the hypothesis that local sales tax reliance influences the square mile size or population density of urbanized areas in the U.S.[9]

Policy Implications

The anti-sprawl group Sprawl Watch believes that "Reducing sprawl will require deemphasizing the role and importance of the automobile."[10] But will adopting policies designed to reduce automobile dependence in U.S. urban areas really decrease the amount of decentralization observed in them? If greater automobile reliance generates greater sprawl, then a public policy designed to get more of an urban area's population out of their automobiles and into alternative forms of transportation (including walking) will result in more compact land use patterns in the urban area, and the environmental and social problems associated with sprawl will be reduced. But if differences in land use patterns across U.S. urban areas are only minimally influenced by auto reliance, the more appropriate policy is one that attempts to directly change land use. It is to these public policy questions that this paper has been devoted. As Rosenthal (2007) succinctly summarizes: "Urban sprawl and cars are the chicken-and-egg question of the environmental debate. Cars make it easier for people to live and shop outside the center city, and this in turn creates a need for more cars."

This paper described an appropriate empirical test of the existence and magnitude of the casual relationships flowing from differences in automobile reliance to differences in sprawl across U.S. urbanized areas. To perform this empirical test, it was necessary to do a few things. First, I picked a way to measure differences in the degree of sprawl across U.S. urban areas. Second, I developed a theoretical model that accounted for the various factors expected to influence differences in this degree of sprawl so the independent influence of automobile use could be isolated and measured. Finally, I appropriately controlled for the simultaneous relationship that theoretically exists between differences in automobile reliance across urban areas and differences in the observed sprawl in these areas.

Performing a simple ordinary least squares regression that did not account for the simultaneous determination of auto reliance and sprawl, I found that a 10 percent reduction in auto reliance in a typical urban area is expected to result in about a 12 percent reduction in sprawl. Such a result offers support for a policy designed to get more people out of their automobiles as an effective tool to reduce sprawl. But the important policy lesson to be learned here is that once the simultaneous nature of auto use and sprawl is controlled for, the potency of this policy tool goes away. The appropriate two-stage regression analyses indicate that a 10 percent reduction in the percentage of households owning one or more autos (the average value of this being nearly 91 percent of households living in U.S. urbanized areas) would only reduce the average 159 square mile U.S. urban area by a little less than a mile, and only raise population density from an average of 2,169 people per square mile to 2,185. By no means are these large reductions in sprawl. The monetized benefits of such a reduction in sprawl is highly unlikely to exceed the dollar cost of the incentives that would be required to reduce automobile ownership by 10 percent, or the

[9] This could be the result of using a wide geographic unit like urbanized area to measure sprawl. If perhaps something like municipal boundary expansion at the fringe of urban areas were instead used, the likelihood of finding a statistically significant influence of local sales tax reliance on sprawl would be greater.
[10] Retrieved December 21, 2007, from www.sprawlwatch.org/reducingmotor.html.

dollar cost of consumer surplus lost if regulation were instead used to bring about such a reduction in automobile reliance. Thus, the primary policy implication to be derived from this research is that feasible reductions in auto reliance will have very little impact on the magnitude of urban decentralization in the U.S.

For broader policy interpretations, it is informative to frame all the regression results in terms of how a hypothetical U.S. urban area, one that is assumed to take on the average values in regard to land area (159 square miles) or population density (2,169 per square mile), would be expected to change if a factor found to exert a statistically significant influence increased by 10 percent (holding all other causal factors constant). The results of such simulations are shown in Tables 3 and 4. For example, if the percent central place(s) population poor of this hypothetical average U.S. urbanized area fell from 16.15 percent to 14.54 percent (or by 10 percent), the regression findings predict that square miles would fall from 159 to about 155 (or a decrease of 2.6 percent). The policy implication is that reducing poverty at the core of a U.S. urban area offers the added payoff of reducing the urban area's footprint and the social concerns associated with greater sprawl.

The simulation results recorded in Tables 3 and 4 clearly indicate that factors falling under the category of "natural evolution" are the most likely to exert statistically significant and high-magnitude influences on the measures of sprawl used here. Unfortunately, causal variables such as per capita income, percent of households earning high incomes, percent of households married, and percent employed in different industrial sectors are not easily altered by public policy. Where this all leads in regard to implications for policy makers intent on using public policy to reduce sprawl (as measured by shrinking the amount of land used in an urbanized area for a given population or by increasing the area's population density) is greater consideration of direct regulations and planning interventions into setting the overall boundary of developable land in an urban area. Evidence of the likely importance

Table 3. Expected square mile increase for respective 10 percent increase in explanatory variables.

Explanatory Variable that Rises by Ten Percent in Value	Expected Increase for U.S. Average Area of 159 Square Miles
"Natural Evolution" Factors	
Population	14.0 square miles
Agricultural Land Price Per Acre	−0.8 square miles
Per Capita Income	18.1 square miles
Percent Households Owning One or More Autos	0.8 square miles
Percent Households Earning > $100,000	5.9 square miles
Percent Households Married	15.2 square miles
Percent Population Greater or Equal 65 Years Old	2.1 square miles
Percent Employed in Wholesale/Warehousing	−1.7 square miles
Percent Employed in Management/Finance/etc.	−1.8 square miles
Percent Employed in Public Administration	−0.7 square miles
"Flight from Blight" Factors	
Percent Central Place(s) Population Poor	4.1 square miles
Central Place(s) Median Age of Housing	−1.3 square miles
Central Place(s) Population Latino	−0.6 square miles
"Fiscalization of Land Use" Factors	
Number Counties in Urbanized Area	0.7 square miles

Table 4. Expected population density increase for respective ten percent increase in explanatory variables.

Explanatory Variable That Rises by Ten Percent in Value	Expected Increase for U.S. Average Population Density of 2,169 People Per Square Mile
"Natural Evolution" Factors	
Agricultural Land Price Per Acre	15.8 people per square mile
Per Capita Income	−219.1 people per square mile
Percent Households Owning One or More Autos	−15.8 people per square mile
Percent Households Earning > $100,000	96.5 people per square mile
Percent Households Married	−246.0 people per square mile
Percent Population Greater or Equal 65 Years Old	−24.9 people per square mile
Percent Employed in Wholesale/Warehousing	26.0 people per square mile
Percent Employed in Management/Finance/etc.	49.6 people per square mile
"Flight From Blight" Factors	
Percent Central Place(s) Population Poor	−37.5 people per square mile
Central Place(s) Median Age of Housing	20.4 people per square mile
Central Place(s) Population Latino	9.3 people per square mile
"Fiscalization of Land Use" Factors	
State's Percent Municipal Revenue Property Taxes	29.7 people per square mile

of statewide measures of this sort to determining differences in the degree of sprawl observed across U.S. urban areas was found in this research through the statistical significance of the set of 49 state dummy variables included in both regressions. Wassmer (2006) and earlier research summarized in a book-length review of this topic by Nelson, Dawkins, and Sanchez (2007) show that the implementation of certain forms of metropolitan-wide growth management and containment programs have reduced the size of U.S. urbanized areas at a magnitude similar to that calculated here for natural evolution and flight from blight factors. If reduced sprawl is the goal, the research results offered here show that policies intent on directly changing urban land use patterns should be preferred to those intent, instead, on getting people out of their automobiles. A policy-induced reduction in auto reliance is not likely to produce much of a reduction in sprawl. Instead, automobile reliance in a U.S. urban area will decline when sprawl declines.

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