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Abstract

Planners are increasingly viewing land use policies as a way to manage transportation demand. Yet the evidence on the link between land use and travel behavior is inconclusive. This paper uses travel diary data for Southern California residents to examine the demand for non-work travel. Both non-work automobile trips and non-work miles travelled by car are modelled as a function of individual sociodemographic variables and land use characteristics near the person's place of residence. The land use variables are rarely statistically significant, and diagnostic tests suggest that land use (and thus residential location choice) is endogenous to non-work travel. The implications are twofold. The link between land use and non-work travel is weak at best, at least for the sample studied here, and future research should treat residential location and thus nearby land use characteristics as endogenous in models of travel behavior.

The idea that land use planning can affect transportation demand is a popular one. Transportation proposals that advocate jobs/housing balance (Cervero, 1989), neotraditional neighborhood design (Duany and Plater-Zyberk, 1991), and transit-oriented development (Calthorpe, 1993; Cervero, 1994) all share the belief that land use policy is a promising transportation planning tool. Even more impressive is the extent to which these policies are being debated and adopted by practicing planners. Examples abound of jobs/housing balancing elements (Association of Bay Area Governments, 1985; Hamilton, et. al., 1991), proposed or existing neotraditional communities that claim to deliver transportation benefits (Calavita, 1993; *U.S. News and World Report*, 1990) and transit-oriented development plans (City of Chula Vista, 1994; City of Los Angeles, 1993; City of San Diego, 1992).

Yet despite all the discussion, the idea that land use planning can influence travel behavior is largely unproven. Until recently, the theoretical underpinnings of the concept have been divorced from standard travel demand models. The evidence used to bolster claims of transportation benefits are either based on simulation studies that lack important behavioral elements or on a body of empirical work which gives what appears to be confusing and even contradictory results. This paper is an attempt to begin to bridge the gap between what practice thinks we know and what we actually understand by formulating and estimating a model of how travel behavior is linked to land use patterns near a person's place of residence. The results provide a framework for rigorously testing the ability of land use policy to affect travel behavior.

Section I: Land Use Policy and Travel Behavior: Theoretical Underpinnings and Empirical Evidence

The idea that land use policy can influence travel behavior stems from the observation that the two variables are typically correlated. For decades, standard four-step travel demand estimation techniques have predicted the number of trips originating from a geographic area (or zone) and the number of trips terminating in a zone based on variables that include population and employment within the zone (Domencich and McFadden 1975; Ortuzar and Willumsen 1994; Kain 1990). Yet the attempt to move from observed relationships between land use and travel to policy tools requires a deeper understanding.

Travel is a derived demand, and can thus be analyzed using the standard tools of microeconomics (see, e.g. Small, 1992). Crane (1996b) formulated a demand model for three modes of travel -- auto trips, walking trips, and transit trips, and then analyzed how both the number of trips and the total miles travelled by each mode respond to changes in street network design, traffic calming policies which slow automobile travel speeds, and land use mix policies which place work and shopping destinations potentially closer to residences. He demonstrated that, under somewhat general conditions, these land use policies will have an ambiguous effect on both the number of automobile trips and the total miles travelled by auto.[1]

Empirical studies give similarly inconclusive results. Studies of jobs/housing balance initially demonstrated that employment centers with higher job/housing ratios also had smaller automobile travel mode splits for their employees (Cervero 1989). Yet more recent work has suggested that the ratio of employment divided by population, by itself, might not be a strong predictor of commuting behavior (Giuliano 1991; Cervero 1995; Levine, 1996).

The claim that transit-oriented design increases rail system ridership is based largely on surveys of residents living near rail transit stations (Cervero 1994; Bernick and Carroll 1991). Yet Cervero (1994) found that 42.5% of the rail commuters living in transit-based housing

[1] An exception is traffic calming policies. In Crane's (1996b) model, if automobile speeds are reduced, e.g. by narrowing streets, both demand for car trips and vehicle miles traveled falls.

commuted by public transit before they moved to their current residence. This suggests that some persons moved into transit-based housing based, in part, on their preference for using transit. It is unclear to what extent transit-based projects can actually change the travel patterns of persons who prefer automobile travel.

Recently, a large body of work has examined the link between various neotraditional design elements and travel behavior. Neotraditional neighborhoods typically include a large number of urban design characteristics, including gridded street patterns, sidewalks and greenbelts to facilitate pedestrian access, front porches and garages behind houses to orient neighborhood life toward the street, and a mix of uses to allow shopping and some work trips to take place within the neighborhood (Calthorpe 1993; Duany and Plater-Zyberk 1991; Katz 1994). The architects and urban designers who have popularized these concepts have argued that such designs bring a broad range of benefits, including but certainly not limited to possible reductions in automobile use, reduced traffic congestion, and improved air quality.

The research on this topic has compared travel behavior in neighborhoods with different design patterns. Simulation studies have found that gridded street networks produce less vehicle miles of travel (McNally and Ryan, 1993), but that research assumed fixed trip frequencies, and thus did not allow for the full range of possible behavioral responses. The literature which compares travel behavior in neighborhoods with different design patterns (e.g. Cervero and Gorham, 1995; Crane and Crepeau, 1996; Ewing, Haliyur, and Page, 1995; Handy, 1993; Kitamura, et. al., 1994; Kockelman, 1996; Kulkarni, 1996), when taken as a body of work, gives generally inconclusive results. For summaries, see Crane (1996a) and Ryan and McNally (1995). More importantly for our purposes, several recent results suggest that land use patterns, while sometimes correlated with travel behavior, might proxy for other variables which better explain travel patterns. Three examples will be given here.

First, Kulkarni (1996) used a one day travel diary and found that residents of grid-oriented neighborhoods in Orange County, California made fewer trips than residents of neighborhoods with more cul-de-sacs and curvilinear street patterns. Yet Kulkarni (1996) showed that the differences in travel patterns are largely due to differences in income across neighborhoods rather than differences in the street network. Second, Kitamura, et. al. (1994) found that travel behavior for individuals in San Francisco Bay Area neighborhoods is explained, in part, by the land use characteristics of the neighborhood of residence. Yet individual attitudes toward travel, the environment, urban living, and work were better predictors of travel behavior, suggesting that land use might either proxy for the attitudes of residents or that attitudes determine both residential location and travel behavior. Third, using travel diary data for San Francisco area residents, Kockelman (1996) found that the number of jobs within 30 miles of one's residence is negatively associated with household vehicle miles travelled (VMT). Yet this can be easily explained by the monocentric urban model, which suggests that persons who live on the urban fringe are trading a long commute (and thus possibly more household VMT) for lower land prices. Kockelman's result persists when attention is restricted to non-work VMT, which is less clearly explained by the monocentric model, but the result still suggests that residence location might be endogenous to travel choices.

Taken collectively, the body of empirical work on land use and travel behavior gives seemingly contradictory results and suggests that land use might proxy for residential location choices and attitudes toward travel. This suggests the following requirements for empirical work.

Section II: Requirements for Empirical Work

Empirical work on this topic should include three characteristics. The research should be developed in the context of a demand model, the location of activities should be modelled as an endogenous choice, and measures of land use should be refined to both correspond more closely to the urban design concepts which are being discussed and to measure the link between neighborhood characteristics and accessibility. Each issue is discussed below.

Land use policies change the price of travel, either for all modes (e.g. by placing job and residence locations closer together) or the relative price for different modes (e.g. traffic calming policies which reduce automobile travel speeds and sidewalk improvements which facilitate pedestrian access, thus increasing the price of auto travel relative to walking.) The response of travel behavior to land use policies should thus be modelled within a demand framework (Crane, 1996b). Like the demand for other goods, travel should be modelled as a function of prices, income, land use variables which affect prices, and "taste" variables which proxy for differences in attitudes toward travel across individuals.

Yet unlike many goods, travel is a derived demand (Small, 1992). Ideally, one would model the demand for goods and services which require travel, and then model the resulting demand for travel. In practice this would be quite complicated. The research below specifies an estimable demand function for travel behavior. That demand function is a reduced form which, theoretically, results from an individual's choice of both what to consume and then how to travel to facilitate that consumption.

Once a travel demand function has been specified, the model needs to recognize that location choice, and thus land use patterns near activities, is endogenous. This problem is most clear for commuting behavior. Monocentric urban models (e.g. Alonso, 1964; Fujita, 1989) assume that residents trade-off accessibility to an exogenous workplace location and land prices. Residential location choice and commute costs are chosen simultaneously in such models. More generally, workplace location is also a choice variable for many persons. A more complete model would treat workplace location, residence location, and commute costs as endogenous choice variables.

For non-work travel a similar problem can arise. As mentioned earlier, it is possible (and some evidence suggests) that persons with particular attitudes toward travel might choose to live in particular neighborhoods. Research that examines whether building more of those neighborhoods will change travel behavior must, at a minimum, treat residential location as endogenous. Ideally, workplace location should also be endogenous, although that is beyond the scope of the current research.

The third requirement is to measure land use in ways that capture meaningful variations. At the most general level, land use policies affect the access provided at a particular location by particular modes of travel. Yet the term "access" is ambiguous, prompting the question "access to what?" Access is a function of both travel times and the number and quality of nearby destinations (Handy, 1994). Some land use policies might facilitate travel to nearby, or neighborhood, destinations, while other policies might improve access to locations throughout the region (Handy, 1993). Of course, different persons will value access to different destinations (Crane and Van Hengel, 1996).

Yet developing a general method for relating land use to accessibility is not a focus of this research. We simply note that land use policies which target accessibility include many concepts. Land use characteristics must be measured carefully so that empirical work corresponds to the theoretical ideas which have been proposed. Having said that, this is an active research area, and authors such as Cervero and Gorham (1995), Crane and Crepeau (1996), Kockelman (1995), and Kulkarni (1996) have made progress in developing increasingly sophisticated land use measures. For that reason, this research will focus more on the issues of demand modelling and endogenous residence location.

Section III: Empirical Model

This paper uses individual travel diary data to study non-work automobile travel. Most land use policies designed to influence transportation behavior specifically target automobile travel. Furthermore, many land use policies (especially neotraditional designs which increase neighborhood accessibility) are intended to influence non-work travel. Finally, individuals often have more discretion over their non-work trips, such that behavioral changes might be most easily observed when looking at non-work travel.

Travel is measured both by trip frequencies and miles travelled for persons who responded to the travel diary which is described in Section IV. The travel diary data allow us to count every trip during the survey days, regardless of whether the origin is the respondent's residence. This counts travel to each destination as a distinct trip, irrespective of any trip chaining behavior. The total number of trips (NT) then reflects the number of destinations visited, and can thus correspond to a measure of the amount of travel in a derived demand framework.

Miles travelled (MT), while also a measure of the quantity of travel consumed, is more problematic. For a given number of trips, persons living further from their destinations will travel longer distances. Thus MT reflects both the demand for travel and the cost of travel (or accessibility). The land use variables used in this study are intended to control for the cost of travel to nearby destinations. Under the maintained hypothesis that those land use variables successfully control for the accessibility characteristics associated with the physical environment, MT is a measure of the quantity of travel consumed. If the maintained hypothesis does not hold, MT confounds both quantity and cost measures. The interpretation of the regression results for MT must be cognizant of that complication.

The travel diary used in this study spanned two days. Both NT and MT are measured using the entire two-day time period.[2] The advantage of using a two-day time window is that irregular travel patterns, which might include some types of non-work travel, can be more accurately observed over two days than one.

A. Base Model

For either measure of non-work travel, a reduced form equation for travel demand is shown below.

$$NWT_i = f(p_i, I_i, SD_i, LU_i) \quad (1)$$

[2] Respondents were randomly assigned days of the week to complete the travel diary, such that all days are represented in the travel diary data.

where NWT = a measure of non-work automobile travel, either trip frequencies (NT) or miles travelled (MT)
p = dollar value unit cost of non-work travel
I = income
SD = sociodemographic variables that proxy for tastes which influence travel behavior
LU = land use characteristics near place of residence

"i" indexes individuals

The sociodemographic (SD) variables are: a dummy variable for gender (FEMALE), the age of the respondent (AGE), a dummy variable that equals one if the respondent is black, hispanic, or asian (NONWHITE), two education dummies equal to one if the respondent did not graduate from high school or is a college graduate, household income and income squared, the number of children under age 16 in the household, and a dummy variable equal to one if the respondent completed the travel diary during a two-day period that contained at least one work day. Many of these variables have been included in other previous studies of the determinants of individual travel behavior (Vickerman, 1972).

The land use variables are described below:

Population density, in 1990, in the census block group that contains the individual's residence. Note that census block groups are smaller than census tracts. Block groups typically contain only a few hundred residences. Block groups thus correspond more closely to the concept of a neighborhood than do tracts. Note that density might proxy both for closer origins and destinations, which decreases the cost of trips, and for more congestion, which increases the cost of trips.

%GRID: The percentage of the street grid within a quarter mile radius of the person's residence which is characterized by four-way intersections.[3] This is based on 1994 census TIGER street maps. The motivation for %GRID is research by Kulkarni (1996), who used cluster analysis to classify twenty neighborhoods in Orange County, California

[3] A quarter mile was chosen because it is considered to be a good estimate of the maximum distance that a person will walk in an urban area (Untermann, 1984) and because it is commonly used in transit-oriented design research (e.g. Bernick and Carroll, 1991).

as traditional neighborhoods (i.e. gridded street patterns typical of pre-World War II development), planned developments (i.e. more recent suburban neighborhoods with curvilinear street patterns), and a mixed category intermediate between traditional and planned. Kulkarni found that the most influential variables in the cluster analysis were those that described the number of street entries to the neighborhood, the street network pattern, population densities, and commercial land uses. Of those, time and data constraints only allowed us to construct a measure of land devoted to four-way intersections. Cervero and Gorham (1995) classified neighborhoods as transit or auto-oriented based in part on a similar assessment of the percentage of four-way intersections in the neighborhood.[4]

RETDEN: Retail employment divided by land area for the census tract that contains the person's residence.

SERVDEN: Service employment divided by land area for the census tract that contains the person's residence.

EMPPOP: Total employment divided by total population for the census tract that contains the person's residence. This is intended to measure the jobs-housing balance near the person's residence. Because this variable is highly skewed by a few tracts with very large employment/population ratios, the log of EMPPOP is used in the regressions reported in Section V. The regressions in Section V were also estimated with the level of EMPPOP, and the results of all hypothesis tests were not sensitive to that specification change.

The land use variables were chosen based on their correspondence to one or more theory of how land use affects travel behavior, given the limitations of data availability and our GIS technology. For example, the gridded street network proposed by neotraditional design advocates is measured by %GRID, while the extent of land use mixing (also advocated by neotraditional design) is measured by RETDEN and SERVDEN. Jobs/Housing balance is measured by EMPPOP. While density has not been mentioned previously in this paper, a large literature has discussed the possibility that density is related to travel behavior and energy consumption. (See, e.g., Newman and Kenworthy 1989 and the critiques of Newman and

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[4] Note that %GRID was not constructed by counting four-way and total intersections. That was not possible given the large number of residence locations in this study and limitations of the GIS software. Instead, for each quarter mile radius area, we marked the area that contained four-way intersections, and that area was measured with a digital planimeter. We believe that this technique gives measures of the street network which are similar to those that would be obtained by counting intersections.

Kenworthy in Gomez-Ibanez, 1991 and Gordon and Richardson, 1989.) Population density is included both to address that literature and because it is an easily available measure of land use character.

Note that retail, service, and total employment were not available for geographic units smaller than census tracts. RETDEN, SERVDEN, and EMPPOP are measured for 1990. Both RETDEN and SERVDEN are intended to proxy for the extent to which commercial and residential uses are mixed near the place of residence. While both are imperfect measures of land use mix, more detailed land use data were not readily available for all the residential locations in this study.

The expected sign for all five land use variables in a regression for NT or MT is indeterminate. All five variables are intended to proxy for land use policies which reduce the travel cost between origins and destinations, e.g. by putting some shopping destinations near a person's residence, in the case of land use mix measured by RETDEN. Because these policies can reduce the cost of making a trip, it is possible that the reduced costs will induce more trip-making.[5] The net result is that the effect on NT or MT of changing any of the five land use variables might be either positive or negative. For a more complete discussion of this, see Crane (1996b).

The pecuniary cost of travel, p_i, is assumed to depend primarily on transit fares and gasoline prices which do not vary across similar individuals. For that reason, p_i is not included in the regressions estimated below. Remaining cost differences due to differences in travel times for persons living at different locations are assumed to be proxied by the land use measures included in LU.

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[5] This complication persists when the dependent variable is travel on a specific mode. For example, policies designed to encourage more walking trips, if they also lower the price of automobile travel, can encourage more car trips.

B. Alternative Model

The model in equation (1) will be tested against an alternative in which residential location choice is endogenous.[6] Individual residential location choice has been analyzed in a discrete choice framework that assumes that, in equilibrium, choosers (residents) are matched to the element in the choice set (locations) which gives them the highest utility (e.g. Levine, 1996). Combining that literature with insights from studies of the decision to move (e.g. Linneman and Graves, 1983; Quigley and Weinberg, 1977; Sarmiento, 1995) and studies of aggregate population change within urban areas (e.g. Boarnet, 1994; Bradbury, Downs, and Small, 1982; Carlino and Mills, 1987) gives the model of residential location choice shown below.

$$ResLoc_i = f(JobLoc_i, CommPref_i, NWT\ Pref_i, LU_i, AmenPref_i, A_i) \qquad (2)$$

where ResLoc = residential location choice

JobLoc = exogenous workplace location

CommPref = measures of preferences toward commuting

NWT Pref = measures of preferences about non-work travel

LU = land use characteristics which affect travel behavior; these characteristics are for all locations in the person's choice set

AmenPref = preferences about non-transportation location-specific amenities

A = location specific amenities which are not related to transportation (examples might include school quality or municipal fiscal policy); these characteristics are for all locations in the person's choice set

"i" again indexes individuals

The motivation for specifying equation (2) is not to estimate a location choice model (although that is possible), but to identify instruments for the endogenous LU variables in equation (1). That requires one further step: Once persons choose a residential location, they

[6] Equation (1) was also tested against an alternative model which included variables which measured attitudes toward driving, transit, and traffic congestion. The attitude variables were based on responses to questions which were included as part of the travel diary survey. Results are not reported here because the attitude variables were jointly insignificant when added to equation (1).

have chosen the land use characteristics near their residence. Thus LU is identically a function of residence location, as shown below.

$$LU_i \equiv f(ResLoc_i) \tag{3}$$

Assuming that substitution of (2) into (3) yields an estimable reduced form for LU, LU would be specified by the relationship shown below.

$$LU_i = f(JobLoc_i, CommPref_i, NWT\ Pref_i, AmenPref_i, A_i) \tag{4}$$

Of the variables in (4), all except A_i coincide with variables already included in equation (1).[7]

The neighborhood amenity variables which will instrument the LU variables are all characteristics of the census block group or census tract which contains the individual's residence. The following four neighborhood amenity variables were used as instruments in this research: the proportion of block group or tract population which is black (%BLACK), the proportion of block group or tract population which is hispanic (%HISPANIC), the proportion of the housing stock in the block group or tract built before 1940 (HousePre40), and the proportion of the block group or tract housing stock built before 1960 (HousePre60). Previous studies have found evidence that neighborhood demographic composition and the age of the housing stock are determinants of residential location choice (Bradbury, Downs, and Small, 1982; Grubb, 1982; Luce, 1994; Mills and Price, 1984; Palumbo, Sacks, and Wasylenko, 1990).

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[7] Those variables which proxy for NWT $Pref_i$ are likely to be the sociodemographic variables included in the SD vector in equation (1). Furthermore, there is likely to be a relationship between job location, attitudes about commuting, and non-work travel, such that $JobLoc_i$ and $CommPref_i$ are not valid instruments for LU in equation (1). The variables that proxy for preferences toward non-transportation amenities ($AmenPref_i$) are likely to be the same demographic variables (e.g. age, gender, household size) which proxy for preferences toward non-work travel, and thus those variables cannot instrument LU in equation (1).

For each of the neighborhood amenity variables, block group values were used when instrumenting variables measured at the block group level, and similarly tract values instrumented variables measured for tracts.[8] A sample first stage regression for block group population density is shown in Appendix A. That appendix gives the results of regressing population density on all the exogenous variables in equation (1) plus the four neighborhood amenity variables listed above. The first stages for the other endogenous land use variables are similar.

Section IV: Data

The data come from the Panel Study of Southern California Commuters which was conducted by the Institute of Transportation Studies (ITS) at the University of California, Irvine. The mail survey ran from 1990 to 1994, completing ten waves. The sample is employer-based. Half of the respondents worked at the Irvine Business Complex, a diversified employment center near Orange County Airport, and the remaining half worked elsewhere throughout the Greater Los Angeles Area.

The panel study was primarily intended to investigate commuting behavior, but it also collected information on nonwork trips. In addition, the study provides a wealth of socio-demographic information about the respondents. The data collection approach was mainly retrospective questioning, but in Wave 9, ITS also used a travel diary. Respondents were asked to list all their trips for two days, indicating trip purpose, miles travelled, travel mode, and other information. The travel diary days were pre-assigned to make sure that we captured tripmaking behavior on all days of the week, workday or nonworkday.

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[8] For %GRID, which was measured for a one-quarter mile radius circle centered on each respondent's residence, block group amenities were used as instruments. This was done because the quarter-mile circles are closer to the scale of block groups than to the scale of tracts.

For this study, we use data from the Wave 9 survey which was conducted in the fourth quarter of 1993. The sample consists of 769 individuals, about equally divided between men and women (see Table 1). Two sample selection issues are important for this analysis.

First, because the original sample was obtained by contacting employers, the survey oversampled whites, highly educated persons, and persons with high income. Table 1 shows that the respondents are mostly whites (86.9%), and have at least some college (86.5%). Table 1 also shows that 30.7% of the respondents have some graduate studies and that the median household income lies somewhere between \$65,000 and \$75,000. The results of this study must be interpreted in light of that fact. Yet for now, note that even restricting attention to an educated, upper middle income, largely suburban population provides interesting information, because many advocates of land use policies have argued for such interventions in low density, suburban environments with demographics that are similar to those in this sample.

Second, because we use data from Wave 9, panel attrition is a potential problem. Attrition can result in sample selection bias if persons who remain in the panel are more likely to have a special interest in the survey topic, or if they have a characteristic that is endogenous to the process being studied. To investigate this concern, the basic models reported later in Tables 4 and 6 were estimated with adjustments for panel attrition.[9] The results, in terms of signs and significance, were essentially the same as what is reported in Tables 4 and 6.[10] This suggests that the attrition process is independent of the travel behaviors studied here, such that the NT and

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[9] The attrition model amounts to using weights for each observation in the regressions in Tables 4 and 6, below. The weights are constructed as follows. A binomial logit model is estimated, where the dependent variable is whether or not a Wave 1 respondent stayed in the sample until Wave 9. The independent variables for the binomial logit model are individual characteristics and travel behaviors which were obtained from the Wave 1 data. The results of the logit model are used to generate the predicted probability of staying in the panel until Wave 9. The weights for each observation are the inverse of the probability of staying in the panel. A complete description of the panel attrition model is given in Sarmiento (1995).

[10] For the NT regressions reported in Table 4, using attrition weights produced no changes in hypothesis tests. For the MT regressions in Table 6, the only changes were that %GRID is significantly positive at the 10% level with attrition weights (as opposed to the 5% level without weights) and population density is significantly negative at the 5% level with weights (as opposed to the 10% level without weights).

MT regressions reported below give results that are valid for the original sample surveyed in Wave 1.

Table 2 summarizes the relevant trip variables such as mode split, number of nonwork trips, and total miles travelled, based on the Wave 9 data. The mode split in Table 2 corresponds to the mode of travel reported for the first trip on the first day of the travel diary. About 96 percent of the respondents used a car, and only 4 percent used other modes such as public transit, walking, or using a bicycle. Of those who used a car, 70.4 percent drove alone, 21.7 percent drove with others, and 7.9 percent rode with others. The respondents reported 0 to 10 nonwork car trips in one day, averaging 1.5 nonwork car trips and driving a total of 40 miles on average.

One major advantage of using the panel is that we have information on the home street addresses of the respondents. Hence we were able to match land use variables from the 1990 census at the census tract and census block group levels. Table 3 gives descriptive statistics for the land use variables that are defined in Section III, above.

Section V: Results

The model in equation (1) was first fit on data for the number of non-work trips in a two-day period (NT).[11] Because NT is a discrete variable, ordered logit regression results are reported in Table 4.[12] Column A of Table 1 has no land use variables, so that the effect of income and other sociodemographic variables can be considered in isolation. Ceteris paribus, females make more non-work automobile trips, older persons make fewer non-work car trips, income is quadratically related to non-work automobile trip-making, persons with more children have more non-work car trips, and persons make fewer non-work car trips during two-day periods that

[11] Note that there are missing observations because some respondents did not answer all survey questions.

[12] Using ordered probit regressions for Table 4 results in only one change. The coefficient on retail employment density is significantly positive at only the 10% level in column B when ordered probit regressions are estimated.

include a work day. All of these results are expected, and the results are similar to other studies of the determinants of individual travel behavior (Vickerman, 1972).

The five land use variables described in Section III are added to the regression model in column B of Table 4.[13] Note that the only statistically significant land use variable (using a 5% two-tailed test) is retail employment density (RETDEN) which is intended to proxy land use mix. Persons living in tracts with higher retail employment density make more non-work automobile trips. The inclusion of total employment density in column B suggests that this result does not proxy for the effect of living in dense employment centers, giving some assurance that the variable proxies for land use mix, as intended.

A likelihood ratio (LR) test for the joint significance of the six land use variables (total employment density included) in column B shows that the variables are not jointly significant at the 5% level. (The LR test statistic is 5.98 and is distributed chi-squared with 6 degrees of freedom.) Note that it is possible to fail to reject joint significance tests even when one or more independent variables are significant (Kennedy, 1985). This suggests that the evidence in favor of a link between land use and travel behavior is weak, at least at this stage of the analysis.

In Table 5, the land use variables are regarded as being endogenous, and are instrumented by the non-transportation amenities described in Section III. Because there are only four instruments, and five land use variables of interest, each instrumental variables regression uses only one (or, in one instance, two) land use variables. This has the added advantage of demonstrating that the results from Table 4 persist when the land use variables are used individually in the model.

Table 5 contains four pairs of regressions. In each pair, the regression is first estimated without instrumenting the land use variable, and then the potentially endogenous land use variable is instrumented. Hausman tests are used to test the hypothesis that each land use

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[13] Column B is fit on only 354 observations because, in addition to missing survey responses, some residence locations could not be matched to GIS TIGER files. Discrepancies in the address given by the survey respondent and inaccuracies in the GIS TIGER file reduced the number of addresses which could be matched.

variable is exogenous to the number of non-work car trips (NT). Because the Hausman test sometimes gives erratic results in logit regressions (Small and Hsiao, 1985, esp. p. 625), a linear probability model is used for all regressions in Table 5.[14]

Column A of Table 5 includes all of the sociodemographic variables in column A of Table 4, plus %GRID. Note that the coefficient on %GRID is positive but insignificant, as it was in column A of Table 4. Column B treats %GRID as an endogenous variable. The %GRID variable was regressed on the instruments (HousePre40, HousePre60, %BLACK, and %HISPANIC, all measured for census block groups), and the predicted value was used in the regression.[15] Predicted %GRID is also insignificant.

The bottom of column B shows the results of two diagnostic tests. The overidentification statistic tests the hypothesis that the instruments are orthogonal to the error term in the regression for number of trips (NT).[16] This condition must be met for the instrumental variables technique to give unbiased and consistent estimates. The null hypothesis for the test is that the instruments are not correlated with the error in the NT regression, and the test fails to reject that hypothesis at the 5% level. (The test statistic is 7.42 and is distributed chi-squared with three degrees of freedom.)

The Hausman statistic tests the hypothesis that the least squares and instrumental variables parameter estimates in columns A and B are the same.[17] The null hypothesis is that %GRID is exogenous and that an instrumental variables specification is not necessary. That hypothesis is rejected at better than the 1% level.

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[14] Using order logit instead of least squares in Table 5 creates only the following changes in the sign and significance of the land use variables: RETDEN would be significantly positive at the 10% level in column G and SERVDEN would be significantly negative at the 10% level in column G.

[15] This is analogous to using the predicted value from a first stage regression in two-stage least squares (2SLS). As in 2SLS, the standard errors reported in Table 5 were calculated using residuals which were obtained by using the actual, rather than predicted, %GRID.

[16] The test statistic is equal to the number of observations times the R^2 from a regression of the 2SLS residuals from the second stage equation on all included and excluded instruments. The statistic is distributed chi-squared with degrees of freedom equal to the number of excluded instruments minus the number of endogenous variables. For an example, see Angrist and Krueger (1989, pp. 15 and 16; 1994).

[17] See Hausman (1978) for a discussion.

The importance of these test results bears repeating. The Hausman and overidentification tests in column B suggest that %GRID is endogenous to NT, and that the four neighborhood amenity variables are valid instruments for %GRID. This suggests that the proportion of land with a grid street pattern near a persons residence is endogenous to travel behavior, and that the instrumental variables strategy used here is a promising solution to that problem.

Similarly to columns A and B, column C includes population density, and column D uses the predicted value of population density. (The predicted value for population density uses census block group values for the four instruments, HousePre40, HousePre60, %BLACK, and %HISPANIC.) Again, neither population density nor the predicted value are significant. The Hausman test rejects the hypothesis that density should be treated as an exogenous variable. The overidentification test rejects the hypothesis that the instruments for density are valid. Note that the null hypothesis is only marginally rejected at the 5% level. Further note that, out of the eight instrumental variables regressions shown in Tables 5 and 7, this is the only instance in which the instruments do not appear to be valid.

In column E of Table 5, log(EMPPOP) is insignificant, and the predicted value is insignificant in column F. The Hausman tests suggests that log(EMPPOP) is endogenous, and the overidentification test suggests that the neighborhood amenity variables are valid instruments for log(EMPPOP). Lastly, RETDEN and SERVDEN are insignificant in column G, their predicted values are insignificant in column H, and again the Hausman and overidentification tests suggest that the instrumental variables approach is necessary and that the instruments are valid.

Table 5 casts further doubt on the effect of land use on travel behavior. The land use variables are, apparently, endogenous, and should be treated as such. With the exception of the overidentification test in column D, Table 5 suggests that neighborhood amenity variables are promising instruments for the endogenous land use variables. When instrumental variables specifications are estimated, the only significant land use variable from Table 4, RETDEN, becomes insignificant. There is some efficiency loss in using any instrumental variables routine, and one would ideally prefer more data than is available in order to rule out the possibility that the land use variables are insignificant simply due to insufficient data (both in terms of observations and available instruments). Yet taken literally, the evidence does not support the hypothesis that land use near a person's residence influences their non-work automobile trip frequencies.

Tables 6 and 7 are similar to Tables 4 and 5, but the dependent variable is the total miles travelled in non-work car trips during the two-day period, MT. All regressions in Tables 6 and 7 use data only for persons who made at least one non-work trip during the two days. Column A of Table 6 regresses MT on the same sociodemographic and income variables as are used in column A of Table 4. Only the dummy variable for a work day during the two-day period is statistically significant. The pattern, which will be repeated throughout Tables 6 and 7, is that the regressions for MT generally have fewer significant variables than the regressions for NT.

The six land use variables are added to the regression in column B of Table 6. %GRID is significantly positive at the 5% level, and population density is significantly negative at the 10% level. While the negative sign on population density is consistent with arguments that higher densities reduce automobile travel, the positive sign on %GRID is the opposite of what would be expected if grid-oriented street designs reduce car travel. The sign pattern on population density and %GRID reinforces the fact that any relationship between land use and travel is complicated.

Table 7 instruments the land use variables, in a manner that is analogous to Table 5. Column A of Table 7 includes only the %GRID land use variable, which is almost significantly positive at the 10% level. Column B uses a predicted value for %GRID which was obtained by regressing %GRID on all exogenous variables plus HousePre40, HousePre60, %BLACK, and %HISPANIC (measured at the block group level). The coefficient on %GRID is not significant in column B, and the Hausman test at the bottom of column B rejects the hypothesis that the OLS estimates in column A are consistent. The overidentification test in column B suggests that the instruments for %GRID are orthogonal to the error in the MT regression.

Similarly, column C includes population density using OLS, and population density is instrumented in column D. Population density is insignificant in both regressions, the Hausman test rejects the hypothesis that density is exogenous, and the overidentification test suggests that the instruments are valid. RETDEN and SERVDEN are included in the OLS regressions in column E, and instrumented in column F, and log(EMPPOP) is included in the OLS regression in column G and instrumented in column H. RETDEN, SERVDEN, and log(EMPPOP) are insignificant in all regressions, the Hausman test suggests that the instrumental variables specifications should be preferred, and the overidentification test suggests that the instruments are valid in columns F and H.

Generally, the MT regressions performed less well (in terms of significant sociodemographic variables) than the NT regressions. As mentioned earlier, MT might potentially confound both travel behavior and accessibility characteristics, and it is possible that this is one reason why the MT regressions have very limited explanatory power. This suggests that the results from the MT regressions should be viewed with some caution.

Section VI: Interpretation and Conclusion

Overall, three important points emerge from the analysis in Tables 4 through 7. First, the influence of the land use variables is quite weak. In the NT regression in Table 4, the variables are not significant as a group, and the land use variables are only rarely significant individually.

Second, the signs of the significant land use variables are sometimes "wrong", at least when compared with what advocates of land use as a travel behavior policy might expect. If retail employment density does proxy for a mix of commercial and residential land uses, persons who live in more "mixed" areas take more non-work car trips, at least based on the results in Table 4. Persons who live in areas with more of a gridded street pattern accumulate more miles of non-work automobile travel. While neither result persists when the land use variable is treated as endogenous, the results suggest the possibility that land use policies designed to promote less travel can actually induce more travel. At best, the relationship between land use and travel behavior is complex.

Third, the land use variables are apparently endogenous to residential location choice. This endogeneity is one of the only robustly significant results that pertain to the land use variables. The concern that persons choose residential locations based in part on their desired travel behavior appears to be quite valid. It is thus especially important to understand the extent to which land use policies change travel behavior as opposed to changing the residential location choice of persons who are predisposed toward certain travel behaviors. Toward that end, the instrumental variables approach examined in this paper appears promising. In seven out of the eight regressions in Tables 5 and 7, the overidentification tests suggest that neighborhood amenities such as demographic composition and housing stock age are valid instruments for the endogenous land use variables.

While the overall message is one of skepticism toward the ability of land use policy to influence travel behavior, some important caveats are in order. First, one must be cautious in interpreting beyond this study's sample. The persons studied here not only lived in a heavily automobile dependent region, but they are predominantly middle income suburban residents who work in major office centers. These are precisely the kinds of persons who might have no alternative to automobile travel, and the descriptive data in Table 2 show that the automobile mode splits are quite high in this sample, even for Southern California. Land use policies might have more of an impact in other urban areas that provide more alternatives to the car. Obvious choices for future study include cities that have promoted both walking and transit alternatives. Portland and San Francisco, among others, come to mind.

Yet the lack of any strong link between land use and travel behavior in our predominantly suburban sample is still important. Some persons have argued that land use policies can be successful in reducing auto dependence in suburban neighborhoods. This research gives little reason to be confident in the prospects for such policies.

The second important caveat to this work is that the relationship between land use and travel behavior appears to be complicated. Future research should focus on several issues. The land use measures can be refined to correspond more closely to the various ideas which have been proposed in policy circles. More instrumental variables and larger sample sizes would increase our confidence in the statistical results. More generally, non-work travel is still poorly understood, as the sometimes poor fit of the regression models in this paper demonstrates.

While the prospects for land use as a transportation policy do not appear bright at this juncture, the need to understand non-work travel persists. With non-work travel accounting for over three-quarters of all trips in many urban areas, forecasting for travel demand, traffic, and air quality impacts requires an understanding of the determinants of non-work travel. To the extent that land use patterns might be part of that puzzle, they can help enhance the accuracy of disaggregated travel demand models which focus on non-work travel (e.g. Recker, McNally, and Root, 1986a and 1986b). Research into the link between land use and travel behavior should continue, even if the prospects for immediate policy application are less than some might have initially hoped.

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Table 1
Summary of Selected Demographic Variables

	Frequency	% Share
Gender		
Male	377	50.9%
Female	364	49.1%
Race		
White	510	86.9%
Nonwhite	73	13.1%
Education		
Did not graduate from high school	10	1.3%
High school graduate	93	12.2%
Some college	234	30.7%
Four-year college degree	188	24.6%
Some graduate study	234	30.7%
Household income		
Less than $15,000	8	0.5%
$15,000 - $24,999	20	1.1%
$25,000 - $34,999	47	2.7%
$35,000 - $44,999	74	6.4%
$45,000 - $54,999	100	10.1%
$55,000 - $64,999	64	8.7%
$65,000 - $74,999	79	10.8%
$75,000 - $84,999	87	11.9%
$85,000 - $94,999	73	10.0%
$95,000 - $119,999	82	11.2%
$120,000 - $149,999	57	7.8%
$150,000 and over	38	5.2%

Table 2
Summary of Selected Trip Variables

	Frequency	% Share
Mode Split		
Drove alone	425	67.4%
Drove with others	131	20.8%
Rode with others	48	7.6%
Rode a bus, train, or trolley	5	0.8%
Walked	7	1.1%
Rode a bicycle	6	1.0%
Rode an airplane	1	0.2%
Other	8	1.3%
Number of Nonwork Car Trips		
0	289	37.6%
1	181	23.5%
2	131	17.0%
3	73	9.5%
4	45	5.9%
5	19	2.5%
6	12	1.6%
7	13	1.7%
8	4	0.5%
9	1	0.1%
10	1	0.1%

	Mean	S.D.
Nonwork trip miles travelled	39.99	56.29

Table 3
Summary of Land Use Variables

	Mean	Median	S. D.
Block Group Population density (per sq. km.)	2,739.89	2,429.42	2,277.58
Census Tract Employment density (per sq. km.)	1,110.00	560.60	1,670.00
Census Tract Retail employment density (per sq. km.)	210.00	128.71	300.00
Census Tract Service employment density (per sq. km.)	450.00	207.64	850.00
Census Tract Employment population ratio	22.25	0.24	200.57
Grid street pattern (% grid within 1/4 mile of residence location)	17.72	7.00	24.01

Table 4: Ordered Logit Models for the Number of Nonwork Auto Trips

Explanatory Variables	Column A		Column B	
	Demographics only		W/ Land use variables	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	0.4799	2.81	0.7549	3.78
Age	-0.0181	-2.26	-0.0118	-1.31
Nonwhite	-0.2181	-0.87	0.1087	0.38
No high school	-0.8427	-0.99	-0.9334	-1.08
College graduate	0.2481	1.40	0.2540	1.22
Household income ($1,000s)	0.0259	2.48	0.0414	3.45
Household income squared	-0.0001	-2.02	-0.0002	-2.85
Number of children <16 years	0.3364	2.96	0.3447	2.64
Work day	-0.5315	-2.80	-0.7128	-3.28
Grid share			0.0038	0.94
Population density (per sq. km., 1,000s)			-0.0521	-1.00
Retail employment density (per sq. km.)			0.8787	1.96
Service employment density (per sq. km.)			-0.3292	-1.40
Employment density (per sq. km.)			-0.0026	-0.03
log(Employment/population)			0.00003	0.05
No. of observations	464		354	
Log likelihood value	-1032.04		-780.07	
Likelihood Ratio = 2(Lu-Lr)			5.98	

Note: 2(Lu-Lr) is from fitting columns A and B on the same observations; Lr is not shown above

Table 5: Linear Probability Models for Nonwork Auto Trips, with Land Use Endogenous

Explanatory Variables	Column A		Column B	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	1.0808	3.58	1.0446	3.39
Age	-0.0235	-1.75	-0.0246	-1.80
Nonwhite	0.4345	1.00	0.3629	0.81
No high school	-1.8425	-1.16	-1.7737	-1.10
College graduate	0.1402	0.44	0.1121	0.35
Household income ($1,000s)	0.0522	2.97	0.0542	3.02
Household income squared	-0.0002	-2.31	-0.0002	-2.36
Number of children <16 years	0.4625	2.35	0.4593	2.31
Work day	-1.0660	-3.28	-1.0614	-3.23
Constant	1.9200	1.88	1.7779	1.70
Grid share	0.0034	0.58		
Predicted grid share			0.0102	1.00
No. of observations	355		355	
R-squared	0.13		0.13	
Overidentification test:			7.42	
Degrees of freedom:			3	
Hausman test:			234.84	
Degrees of freedom:			11	

Table 5 continued: Linear Probability Models of Nonwork Auto Trips, Endogenous Land Use

Explanatory Variables	Column C		Column D	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	1.0974	3.67	1.1745	3.79
Age	-0.0231	-1.72	-0.0247	-1.82
Nonwhite	0.4793	1.11	0.6026	1.33
No high school	-1.7228	-1.09	-1.5493	-0.96
College graduate	0.2168	0.69	0.2582	0.81
Household income ($1,000s)	0.0479	2.73	0.0422	2.28
Household income squared	-0.0002	-2.16	-0.0001	-1.86
Number of children <16 years	0.5020	2.59	0.4756	2.42
Work day	-1.0298	-3.18	-0.9769	-2.96
Constant	2.2350	2.13	2.9109	2.34
Population density (per sq. km., 1,000s)	-0.0508	-0.71		
Predicted population density (1,000s)			-0.2141	-1.23
No. of observations	360		360	
R-squared	0.13		0.13	
Overidentification test (chi-squared):			7.99	
Degrees of freedom:			3	
Hausman test (chi-squared):			382.09	
Degrees of freedom:			11	

Table 5 continued: Linear Probability Models of Nonwork Auto Trips, Endogenous Land Use

Explanatory Variables	Column E		Column F	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	1.0702	3.58	0.8947	2.45
Age	-0.0223	-1.66	-0.0220	-1.43
Nonwhite	0.4472	1.03	0.5482	1.10
No high school	-1.7851	-1.13	-1.1578	-0.62
College graduate	0.1849	0.59	0.0394	0.11
Household income ($1,000s)	0.0499	2.86	0.0484	2.43
Household income squared	-0.0002	-2.24	-0.0002	-1.72
Number of children <16 years	0.5212	2.67	0.6248	2.65
Work day	-1.0449	-3.23	-1.1322	-3.02
Constant	2.0853	2.05	3.3119	2.27
log(Employment/population)	0.0735	0.73		
Predicted log(employment/population)			1.1137	1.44
No. of observations	359		359	
R-squared	0.13		0.13	
Overidentification test:			2.91	
Degrees of freedom:			3	
Hausman test:			663.1	
Degrees of freedom:			11	

Table 5 continued: Linear Probability Models of Nonwork Auto Trips, Endogenous Land Use

Explanatory Variables	Column G		Column H	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	1.1015	3.68	0.9052	2.24
Age	-0.0206	-1.53	-0.0458	-1.58
Nonwhite	0.4571	1.05	0.4417	0.81
No high school	-1.8536	-1.17	-1.6292	-0.82
College graduate	0.1983	0.63	-0.0810	-0.19
Household income ($1,000s)	0.0500	2.84	0.0576	2.36
Household income squared	-0.0002	-2.23	-0.0002	-1.92
Number of children <16 years	0.5164	2.66	0.2547	0.69
Work day	-1.0442	-3.23	-1.0958	-2.67
Constant	1.8588	1.79	2.3265	1.12
Retail employment density (per sq. km.)	0.8424	1.24		
Service employment density (per sq. km.)	-0.3235	-1.12		
Predicted retail employment density			-4.4511	-0.66
Predicted service employment density			3.6421	1.01
No. of observations	359		359	
R-squared	0.13		0.13	
Overidentification test:			3.37	
Degrees of freedom:			2	
Hausman test:			910.64	
Degrees of freedom:			12	

Table 6: Regression Models for Nonwork Miles Travelled by Car

Explanatory Variables	Column A		Column B	
	Demographics only		W/ Land use variables	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	5.2838	0.90	0.1851	0.05
Age	-0.0452	-0.17	-0.2047	-1.13
Nonwhite	-7.5430	-0.87	-4.1889	-0.72
No high school	-17.3913	-0.53	-22.8567	-1.19
College graduate	5.6828	0.93	-2.4923	-0.60
Household income ($1,000s)	0.4487	1.22	0.0764	0.30
Household income squared	-0.0021	-1.07	-0.0001	-0.06
Number of children <16 years	4.3161	1.16	-0.3087	-0.12
Work day	-31.1800	-4.91	-19.3293	-4.52
Grid share			0.1801	2.19
Population density (per sq. km.)			-0.0022	-1.95
Retail employment density (per sq. km.)			3.6058	0.39
Service employment density (per sq. km.)			-5.2067	-1.04
Employment density (per sq. km.)			1.501	0.72
log(Employment/population)			-0.2822	-0.15
constant	37.09720	1.79	57.9843	3.95
No. of observations	403		305	
R-squared	0.07		0.11	

Table 7: Regression Models for Nonwork Miles Travelled by Car, with Land Use Endogenous

Explanatory Variables	Column A		Column B	
	OLS		Instrumental Variables	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	-0.5194	-0.13	-0.1870	-0.05
Age	-0.2036	-1.14	-0.1799	-1.00
Nonwhite	-4.3448	-0.76	-3.0105	-0.52
No high school	-25.6893	-1.34	-24.8689	-1.29
College graduate	-2.7822	-0.68	-1.4343	-0.35
Household income ($1,000s)	0.1486	0.59	0.0779	0.31
Household income squared	-0.0004	-0.28	-0.0001	-0.08
Number of children <16 years	-0.4545	-0.18	-0.0045	-0.002
Work day	-20.1299	-4.77	-19.9693	-4.72
Grid share	0.1247	1.63	-0.0033	-0.03
constant	51.5532	3.65	55.3026	3.82
No. of observations	306		306	
R-squared	0.09		0.08	
Overidentification test (chi-squared):			7.22	
Degrees of freedom (chi-squared):			3	
Hausman test:			1242.84	
Degrees of Freedom:			11	

Table 7 (cont.): Regression Models for Nonwork Miles Travelled by Car, Endogenous Land Use

Explanatory Variables	Column C		Column D	
	OLS		Instrumental Variables	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	0.2687	0.07	0.7195	0.18
Age	-0.1813	-1.03	-0.2016	-1.13
Nonwhite	-2.1690	-0.39	-1.4313	-0.24
No high school	-22.6916	-1.19	-22.2397	-1.15
College graduate	-1.0355	-0.26	-0.7481	-0.18
Household income ($1,000s)	0.0344	0.14	-0.0147	-0.06
Household income squared	0.0001	0.05	0.0002	0.21
Number of children <16 years	-0.0472	-0.02	-0.3794	-0.15
Work day	-19.5466	-4.66	-19.3416	-4.55
Population density (per sq. km.)	-0.0014	-1.43	-0.0022	-0.87
constant	60.1524	4.21	64.9232	3.66
No. of observations	311		311	
R-squared	0.09		0.08	
Overidentification test:			6.93	
Degrees of freedom:			3	
Hausman test:			401.23	
Degrees of Freedom:			11	

Table 7 (cont.): Regression Models for Nonwork Miles Travelled by Car, Endogenous Land Use

Explanatory Variables	Column E		Column F	
	OLS		Instrumental Variables	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	0.0913	0.02	-0.5123	-0.01
Age	-0.1699	-0.95	-0.1680	-0.55
Nonwhite	-3.5036	-0.62	-3.0465	-0.54
No high school	-25.1928	-1.31	-25.0641	-1.31
College graduate	-1.2528	-0.31	-1.0065	-0.23
Household income ($1,000s)	0.0491	0.20	0.0554	0.20
Household income squared	0.00004	0.02	0.000004	0.003
Number of children <16 years	0.0738	0.03	0.0987	0.03
Work day	-20.1620	-4.79	-19.9710	-4.70
Retail employment density (per sq. km.)	3.0865	0.35	-0.6093	-0.01
Service employment density (per sq. km.)	-3.0633	-0.76	-2.1447	-0.06
constant	56.5327	3.94	56.487	2.76
No. of observations	310		311	
R-squared	0.09		0.08	
Overidentification test:			3.62	
Degrees of freedom:			2	
Hausman test:			288.99	
Degrees of Freedom:			12	

Table 7 (cont.): Regression Models for Nonwork Miles Travelled by Car, Endogenous Land Use

Explanatory Variables	Column G		Column H	
	OLS		Instrumental Variables	
	Coefficient	t-statistic	Coefficient	t-statistic
Female	-0.1495	-0.04	-0.0379	-0.01
Age	-0.1868	-1.05	-0.1805	-1.02
Nonwhite	-3.6157	-0.64	-3.1300	-0.56
No high school	-24.6153	-1.28	-25.4107	-1.29
College graduate	-1.5287	-0.38	-1.2904	-0.30
Household income ($1,000s)	0.0727	0.29	0.0813	0.33
Household income squared	-0.0001	-0.06	-0.0001	-0.10
Number of children <16 years	0.7222	0.03	-0.1055	-0.04
Work day	-20.0686	-4.77	-19.8894	-4.67
log(Employment/population)	0.0668	0.05	-0.9906	-0.12
constant	55.9132	4.00	53.9996	3.12
No. of observations	310		310	
R-squared	0.08		0.08	
Overidentification test:			4.83	
Degrees of freedom:			3	
Hausman test:			118.4	
Degrees of Freedom:			11	

Appendix A: First Stage Regression for Block Group Population Density

Independent Variable	Coefficient	t-statistic
%HISPANIC	42.91	6.72
%BLACK	-17.94	-1.27
HousePre40	18.74	1.46
HousePre60	5.77	1.19
Female	436.54	2.07
Age	-16.13	-1.67
Nonwhite	366.04	1.16
No high school	575.09	0.62
College graduate	350.74	1.57
Household income ($1,000s)	-20.53	-2.04
Household income squared	0.11	1.67
Number of children < 16 years	-171.70	-1.27
Work day	280.26	1.21
Constant	3093.52	4.22
No. of observations	401	
R-squared	0.22	
Adjusted R-squared	0.19	