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**THE IMPACT OF URBAN SPATIAL STRUCTURE  
ON TRAVEL DEMAND IN THE UNITED STATES**

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## **I. Introduction**

### **A. Motivation and Purpose**

This paper addresses two questions: (1) How do measures of urban sprawl—measures that describe the spatial distribution of population and jobs-housing balance—affect the annual miles driven and commute mode choices of U.S. households? (2) How does the supply of public transportation affect miles driven and commute mode choice? In the case of public transit we are interested both in the extent of the transit network (annual route miles supplied for rail and bus) and also in the proximity of transit to people's homes (distance to the nearest transit stop).

Two issues motivate our work. The first is a concern that subsidies to private home ownership and a failure to internalize the negative externalities associated with motor vehicles have caused urban areas to be much less densely populated than they should be (Brueckner 2000; Wheaton 1998).<sup>1</sup> This has, in turn, further exacerbated the negative externalities associated with motor vehicles (especially air pollution and congestion) by increasing annual miles driven (Kahn 2000). The important question is: How big is this effect? How much has sprawl increased annual miles driven, either directly, by increasing trip lengths, or indirectly, by making public transportation unprofitable and thus reinforcing reliance on the automobile?

The second motivation is more policy-oriented. If it is a social goal to reduce the externalities associated with motor vehicles, and if there is a reluctance to rely on price instruments such as gas taxes and congestion taxes, could non-price instruments be effective in reducing annual VMTs? Increasing the supply of public transportation is one policy option, i.e., increasing route miles or the number of bus stops (see, for example, Baum-Snow and Kahn 2000, Lave 1970); another option is to change zoning laws to reduce sprawl or improve jobs-housing

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<sup>1</sup> For a survey of the literature on the causes of metropolitan suburbanization see Mieszkowski and Mills (1993).

balance (see Boarnet and Sarmiento 1996, Boarnet and Crane 2001, Crane and Crepeau 1998). Our estimates of the quantitative impact of various measures of sprawl on annual household vehicle miles traveled (VMTs) are suggestive of the magnitude of effects that one might see if these measures could be altered by policies to increase urban density. We also predict the impact of policies that increase transit availability on both average annual VMTs and on the percentage of commuters who drive.

### **B. Approach Taken**

We address these issues by adding city-wide measures of sprawl and transit availability to the 1990 Nationwide Personal Transportation Survey (NPTS). The survey contains information on automobile ownership and annual miles driven for over 20,000 U.S. households. It also contains information on the commuting behavior of workers within these households. For NPTS households living in 119 Metropolitan Statistical Areas (MSAs) we construct city-wide measures of the spatial distribution of population and of jobs-housing balance. Our *population centrality* measure plots the cumulative percent of population living at various distances from the CBD against distance (measured as a percent of city radius) and uses this to calculate a spatial GINI coefficient. Our measure of *jobs-housing balance* compares the percent of jobs in each zip code of the city with the percent of population in the zip code. It captures not only availability of employment relative to housing, but the availability of retail services to consumers.

To characterize the transport network we compute city-wide measures of transit supply—specifically, bus route miles supplied and rail route miles supplied, normalized by city area. The road network is characterized by square miles of road divided by city area.

A key feature of our sprawl and transport measures is that they are exogenous to the individual household. This stands in contrast to the standard practice in the empirical literature. Studies that examine the travel behavior of individual households have often characterized urban

form using variables that are clearly subject to household choice. The population density of the census tract or zip code in which the household lives is often used as a measure of urban sprawl (Train 1986; Boarnet and Crane 2001; Levinson and Kumar 1997), and the distance of a household's residence from public transit as a measure of availability of public transportation (Boarnet and Sarmiento 1996, Boarnet and Crane 2001).<sup>2</sup> Coefficient estimates obtained in these studies are likely to be biased if people who dislike driving locate in high-density areas where public transit is more likely to be provided. In addition to using city-wide measures of sprawl and transit availability, we address the endogeneity of "proximity to public transit" by instrumenting the distance of the household to the nearest transit stop.

We use these data to estimate two sets of models. The first is a model of commute mode choice (McFadden 1974), in which we distinguish 4 alternatives—driving, walking/bicycling, commuting by bus and commuting by rail. We estimate this model using workers from the NPTS who live in one of the 28 cities in the U.S. that have some form of rail transit. The second set of models explains the number of vehicles owned by households and miles driven per vehicle. These are estimated using the 7,798 households in the NPTS who have complete vehicle data and who live in one of the 119 MSAs for which we have computed both sprawl and transit variables.

### **C. Results**

Our preliminary results suggest that urban form and public transit supply have a small but significant impact on travel demand. In the mode choice model, a 10% increase in jobs-housing imbalance increases the probability of taking private transport to work by 2.1 percentage points. A 10% increase in population centrality reduces the probability of driving to work by 1.3 percentage points. In cities with rail, a 10% increase in rail supply implies a reduction in the probability of driving of 2.5 percentage points. These effects are relatively large compared with

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<sup>2</sup> For a review of the literature, see Badoe and Miller (2000).

the effects of individual characteristics. For example, the impact of a 10% increase in jobs-housing imbalance on the probability of driving is twice as large (in absolute value) as an increase in income of 10%.

The impact of urban sprawl (population centrality) on annual household VMTs appears to occur primarily by influencing the number of cars owned rather than miles traveled per vehicle. Specifically, a 10% increase in population centrality increases the probability that a household will not own a car by one percentage point (from 0.16 to 0.17 in our sample). This, however, implies a rather small decrease in expected miles driven by a randomly chosen household in our sample; viz., a reduction of approximately 88 miles from a base of about 18,000 miles annually. Our other measure of sprawl, jobs-housing imbalance, has no impact on the number of vehicles owned and a very small impact on miles driven per vehicle (for two-car households only), a result that accords with Giuliano and Small (1993). In contrast, the supply of rail transit (route miles supplied) affects both the number of vehicles owned and miles driven per vehicle, conditional on a city having rail transit. The elasticity of VMTs with respect to rail supply is, however, small (about -0.10) as is the impact of distance to the nearest transit stop, properly instrumented, on VMTs (elasticity of 0.21).

The rest of the paper is organized as follows. Section II describes our measures of population centrality and jobs-housing balance, and compares these measures with traditional sprawl measures. It also describes our city-wide transit variables and as well as our instrument for proximity to public transportation. Section III presents the results of our commute mode choice model, and section IV our model of automobile ownership and VMTs. Section V concludes.

## **II. Measures of Sprawl and the Transport Network**

## A. Population Centrality

Glaeser and Kahn (2001) describe the spatial distribution of population in a city by plotting the percent of people living  $x$  or fewer miles from the CBD as a function of  $x$  (distance from the CBD). The steeper this curve is, the less sprawled is the city. Our measure of population centrality is a variant on this approach: We plot the percent of population living within  $x$  percent of the distance from the CBD to edge of the urban area against  $x$  and compute the area between this curve and a curve representing a uniformly distributed population.<sup>3</sup> (See Figure 1.) For the urban areas we use the urbanized portion of the MSAs in our sample as defined by the Census in 1990. Our reason for using the *percent of maximum city radius* (rather than absolute distance) on the x-axis is to ensure that our measure is not biased against large cities.

Figure 1 illustrates our measure. The horizontal axis measures distance to CBD as a percent of maximum city radius and the vertical axis the cumulative percent of the population. In the city pictured here, 45 percent of the population lives within 10 percent of the distance from the CBD to the edge of the urbanized area, and 90 percent of the population lives within 40 percent of this distance. This curve is compared to the 45-degree line, which corresponds to a city in which population is uniformly distributed. Our population centrality measure is the area between the two curves. Population centrality thus varies between 0 (for a perfectly sprawled city) to  $\frac{1}{2}$  (for a city with all population residing at the CBD). Larger values of the measure thus imply a more compact city.

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<sup>3</sup> The locations of the CBDs are given by the *1982 Economic Censuses Geographic Reference Manual*, which identifies the CBDs by tract number. For polycentric cities, we have computed this measure in reference to the main CBD.

## **B. Jobs-Housing Imbalance**

The location of employment relative to housing may affect both commute length (which accounts for 33% of miles driven in the 1990 NPTS) as well as the length of non-commute trips.<sup>4</sup> To measure the balance of jobs versus housing we calculate the percent of total population and the percent of total employment located in each zip code in the urbanized portion of each MSA. The absolute difference between the two percentages is calculated and normalized by the percent of population in the zip code. This balance measure must lie between 0 (perfect balance) and 1 (perfect imbalance). We use the median value of the measure across all zip codes to measure job-housing imbalance. (*Imbalance* since higher values imply greater imbalance.)<sup>5</sup>

Our jobs-housing imbalance measure has several shortcomings. It is clearly sensitive to the size of the geographic units used. Since zip codes are the only units for which we were able to obtain employment data, we have tried to minimize this problem by taking the median of the jobs-housing imbalance measure across zip codes. A second problem is that our employment data, which come from *1990 Zip Code Business Patterns* (U.S. Census Bureau), exclude government workers and the self-employed.

How different are our measures from traditional measures of urban sprawl? Urban sprawl is often measured using average population density in a metropolitan area or the slope of an exponential population density gradient. As Malpezzi (1999) and Glaeser and Kahn (2001) have pointed out, exponential population density gradients typically do not fit modern cities very well; hence we have chosen not to use this measure. Average population density is clearly a blunt measure of sprawl, and is only weakly correlated with population centrality ( $r = 0.164$ ). Indeed, a

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<sup>4</sup> For households residing in the urbanized portion of the 131 largest metropolitan areas, work trips account for approximately 33 percent of miles driven, “family business” trips for 19% of miles driven and shopping trips for 11% of miles driven, based on data in the 1990 NPTS Trip File.

<sup>5</sup> The sources of data for our jobs-housing balance measure, as well as for all other variables are given in Appendix A (Data Appendix.)

regression of population centrality on land area, population and population density using the 122 metropolitan areas for which we have computed both population centrality and jobs-housing imbalance<sup>6</sup> yields an  $R^2$  of only 0.08.<sup>7</sup> In our analyses below, we control for land area (area of the urbanized portion of the MSA) and population density when examining the impact of our sprawl measures.

Table 1 further illustrates the fact that population centrality and jobs-housing imbalance capture different aspects of sprawl than average population density.<sup>8</sup> Using a rank of “1” to indicate the least sprawled MSA in our sample, Table 1 compares the rankings of selected cities based on our measures of sprawl against rankings based on population density. The New York MSA (which includes Northern NJ and Long Island) is, not surprisingly, the 3<sup>rd</sup> least sprawled MSA based on population density. It also ranks high in terms of population centrality; however, it is squarely in the middle of our 122 cities in terms of jobs-housing balance—as the 62<sup>nd</sup> most balanced city. San Diego, which is the 8<sup>th</sup> least sprawled city based on population centrality and the 15<sup>th</sup> least sprawled based on population density, ranks as the 120<sup>th</sup> least balanced city in terms of our jobs-housing balance measure. The table thus illustrates the fact that our measures capture dimensions of the urban structure that are missing in the population density measure.

### **C. Measures of the Extent of the Transport Network and Transit Availability**

Reliance on public transportation, whether for commute or non-commute trips, depends on both the extent of the transport network and the proximity of transit stops to housing and work locations. We measure the extent of the public transport network by the number of bus route miles supplied in 1990, divided by the size of the urbanized area (in  $\text{km}^2$ ), and by the number of

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<sup>6</sup> We attempted to construct population centrality and jobs-housing balance measures for the 131 largest MSAs (defined in terms of population). Data were, however, available for both measures for only 122 of these MSAs.

<sup>7</sup> Adding jobs-housing imbalance to this regression raises the  $R^2$  to only 0.13; hence our two sprawl measures capture different phenomena.

<sup>8</sup> Appendix B presents summary statistics for sprawl and transit variables for all cities in our sample.



rail route miles supplied in 1990, divided by the size of the urbanized area. The extent of the road network is measured by lane density—miles of road multiplied by average road width (for different categories of road) divided by the size of the urbanized area (in km<sup>2</sup>).

In other travel demand studies, proximity to public transportation is usually measured by a household's distance to the nearest transit stop (Walls, Harrington and Krupnick 2000). This measure is likely to overstate (in absolute value) the impact of transit availability on mode choice since households that plan to use public transit frequently will locate near bus and metro stops. To handle this problem we construct the following instrument. For each household we identify the set of census tracts where the household could afford to live in the city in which it currently lives. This is the set of tracts that have median household income, based on 1990 Census data, less than or equal to the household's own income *or* to the median income of the zip code in which the household currently lives.<sup>9</sup> Unfortunately we cannot measure the number of transit stops in each census tract. What we can measure is the percent of people in each tract who usually rode public transportation to work in 1990. We average this number across all tracts that household *i* can afford. Our instrument is obtained by regressing household *i*'s distance to the nearest transit stop on the average transit usage variable.

Table 2 presents summary statistics for our sprawl and transit measures for the 119 cities in our sample that have data on both sets of variables. Not surprisingly, the supply of non-rail transit is twice as great in the 28 rail cities in our sample as in the other 91 cities, suggesting an attempt to link rail and bus networks. Average distance to the nearest transit stop (as originally reported and in instrumented form) is also lower in rail than in non-rail cities. The higher lane density in these cities presumably reflects the fact that rail supply and lane density are both positively correlated with population density.

### **III. Commute Mode Choice Models**

We link the measures of sprawl and transit availability described in the last section with the 1990 Nationwide Personal Transportation Survey (NPTS) to estimate their impact on the choice of “usual mode” of commute to work.

#### **A. The NPTS Worker Sample**

The 1990 NPTS consists of 22,317 households living in urban and rural areas of the US. 10,349 of these household lived in the urbanized portion of the 119 metropolitan areas for which we have data on both sprawl and transport measures. These households constitute our core sample. To obtain significant variation in commute mode choice, we decided to focus on only those cities with some rail transit, which reduced the sample to 28 cities. The 5,430 workers in our sample households in these cities are used to estimate multinomial logit models of commute mode choice. We distinguish four usual commute modes—private transportation, non-rail transit, rail transit and non-motorized transit. Table 3 shows the percent of workers using each mode. The percent of workers using private transport (77.2%) is lower than the average for all workers in the NPTS (86.5%) This is in part because we are focusing on cities with rail transit and in part because workers in the New York metropolitan area constitute 20% of our sample.<sup>10</sup> Between 7 and 9 percent of our sample uses public transit (7.2% for bus; 8.6% for rail), while approximately 7 percent either bikes or walks to work.

Table 3 also presents mean respondent characteristics by usual commute mode. Bus riders have significantly lower incomes, on average, than people who drive or take the train to work. They also have significantly less education and are more likely to be black than workers who drive or walk to work. The racial differences across transit modes are indeed striking:

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<sup>9</sup> Residential location is known only at the zip code level (rather than the census tract) in the 1990 NPTS.

whereas 79% of persons who drive to work are white, only 49% percent of bus riders are white and only 54% of train riders are white. Rail riders have incomes only slightly below those of persons who drive to work, but have fewer children. The last row of the table suggests that riders of public transit self-select to live near public transit. The average distance to the nearest transit stop is 2-3 blocks for rail and bus riders, but over 13 blocks for commuters who drive.

Results for our commute mode choice equations appear in Table 4. In all models the omitted mode is driving to work; hence all coefficients should be interpreted relative to this category. In contrast to the mode choice literature, which emphasizes the impact of time and money costs on mode choice, we examine solely the impact of family and worker characteristics, as well the impact of sprawl and transit availability on usual commute mode. The three equations in the table differ in their representation of urban sprawl and the transit network. Equation (1), which measures sprawl by average population density and the area of the urbanized portion of the MSA, and transit availability by (uninstrumented) distance to the nearest transit stop, is a “traditional” equation against which we measure our results. Equation (2) replaces the endogenous measure of transit availability with city-wide measures of road density and rail and bus route miles supplied. Population centrality and jobs-housing balance are also added to the equation. Equation (3) adds our instrument for distance to the nearest transit stop to equation (2).

The household characteristic results largely mirror Table 3. Workers in higher income households are less likely to ride public transportation or walk than to drive, and workers who are white are significantly less likely to ride public transit than to drive. Being female increases a worker’s chances of riding public transit, and having more education increases the chances that a worker takes rail or walks to work.

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<sup>10</sup> The impact on our results of deleting New York City residents from our sample is noted below.

From the perspective of sprawl and transit availability, three results stand out: (1) Densification of the rail network increases the probability that a worker does not drive to work, with the strongest effect occurring for persons who take rail to work.<sup>11</sup> (2) Increasing the supply of non-rail transit increases the chances that this mode is used, but the effects are not as pronounced as for rail. (3) People are more likely to ride the bus, or bicycle or walk to work the less sprawled the city is (in terms of population). (4) People are less likely to use non-driving modes the greater is jobs-housing imbalance. It is also interesting to note that the traditional measures of sprawl—land area and average population density are either insignificant or have the wrong sign.

As equation (3) indicates, when we add the instrumented distance to the nearest transit stop to equation (2), being farther from a transit stop significantly reduces the probability of taking bus or rail, and our variables of interest maintain their significance.

To see the quantitative impacts of the coefficients in the multinomial logit model, we have computed the impact on the probability of driving of a 10% change in each of the variables of interest. For example, we increase job-housing imbalance by 10% in all cities and see how this alters the probability of each worker in our sample choosing each mode. The average change in the probability of driving is shown in Table 5.

What is striking is that the impact of a 10% change in Population Centrality and Jobs-Housing Imbalance on the probability of driving is larger in absolute value than a 10% change in income or education,<sup>12</sup> although smaller than the impact of gender on the probability of driving to work. (Changing the commuter from male to female reduces the probability of driving by 3.0

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<sup>11</sup> The fact that an increase in rail miles supplied increase the chances of riding the bus to work or walking requires further explanation. It is possible that rail supply is picking up some of the effects of population density.

<sup>12</sup> This result continues to hold when NYC residents are omitted from the analysis. The a 10% increase in population reduces the chance of driving by 2.6 percentage points, while a 10% increase in jobs-housing balance increases the probability of driving by 1.1 percentage points.

percentage points.) The impact of the transit stop variable is less pronounced; however, the effect of the correctly instrumented distance is larger than when uninstrumented distance is used. Clearly one must be cautious in drawing policy implications from a single cross-section, but the results suggest that, for mode choice, the spatial configuration of jobs and population matters, at least in rail cities.

#### **IV. Models of Automobile Ownership and Annual VMTs**

Urban form and transit supply may influence household VMTs either by affecting the number of cars owned and/or the number of miles each car is driven. We therefore estimate a model to explain the number of cars owned and the demand for VMTs per vehicle (Train 1986; Walls, Harrington and Krupnick 2000; West 2000). The model is estimated in two parts. We first estimate a multinomial logit model to explain whether the household owns zero, one, two, or three-or-more vehicles. We then estimate separate equations to explain annual VMTs per vehicle for households that own one, two, or three-or-more vehicles. Because unobservable factors that explain the number of vehicles owned may be correlated with the error terms in the VMT per vehicle equations, we use the selectivity correction approach developed by Dubin and McFadden (1984) to estimate the demand for VMT equations.

These models are estimated using all households in the 1990 NPTS living in the urbanized portions of the 119 MSAs for which city-wide sprawl and transit measures have been computed and for whom complete data on VMTs are available. The subset of these households for which all other household variables are available is 7,798. It should be noted that the number of households in our 119 cities with complete household data but missing VMT data is considerably larger (9,719), since roughly 20% of NPTS households in urban areas do not have complete data on miles driven.

Table 6a compares the characteristics of households with and without complete VMT data. The fact that the two samples are so similar in their observable characteristics suggests that VMT data are not selectively missing.<sup>13</sup> In the sample with complete data, approximately 16 percent of households own no cars, 41 percent own one car, 33 percent own two cars and 10 percent own three or more vehicles. Although annual VMTs per vehicle decline with number of vehicles owned (see Table 6b), on average two-vehicle households drive approximately 10,800 miles per year more than one-vehicle households. Households with three vehicles drive approximately 10,900 miles per year more than two-vehicle households.

### **A. Models of Vehicle Ownership**

The household's choice of how many vehicles to own is made by comparing the utility it receives from each possible vehicle bundle.<sup>14</sup> We assume that this depends on household income net of the fixed costs of vehicle ownership, on the price per mile traveled, on household characteristics and on measures of urban form and transit supply. The fixed costs of vehicle ownership include the costs of interest and depreciation on the vehicle, as well as the cost of automobile insurance. The fixed costs of vehicle ownership, which vary by income group, reflect the cost of owning the "typical" vehicle owned by households in the income group. (Appendix C describes our calculation of the fixed costs of vehicle ownership and the price per mile traveled.) Price per mile is the price of gasoline in the household's MSA divided by the average fuel efficiency (miles per gallon) of vehicles owned by households in the household's income group (see Appendix C).

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<sup>13</sup> The most common form of missing data occurs when a household fails to report miles driven for one of its vehicles.

<sup>14</sup> Formally, for each possible vehicle bundle the household chooses the optimal number of miles to drive each vehicle. These demand functions, when substituted into the household's utility function, yield an indirect utility function, conditional on owning a particular vehicle bundle. The discrete choice of how many vehicles to own is made by comparing the conditional indirect utility of each vehicle bundle.

Table 7 presents three vehicle ownership models. The omitted category in each model is “owns no cars.” The three models in the table differ in their representation of urban sprawl and the transit network. As in Table 4, equation (1) measures sprawl by average population density and the area of the urbanized portion of the MSA, and transit availability by (uninstrumented) distance to the nearest transit stop. Equation (2) replaces the endogenous measure of transit availability with city-wide measures of road density and rail and bus route miles supplied. Population centrality and jobs-housing imbalance are also added to the equation. Equation (3) adds our instrument for distance to the nearest transit stop to equation (2).

The impact of household characteristics on vehicle ownership are largely as expected. Having working adults in the household increases the likelihood of vehicle ownership, with the impact of working females being at least as great as the impact of working adult males. Non-working adults have no effect on the probability of owning one vehicle, but increase the chances of owning two or three vehicles. The logarithm of income net of the fixed costs of car ownership increases the probability of owning a vehicle, with the impact being greater for three or more cars than for two cars, and greater for two cars than for one car. Similar effects are observed for education (measured as years of schooling of the most educated person in the household) and for being white. Interestingly, living in a rainy city increases the probability of owning one, two or three or more vehicles.

Of our two measures of sprawl, only population centrality has a significant impact on the odds of car ownership. Households in less sprawled cities (cities with more centralized populations) are less likely to own one vehicle (compared to none) and less likely to own two vehicles (compared to none). Jobs-housing imbalance, by contrast, is never significantly different from zero at conventional levels.

Among measures of transit, lack of availability of public transit, as measured by instrumented distance from the nearest transit stop, significantly increases the probability of car ownership, for each vehicle category. Greater rail supply reduces the likelihood of vehicle purchase, conditional on a city having a rail system to begin with.<sup>15</sup>

## **B. VMTs per Vehicle**

Table 8 presents demand functions for VMTs per vehicle, estimated separately for one, two and three-or-more vehicle households. The selectivity correction term added to each equation is based on equation (3) of Table 7, and the same set of variables enter the VMT demand equations as appear in equation (3) of Table 7. Because the demand for VMTs equation fits poorly for three-or-more vehicle households, our discussion focuses on the equations for one- and two-vehicle households.

The impact of household characteristics on VMTs per vehicle is, not surprisingly, different for one- v. two-vehicle households. The number of workers in a one-vehicle household has a stronger effect on annual VMTs than in a two-vehicle household, possibly because only one car is used for commuting in a two-vehicle household. Income (net of the fixed costs of car ownership) and education both increase annual VMTs per vehicle; however, the effect is more pronounced in the case of one-vehicle households.

Our sprawl and transit measures generally have no significant impact on VMTs per vehicle, with the exception of jobs-housing imbalance in the case of two-vehicle households. Increases in rail supply, conditional on the city having a rail system, reduce annual VMTs, but this effect is statistically significant only for one-vehicle households. Although the coefficient of fuel cost per mile is always negative, it is never statistically significant. This is very likely because this variable is measured with error. To avoid endogeneity problems we have divided

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<sup>15</sup> Note that equations (2) and (3) include a dummy variable (Rail Dummy) equal to one if a rail system is present and



the annual price of gasoline in household  $i$ 's MSA by the average fuel economy of vehicles owned by households in  $i$ 's income class. The price of gasoline (averaged across the MSA) divided by the average fuel economy measure is a crude approximation to the price per mile facing an individual household.

What do tables 7 and 8 imply about the net effects of sprawl and public transit on annual VMTs? Table 9a calculates the impacts of the coefficients of the vehicle ownership models on the probability of households owning zero, one, two or three-or-more cars. As in Table 5, we increase each variable in the table by 10% in all cities and see how this alters the probability of each household in our sample choosing each vehicle bundle. The average changes in the probabilities of vehicle ownership are shown in Table 9a.

The impacts of changes in population centrality, rail supply (conditional on having a rail system) and instrumented distance to the nearest transit stop on vehicle ownership are all small. In absolute value terms, a 10 percent change in each of these variables changes the probability of owning no car by one percent or less. Table 9b spells out the implications of these changes for the expected number of miles driven for the households in our sample. The largest change in average annual VMTs per household is 388 miles, for (instrumented) distance to the nearest transit stop. This implies an elasticity of VMTs with respect to this variable of 0.22. The elasticity of VMTs with respect to population centrality and the supply of rail transit are 0.05 and 0.08 in absolute value.

## **V. Conclusions**

The results presented above suggest that measures of urban sprawl (population centrality), jobs-housing balance and transit availability (rail supply and instrumented distance to the nearest

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zero if it is not. Rail Supply may therefore be interpreted as the product of rail miles supplied and the Rail Dummy.

transit stop) may have modest effects on the commute mode choices and annual VMTs of U.S. households. The results must, of course, be interpreted with caution—results for commute mode choice are based on only 28 cities with some form of rail transit. Although the results remain significant when the New York City metropolitan area is removed from the sample, coefficient estimates vary depending on whether or not it is included. Results for annual household VMTs are based on a broader sample; however, the sample consists of a single cross-section of households.

It is, nonetheless, of interest to compare our results with other cross-sectional studies that have attempted to estimate the price elasticity of demand for VMTs. This gives some indication of the possible magnitude of the effect of price instruments (e.g., gasoline taxes) v. non-price instruments (policies to reduce urban sprawl or increase public transit supply). Viewed from this perspective, the effects reported in Table 9b do not appear so small. In a recent paper, Parry and Small (2001) report an average estimate of the price elasticity of VMTs in the United States of only -0.15. This is of the order of magnitude that we find for (instrumented) distance to the nearest transit stop. In the final analysis, however, it must be acknowledged that the impacts of urban form and transit supply on travel demand, as measured in this paper, appear quite small.

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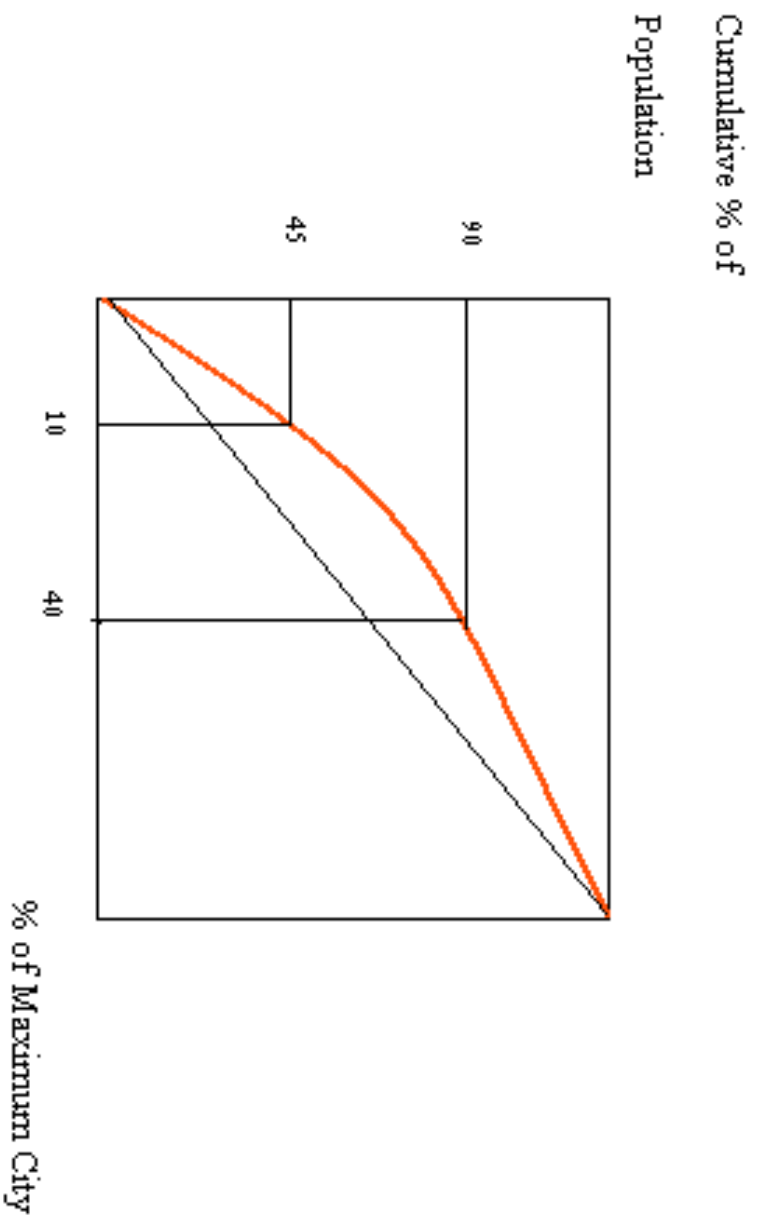
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Figure 1: Population Centrality Measure



**Table 1.**  
**Rankings of Selected Cities Based on Different Measures of Sprawl**

Urbanized Area	Land Area (km <sup>2</sup> )	Population	Rankings (1 = Least Sprawl)		
			Population Density	Jobs-Housing Imbalance	Population Centrality
New York, NY	768	16,044,012	3	62	6
Chicago, IL	410	6,792,087	6	45	62
San Francisco, CA	226	3,629,516	10	44	27
Philadelphia, PA	302	4,222,211	11	25	19
Washington, DC-MD-VA-WV	245	3,363,031	14	29	40
San Diego, CA	179	2,438,417	15	120	8
Detroit, MI	290	3,697,529	20	52	92
Boston, MA	231	2,775,370	22	32	26
Providence-Fall River-Warwick, RI-MA	77	846,293	33	116	25
Rochester, NY	57	619,653	35	101	61
Phoenix-Mesa, AZ	192	2,006,239	38	21	60
St. Louis, MO-IL	189	1,946,526	40	43	74
Cleveland, OH	165	1,677,492	42	112	80
Tampa-St. Petersburg-Clearwater, FL	168	1,708,710	43	66	90
San Antonio, TX	113	1,129,154	46	22	88
Houston, TX	305	2,901,851	48	95	108
New Haven-Meriden, CT	49	451,486	54	106	3
Milwaukee-Waukesha, WI	133	1,226,293	55	87	29
Wilmington-Newark, DE-MD	49	449,616	56	107	22
Cincinnati, OH-KY-IN	133	1,212,675	58	86	68
Wichita, KS	37	338,789	60	13	113
Sarasota-Bradenton, FL	50	444,385	61	47	5
Worcester, MA-CT	36	315,666	63	62	1
Albuquerque, NM	58	497,120	71	39	77
Fort Myers-Cape Coral, FL	32	220,552	93	54	97
Fayetteville, NC	35	241,763	95	4	117
Corpus Christi, TX	40	270,006	98	41	52
Utica-Rome, NY	24	158,553	99	23	2
Columbia, SC	52	328,349	104	33	96
Pensacola, FL	40	253,558	105	90	119
Huntsville, AL	34	180,315	114	34	44
Savannah, GA	39	198,630	117	37	77

**Table 2. Summary Statistics for City Level Variables in Various City Samples**

Variable	All Cities		Rail Cities		Non-Rail Cities	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Number of Observations	119		28		91	
Annual Rainfall (inches)	41.33	16.50	40.28	18.17	41.66	16.05
Annual Snowfall (10 inches)	1.62	2.22	1.49	1.92	1.67	2.31
Population Density (population per 1,000 km <sup>2</sup> )	0.95	0.35	1.26	0.43	0.86	0.26
Land Area (1,000 km <sup>2</sup> )	0.99	1.08	1.96	1.58	0.69	0.62
Lane Density (lane area per square mile)	0.04	0.01	0.05	0.01	0.04	0.02
Indicator for Rail Transit	0.24	0.43	1.00	0.00	0.00	0.00
Supply of Rail Transit (million miles per km <sup>2</sup> )	0.17	0.65	0.71	1.19	-	-
Supply of Non-Rail Transit (million miles per km <sup>2</sup> )	0.01	0.01	0.02	0.01	0.01	0.01
Population Centrality	0.15	0.02	0.16	0.02	0.15	0.02
Jobs-Housing Imbalance	0.55	0.11	0.55	0.09	0.55	0.11
Distance to Nearest Transit Stop (blocks)	16.22	10.40	13.16	7.00	17.13	11.09
Instrumented Distance to Nearest Transit Stop (blocks)	20.00	2.66	17.37	3.67	20.78	1.61

**Table 3. Summary Statistics for Mode Choice Sample**

	<b>Private Transport Users</b>		<b>Non-Rail Transit Users</b>		<b>Rail Transit Users</b>		<b>Non-Motorized Transport Users</b>	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Number of Observations	4191	(77.2%)	393	(7.2%)	471	(8.7%)	375	(6.9%)
Age of Worker	37.80	12.53	36.87	13.60	35.22	12.52	36.41	13.87
Indicator for Female Worker	0.45	0.50	0.56	0.50	0.49	0.50	0.50	0.50
Number of Adults in Household	2.26	0.91	2.30	1.24	2.43	1.32	2.17	0.94
Number of Children in Household	0.97	1.17	0.91	1.24	0.73	1.09	0.89	1.19
Household Income / \$ 5,000	9.78	4.02	7.64	4.03	9.13	4.15	8.37	4.22
Years of Education	14.60	2.30	13.88	2.58	14.76	2.37	14.48	2.53
White Household	0.79	0.41	0.49	0.50	0.54	0.50	0.77	0.42
Black Household	0.11	0.31	0.32	0.47	0.25	0.43	0.12	0.33
Distance to Nearest Transit Stop (blocks)	13.57	22.37	2.27	9.20	2.25	7.47	5.78	15.66
Instrumented Distance to Nearest Transit Stop (blocks)	16.17	4.95	11.35	6.31	6.93	4.77	13.30	6.29



**Table 4 (Continued)**

	Non-Rail		(A1) Rail		Non-Motor		Non-Rail		(A2) Rail		Non-Motor		Non-Rail		(A3) Rail	
Age of Worker	-0.053 (3.19)***	-0.064 (3.62)***	-0.085 (4.32)***	-0.050 (3.16)***	-0.064 (3.99)***	-0.084 (4.06)***	-0.050 (2.92)***	-0.065 (4.16)***	-0.084 (4.02)***							
Age of Worker Squared	0.001 (3.47)***	0.001 (3.05)***	0.001 (3.98)***	0.001 (3.39)***	0.001 (3.28)***	0.001 (3.66)***	0.001 (3.19)***	0.001 (3.46)***	0.001 (3.64)***							
Indicator for Female Worker	0.352 (1.83)*	0.258 (3.11)***	0.009 (0.07)	0.368 (1.97)**	0.293 (3.34)***	0.026 (0.21)	0.423 (2.24)**	0.309 (3.45)***	-0.020 (0.15)							
Number of Adults in the Household	0.020 (0.28)	0.013 (0.23)	-0.072 (1.25)	0.015 (0.25)	0.006 (0.12)	-0.079 (1.43)	-0.029 (0.38)	-0.008 (0.15)	-0.056 (0.90)							
Number of Children aged 5-21	-0.101 (1.53)	-0.205 (2.42)**	-0.119 (2.12)**	-0.110 (1.70)*	-0.206 (2.45)**	-0.125 (2.38)**	-0.087 (1.41)	-0.197 (2.26)**	-0.112 (2.20)**							
Interaction between Female Indicator and Number of Children	0.028 (0.30)	-0.063 (0.48)	0.197 (2.44)**	0.010 (0.11)	-0.081 (0.61)	0.193 (2.46)**	-0.021 (0.23)	-0.095 (0.70)	0.202 (2.49)**							
Household Income / \$5000	-0.100 (7.28)***	-0.032 (2.30)**	-0.091 (5.97)***	-0.114 (8.65)***	-0.059 (3.46)***	-0.103 (6.88)***	-0.095 (5.98)***	-0.017 (1.00)	-0.100 (5.46)***							
Years of Schooling of Most Educated Member	-0.012 (0.33)	0.093 (1.61)	0.061 (2.17)**	-0.003 (0.07)	0.099 (1.56)	0.064 (2.14)**	0.001 (0.03)	0.092 (1.53)	0.059 (2.02)**							
White Household	-0.698 (4.70)***	-0.683 (3.46)***	0.224 (0.98)	-0.726 (4.80)***	-0.723 (3.27)***	0.221 (0.94)	-0.737 (4.07)***	-0.704 (3.26)***	0.291 (1.14)							
Black Household	0.292 (1.81)*	0.010 (0.07)	-0.045 (0.14)	0.492 (2.49)**	0.141 (0.72)	0.108 (0.35)	0.494 (2.53)**	0.137 (0.81)	0.106 (0.31)							
Annual Rainfall (Inches)	0.012 (1.73)*	0.030 (1.91)*	0.006 (1.38)	-0.003 (0.36)	-0.020 (1.43)	-0.003 (0.86)	0.008 (1.00)	-0.042 (1.93)*	-0.004 (0.87)							
Annual Snowfall (10 Inches)	-0.060 (0.75)	-0.172 (0.91)	-0.017 (0.35)	-0.235 (2.61)***	-0.061 (0.39)	-0.079 (1.83)*	-0.171 (1.99)**	-0.102 (0.71)	-0.083 (1.72)*							
Vehicle Operating Cost Per Mile	0.230 (0.59)	1.141 (3.00)***	0.349 (1.33)	0.314 (1.12)	0.619 (2.18)**	0.219 (1.66)*	0.194 (0.74)	0.722 (2.63)***	0.224 (1.65)*							
Population Density (1000 people/km2)	0.093 (0.36)	-1.022 (1.80)*	0.208 (0.80)	-2.460 (2.66)***	-1.385 (1.32)	-0.842 (2.19)**	-2.034 (3.25)***	-1.918 (1.52)	-0.849 (2.05)**							

**Table 4 (Continued)**

	Non-Rail	(A1) Rail	Non-Motor	Non-Rail	(A2) Rail	Non-Motor	Non-Rail	(A3) Rail	
Land Area (1000 km2)	0.180 (4.65)***	0.656 (5.86)***	0.131 (2.48)**	0.131 (1.10)	-0.018 (0.08)	0.006 (0.11)	0.159 (1.60)	-0.077 (0.34)	-0.004 (0.07)
Distance to Nearest Transit Stop	-0.042 (5.04)***	-0.035 (5.95)***	-0.019 (3.29)***						
Density of Road Network				0.190 (2.71)***	-0.064 (1.04)	0.089 (3.32)***	0.181 (3.26)***	-0.044 (0.71)	0.097 (2.96)***
Supply of Rail Transit				24.120 (1.76)*	126.257 (4.31)***	23.395 (3.93)***	-5.792 (0.49)	131.164 (3.69)***	18.875 (2.37)**
Supply of Non-Rail Transit				39.468 (2.27)**	26.297 (0.68)	10.618 (1.15)	35.233 (2.75)***	29.324 (0.80)	9.552 (1.02)
Population Centrality				17.394 (2.96)***	-20.723 (1.71)*	10.601 (3.70)***	20.787 (3.53)***	-24.198 (1.69)*	10.997 (3.34)***
Jobs-Housing Imbalance				-4.015 (2.19)**	-3.985 (1.37)	-1.639 (3.68)***	-2.815 (1.98)**	-4.790 (1.68)*	-1.684 (3.11)***
Distance to Nearest Transit Stop (Instrumented)							-0.062 (3.23)***	-0.088 (4.83)***	-0.022 (0.89)
Constant	-2.279 (1.06)	-9.825 (3.61)***	-3.483 (2.56)**	-4.044 (1.55)	1.802 (0.45)	-3.750 (3.12)***	-4.465 (1.67)*	4.689 (1.07)	-3.530 (2.46)**
Observations		5430			5529			5321	

Absolute value of z statistics in parentheses \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

**Table 5. Marginal Effects for Commute Mode Choice Models**

An Increase of...	In the Variable	Induces a Percentage Point Change in the Probability of Using Private Transport to Work of...
0 to 1	Indicator for Female Worker	-3.0
10%	Household Income	+0.8
10%	Years of Schooling	-1.0
10%	Supply of Rail Transit	-2.5
10%	Supply of Non-Rail Transit	-0.8
10%	Population Centrality	-1.3
10%	Jobs-Housing Imbalance	+2.1
10%	Distance to Nearest Transit Stop	+0.2
10%	Instrumented Distance to Nearest Transit Stop	+0.8

**Table 6a. Summary of Household Characteristics for Vehicle Ownership Sample**

Variable	Urbanized Area NPTS Sample		Households with Complete Data	
	Mean	Std. Dev.	Mean	Std. Dev.
Observations	9719		7798	
No. of Elderly in Household	0.25	0.54	0.24	0.54
No. of Working Adult Males	0.56	0.59	0.56	0.58
No. of Working Adult Females	0.51	0.57	0.50	0.56
No. of Non-Working Adults	0.34	0.57	0.32	0.56
No. of Working Children (aged 17-21)	0.10	0.34	0.08	0.31
No. of Non-Working Children (ages 0 to 21)	0.67	1.05	0.64	1.03
Household Income / \$5000	10.23	0.77	10.25	0.76
Years of Schooling of Most Educated Member	13.90	2.61	14.02	2.64
Indicator for White Household	0.78	0.41	0.80	0.40
Indicator for Black Household	0.14	0.35	0.13	0.33
Distance to Nearest Transit Stop (blocks)	13.52	22.83	13.25	22.61
Instrumented Distance to Nearest Transit Stop (blocks)	17.27	5.34	17.28	5.36
0-Vehicle Household Dummy	0.13	0.33	0.16	0.37
1-Vehicle Household Dummy	0.42	0.49	0.41	0.49
2-Vehicle Household Dummy	0.34	0.47	0.33	0.47
3 or More Vehicle Household Dummy	0.12	0.32	0.10	0.30

**Table 7 (continued)**

	(B1)			(B2)			(B3)		
	1-Car	2-Car	3-Car	1-Car	2-Car	3-Car	1-Car	2-Car	3-Car
Number of Elderly in Household	0.128 (1.59)	0.609 (5.30)***	0.594 (4.53)***	0.108 (1.38)	0.573 (5.11)***	0.582 (4.32)***	0.147 (1.88)*	0.608 (5.35)***	0.621 (4.61)***
No. of Working Adult Males	0.468 (4.82)***	1.275 (11.48)***	1.688 (12.77)***	0.490 (5.31)***	1.267 (11.66)***	1.690 (12.70)***	0.507 (5.64)***	1.288 (11.82)***	1.712 (12.55)***
No. of Working Adult Females	0.643 (4.40)***	1.375 (6.68)***	1.885 (9.18)***	0.647 (4.48)***	1.341 (6.54)***	1.899 (9.09)***	0.661 (4.41)***	1.354 (6.40)***	1.924 (8.98)***
No. of Non-Working Adults	0.159 (1.28)	0.833 (6.44)***	1.348 (8.03)***	0.147 (1.25)	0.811 (6.32)***	1.359 (8.31)***	0.179 (1.61)	0.841 (6.63)***	1.396 (8.60)***
No. of Working Children (aged 17-21)	-0.268 (1.60)	0.431 (2.43)**	1.395 (5.85)***	-0.327 (2.02)**	0.396 (2.32)**	1.318 (5.78)***	-0.323 (2.00)**	0.391 (2.32)**	1.316 (5.85)***
No. of Non-Working Children (ages 0 to 21)	0.027 (0.66)	0.149 (3.22)***	0.018 (0.30)	0.029 (0.70)	0.158 (3.37)***	0.021 (0.33)	0.033 (0.78)	0.160 (3.35)***	0.027 (0.42)
In (Income Net of Annualized Fixed Cost of Car Ownership)	0.332 (5.64)***	1.003 (10.67)***	1.621 (12.55)***	0.359 (6.57)***	1.124 (11.43)***	1.741 (13.60)***	0.365 (6.28)***	1.064 (9.64)***	1.591 (10.46)***
Years of Schooling of Most Educated Member	0.146 (7.20)***	0.246 (9.59)***	0.248 (8.33)***	0.156 (6.71)***	0.253 (9.06)***	0.261 (8.18)***	0.156 (6.46)***	0.254 (8.74)***	0.264 (8.09)***
White Household	0.717 (4.52)***	0.856 (3.69)***	0.759 (2.59)***	0.737 (4.54)***	0.856 (3.78)***	0.751 (2.59)***	0.729 (4.48)***	0.815 (3.56)***	0.700 (2.41)**
Black Household	-0.274 (1.08)	-0.235 (0.82)	-0.423 (0.96)	-0.336 (1.28)	-0.362 (1.26)	-0.553 (1.30)	-0.319 (1.24)	-0.357 (1.25)	-0.566 (1.32)
Annual Rainfall (Inches)	-0.004 (1.31)	-0.005 (1.05)	-0.005 (0.74)	0.008 (2.01)**	0.009 (1.77)*	0.013 (2.14)**	0.011 (2.81)***	0.014 (2.91)***	0.020 (3.23)***
Annual Snowfall (10 Inches)	-0.021 (0.85)	0.029 (0.71)	0.027 (0.55)	-0.009 (0.39)	0.024 (0.82)	0.007 (0.16)	-0.005 (0.21)	0.033 (1.06)	0.018 (0.41)
Vehicle Operating Cost Per Mile	-0.196 (0.91)	-0.522 (1.47)	-0.491 (1.20)	0.191 (1.27)	0.036 (0.13)	0.232 (0.78)	0.262 (1.67)*	0.161 (0.57)	0.415 (1.23)
Population Density (1000 people/km2)	0.016 (0.11)	-0.014 (0.06)	0.235 (0.73)	0.630 (2.79)***	0.593 (2.37)**	0.695 (2.05)**	0.630 (3.05)***	0.599 (2.40)**	0.684 (1.81)*
Land Area (1000 km2)	-0.185 (7.63)***	-0.245 (5.37)***	-0.301 (4.31)***	-0.048 (1.30)	-0.027 (0.50)	-0.014 (0.19)	-0.006 (0.16)	0.038 (0.65)	0.074 (0.91)

**Table 7 (continued)**

	(B1)			(B2)			(B3)		
	1-Car	2-Car	3-Car	1-Car	2-Car	3-Car	1-Car	2-Car	3-Car
Distance to Nearest Transit Stop	0.009 (3.92)***	0.015 (5.45)***	0.016 (4.98)***						
Density of Road Network				-3.729 (0.61)	-4.329 (0.68)	2.220 (0.31)	-4.507 (0.80)	-5.787 (0.98)	0.098 (0.01)
Indicator for Rail Transit				-0.145 (1.60)	-0.091 (0.80)	0.109 (0.74)	-0.087 (1.02)	-0.002 (0.02)	0.209 (1.13)
Supply of Rail Transit				-27.755 (5.21)***	-42.065 (5.67)***	-57.813 (5.80)***	-25.158 (4.97)***	-34.657 (4.47)***	-45.509 (3.51)***
Supply of Non-Rail Transit				-11.862 (1.66)*	-17.373 (1.62)	-17.144 (1.27)	-9.218 (1.40)	-11.935 (1.14)	-8.660 (0.59)
Population Centrality				-5.907 (2.75)***	-6.563 (2.33)**	-5.623 (1.57)	-5.957 (2.72)***	-6.427 (2.11)**	-5.326 (1.34)
Jobs-Housing Imbalance				0.536 (1.09)	-0.256 (0.42)	-0.916 (1.37)	0.450 (0.98)	-0.374 (0.63)	-1.075 (1.49)
Distance to Nearest Transit Stop (Instrumented)							0.043 (3.21)***	0.083 (4.29)***	0.120 (3.18)***
Constant	-3.407 (2.32)**	-11.668 (4.73)***	-20.600 (6.64)***	-6.107 (5.07)***	-15.586 (7.25)***	-25.707 (10.05)***	-7.579 (5.78)***	-17.594 (7.60)***	-27.958 (9.62)***
Observations	7925			7882			7798		

Absolute value of z statistics in parentheses  
 \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

<b>Table 8. ln(VMTs per Vehicle) Equations</b>	1-Car Households	2-Car Households	3 or More Car Households
Number of Elderly in Household	-0.129 (2.36)**	-0.156 (4.51)***	-0.005 (0.10)
No. of Working Adult Males	0.519 (7.45)***	0.072 (2.26)**	0.059 (1.01)
No. of Working Adult Females	0.300 (5.19)***	-0.006 (0.18)	-0.007 (0.11)
No. of Non-Working Adults	0.126 (1.85)*	-0.084 (2.65)***	0.024 (0.34)
No. of Working Children (aged 17-21)	0.472 (4.57)***	0.193 (4.59)***	0.040 (0.44)
No. of Non-Working Children (ages 0 to 21)	0.050 (2.18)**	-0.002 (0.12)	-0.034 (1.27)
ln(Income Net of Annualized Fixed Cost of Car Ownership)	0.283 (7.76)***	0.103 (2.24)**	0.089 (0.93)
Years of Schooling of Most Educated Member	0.045 (3.59)***	0.017 (1.92)*	0.015 (0.97)
White Household	0.042 (0.44)	0.134 (1.65)	-0.036 (0.37)
Black Household	-0.053 (0.38)	-0.014 (0.13)	0.129 (0.96)
Annual Rainfall (Inches)	0.002 (0.97)	0.001 (0.47)	0.002 (0.69)
Annual Snowfall (10 inches)	-0.022 (1.34)	0.002 (0.27)	0.004 (0.19)
Vehicle Operating Cost Per Mile	-0.078 (1.24)	-0.005 (0.08)	-0.045 (0.52)
Population Density (1000 people/km2)	-0.175 (1.86)*	0.007 (0.08)	0.161 (1.20)
Land Area (1000 km2)	0.015 (0.96)	0.016 (1.05)	-0.029 (1.43)
Density of Road Network	4.926 (2.68)***	1.315 (0.78)	-2.032 (0.57)
Indicator for Rail Transit	0.060 (1.17)	0.118 (2.41)**	-0.017 (0.25)
Supply of Rail Transit	-6.265 (2.30)**	-3.264 (1.16)	-0.758 (0.18)
Supply of Non-Rail Transit	-2.506 (0.80)	-7.574 (1.53)	-1.898 (0.36)
Population Centrality	1.314 (1.40)	0.760 (0.84)	-0.962 (0.87)
Jobs-Housing Imbalance	0.356 (1.39)	0.554 (2.57)**	0.396 (1.34)
Distance to Nearest Transit Stop (Instrumented)	0.011 (1.25)	0.007 (0.77)	0.003 (0.14)
Selectivity Correction Factor	0.102 (2.63)***	0.027 (1.18)	0.000 (0.00)
Constant	5.316 (9.20)***	7.263 (11.05)***	8.063 (4.73)***
Observations	3225	2541	784
R-Squared	0.17	0.08	0.03

|Robust t statistics| in parentheses

\* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

**Table 9a. Marginal Effects for Vehicle Ownership Models**

An Increase of...	In the Variable	Induces the Following Percentage Point Change in the Probability of Owning..			
		No Car	1-Car	2-Car	3 or More Cars
10%	Household Income	-5.3	-10.5	+7.1	+8.6
10%	Years of Schooling	-2.2	-0.9	+2.5	+0.7
10%	Supply of Rail Transit	+0.4	-0.2	-0.2	-0.1
10%	Population Centrality	+1.0	-0.6	-0.4	+0.0
10%	Distance to Nearest Transit Stop	-0.1	-0.1	+0.1	+0.1
10%	Instrumented Distance to Nearest Transit Stop	-0.8	-0.9	+0.9	+0.8

Note: Marginal Effects Calculated based on Model B2 in Table 7, with the exception of Distance to Nearest Transit Stop (model B1) and Instrumented Distance to Nearest Transit Stop (Model B3).

**Table 9b. Total Effects on VMTs per Household\***

An Increase of...	In the Variable	Changes Average VMT per Household in Our Sample by:
10%	Population Centrality	-88 miles (-0.5%)
10%	Supply of Rail Transit (in Rail Cities)	-143 miles (-0.8%)
10%	Instrumented Distance to Nearest Transit Stop	+388 miles (+2.2%)

\*The calculations conservatively assume that households own a maximum of 3 cars and that effects are zero when they are statistically insignificant



## **Appendix A Data Appendix**

### VMT, Mode Choice and Individual/Household Characteristics:

These data come from the various datasets of the *1990 Nationwide Personal Transportation Survey (NPTS)*. The datasets include separate files for vehicles, individuals, households as well as trips that household members took in their given 24-hour travel period. We used information from the vehicle dataset to re-construct the annual VMTs per household. The household annual VMTs were obtained by summing the per vehicle VMTs of all of the household's vehicles. If a vehicle had been owned less than a year, annualized VMTs for the vehicle were calculated using the following formula: the reported vehicle miles were divided by the number of months the car had been owned and then multiplied by 12 to get the annual figure. About 33 percent of the households in the probit sample had owned at least one vehicle less than a month. VMTs per car were capped at 115,000 miles as done in the original dataset. This affected 21 households in our sample. In the original household dataset households which had reported that they had cars, but did not report any VMTs for any of their cars were given zero household VMTs. We, on the other hand, assigned these households with missing VMT information and thus they did not enter in our analyses. We also assigned household VMT as missing when there was incomplete information on some of the cars owned by the household. Of the 10,718 households in the urbanized areas of interest, we lost 2,085 households due to completely or partially missing VMT data.

The household composition variables – number of elderly, number of working adult males, number of working adult females, number of working children (ages 15 to 21), number of non-working children (ages 0 to 21) – were constructed from the individual level file. The education of the most educated person in the household was also obtained from this dataset. The household income was also obtained from the household level dataset. If, however, the income data were missing for a household, it was predicted using the other household level variables. There are 1,850 households in our probit sample for which predicted income is used. The race variables and the distance to the nearest transit stop were obtained from the household level dataset.

### Population Centrality and Compactness Measures:

These measures were calculated from the *1990 Decennial Census of Population and Housing Characteristics* as reported in the 1990 Census CD (Geolytics Inc.).

### Jobs-Housing Imbalance Measure:

The jobs measure was calculated using the employment data at the zip code level from the *1990 Zip Code Business Patterns*. Note these data do not include self-employed persons, domestic service workers, railroad employees, agriculture production workers, and most government employees. The total number of employees was obtained by multiplying the various

number of employees size categories by the mid-point of the range. The population figures at the zip code come from the *1990 Decennial Census of Population and Housing Characteristics*. Only zip codes that were in the urbanized part of an MSA were used. To construct the measure we calculated the percent of population living in each zip code and percent of employment in each zip code. The total population and total employment used for these calculations were obtained by summing the population and employment of each zip code within the urbanized area for urbanized area totals. We then generated a measure of imbalance by the following formula: the absolute value of the difference of the employment proportion and population proportion in a particular zip code normalized by the proportion of people living in the zip code. The median value of this number became the measure of imbalance in each urbanized area.

#### Urban Area and Urban Land Area:

These figures come from the *1990 Decennial Census of Population and Housing Characteristics*.

#### Rail and Non-Rail Transit Data:

These data come from the *1994 National Transit Database*. Transit agencies are grouped by urbanized areas and transit data provided by these agencies are summed to yield the transit figures. The only exception is the New Jersey Transit Agency which is divided between Philadelphia, Trenton and New York, with shares of 10, 20 and 70 percent, respectively.

#### Lane Density:

The data are calculated from the *1990 Highway Statistics*. First, the number of lane miles per urbanized area is calculated and multiplying by an estimated lane width (thirteen feet). The resulting area of road is divided by the corresponding land area in the *1990 Highway Statistics*.

#### Weather Data:

The weather data come from the National Oceanic and Atmospheric Administration's TD3220 files for 1990. The data are from a weather station in or near the urbanized area. Snowfall is measured in tens of inches and rainfall is measured in hundreds of inches.

#### Gas Price Data:

Gas price data were obtained from Walls, Harrington and Krupnick (2000).

#### Instrumented Distance to Local Transit:

First, each household in our sample was assigned to all the census tracts that they could afford to live in based on their income. To correct for the fact that some households reside in tracts where the average income is higher than their own income an "effective" income was

determined for each household. The effective income was based on estimates obtained from the *1995 Nationwide Personal Transportation Survey* where both the household's income and the mean income of the block group in which the household lives in are reported. For the urban households in the 1995 NPTS, the maximum of the household's income and the mean income of the block group in which they resided was determined. This maximum of these two incomes became the effective income. The effective income in the 1995 sample was regressed on the household's own income, household composition variables as well as educational attainment and race. The coefficient estimates from this regression were used to calculate the effective income for the 1990 NPTS sample. If the effective income generated by this method was more than the household's reported income, the effective income was used to determine which are the census tracts that the household could afford to live in, otherwise the household's reported income was used for the determination. Once the affordable tracts in the household's urbanized area were identified, the mean proportion of the population in the tract using public transit as their main means of commuting was computed. This average percent of people using public transit for commuting became the instrument for local availability of public transit. The data on percentage of tract population using various means of transportation to work were obtained from the *1990 Decennial Census of Population and Housing Characteristics*.

#### Bibliography:

Department of Transportation. *1990 Nationwide Personal Transportation Survey*, found at <http://www-cta.ornl.gov/npts/1990/index.html>

Office of Highway Policy Information. *Highway Statistics 1990*, Federal Highway Administration, Tables HM-71 and HM-72.

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Federal Transit Administration. *1994 National Transit Database* found at <http://www.fta.dot.gov/ntl/database.html>



**Appendix B**

Urbanized Area	Number Reporting Commute Mode Choice	% taking Private Transport to Work	% taking Non-Rail Public Transit to Work	% taking Rail Public Transit to Work	% taking Non-Motorized Modes to Work	Rail Transit Supply (10000 miles per km2)	Non-Rail Transit Supply (10000 miles per km2)	Lane Density (area of roads per square mile of land)	Land Area (km2)	Population	Density (people per square kilometer)	Jobs-Housing Imbalance (standardized)	Population Centrality (standardized)	Average VMTs per Household (unconditional)	Number of Households with Complete Data
Akron, OH	48	95.8	0.0	0.0	4.2	0.0	0.8	0.06	666	527,863	793	-1.94	-1.06	21,025	33
Albany-Schenectady-Troy, NY	42	78.6	11.9	0.0	9.5	0.0	1.3	0.03	540	509,106	942	-0.31	0.73	14,130	28
Albuquerque, NM	28	92.9	0.0	0.0	7.1	0.0	0.8	0.05	585	497,120	850	0.49	-0.52	25,426	23
Allentown-Bethlehem-Easton, PA	43	83.7	0.0	0.0	16.3	0.0	0.8	0.05	368	410,436	1,115	-1.00	1.80	13,125	27
Anchorage, AK	16	93.8	0.0	0.0	6.3	0.0	0.5	0.03	418	221,883	531	-	1.20	11,750	16
Atlanta, GA	202	88.1	4.0	4.0	4.0	0.7	1.0	0.04	2,944	2,157,806	733	0.47	-1.83	23,868	127
Augusta-Aiken, GA-SC	9	100.0	0.0	0.0	0.0	0.0	0.2	0.03	489	286,538	586	-0.60	-0.65	14,220	5
Austin-San Marcos, TX	52	90.4	5.8	0.0	3.8	0.0	1.9	0.10	708	562,008	794	0.66	0.33	18,948	41
Bakersfield, CA	13	92.3	7.7	0.0	0.0	0.0	1.0	0.04	255	302,605	1,189	-0.36	-1.08	21,059	13
Baltimore, MD	161	82.0	9.3	1.2	7.5	0.8	1.4	0.04	1,535	1,889,873	1,232	-0.07	1.02	19,294	105
Baton Rouge, LA	24	100.0	0.0	0.0	0.0	0.0	0.3	0.04	480	365,943	762	1.03	-0.07	39,300	10
Biloxi-Gulfport-Pascagoula, MS	5	100.0	0.0	0.0	0.0	0.0	0.0	0.04	334	179,643	538	-	1.42	13,380	5
Birmingham, AL	42	95.2	0.0	0.0	4.8	0.0	0.3	0.04	1,033	622,074	602	1.09	0.09	17,822	26
Boston, MA-NH	163	74.2	3.1	9.2	13.5	1.8	1.3	0.04	2,308	2,775,370	1,202	-0.63	0.66	20,630	107
Bridgeport, CT	278	94.2	1.1	1.8	2.9	0.0	0.6	0.05	416	413,863	995	-1.71	1.57	19,046	204
Buffalo-Niagara Falls, NY	36	97.2	2.8	0.0	0.0	0.1	1.1	0.04	739	954,332	1,291	-1.36	-0.43	18,090	37
Canton-Massillon, OH	36	100.0	0.0	0.0	0.0	0.0	0.4	0.07	282	244,576	866	-0.20	-0.14	22,411	26
Charleston-North Charleston, SC	25	92.0	0.0	0.0	8.0	0.0	0.2	0.02	650	393,956	606	-0.07	0.49	18,463	14
Charlotte-Gastonia-Rock Hill, NC-SC	81	93.8	3.7	0.0	2.5	0.0	0.9	0.04	626	455,597	728	2.22	-1.40	20,655	45
Chattanooga, TN-GA	43	93.0	0.0	0.0	7.0	0.0	0.3	0.03	665	296,955	446	0.80	-1.18	17,222	28
Chicago, IL	474	80.2	5.9	7.2	6.8	1.9	2.7	0.05	4,104	6,792,087	1,655	-0.26	-0.16	16,486	318
Cincinnati, OH-KY-IN	118	94.1	1.7	0.0	4.2	0.0	1.1	0.03	1,325	1,212,675	915	-0.54	-0.34	21,719	87
Cleveland, OH	123	86.2	8.1	1.6	4.1	0.2	1.4	0.04	1,647	1,677,492	1,019	-1.59	-0.54	17,282	83
Colorado Springs, CO	39	97.4	2.6	0.0	0.0	0.0	0.6	0.04	457	352,989	772	0.87	-	16,927	29
Columbia, SC	26	100.0	0.0	0.0	0.0	0.0	0.4	0.04	515	328,349	638	0.58	-0.82	15,826	21
Columbus, GA-AL	17	100.0	0.0	0.0	0.0	0.0	0.4	0.03	343	220,698	643	1.51	-1.55	55,563	8
Columbus, OH	101	86.1	9.9	0.0	4.0	0.0	1.0	0.05	893	945,237	1,058	-0.90	-0.54	20,036	63

Urbanized Area	Number Reporting Commute Mode Choice	% taking Private Transport to Work	% taking Non-Rail Public Transit to Work	% taking Rail Public Transit to Work	% taking Non-Motorized Modes to Work	Rail Transit Supply (10000 miles per km2)	Non-Rail Transit Supply (10000 miles per km2)	Lane Density (area of roads per square mile of land)	Land Area (km2)	Population	Density (people per square kilometer)	Jobs-Housing Imbalance (standardized)	Population Centrality (standardized)	Average VMTs per Household (unconditional)	Number of Housholds with Complete Data
Corpus Christi, TX	12	100.0	0.0	0.0	0.0	0.0	0.9	0.06	403	270,006	670	0.48	-0.02	20,810	10
Dallas, TX	170	94.1	2.4	0.0	3.5	0.0	1.2	0.06	3,737	3,198,259	856	1.06	0.05	22,318	124
Davenport-Moline-Rock Island, IA-IL	28	100.0	0.0	0.0	0.0	0.0	0.7	0.04	378	264,018	698	-1.46	0.21	15,839	19
Daytona Beach, FL	16	100.0	0.0	0.0	0.0	0.0	0.6	0.04	331	221,341	669	-1.62	1.35	19,226	14
Dayton-Springfield, OH	64	96.9	0.0	0.0	3.1	0.0	1.3	0.05	708	613,467	866	-0.70	-0.21	21,593	50
Denver, CO	156	88.5	4.5	0.0	7.1	0.0	2.3	0.07	1,188	1,517,977	1,277	0.44	-1.05	20,804	108
Des Moines, IA	24	100.0	0.0	0.0	0.0	0.0	0.4	0.05	414	293,666	710	-0.26	-0.67	24,629	16
Detroit, MI	307	94.5	1.0	0.0	4.6	0.0	1.0	0.05	2,899	3,697,529	1,275	0.18	-0.77	22,134	220
El Paso, TX	25	96.0	4.0	0.0	0.0	0.0	1.3	0.07	571	571,017	1,000	1.18	-0.88	22,135	19
Fayetteville, NC	13	92.3	0.0	0.0	7.7	0.0	0.2	0.03	355	241,763	681	2.06	-1.60	20,705	9
Flint, MI	14	92.9	0.0	0.0	7.1	0.0	1.0	0.04	424	326,023	768	-1.00	-0.08	19,343	13
Fort Lauderdale, FL	87	96.6	1.1	0.0	2.3	0.0	2.0	0.05	847	1,238,134	1,461	0.25	-1.27	20,238	76
Fort Myers-Cape Coral, FL	25	96.0	0.0	4.0	0.0	0.0	0.6	0.03	322	220,552	686	0.14	-0.86	16,816	19
Fort Wayne, IN	25	92.0	0.0	0.0	8.0	0.0	0.4	0.05	270	248,424	922	0.23	-0.65	12,822	18
Fresno, CA	27	81.5	3.7	0.0	14.8	0.0	1.0	0.06	344	453,388	1,319	-0.18	-0.81	21,733	27
Grand Rapids-Muskegon-Holland, MI	54	88.9	0.0	0.0	11.1	0.0	0.7	0.04	578	436,336	755	-0.67	0.09	22,392	34
Greenville-Spartanburg-Anderson, SC	20	95.0	5.0	0.0	0.0	0.0	0.5	0.03	384	248,173	647	-0.53	-0.41	32,330	13
Harrisburg-Lebanon-Carlisle, PA	31	90.3	0.0	0.0	9.7	0.0	0.3	0.04	388	292,904	755	-0.89	0.13	27,192	21
Hartford, CT	358	90.2	3.9	0.0	5.9	0.1	1.3	0.03	625	546,198	874	-1.79	0.83	20,457	267
Honolulu, HI	36	80.6	13.9	0.0	5.6	0.0	5.5	0.03	359	632,603	1,761	2.01	1.53	13,512	27
Houston, TX	233	95.7	0.9	0.0	3.4	0.0	1.4	0.05	3,049	2,901,851	952	0.80	-1.14	25,771	147
Huntsville, AL	6	83.3	0.0	0.0	16.7	0.0	0.3	0.02	343	180,315	526	0.56	0.14	14,844	6
Indianapolis, IN	1043	93.8	2.8	0.3	3.2	0.0	0.5	0.04	1,214	914,761	753	-0.47	-0.82	19,912	754
Jackson, MS	12	100.0	0.0	0.0	0.0	0.0	0.2	0.04	562	289,285	515	0.51	-0.56	23,483	8
Jacksonville, FL	56	98.2	0.0	0.0	1.8	0.0	0.6	0.03	1,315	738,413	562	1.41	-0.06	21,231	42

Urbanized Area	Number Reporting Commute Mode Choice	% taking Private Transport to Work	% taking Non-Rail Public Transit to Work	% taking Rail Public Transit to Work	% taking Non-Motorized Modes to Work	Rail Transit Supply (10000 miles per km2)	Non-Rail Transit Supply (10000 miles per km2)	Lane Density (area of roads per square mile of land)	Land Area (km2)	Population	Density (people per square kilometer)	Jobs-Housing Imbalance (standardized)	Population Centrality (standardized)	Average VMTs per Household (unconditional)	Number of Housholds with Complete Data
Kansas City, MO-KS	120	90.8	4.2	0.0	5.0	0.0	0.5	0.05	1,973	1,275,317	646	0.65	-1.03	21,676	76
Knoxville, TN	23	95.7	4.3	0.0	0.0	0.0	0.3	0.03	567	304,466	537	-0.19	0.42	19,528	17
Lansing-East Lansing, MI	24	91.7	4.2	0.0	4.2	0.0	1.2	0.04	256	265,095	1,037	-0.67	-0.78	14,984	14
Las Vegas, NV-AZ	46	100.0	0.0	0.0	0.0	0.0	1.7	0.11	598	697,348	1,165	2.13	-0.60	20,149	26
Lawrence, MA-NH	15	86.7	6.7	0.0	6.7	0.0	0.5	0.04	286	237,362	830	0.40	1.17	27,794	13
Lexington, KY	28	92.9	0.0	0.0	7.1	0.0	0.5	0.03	254	220,701	868	0.02	0.15	25,707	15
Little Rock-North Little Rock, AR	30	93.3	0.0	3.3	3.3	0.0	0.4	0.07	516	305,353	592	0.17	-0.76	19,846	27
Lorain-Elyria, OH	0	-	-	-	-	0.0	0.1	0.03	381	224,087	589	-0.50	0.09	16,984	8
Los Angeles-Long Beach, CA	543	87.7	6.6	0.0	5.7	0.1	2.8	0.06	5,091	11,402,946	2,240	-0.29	0.84	20,579	370
Louisville, KY-IN	61	90.2	4.9	0.0	4.9	0.0	1.4	0.04	732	754,956	1,032	0.13	-1.05	22,919	44
Lowell, MA-NH	22	86.4	4.5	4.5	4.5	0.0	0.5	0.04	174	181,651	1,046	-2.12	1.58	22,994	14
Madison, WI	19	73.7	5.3	0.0	21.1	0.0	2.1	0.05	253	244,336	965	-1.45	0.31	19,086	14
McAllen-Edinburg-Mission, TX	2	100.0	0.0	0.0	0.0	0.0	0.0	0.07	322	263,192	817	-0.13	0.51	16,314	7
Melbourne-Titusville-Palm Bay, FL	30	100.0	0.0	0.0	0.0	0.0	0.6	0.02	604	305,978	507	1.52	0.57	26,488	27
Memphis, TN-AR-MS	43	93.0	2.3	2.3	2.3	0.0	0.8	0.04	883	825,193	934	0.79	-1.17	20,515	25
Miami, FL	88	81.8	6.8	1.1	10.2	0.7	3.8	0.06	913	1,914,660	2,096	-0.88	-0.32	16,320	61
Milwaukee-Waukesha, WI	100	87.0	8.0	0.0	5.0	0.0	1.7	0.04	1,326	1,226,293	925	-0.59	0.55	16,457	72
Minneapolis-St. Paul, MN-WI	154	81.2	7.8	0.0	11.0	0.0	0.9	0.04	2,753	2,079,676	755	-	-0.34	20,121	120
Mobile, AL	30	90.0	0.0	0.0	10.0	0.0	0.3	0.03	593	300,912	507	0.60	-0.47	19,900	21
Modesto, CA	13	100.0	0.0	0.0	0.0	0.0	1.3	0.07	135	230,609	1,708	-2.20	-0.69	15,265	14
Montgomery, AL	28	89.3	3.6	0.0	7.1	0.0	0.4	0.03	405	210,007	518	-2.01	-0.02	14,938	15
Nashville, TN	57	96.5	1.8	0.0	1.8	0.0	0.4	0.03	1,252	573,294	458	0.83	-0.95	24,109	40
New Haven-Meriden, CT	322	89.4	2.8	0.6	7.1	0.0	0.9	0.04	486	451,486	929	-1.36	2.13	19,442	251
New Orleans, LA	69	87.0	8.7	0.0	4.3	0.1	2.1	0.04	700	1,040,226	1,487	0.28	0.42	17,218	60
New York, NY	1162	42.3	13.9	33.6	10.1	5.7	3.0	0.05	7,683	16,044,012	2,088	0.04	1.80	9,411	949
Norfolk-Virginia Beach-Newport News, VA-NC	111	86.5	3.6	0.0	9.9	0.0	0.4	0.02	1,719	1,323,098	770	0.11	0.36	18,574	74

Urbanized Area	Number Reporting Commute Mode Choice	% taking Private Transport to Work	% taking Non-Rail Public Transit to Work	% taking Rail Public Transit to Work	% taking Non-Motorized Modes to Work	Rail Transit Supply (10000 miles per km2)	Non-Rail Transit Supply (10000 miles per km2)	Lane Density (area of roads per square mile of land)	Land Area (km2)	Population	Density (people per square kilometer)	Jobs-Housing Imbalance (standardized)	Population Centrality (standardized)	Average VMTs per Household (unconditional)	Number of Housholds with Complete Data
Oakland, CA	155	85.8	3.9	4.5	5.8	0.0	1.2	0.05	2,264	3,629,516	1,603	0.44	0.64	20,428	115
Oklahoma City, OK	55	94.5	1.8	0.0	3.6	0.0	0.2	0.04	1,675	784,425	468	1.05	-0.17	21,347	43
Omaha, NE-IA	44	95.5	4.5	0.0	0.0	0.0	0.9	0.05	500	544,292	1,089	0.68	-0.74	21,200	30
Orlando, FL	86	97.7	0.0	0.0	2.3	0.0	1.2	0.04	1,022	887,126	868	1.25	-1.36	22,017	52
Pensacola, FL	12	91.7	0.0	0.0	8.3	0.0	0.3	0.04	402	253,558	630	-0.63	-1.81	27,196	9
Peoria-Pekin, IL	18	88.9	5.6	0.0	5.6	0.0	0.5	0.03	334	242,353	725	-0.05	-0.41	14,576	14
Philadelphia, PA-NJ	363	81.8	6.3	5.0	6.9	1.4	2.1	0.04	3,015	4,222,211	1,400	-0.68	0.83	16,319	258
Phoenix-Mesa, AZ	160	92.5	2.5	0.0	5.0	0.0	0.9	0.04	1,919	2,006,239	1,045	0.98	-0.14	23,984	115
Pittsburgh, PA	130	80.0	10.0	1.5	8.5	0.1	1.9	0.03	2,015	1,678,745	833	-0.32	0.70	16,880	103
Portland-Vancouver, OR-WA	0	-	-	-	-	0.2	2.6	0.05	1,005	1,172,158	1,166	0.07	-0.92	18,312	56
Providence-Fall River-Warwick, RI-MA	55	89.1	5.5	1.8	3.6	0.0	1.2	0.04	774	846,293	1,094	-1.90	0.70	20,321	39
Provo-Orem, UT	12	100.0	0.0	0.0	0.0	0.0	0.0	0.03	258	220,556	855	-0.66	2.05	21,478	6
Raleigh-Durham-Chapel Hill, NC	53	96.2	3.8	0.0	0.0	0.0	1.0	0.04	456	305,925	671	0.19	-1.21	23,772	39
Richmond-Petersburg, VA	32	78.1	12.5	0.0	9.4	0.0	0.7	0.04	784	589,980	753	-1.54	-0.38	15,551	28
Riverside-San Bernardino, CA	169	94.7	1.2	0.0	4.1	0.0	1.0	0.04	1,192	1,170,196	982	-	-	27,979	116
Rochester, NY	55	92.7	1.8	0.0	5.5	0.0	1.1	0.04	570	619,653	1,087	-0.98	-0.15	22,581	42
Rockford, IL	9	88.9	11.1	0.0	0.0	0.0	0.6	0.05	236	207,826	881	-0.65	0.14	13,988	8
Sacramento, CA	80	92.5	3.8	0.0	3.8	0.2	1.1	0.05	865	1,097,005	1,269	-0.22	-0.35	23,468	62
Salt Lake City-Ogden, UT	66	90.9	1.5	0.0	7.6	0.0	0.7	0.04	2,751	3,043,531	1,106	0.49	-0.95	19,431	40
San Antonio, TX	80	97.5	1.3	0.0	1.3	0.0	2.4	0.07	1,135	1,129,154	995	0.97	-0.72	21,401	60
San Diego, CA	219	90.9	1.4	0.9	6.8	0.2	1.6	0.04	1,788	2,348,417	1,314	2.28	1.73	25,283	141
San Francisco, CA	112	68.8	18.8	3.6	8.9	2.1	2.1	0.05	2,264	3,629,516	1,603	0.44	0.64	19,370	64
San Jose, CA	93	89.2	2.2	1.1	7.5	0.2	2.1	0.06	877	1,435,019	1,637	0.50	0.10	19,159	67
Santa Rosa, CA	17	76.5	11.8	0.0	11.8	0.0	1.3	0.04	174	194,560	1,118	-0.44	0.47	15,950	14
Sarasota-Bradenton, FL	29	100.0	0.0	0.0	0.0	0.0	0.5	0.03	500	444,385	889	0.31	1.84	23,781	25
Savannah, GA	17	70.6	29.4	0.0	0.0	0.0	0.6	0.02	390	198,630	509	0.50	-0.51	8,038	13



Urbanized Area	Number Reporting Commute Mode Choice	% taking Private Transport to Work	% taking Non-Rail Public Transit to Work	% taking Rail Public Transit to Work	% taking Non-Motorized Modes to Work	Rail Transit Supply (10000 miles per km2)	Non-Rail Transit Supply (10000 miles per km2)	Lane Density (area of roads per square mile of land)	Land Area (km2)	Population	Density (people per square kilometer)	Jobs-Housing Imbalance (standardized)	Population Centrality (standardized)	Average VMTs per Household (unconditional)	Number of Housholds with Complete Data
Scranton-Wilkes-Barre-Hazleton, PA	26	76.9	3.8	0.0	19.2	0.0	0.4	0.03	521	388,225	745	-1.46	0.88	8,112	26
Seattle-Bellevue-Everett, WA	136	87.5	7.4	0.0	5.1	0.0	3.3	0.05	1,523	1,744,086	1,145	1.29	0.27	20,795	111
Shreveport-Bossier City, LA	14	85.7	7.1	0.0	7.1	0.0	0.6	0.03	379	256,489	676	0.99	-1.75	13,017	18
South Bend, IN	16	87.5	12.5	0.0	0.0	0.0	0.6	0.04	312	237,932	763	-1.28	0.37	12,363	13
Spokane, WA	19	84.2	10.5	0.0	5.3	0.0	2.5	0.05	294	279,038	948	0.13	0.82	13,098	21
Springfield, MA	40	90.0	5.0	0.0	5.0	0.0	0.7	0.04	782	532,747	681	-0.46	0.43	18,800	28
St. Louis, MO-IL	162	91.4	4.3	0.0	4.3	0.1	1.3	0.05	1,886	1,946,526	1,032	0.46	-0.43	20,442	136
Stockton-Lodi, CA	29	89.7	6.9	0.0	3.4	0.0	1.1	0.06	191	262,046	1,371	-0.10	-0.11	23,888	20
Syracuse, NY	29	93.1	0.0	3.4	3.4	0.0	1.4	0.05	346	388,918	1,124	0.49	1.03	17,599	20
Tacoma, WA	35	97.1	0.0	0.0	2.9	0.0	1.9	0.04	603	497,210	825	1.10	-0.66	22,561	19
Tampa-St. Petersburg-Clearwater, FL	130	91.5	2.3	0.0	6.2	0.0	0.5	0.04	1,683	1,708,710	1,015	-0.10	-0.75	15,382	116
Toledo, OH	34	94.1	2.9	0.0	2.9	0.0	0.9	0.05	501	489,155	977	-0.66	-0.49	18,164	24
Trenton, NJ	23	87.0	4.3	0.0	8.7	1.6	4.3	0.05	248	298,602	1,203	-0.21	-0.03	19,638	16
Tucson, AZ	47	93.6	0.0	0.0	6.4	0.0	1.3	0.08	639	579,235	907	1.77	-0.95	18,623	43
Tulsa, OK	24	100.0	0.0	0.0	0.0	0.0	0.5	0.06	788	474,668	602	1.40	-0.23	19,723	25
Utica-Rome, NY	9	88.9	11.1	0.0	0.0	0.0	0.5	0.03	237	158,553	669	0.85	2.46	25,867	6
Ventura, CA	0	-	-	-	-	0.0	0.3	0.04	407	480,482	1,181	-	-	-	0
Washington, DC-MD-VA	361	80.1	8.3	5.0	6.6	1.7	1.9	0.04	2,447	3,363,031	1,375	0.66	0.27	20,562	214
West Palm Beach-Boca Raton, FL	42	92.9	0.0	0.0	7.1	0.0	0.4	0.04	794	794,848	1,001	-0.22	1.09	22,116	34
Wichita, KS	31	93.5	0.0	0.0	6.5	0.0	0.6	0.04	374	338,789	905	1.21	-1.35	17,313	19
Wilmington-Newark, DE-MD	32	100.0	0.0	0.0	0.0	0.0	1.2	0.05	487	449,616	924	-1.36	0.82	13,918	25
Worcester, MA-CT	13	84.6	0.0	0.0	15.4	0.0	1.0	0.03	359	315,666	878	-0.06	2.74	24,228	9
Youngstown-Warren, OH	34	100.0	0.0	0.0	0.0	0.0	0.3	0.06	433	361,627	834	-0.23	-0.18	21,154	26



## Appendix C

### Calculation of Fixed Costs of Vehicle Ownership and Average Fuel Economy

To calculate the fixed costs of vehicle ownership we divide the households in our sample into three income groups (0-29,999; 30,000-59,999; 60,000+) and calculate an average cost of vehicle ownership based on the makes, models and vintages of automobiles owned by households in that group.

In general, the cost of owning a car of vintage  $v$  in 1990 would be the cost of buying that car in 1990,  $P_v$ , times the sum of the rate of interest ( $r$ ) and the rate of depreciation ( $d$ ), plus insurance costs,  $I_v$ .

$$\text{Fixed Costs of Car Ownership} = (r + d) P_v + I_v.$$

Unfortunately, our data on insurance costs, average insurance expenditures per auto (Insurance Information Institute), are available only at the state level and do not vary with make, model or vintage. We assume  $r = 0.10$  and  $d = 0.05$ . To compute an average value of  $P_v$  for each income group we divide the vehicles owned by each income group into three vintage categories—New (1991-1987), Medium (1986-1980) and Old (1979-1975). As Table A.1 indicates, higher income households are more likely to own newer cars.

**Table A.1. Car Vintage by Income Class (%)**

	<b>Income</b>		
<b>Vintage</b>	<i>High</i>	<i>Medium</i>	<i>Low</i>
<i>Old</i>	11.9	18.7	27.4
<i>Medium</i>	39.8	43.6	46
<i>New</i>	48.3	37.4	26.6

For each of the 9 vintage/income groups in Table A.1 we selected the 10 make/model combinations owned by the greatest number of households. An average value of  $P_v$  was calculated by weighting 1990 *Kelley Blue Book* suggested retail prices for each of the 10 make/model combinations by the share of consumers buying each model. The resulting average prices are shown in Table A.2.

**Table A.2. Average Car Price by Vintage and Income Class (\$)**

	<b>Income</b>		
<b>Vintage</b>	<i>High</i>	<i>Medium</i>	<i>Low</i>
<i>Old</i>	1645	1540	1528
<i>Medium</i>	4225	3721	3538
<i>New</i>	12629	10568	9296

The average price for each income group was computed by weighting  $P_v$  for each vintage by the fraction of the income group buying that vintage (Table A.1).

Average fuel economy was calculated in a similar fashion, based on the fuel economy of top ten selling make/model combinations in each income/vintage class. The average miles per gallon for each income group was computed by weighting the numbers in Table A.3 by the fraction of the income group buying that vintage (Table A.1).

**Table A.3. Average Miles per Gallon by Vintage and Income Class**

	<b>Income</b>		
<b>Vintage</b>	High	Medium	Low
Old	14.2	14.2	14.2
Medium	22.5	24.6	22.5
New	24	24	25.5