Chapter 6

Results of the Analysis of Household Travel Time

In this section the results of the models that estimated household travel time are set out and discussed. The consistency of the results with expectations are discussed for each variable.

The dependent variable in each model that estimated household travel time was the log of household travel time. Since the log specification complicates interpretation of the results, for each significant regressor a linear approximation of the change in household travel time attributable to a change in the regressor is calculated based on the estimated parameters holding all other regressors constant at their respective means. In the case of the two variables, access to the central business district and access to the nearest subcenter, the change is based upon adding fifteen minutes to the time to access the center. For all other continuous variables the change is based on an increase of one standard deviation from the mean. For discrete variables, it is based on an increase of one unit from the mean. For dummy variables the change is based on the difference between a zero and a one for the dummy condition.

Models without Neighborhood Characteristics

Complete results for the models that exclude any neighborhood variables, including calculations of changes in travel times, appear in Table 6.1. The discussion will begin with the variables that measure accessibility of centers as these are the focus of this research. The results for all three models and their relationships to each other will be discussed prior to considering the results for the other variables. The discussion will then proceed to the household characteristics variables, following the same process. The results for each variable will be discussed for all three models, as well as their differences and their similarities, prior to considering the next variable.

Table 6.1 Models without neighborhood effects

Model	***City***		***Suburbs***		***Outlying Area***	
Variable	*Parameter Estimate*	*Time change (hours)*	*Parameter Estimate*	*Time change (hours)*	*Parameter Estimate*	*Time change (hours)*
Intercept	-0.372* (.184)		-0.965* (.289)		0.565* (.239)	
Time/distance variables (time change from a move that increases travel time to the central business district or nearest subcenter by 15 minutes)						
Travel time to the CBD	0.792* (.421)	0.243	1.581* (.806)	-0.094	-0.739* (.149)	-0.393
Travel time to the CBD squared			-1.144* (.558)			
Travel time to the nearest subcenter	-0.391 (.402)	-0.360	0.356* (.089)	0.193	-0.039 (.116)	-0.023
Dummy Variables (time change from change in the dummy condition)						
Household income less than $10,000	0.033 (.354)	0.064	-0.261* (.108)	-0.495	-0.448* (.128)	-0.908
Household income of $10,000-20,000	-0.098 (.094)	-0.177	-0.219* (.075)	-0.424	-0.308* (.113)	-0.667
Household income of $20,000-30,000	-0.050 (.088)	-0.093	-0.100* (.056)	-0.205	-0.219* (.078)	-0.495
Household income of $30,000-50,000	-0.096** (070)	-0.174	-0.103* (.038)	-0.212	-0.090** (.055)	-0.216
Household income of $75,000-100,000	-0.124** .089)	-0.221	0.012 (.035)	0.026	0.094* (.056)	0.247
Household income of $100,000-125,000	0.049 (.095)	0.095	0.029 (.049)	0.064	-0.014 (.093)	-0.035
Household income of more than $125,000	-0.160* (.088)	-0.281	0.073** (.053)	0.164	-0.196 (.179)	-0.448
Townhouse	-0.010	-0.019	0.020	0.041	-0.092**	-0.210

	(.064)		(.035)		(.064)	
Apartment	-0.082 (.074)	-0.147	-0.012 (.047)	-0.025	-0.095 (.102)	-0.216
Owner	0.034 (.062)	0.060	0.104* (.039)	0.209	0.199** (.070)	0.434
Moved to present residence between 1980 and 1990	0.061 (.059)	0.108	0.037 (.035)	0.076	0.161* (.062)	0.357
Moved to present residence after 1990	0.085** (.060)	0.151	0.057** (.039)	0.118	0.178* (.066)	0.397
Discrete Variables (time change from an increase of one from the mean)						
Number of children	-0.020 (.050)	-0.001	0.053* (.019)	0.111	0.056* (.021)	0.135
Number of working adults	0.411* (.055)	0.766	0.451* (.042)	1.176	0.351* (.072)	0.981
Number of nonworking adults	0.266* (.045)	0.284	0.220* (.039)	0.507	0.094** (.067)	0.229
Number of licensed drivers	0.043 (.049)	0.079	0.075* (.042)	0.161	0.179* (.073)	0.458
Number of vehicles	0.062** (.040)	0.114	0.056* (.020)	0.118	0.043* (.026)	0.103
Continuous Variables (time change from an increase of one standard deviation from the mean)						
Percent of household trips by transit	0.403* (.082)	0.254	0.484* (.064)	0.202	1.417* (.219)	0.188
Observations	711		1937		957	
Mean Square Error	.365		.336		.416	
Durbin Watson	1.976		2.07		1.99	
F-Statistic	11.860		54.42		29.06	
Significance	.000		.000		.000	
R^2	.256		.374		.383	

Asymptotic standard deviations in parentheses

* significant at α=.05

** significant at α=.10

Center Accessibility

The City Model

In the city model, which includes only observations from the City of Washington, the parameter estimate on access to the central business district is significant and positive. The simple linear calculation suggests that the choice of a housing location that adds one-quarter hour to the central business district access over the mean will increase total household travel time by slightly less than one-quarter hour, holding all other variables constant at their means. This simple calculation, however, is not very revealing since it is a linear estimation of only a short segment of the curve suggested by the parameter estimate. While the linear approximation is helpful for understanding the influence of access to the central business district on household travel time the nonlinear relationship between household travel time and access to the central business district clouds any interpretation of the result. A more complete representation of the relationship is a graph of household travel time as a function of access to the central business district holding all other variables constant at their means. Such a graph appears as Figure 6A below.

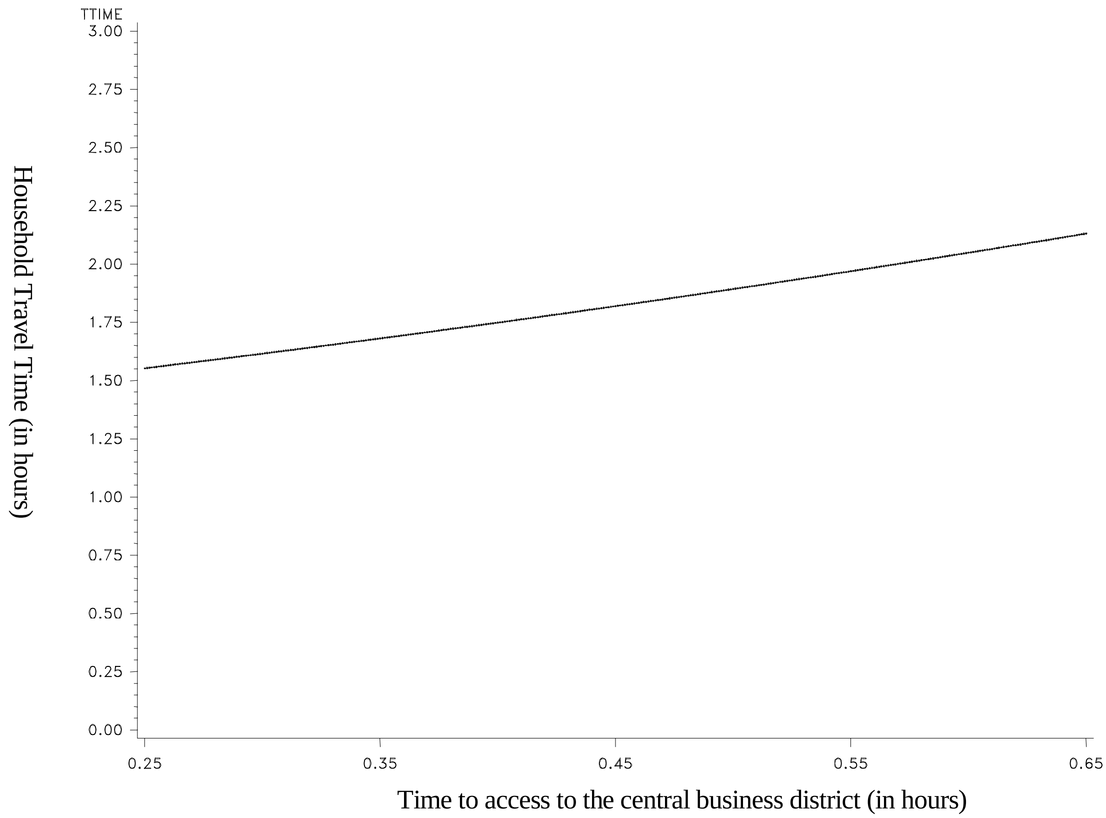


Figure 6A*. *Household travel time as a function of access to the central business district for the city model without neighborhood characteristics

Close examination reveals an almost one to one relationship between access to the central business district and total household travel. If an extreme, literal interpretation of the monocentric model is taken, one would expect a substantially larger coefficient. The model assumes that jobs, goods and services are densely concentrated at the center. At a minimum, each household could be expected to have one person that accesses the center every day. Doing so would entail adding twice the increase in the time to access the center to household travel time. More liberal (and realistic) interpretations of the central place theory assume economic activity is spread in and around the center with the greatest density at the center. Adopting this interpretation, the model's predicted household travel times appear more reasonable, as households with less access to the center may be predicted to obtain the goods and services that they desire at locations that are outside the center.

The parameter estimate for access to the nearest subcenter in the city model was not significant. This result is not surprising since city residents have relatively easy access to the central business district. The central business district is the largest, most diverse concentration of economic activity. One would expect subcenters to have little or no influence on city residents as they have all of the commercial and cultural benefits of the central business district closer at hand. Therefore, the insignificant estimate on access to the nearest subcenter found in the city model is not surprising. This finding also does not imply that the metropolitan area as a whole is not polycentric. Polycentricity is a phenomenon that has occurred, in part, for the benefit of suburban residents. The only benefit that city residents should be expected to realize from polycentricity is an indirect side effect, the reduction of congestion in and around the city center. Consequently, the city model's finding with respect to access to the nearest subcenter is inconsequential.

Before turning to the suburban model two aspects of the metropolitan model are worth pointing out. First, the mean daily travel time for households in the city sample is the lowest of the three models, approximately one quarter hour less than that of households in the suburban sample and over one half hour less than that of households in the outlying areas model. Second, locating in or close to the central business district minimizes household travel times. These two factors alone suggest a household travel times are increasing as access to the central business district declines as purported by the monocentric and limited polycentric models. The results of this model alone are an incomplete representation of the influence of access to centers on household travel time, as the model only covers a small portion of the metropolitan area. The results, however, are important to understanding the area as a whole.[1]

The Suburban Model

Unlike the city model, misspecification testing of the suburban model suggested the need to include the square of access to the central business district. In this model both linear and squared measures of access to the central business district, as well as the measure of

[1] Recall that the variation in the influence of center access across the metropolitan area, shown by the tests of parameter stability, prevented using an econometric model that included the metropolitan area in its entirety.

access to the nearest subcenter, were found to be significant determinants of household travel time. The parameter estimate on the linear measure of access to the central business district is positive and the parameter estimate the square of access to the central business district is negative. Interpreting the effect of access to the central business district on household travel is obscured both by the opposite signs on the parameters and the nonlinear relationship with the dependent variable in the equation estimated. Using the simple linear approximation the parameter estimates suggest household travel time decreases by less than five minutes when the time to access the central business district is increased by one-quarter of an hour from the mean, holding all other variables constant at their means. The result is the opposite of that predicted by the monocentric and polycentric models. While the simple calculation is helpful for interpreting effects suggested by the coefficients of the estimation, it presents an incomplete picture of the relationship between household travel time and access to the central business district. A graph of household travel time as a function of the time to access the central business district (of the same form as the one above for the city model) is particularly helpful in interpreting the results given the quadratic term in this model. A graph of the relationship for the suburban model appears as Figure 6B below.

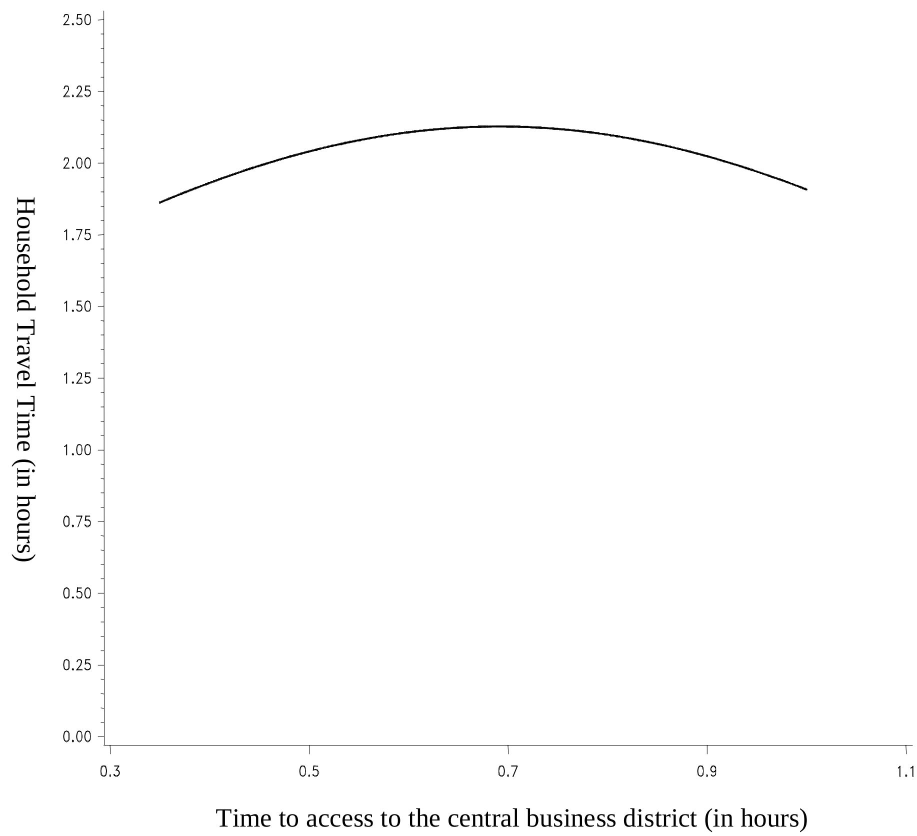
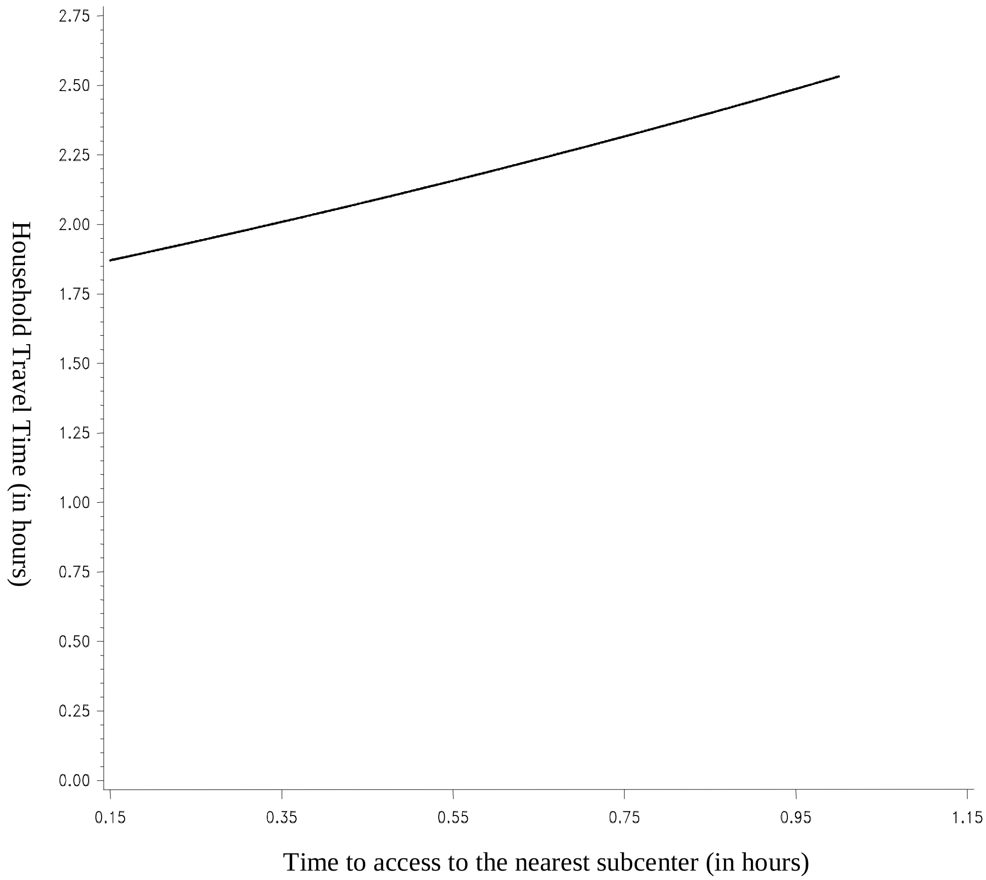


Figure 6B. Household travel time as a function of access to the central business district for the suburban model without neighborhood characteristics

The graph suggests that although access to the central business district is a statistically significant determinant of household travel time, the relationship has little economic significance. The entire range of household travel times is approximately one-quarter hour. Unlike the graph for the city model, the graph for the suburban model is not monotonic. Because the relationship is quadratic household travel time reaches a peak between .6 and .7 hours from the central business district and declines thereafter. The predicted household travel time is lowest for the inner most households, however, the most outlying households in the model have predicted travel times less than ten minutes greater than the minimum. The graph suggests that household travel time is minimized (trivially) by either living very close to or far from the central business district.

The relationship of household travel time to the access to the nearest subcenter is more easily interpreted since access to the nearest subcenter appears in the suburban model as a linear term only. In the suburban model worsening access to the nearest subcenter by one-quarter hour will increase household travel time by between five and ten minutes. A graph of the relationship between household travel time and access to the nearest subcenter appear as Figures 6C.



Figures 6C. Household travel time as a function of access to the nearest subcenter for the suburban model without neighborhood characteristics

This graph suggests that in the suburban area access to the nearest subcenter is more important to household travel time than access to the central business district. This result is not surprising, given that transport between subcenters is poor, as shown in Chapter 3. The relationship is increasing and monotonic. So, in all cases a household at a location more removed from the nearest subcenter will undertake more household travel. The graph of access to the nearest subcenters has a much broader range of predicted household travel times than the graph of access to the central business district. Predicted household travel times in the graph vary by almost three-quarters of an hour, from a low of approximately one and three-quarters hours to a high of over two and one-half hours. These results suggest that households do reduce their travel time significantly by locating close to an economic concentration. The economic significance of the savings, however, may be debated and will be discussed later. Notably, the relationship revealed by the estimation is less than one to one.

To fully understand the implications of the suburban model's results, however, one must examine the interaction of the parameter estimates for all three access variables; access to the central business district, its square and access to the nearest subcenter.[2] By examining the combined effects across the landscape one can see whether centers' influences are as they appear when independently analyzed. Figure 6C is a map of the Washington, D.C. metropolitan area's economic centers (in black) and transportation analysis zones.

[2] In each of the above graphs each access variable is graphed controlling for the others. To fully understand the influence of access to centers on household travel times we must examine the spatial interaction of all three access variables on one graph.

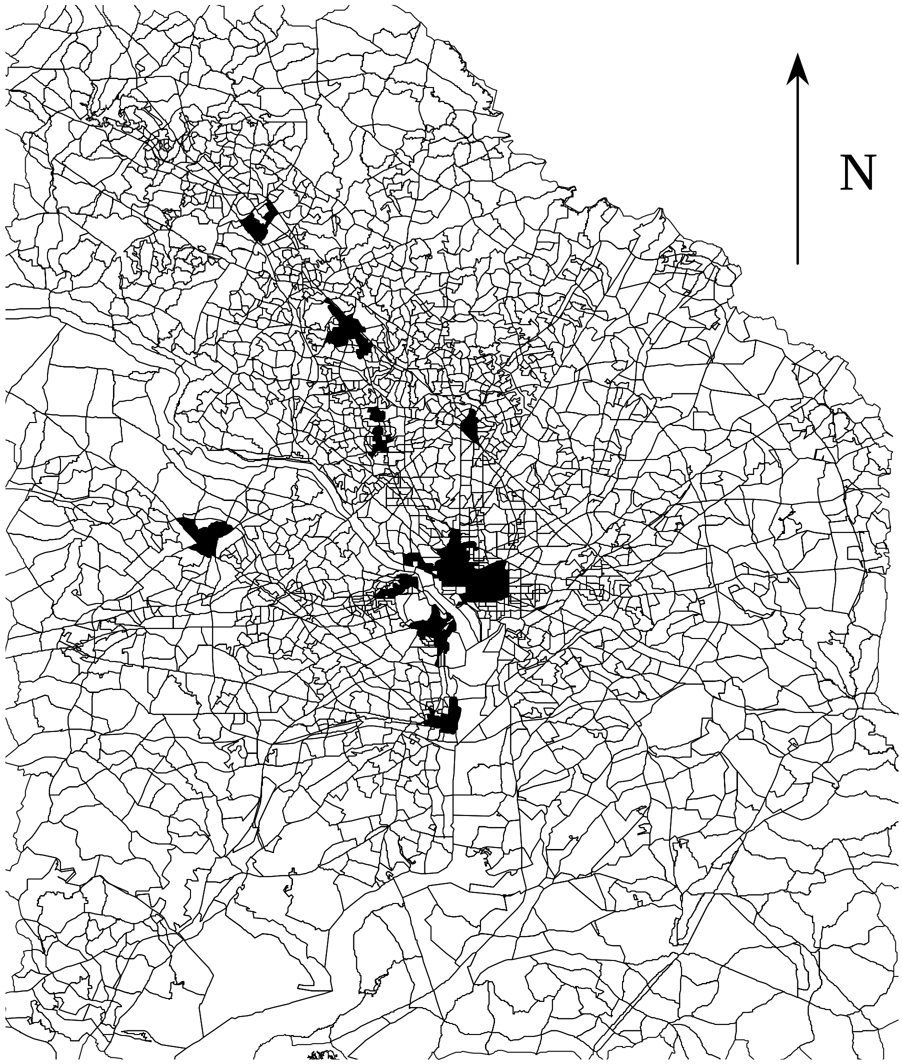


Figure 6D. Subcenters and Transportation Analysis Zones in the Metropolitan Washington, D.C Area

Table 6.2 Location of Metropolitan Washington Subcenters Relative to the Central Business District

Subcenter	*Travel Time from central business district*	*Direction from central business district (degrees from north)*
Silver Spring, MD	.573	7^o
Alexandria, VA	.533	187^o
Crystal City, VA	.438	200^o
Arlington, VA	.398	253^o
Tysons Corners, VA	.643	277^o
Bethesda, MD	.590	343^o
Gaithersburg, MD	.899	344^o
Rockville, MD	.742	349^o

The largest center, in the middle of the figure, is the central business district. The four most northern subcenters are in Maryland.[3] The four to the west and southwest of the central business district are in Virginia. Notable is the absence of any subcenters on the eastern side of the central business district. Table 6.2 identifies the location of each of the subcenters relative to the central business district using direction and travel times.[4] The figure and table are useful as they form a base from which to analyze the following figures, which depict the interactions of the three access variables across their respective samples. Figures 6D, 6E and 6F are mappings of household travel times generated from the parameter estimates from the suburban model. The x-y plane that forms the base of each figure should be looked at as a map of the Washington, D.C. metropolitan area with the central business district at its center.[5] Subcenters are located on the x-y plane using their locations relative to the central business district as set out in Table 6.2. The contours in the figures show household travel times generated by the parameter estimates using household locations relative to the central business district and the subcenters. The central business district is at the center of the graph, but the graph does not include the city, which appears as a hole in the center. All housing locations in an economic center are assumed to have the same access to the economic activity in that center.[6] As a consequence, relatively flat areas appear at each subcenter.

[3] Recall that because of their proximity to one another, the two concentrations closest to the central business district to the northwest were considered a single subcenter (the Bethesda subcenter) throughout the analysis.

[4] Directions are from the centroid of the central business district to the centroid of the respective subcenter.

[5] Distances in the x-y plane of the figures are all by travel times since those units were used in the econometric models. They assume that travel takes the same time in any direction. This is likely an inaccurate assumption since the congestion will vary throughout the metropolitan area. The figures, however, are illustrative of the benefits of housing in locations with access to economic centers.

[6] These times were the minimum average travel time to the central business district or subcenter (as the case may be) from the summary statistics for the samples.

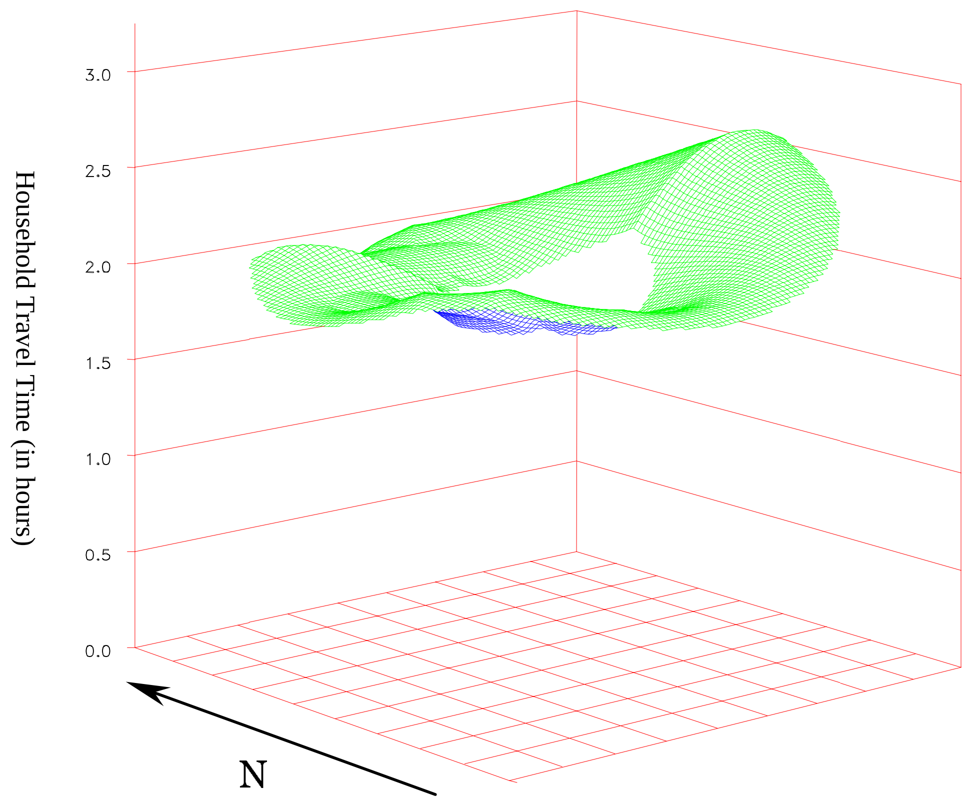


Figure 6E. Predicted household travel times from the suburban model (View1)

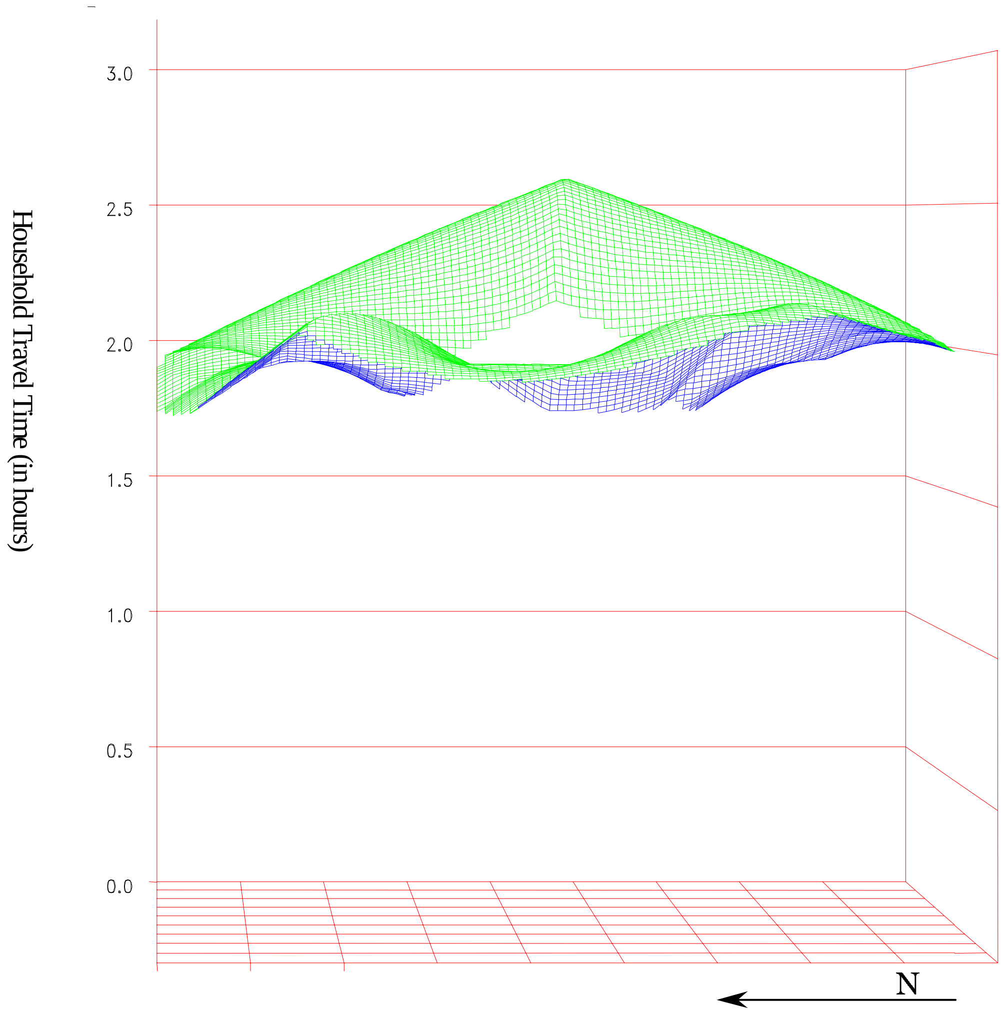


Figure 6F. Predicted household travel times from the suburban model (View 2)

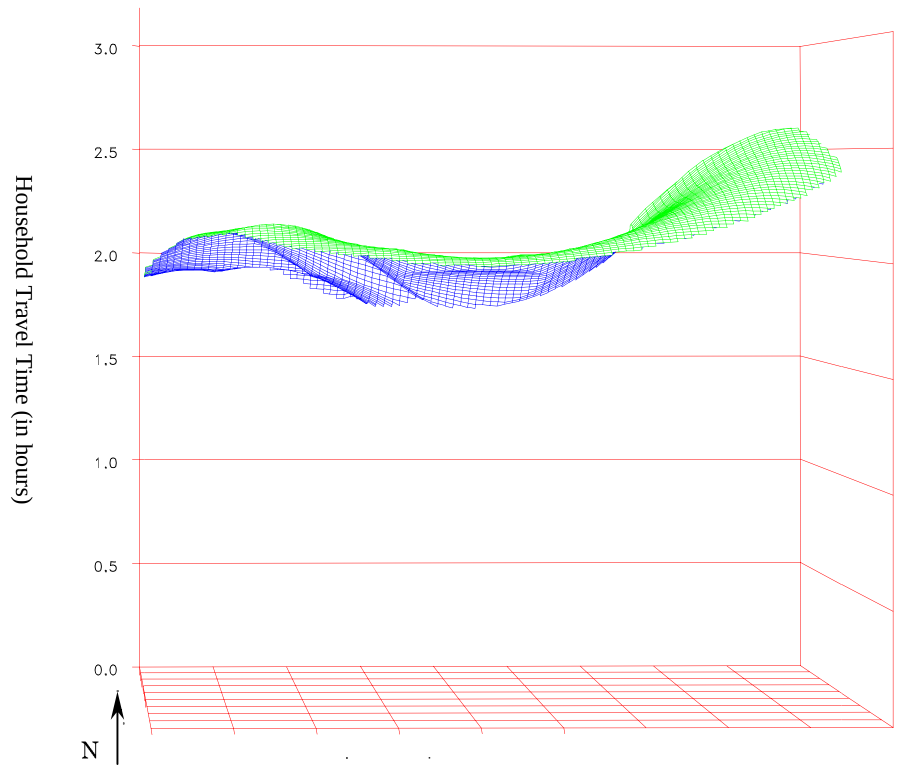


Figure 6G. Predicted household travel times from the suburban model (View3)

Clear from the figures is that travel times are minimized by choosing housing locations in or very close to the central business district. Considering the estimation results independently suggested that access to subcenters might have a greater influence on household travel times. Yet, since the influence of the central business district spans the entire metropolitan area, its affect on household travel overshadows that of the subcenters. Locating close to or in a subcenter does reduce travel times, yet, subcenters have less influence than the central business district. Even though the suburban model includes no households in the central business district, the overall form of the figure is dominated by the influence of the central business district.

In the graphs the contours rise sharply from the central business district (particularly in the east) and from the subcenters. To understand the figure (and the results of the estimation) it is helpful to consider differences between the eastern and western suburbs.[7] On the eastern side of the city, household travel times rise dramatically from the central business district. Because of the absence of subcenters, the eastern side of the city has a distinctly monocentric character with respect to household travel time. The contour rises sharply and smoothly out from the central business district, from lows of about two hours at the edge of the central business district to a highs in excess of two and one-half hours near the fringe. The western side of the city has an altogether different form. The graph undulates between subcenters reaching its minimum in two places; once near the close-in Virginia subcenters and again near the northernmost Maryland subcenter. The maximum to the west is also found in two locations; once to the northwest of the central business district and again to the southwest. Both areas are substantially removed from both the central business district and any of the subcenters. While the range of values, one-half hour, may be viewed as significant, the form of the western suburbs is distinctly polycentric, lacking the clear dependence on the central business district found to the east. The influence of the subcenters has reduced household travel times throughout the western suburbs. In the graph predicted household travel times range from a low of one and three-quarters hours to a high

[7] Independent regressions of the eastern and western sides of the city gave very similar parameter estimates, suggesting that the estimates from the regression including both sides of the city are accurate.

in excess of two and one-half hours. This variation suggests centers (both the central business district and the subcenters) have a discernable influence on household travel time.

The most prominent difference between the city model and suburban model results is the significance of the parameter estimate on travel time to the nearest subcenter. The only differences between the two models are the sample used in the estimation and the addition of a term, the square of the access to the central business district. The characteristics of the samples explain the different estimates on travel time to the nearest subcenter. The city model includes only households in the city of Washington, D.C. The suburban model includes all households within one hour of the central business district but excludes all city residents. Polycentric gradients are typically thought of as a suburban phenomenon. City residents travel times should be influenced by the accessibility of only one center, the central business district. The greatest selection of goods and services is likely to be found in the central business district, which will be the closest center to city residents. Peripheral subcenters, on the other hand, will have a less complete selection of employment, good and services. For suburban residents a nearby subcenter may be a partial substitute for the more distant central business district. Central business district access, however, may remain important to suburban residents, as it contains the greatest variety of employment, goods and services. The suburban model should therefore be used to determine whether household travel times are influenced by subcenter accessibility.

While the influence of subcenters clearly differs across the city and the suburban samples, the relationship between household travel time and access to the central business district is similar across the two models. Although the two samples do not overlap – one includes only city residents, the other includes only residents of suburban jurisdictions – travel times to the central business district in the two samples do overlap. In the city model travel times to the central business district range from one-quarter to two-thirds of an hour. In the suburban model they range from one-third to one hour. In both models the predicted household travel time for the mean household residing one-third hour from the central business district is approximately 1.7 hours. The predicted household travel time for the mean household residing two-thirds of an hour from the central business district in the city model is approximately two and one-quarter hours. In the suburban model, to the east of the city, where subcenters have little influence, the travel time for the mean household located two-thirds of an hour from the central business district would also be approximately two and one-quarter hours. The consistency of the predicted household travel times from the two models is evidence that the results are robust.

One other aspect of the graphs of predicted travel times from the suburban model merits discussion here. At the periphery on all sides the graph turns downward slightly. As noted early this likely results from both the flattening of the gradient observed as one moves out from the central business district, which may arise in part from less congestion in outlying areas. This influence, in and of itself, is quite minimal but when combined with the influence of a nearby subcenter in the northern Maryland suburbs appears to be large. This decline at the periphery suggests the edge of the gradient. Theory suggests that land use in this area will be a mixture of suburban housing and rural uses. To determine the extent of this decline it is helpful to consider the outlying areas model.

The Outlying Areas Model

The decline in the gradient at approximately one-hour travel time from the CBD is understandable once the results of the outlying area model are considered. In the outlying area model (which omitted the squared distance term) travel time to the central business district is significant and negative, while travel time to the nearest subcenter is insignificant.[8] To aid in understanding the relationship a graph of predicted household travel time relative to distance to the central business district appear appears as Figure 6H.

[8] The misspecification that compelled inclusion of the squared term in the suburban models was not present in the outlying area model.

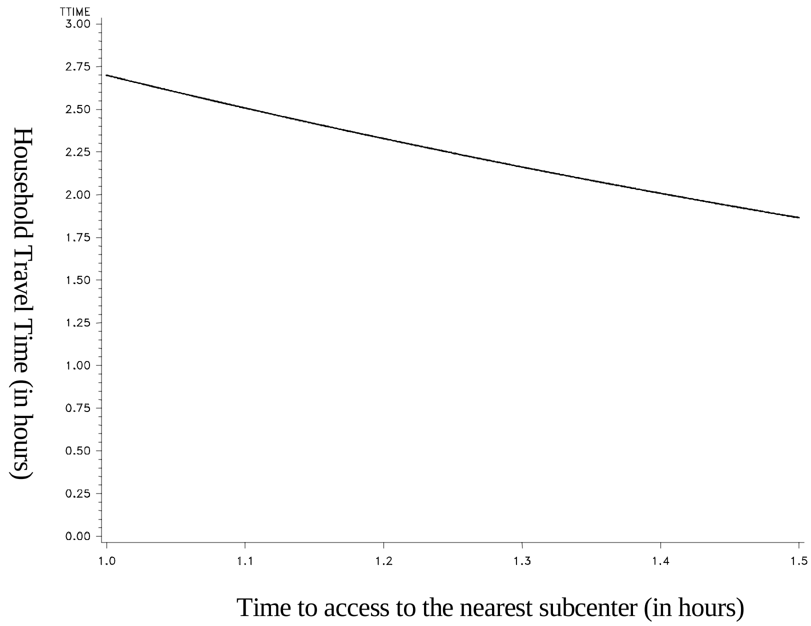


Figure 6H. Predicted household travel times from the outlying areas model

The graph shows that household travel time falls sharply from a high of two and three-quarters hours for households located at the interior of the sample (one hour from the central business district) to a low of less than two hours for households most distant from the central business district. The result is notable since all of the observations in the sample used in the outlying area model are more distant from the central business district than all of the subcenters.[9] On first examination the negative parameter estimate on distance to the central business district would appear to suggest that household access to the economic activity of the metropolitan area is not only less important in these outlying households but causes congestion increasing household travel times. Before accepting this conclusion, the composition of these outlying areas must be considered. The interior edge of this sample is likely to be composed of primarily households that commute to destinations within the metropolitan area. These households have the highest predicted travel time of any households in any of the models. Households more distant from the central business district are less likely to be reliant on the metropolitan area so likely spend less time traveling. This result comports with urban economic theory, which predicts that travel times will reach their

[9] The minimum travel time to the central business district of households included in the outlying areas model is 1 hour. The furthest outlying subcenter is .88 hours from the central

maximum at the outside fringe of the gradient. This picture becomes clearer when considering the parameter estimates on the income dummies. To help explain this phenomenon, as well as to understand the influence of other factors on household travel, the discussion will now turn to the household characteristics beginning with household income.

Household Characteristics

In both the suburban and outlying areas models household income dummies below the median are significant and negative suggesting that households with lower incomes spend less time in travel. Parameter estimates for these variables also decrease in absolute value with income reinforcing confidence in the accuracy of the relationship. Parameter estimates indicate travel time reductions ranging from one half hour for the lowest income group to one quarter hour for the income group just below the median. In the suburban model the trend continues but is less clear for households above the median, as all three estimates are positive on these parameters although two are insignificant. In the outlying areas model the only income dummy variable above the median that is significant is positive. This rise in travel with income may be derived from three sources. First, as purported by the theory underlying wage gradients, household members may be willing to travel further from home for higher paying jobs.[10] This is particularly strong in the outlying areas model where the estimates on income dummies below the median are a substantially larger in absolute value than those in the suburban model. This helps to clarify the understanding of this fringe area being in the transition from urban to rural as proposed above. Low-income households in this area are likely employed in and depend on the rural economy. This is reflected in their lower predicted household travel times. High-income households, on the other hand, are more likely dependent on the metropolitan economy; hence, their higher predicted household travel times. Households that travel into the metropolitan area for work may obtain the benefit of higher paying jobs found in the

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business district.

[10] Under wage gradient theory the best paying jobs are located at centers as firms choosing more central sites gain agglomeration economies. In a competitive market some of these economies are passed on to employees in higher wages (See for example, Muth, 1969; White, 1988a; Straszheim, 1987). Since job location is not indicated in the model this must be interpreted only as a willingness to travel greater distances to and from work.

metropolitan market. This is likely reflected in the area's housing market as the households drawing higher incomes from the metropolitan economy compete with lower income households reliant on the local, fringe economy. When considered together with the sharply decreasing predicted travel times in the area, one can see that standard rent and density gradients may emerge. The decrease in household travel time with distance from the central business district suggest that fewer households are relying on the metropolitan economy for their incomes. So, the further one moves from the central business district the lower housing prices should be observed as the competition for housing in the market is more from households dependent on the rural economy which can be expected to pay a lower wage.

A second reason that the increase in household travel with income may be observed is simply that preferences, most importantly those that affect housing location, may vary with household income.[11] Higher income households may choose to incur higher travel expenses by a housing location further from work (and other travel destinations) to obtain the housing qualities they desire. A third possible cause of this relationship is that travel may be a normal good. So, higher income households may simply be more willing to spend more time in travel to access more or more distant locations as they desire.[12]

The income dummies in the metropolitan model (which includes city residents) present a different picture. The signs and significance of parameter estimates on those variables follow no pattern leaving income effects indeterminate. Travel in the city appears not to be a normal good. The insignificance of the income parameters supports the conclusion that the metropolitan core is more heterogeneous than suburban and outlying areas. Goods, services and jobs of all types may be more integrated so that people can reach all the different types of facilities and employment are equally accessible. In the city it is not necessary to incur additional travel to obtain a better paying job or access the cultural, commercial and social facilities one desires.

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[11] While not a settled issue, many economists believe that land is a normal good (Straszheim, 1987 at 723; Mieszkowski and Mills, 1993 at 136; Anas, Arnott and Small, 1998, at1436). Consequently, households with larger incomes are thought to desire outlying areas where land is believed to be less expensive and greater travel costs must be incurred.

[12] These findings seem to override any influence of the increase in opportunity cost of time. They are, however, yet, they are consistent with the expectations of labor and urban economists.

An additional explanation for the ambiguous results on the income variables in the city model is that travel constraints on lower income residents and travel benefits to higher income residents that exist in the suburbs and outlying areas are not present in the city. Public transportation is more available in the city and walking is a more practical mode than in disperse suburbs. On congested city streets devoting greater resources to travel by purchasing an additional car will not provide the same benefit as it would outside the city. A third influence may be that travel preferences of city dwellers may differ from those of suburban residents. As noted above, city residents of all incomes may be more likely to walk streets as an activity rather than view daily travel as a means to access different locations.

All models included dummy variables for homeownership. These were significant and positive in all the suburban and outlying areas models. The results suggest that households are willing to add an additional ten minutes to their daily travel to obtain homeownership.[13] The parameter estimate on the dummy signifying whether a household moved to its present home after 1990 is significant and positive in all three models, while the estimate on the dummy for households that last moved between 1980 and 1990 is positive and significant in the outlying areas model. This may be counter to the conventional notion that households making recent moves will do so to reduce travel expenditures. Since data are not available for when households moved to the D.C. metropolitan area, it may instead show that recent arrivals (particularly in the suburbs) less familiar with the area are less able to choose a household location that minimizes household travel burdens. The result in the outlying areas model is particularly interesting since that is the area that is likely undergoing conversion from rural to suburban. The parameter estimates for these variables are substantially larger than the estimates from the city and suburban models. More recent movers in these areas are likely to be households that have undertaken additional travel to purchase recently constructed housing further out on the rent gradient. These households are more likely to have ties to the metropolitan area than the longer term residents, dependent on the local economy, that resided in the area prior to grow pressures from the metropolitan area.

[13] Dummy variables for apartments and townhouses were also included in the models. These variables, however, were not significant.

The three measures of household size - number of working adults, nonworking adults and children - all have significant positive parameter estimates in the suburban and outlying areas models. Both parameters for the number of adult household members are larger in magnitude than those for children suggesting that the additional household travel induced by a child is less than that of an adult. Working adults has a larger parameter estimate than nonworking adults, suggesting that travel to and from work continue to account for a large portion of household travel. An additional nonworking adult is estimated to contribute between one-half hour and twenty minutes to household travel time, while a working adult is estimated to increase household travel by approximately one hour. The parameter estimate for children suggests an increase of travel time of between five and seven minutes for an additional child.

In the city model only the number of working adults and nonworking adults were significant. The magnitude of the parameter estimates were much smaller than those from the suburban and outlying areas models. The result is consistent with theory since in the city is a concentration of jobs, goods and services. An additional adult in a city household will not need to travel as much to access the various of jobs, goods and services that they desire.

The parameter estimate on children is insignificant in the city model. This suggests that parents in households in the city do less ferrying of their children to school and other activities than suburban parents. This may be because children (particularly adolescents) are more able to travel on their own in the city by walking or taking public transportation.

The number of licensed drivers and number of vehicles both have significant positive parameters in the suburban and outlying areas models. In the city model only the parameter estimate on the number of vehicles is significant. In the suburban model parameter estimates indicate increases in household travel times of approximately five to ten minutes for both of these variables. These results are consistent with expectations as both make travel more accessible to the household. The ownership of an additional vehicle also represents a sunk cost the benefit from which may be maximized by undertaking more travel. Parameter estimate on the number of licensed drivers in the outlying areas model is much larger than the estimate in the suburban model. The increase suggests that in outlying areas alternative modes of transportation to the car are less available so additional drivers are likely to have a greater influence on total household travel.

Lastly, the percentage of household trips by public transportation also has significant positive parameter estimates in all three models, suggesting that travel by transit may be slower than that of other modes and therefore contributes to household travel time. The parameter estimate suggests that an increase in the percent household trips by transit by about 10% will increase household travel times by between ten and fifteen minutes. The increasing estimates from the metropolitan to the suburban to the outlying areas models is likely a reflection of the decline in quality of public transportation as one moves further from the metropolitan core. The fact the metropolitan model's parameter estimate is significant and not substantially different from the estimate from the suburban model suggests that even in the city proper the use of an automobile is time saving. This result should be troubling to transportation experts and urban planners that advocate dense, mixed use development as a means to encourage transit use.[14] Although it is not a direct test of travel times in dense, mixed use neighborhoods, the result suggests that even in dense, transit oriented developments use of a car will reduce travel times. If this is so shifting from auto to public transportation even in these neighborhoods will depend strictly on a preference for public transportation over auto travel.

None of the models discussed above included any neighborhood characteristics. Economists, however, have used a variety of neighborhood characteristics in estimating rent gradients and in testing the influence of city form on commuting times. Estimating a second set of models that include neighborhood characteristics variables is useful for revealing whether the models estimated without those characteristics are robust.

Models including Neighborhood Characteristics

The second set of models estimated for each sample included additional variables identifying neighborhood characteristics. Since the results of these models are similar to those of the models without neighborhood characteristics the discussion will focus on the differences in the results. Full results from the models appear in Table 6.3 below.

[14] See for example, Duany and Plater-Zyberk (1992) and Rabinowitz, et al. (1991).

Table 6.3 Models with neighborhood effects

Model	***City Proper***		***Suburbs***		***Outlying Areas***	
Variable	*Parameter Estimate*	*Time change (hours)*	*Parameter Estimate*	*Time change (hours)*	*Parameter Estimate*	*Time change (hours)*
Intercept	-0.662** (.451)		-1.144* (.442)		0.899* (.533)	
Time/distance variables (time change from a move that increases travel time to the CBD or nearest subcenter by 15 minutes)						
Travel time to the CBD	0.587 (.618)	0.263	1.291** (.933)	-0.123	-0.771* (.195)	-0.409
Travel time to the CBD squared			-0.995** (.630)			
Travel time to the nearest subcenter	-0.414 (.465)	-0.164	0.360* (.100)	0.194	0.049 (.185)	0.028
Dummy Variables (time change from change in the dummy condition)						
Household income less than $10,000	0.046 (.096)	0.064	-0.263* (.106)	-0.501	-0.433* (.130)	-0.882
Household income of $10,000-20,000	-0.090 (.094)	-0.118	-0.223* (.076)	-0.433	-0.328* (.117)	-0.701
Household income of $20,000-30,000	-0.038 (.089)	-0.050	-0.102* (.056)	-0.210	-0.207* (.078)	-0.470
Household income of $30,000-50,000	-0.091** (.070)	-0.118	-0.105* (.038)	-0.216	-0.092* (.054)	-0.221
Household income of $75,000-100,000	-0.098 (.087)	-0.127	0.003 (.036)	0.008	0.097* (.057)	0.256
Household income of $100,000-125,000	0.074 (096)	0.104	0.022 (.049)	0.049	-0.003 (.095)	-0.007
Household income of more than $125,000	-0.127** (.089)	-0.162	0.063 (.054)	0.140	-0.201 (.183)	-0.457
Townhouse	-0.049 (.069)	-0.085	0.037 (.039)	0.076	-0.069 (.067)	-0.157

Apartment	-0.109** (.080)	-0.184	0.032 (.053)	0.066	-0.058 (.108)	-0.133
Owner	0.037 (.062)	0.062	0.104* (.039)	0.210	0.157* (.071)	0.348
Moved to present residence between 1980 and 1990	0.068 (.059)	0.111	0.036 (.035)	0.073	0.147* (.063)	0.327
Moved to present residence after 1990	0.088** (.061)	0.146	0.058** (.039)	0.119	0.160* (.068)	0.360
Northeast D.C.	0.043 (.076)	0.072				
Southwest D.C.	0.179 (.144)	0.325				
Southeast D.C.	-0.041 (.093)	-0.067				
Maryland			0.008 (.033)	0.016	0.104* (.052)	0.242
Discrete Variables (time change from an increase of one from the mean)						
Number of children	-0.027 (.050)	-0.045	0.049* (.019)	0.103	0.051* (.021)	0.123
Number of working adults	0.409* (.056)	0.841	0.451* (.042)	1.178	0.343* (.072)	0.955
Number of nonworking adults	0.270* (.046)	0.517	0.220* (.039)	0.507	0.081 (.068)	0.197
Number of licensed drivers	0.044 (.049)	0.074	0.071* (.042)	0.152	0.190* (.073)	0.488
Number of vehicles	0.056** (.041)	0.096	0.057* (.020)	0.120	0.041** (.026)	0.097
Continuous Variables (time change from an increase of one standard deviation from the mean)						
Percent of household trips by transit	0.399* (.082)	0.234	0.478* (.064)	0.199	1.508* (.230)	0.201
Percent of neighborhood that drives alone commuting to work	0.365 (.286)	0.079	0.134 (.202)	0.034	-0.328 (.269)	-0.063
Percent of neighborhood that takes the subway	0.018 (.230)	0.004	0.223 (.274)	0.039	1.749 (1.962)	0.053

commuting to work						
Percent of neighborhood that is nonwhite minority	-0.006 (.107)	-0.004	0.025 (.093)	0.012	-0.147 (.193)	-0.040
Percent of the neighborhood that is under 18	0.150 (.429)	0.021	0.263 (.255)	0.044	0.257 (.355)	0.039
Percent of dwellings in the neighborhood that are single family detached	-0.117 (.127)	-0.054	-0.031 (.061)	-0.024	0.127** (.098)	0.090
Percent of dwellings in the neighborhood that are occupied	0.310 (.489)	0.029	-0.015 (.252)	-0.002	-0.259 (.385)	-0.033
Average age of dwellings in the neighborhood	0.002 (.003)	0.029	0.001 (.001)	0.016	-0.003** (.003)	-0.083
Average number of rooms in dwellings in the neighborhood	-0.019 (.021)	-0.049	0.023* (.014)	0.079	0.001 (.030)	0.001
Observations	711		1937		957	
Mean Square Error	.367		.336		.391	
Durbin Watson	1.967		2.08		2.01	
F-statistic	7.891		38.22		20.48	
Significance	.000		.000		.000	
R^2	.263		.376		.391	

Asymptotic standard deviations in parentheses
* significant at α =.05
** significant at α =.10

Access to the central business district and its square are both significant in the suburban model, as was access to the central business district in the city and outlying areas models. In the city and suburban models the parameter estimates are slightly less in absolute value than their counterparts in the models without neighborhood characteristics. This seems to arise from the inclusion of the jurisdictional dummy variables (i.e., the different D.C. dummies and the Maryland dummy). No intuitive explanation for this difference, however, is apparent. This decline is caused by the interaction of neighborhood characteristics with the access variables. The changes are not surprising and are consistent with urban economic theory, as one would expect some interaction between neighborhood characteristics and access to the central business district. The interaction was not prevalent in the suburban model with neighborhood characteristics where the parameter estimate on access to the nearest subcenter continued to be significant and was similar to that in the models without neighborhood characteristics.

Neighborhood characteristics are for the most part insignificant. In the suburban models the parameter estimates on the average number of rooms in the neighborhood is significant and positive. This suggests that people are willing to travel additional time to live in neighborhoods with larger houses. This may be expected, as those neighborhoods are likely to be more affluent. Average room size may also serve as a proxy for house size. If interpreted as a proxy for house size the result suggest that households will undertake more travel to live in a large home.

The most revealing aspect of the models with neighborhood characteristics is their similarity to the results from the models that excluded neighborhood variables. The results suggest that neighborhood influences are for the most part explained by access to economic centers. This finding, in and of itself, suggests that these centers exert a discernable influence on the urban landscape.

Conclusion

The results reveal that the travel time to the central business district and identifiable economic centers influence total time spent in household travel in the Washington, D.C. metropolitan area. While there are significant statistical differences, the effect on total time spent may be economically insignificant. In all three models access to the central business district has a statistically significant influence on household travel times. The influence of access to subcenters, however, is imperceptible within the city proper and in the distant outlying areas. In areas removed from the central business district and other economic centers predicted household travel times are substantially greater than those of households in and around centers. To help determine whether households value access to economic centers and understand the relationship between access to those centers and household travel time two additional issues will be explored; the use of joined trips and the rent gradient in the study area.

The brief examination of joined trips in the next chapter will help to reveal whether people with poor access to economic centers rely on joined trips to reduce travel times. By joining trips to many locations in a single trip from home a households may either continue to take advantage of the economic opportunities in and around identifiable centers or disperse throughout suburban areas with minimum additional travel. By showing the variation of housing prices across the area, the rent gradient will also help to determine the degree to which households in the area value access to economic centers. For this reason, a rent gradient will be estimated to help interpret the results in this section.