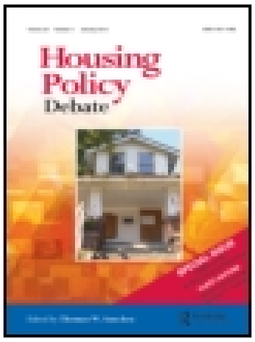

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Another Look at Location Affordability: Understanding the Detailed Effects of Income and Urban Form on Housing and Transportation Expenditures

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ABSTRACT

Findings from a study using the Panel Survey of Income Dynamics (PSID) and detailed urban environment and transit data support the location affordability hypothesis. Households in location-efficient places spent significantly less on household transportation, enough to offset high housing costs. Walkable blocks and good transit especially contribute to these savings. But households with very low incomes (below 35% AMI) do not see significant enough savings. Authors recommend investments in transit, sidewalks, and economic development in disinvested areas; the preservation and creation of affordable housing of all types and tenures; and more supports for households with very low incomes.

For decades, researchers have explored how location efficiency (LE) affects housing affordability, including incorporating transportation costs into a holistic housing affordability measure known as location affordability. Others have argued that estimated transportation savings from LE may be overstated because of limits in data and methods. Smart and Klein's 2018 article in *Housing Policy Debate* analyzed the PSID and found "no evidence to support the location affordability hypothesis." Considering their study's policy implications, as well as its methodological limitations, we tested the PSID data at a smaller geography using more detailed household and urban form variables, per the LE literature. With this approach, we find statistically significant and meaningful transportation cost differences that are enough to offset higher housing prices for several income groups. However, the transportation savings for households in the lowest-income group in urban areas do not offset high housing costs. Because location-affordable places are in short supply, and the extreme shortage of affordable housing, both housing and transportation investments are needed to support households with low and moderate incomes. Expanding location affordability regionally will also help to address climate change and expand access to job opportunities, goods, services, and other amenities.

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Housing and transportation costs, together, can easily make up about half of a household's total expenses (Haas, Makarewicz, Benedict, Sanchez, & Dawkins, 2006). Because both costs are influenced by the characteristics of the surrounding place, a growing body of research has investigated how a household's location affects the combination of these two costs, and the trade-offs between the

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two. This more holistic measure of location affordability has been the subject of local and national policies on where to build affordable housing and where to invest in transportation infrastructure. It also has been the subject of dozens of research articles, including several published in this Journal (see the 2016 special issue on Location Affordability: vol. 26, issue 3). But debate remains on whether models that predict location affordability are accurate given the influence and complexity of household characteristics, preferences, and trip-making decisions (Smart & Klein, 2018; Stevens, 2017). The purpose of this article was to provide another attempt to model location affordability, given the importance to households with low and moderate incomes. We find that the urban form of a place affects both housing and transportation costs.

The idea of location affordability was spurred by the Center for Neighborhood Technology (CNT)'s development of the Housing and Transportation Affordability Index, or H + T, in 2005 (Center for Transit Oriented Development, & Center for Neighborhood Technology, 2006; Haas, Makarewicz, Benedict, & Bernstein, 2008) and their subsequent development of the Location Affordability Index (LAI) for the U.S. Department of Housing and Urban Development (HUD) in 2014 (Haas, Newmark, & Morrison, 2016). These and subsequent transportation cost models by other researchers produce estimates or indices of household transportation costs or burdens associated with the urban form of places given a household's characteristics (Coulombel, 2018; Hamidi, Ewing, & Renne, 2016; Isalou, Litman, & Shahmoradi, 2014; Panou & Proios, 2013; Zheng, Liu, & Sun, 2011). The models build on the concept of location efficiency (LE), which is based on hundreds of empirical studies on the influences of urban form on travel behavior, one of the most studied planning topics, and widely accepted theory (Ewing & Cervero, 2010; Stevens, 2017). When combined with household demographics, urban form characteristics—often referenced as the Ds (density of population and/or jobs, diversity of land uses, street designs oriented to pedestrians, and distance to transit, amenities, jobs, etc.; Cervero & Kockelman, 1997)—can influence household travel in terms of trip frequency, trip length, and mode choice (Ewing & Cervero, 2010). This in turn may influence vehicle ownership and operations, a major driver of transportation costs (U.S. Bureau of Labor Statistics, 2018).

As noted above, some researchers have raised concerns regarding efforts to accurately measure the transportation cost aspects of location affordability. Most recently, Smart and Klein (2018), in this journal, used a nationally representative longitudinal survey of families, the Panel Study of Income Dynamics (PSID), to test the location affordability hypothesis. The PSID data allowed them to use actual expenditures of individual households rather than estimated expenses of aggregate households within a geography. Their analysis showed that "transportation expenditures are primarily driven by income and household characteristics, not whether one lives near high-quality transit service" (p. 393). They concluded that "the existing research on housing and transportation expenditures may significantly overstate its case" (2018, p. 393). Their finding that household characteristics are a stronger predictor than the LE of locations is not new, nor have H + T researchers claimed otherwise. But their finding that accessibility has virtually no effect is noteworthy given findings from other studies.

Thus, in this study we used the PSID data in a way that builds on Smart and Klein's work and adjusts for several shortcomings we see in their approach, which we explain in the next section. In the current period, in which households with low incomes are taking out more, and more expensive, car loans than home loans (Arnold, 2019; Grabar, 2017; Kane, 2020); housing affordability is a problem in every metro area, county, and state (Aurand, Cooper, Emmanuel, Rafi, & Yentel, 2019); and vehicle emissions are a significant contributor to climate change, it is important to determine whether and how planning interventions have the potential to reduce a household's transportation expenditures and vehicle use, or whether household transportation expenditures are purely a matter of preference, household structure, and travel needs that cannot be moderated by the urban environment, including frequent and accessible transit, walkability, and nearby mixed uses, such as retail and services.

In our analysis, we used the 2015 PSID data at the census block-group level (instead of the tract) to test, through descriptive statistics and ordinary least squares (OLS) regression, the relationships between PSID participants' reported transportation and housing costs and detailed characteristics of their household and details about their location (i.e., measures of urban form and transit accessibility). The 2015 PSID expenditures correspond to the latest available years for the CNT H + T data at the block-group level, including their detailed AllTransit database, which has more complete transit data for the entire country than other national transit databases. We then tested whether this relationship varied across different urban forms by household incomes, from urban to rural, and in a multivariate regression model. We did not attempt to replicate the portion of Smart and Klein's study examining a subset of the PSID participants who moved.

Findings from our analysis of PSID households are more in line with those of earlier locational affordability studies, that households living in locations with high levels of accessibility tend to have lower transportation costs, controlling for household income, size (number of adults and children), and commuters. We tested a model with and without car ownership to show that about half of the savings from living in an accessible place is due to differences in car ownership. Unsurprisingly, cost savings were more substantial for those households who took advantage of their proximity to transit by using it at least occasionally, as measured by their expenditures on public transit. The relationship with urban form held up across income groups. We show both statistically significant and meaningful average transportation cost savings for each of five income groups in both absolute terms and as a share of income, from $1,081 for renter households earning 35% of their area's median income (AMI) to more than $5,000 for homeowners earning at or above 200% of their region's AMI. With the exception of households in the lowest-income group (less than 35% of their region's AMI), households in the most urban neighborhoods (represented by block groups) also had lower combined average housing and transportation costs (H + T) as a percentage of income, ranging from 6% to 25% lower than in locations with more suburban forms.

Our findings confirm the need to create and preserve affordable housing in ways that account for a household's transportation costs, given the accessibility of a location and the household's characteristics. With the observed potential for transportation cost savings and documented individual and population-level health benefits in accessible places, planners should continue their efforts to improve accessibility in more and different neighborhood types—not just the most urban ones—and continue to preserve and create more affordable housing in location-efficient places.

Literature Review

In this review we begin with an analysis of the methods and framing of Smart and Klein (2018) before summarizing the literature on the built environment's effects on transportation costs; the influences of specific socioeconomic variables; the importance of measurement, in terms of both geographic scale and the specification of built-environment variables; and built-environment interactions with housing costs.

Smart and Klein's 2018 Study in *Housing Policy Debate*

Smart and Klein's (2018) article included two analyses that examined the location affordability hypothesis using PSID data. One looked at the relationship between transportation costs and housing expenditures and a measure of transit access to jobs. The other looked at whether people who moved to a place with transit access to more jobs within 30 min realized transportation cost savings. In the following, we summarize their article's framing and method.

Framing

Beginning in their abstract, Smart and Klein summarize the location affordability argument as follows: "were families to move to more compact, transit accessible, walkable neighborhoods, they *would* [emphasis added] reduce their driving and, possibly, forgo the need for one or more cars, thus saving them money." Proponents and researchers who have factored location affordability into planning and policy discussions are more likely to say these families *could* or *can* be more likely to save money by living in such places, acknowledging other numerous factors and the complexities of each family's circumstances (Center for Neighborhood Technology, 2010, p. 14; Guerra, Caudillo, Goytia, Quiros, & Rodriguez, 2018, p. 3; Haas et al., 2008, p. 65, 69).

Further, the major contribution Smart and Klein attempt to make is to argue that the location affordability hypothesis is "not as clear cut" (p. 393) as has been stated in the literature, and that household characteristics, like income, are better predictors of transportation costs than are transit or urban form attributes. They repeat this criticism in their conclusion, stating that the location affordability methodology "overlooks something important: whereas transit access may allow some families to reduce their transportation spending, many other factors influence family-level transportation spending" (p. 406). Their model, they continue, shows that "income and family composition matter considerably more than access to transit does" (p. 406). To our knowledge, the location affordability literature has never suggested that these relationships are clear cut (Ganning, 2017; Haas et al., 2008, 2016; Hamidi et al., 2016). And researchers working in this space have generally made it clear that transit and urban form attributes, although important, are secondary to individual and household characteristics (Ewing & Cervero, 2001; Haas et al., 2008; Ewing & Cervero, 2010; Stevens, 2017). We also see a tendency to dismiss as inconsequential the savings Smart and Klein do observe that would be quite significant in the life of a household with a low income. For example, their calculations show that the average annual transportation cost savings for those living in places they classified as high-transit locations amounts to nearly 7% of the median household income. If we apply a similar savings to a household earning 50% of the U.S. median income in 2019, $31,515, the transportation savings could be, on average, $2,206, or about what the household spends annually on electricity and telephone service, or about a third of their total food expenditure (U.S. Bureau of Labor Statistics, 2018).

Accessibility Measure

Smart and Klein criticize—fairly, we think—the tendency of location affordability researchers to devise complex accessibility measures yet rely upon imperfectly predicted aggregate travel expenditure data for the dependent variable. In their effort to improve upon the research using the individual-level PSID expenditure data, however, Smart and Klein's use of a simplified accessibility measure for their independent variable reduces the power of the individual data from the PSID. Past research clearly demonstrates the necessity of using multiple indicators of accessibility (Boarnet, Joh, Siembab, Fulton, & Nguyen, 2011; Cervero & Kockelman, 1997) at a fine-grained geographic scale (Cervero & Kockelman, 1997; Krizek, 2000; Lee & Moudon, 2006) to begin to determine the influence of urban form on travel behavior. For most of their analysis, however, Smart and Klein use a single indicator of accessibility, the number of jobs accessible by public transit within 30 minutes, and at the census tract level. It is also based on the National Transit Database (NTDB), which may not have all transit agency data. This method is problematic because it does not factor in multiple other location attributes known to be predictors of travel behavior and transportation costs, including urban form and accessibility of nonwork destinations, such as retail, services, recreation, and education. Guerra et al. (2018) found that transit accessibility without urban form data is not by itself predictive of transit use. Their measurement scale also may generalize how transit access varies more within a census tract than it does at the finer-grained block-group level. Although most block groups within a tract are similar, as intended by the census, we observed numerous instances of significant differences in the values for urban form characteristics among block groups within the same tract.

In addition, their limited indicator of accessibility is then transformed into a *z* score normalized to each region's mean transit accessibility. A household's job accessibility by transit relative to a regional average might be a useful indicator to judge relative accessibility within a region, but as a standalone accessibility measure to compare transit access nationally to determine whether someone will benefit from transit proximity, it is problematic. To illustrate, we used the approach described by Smart and Klein to calculate a similar regionally normalized *z* score for a variable that measures access to jobs via transit. In Grand Rapids, Michigan (the most average Combined Statistical Area [CSA] in the United States in terms of jobs accessible by transit) the block group in the PSID with the highest number of jobs accessible by transit had access to just over 20,000 jobs. This earned it a *z* score of 2.77. In contrast, the block group with the highest transit accessibility score in the PSID data set for the Washington, DC, CSA had access to over 800,000 jobs by transit, earning it a *z* score of 2.55, which is notably lower than that of the block group in Grand Rapids, despite having access to 40 times as many jobs. Giving a similar *z* score to these two vastly different transit and job environments (2.77 compared with 2.55) to represent each place's accessibility would, predictably, weaken the association with transportation expenditures and likely contributes to the nearly non-existent relationship they report in their study. Additionally, although they used a continuous measure for a tract's transit quality, they categorized neighborhoods throughout the text and within their figures as transit rich and transit poor, or high transit and low transit, which implies that neighborhoods are one or the other. Use of these two broad groups masks the variation along the continuum of transit service, which is important to understand when studying the exact influence of urban form and transit quality on household travel and the related costs (Bagley, Mokhtarian, & Kitamura, 2002).

Household Characteristics

Similar to their discussion of transit quality, Smart and Klein use a dichotomous *poor* or *not poor* indicator of whether a family was living below the poverty line to make comparisons. Comparing households below the poverty line with all other households misses an important opportunity for further unpacking associations and travel behavior decisions at additional income levels (e.g., the working poor, middle-income households, and high-income households).

The Built-Environment Effect on Transportation Expenditures

Although few studies have looked at actual transportation costs associated with household travel, hundreds of studies have assessed the influence of the built environment on individual travel patterns, including trip lengths, trip frequencies, and trip modes. These have been summarized in meta-analyses as well as literature reviews (Cao, Mokhtarian, & Handy, 2009; Ewing & Cervero, 2001, 2010; Stevens, 2017). Most studies have used some measure of the built environment typically related to a combination of the various Ds identified by Cervero and Kockelman (1997), mentioned above, as well as another D: demographics. Transportation cost studies are built on this literature, so it is important to first briefly summarize their findings.

In Ewing and Cervero's (2001) synthesis of 50 studies of travel and the built environment, they determined trip frequencies were primarily a function of the socioeconomics of the traveler and secondarily of the built environment. But the influence on trip lengths was reversed, with the built environment being the primary influence. A traveler's mode choice was a function of both, but socioeconomics probably had a greater influence. When a traveler's overall or cumulative vehicle miles and vehicle hours traveled (VMT and VHT) were assessed, the built environment was much more significant, given the influence of the built environment on trip lengths and, in turn, the influence of trip lengths on overall trip miles and hours. The same authors performed a more specific and larger meta-analysis in 2010, in which they examined 50 empirical studies through 2009 to pool effect sizes and elasticities. Their results show that elasticities for separately measured built environment characteristics are relatively weak, with the maximum being 0.39 for the influence of intersection densities by itself. The authors note, however, that a combination of many variables (e.g., intersection design, population density, and destination accessibility) could result in a higher combined elasticity (Ewing & Cervero, 2010).

Several studies have used regional travel surveys to show this relationship. Boarnet et al. (2011) used the Southern California region's travel survey to test the differences between residents' walking and driving trips in eight places in southern California that they characterized by the four Ds, as well as either mixed-use compact centers or auto-oriented linear corridors. People living in the compact-centers place type walked more, drove less, and made more of their trips close to home. When the authors controlled for demographics and attitudes, they found no difference in daily driving trips between residents in centers and corridors, but did find that people who lived in the compact centers made more walking trips and had shorter trip distances, which led to a higher number of weekly trips. The trip-making of households in the mixed-use compact centers suggests the proximity of nearby goods and services can reduce travel costs by allowing short walking trips to replace longer driving trips.

Many studies use unique data sets. Holtzclaw, Clear, Dittmar, Goldstein, and Haas (2002) used millions of household records on auto ownership and VMT for households aggregated to 2,820 travel analysis zones within three regions: San Francisco and Los Angeles, California; and Chicago, Illinois. They regressed these data against urban form to predict vehicle ownership and VMT. These models were used to create the location-efficient mortgage, based on the premise that lower transportation costs might allow one to afford a slightly higher mortgage. The variables that best predicted vehicles per household were net residential density, per capita income, household size, and access to transit.

In a 2005 report using the 2002–2003 Consumer Expenditure Survey (CES) Public Use Microsample Data for households with two or more persons, Bernstein, Makarewicz, and McCarty (2005) found that households that earned $45,000 and owned one or zero cars had a $3,000 difference in transportation costs depending on whether they used transit ($7,315 compared with $4,372). Deka's study on household expenditures using the 2010 CES also found that households that spent more on public transit spent less on transportation generally (2015).

Although criticized by other studies for using aggregate data, as well as for some of their data sources and methods, research teams from the CNT (Haas et al., 2008; Haas, Morse, Becker, Young, & Esling, 2013; Haas et al., 2016) found with various iterations of their models that places with a mix of urban characteristics (e.g., high density, high transit connectivity, high job accessibility, high intersection density and/or small block sizes) and low shares of single-family housing would predict significantly lower auto ownership, lower VMT, and higher transit use, but that the actual expenditures would vary by household size, income, and number of workers.

Hamidi et al. (2016) used unique disaggregate data sets to estimate household transportation costs for residents utilizing the Housing Choice Voucher affordable housing program. On average, households spent 14.65% of their income on transport. But these averages spanned from 3.5% in downtown Los Angeles to 28% in the Wheeling, West Virginia-Ohio metropolitan area. Their data included detailed respondent location data from the National Household Travel Survey (NHTS) in 15 metro areas, which allowed them to calculate the number and length of trips, to which they applied auto or transit costs, as appropriate. They found that several measures of urban form related to the Ds, along with household characteristics, best predicted actual VMT. Specifically,

> The likelihood of any VMT declines with percentage of regional employment accessible within 10 minutes by automobile, with land use entropy within a quarter mile of a household, with intersection density within a half mile, with percentage of four-way intersections within a half mile, and with average transit frequency within a quarter mile of the block group. Basically, those who live in highly accessible places (characterized by these five D variables) are better able to make do without automobile trips. (p. 444)

Further, they found that these more affordable locations were in at least 15 metro areas, but 70 of the 322 U.S. metro areas had no affordable locations in terms of transport costs. They also found that of the households that used transit, transit trips were positively associated with household size and land-use entropy within a quarter mile of home and negatively associated with income. They did not find that transit frequency affected transit trips.

Using 2000 census data and structural equation modeling, Gao, Mokhtarian, and Johnston (2007) found that high job accessibility negatively affected auto ownership. This is likely due to the correlation between high job accessibility and high accessibility to shopping, and social and recreational destinations (Srour, Kockelman, & Dunn, 2002).

Socioeconomics, Travel Behavior, and Transport Costs

Early theorists on auto ownership noted the difficulty in modeling current and future auto ownership because of data limitations and the many variables affecting auto ownership decisions, such as economic necessity, household location choices, the presence of transit, household size and income, economic growth, the relative price of other commodities, the cost of autos, and consumer tastes or preferences (Evans, 1970). Of these, household size and income are key variables because they influence the choice set. Income affects where a household can live, and thus which modes are available, as well as which modes they can afford, and household size influences the number of travelers, trips, and destinations, which in turn affect mode choice (Zhang, 2006). Income may also influence preferences, status, or job requirements. When looking at aggregate travel patterns, Pucher and Renne (2003) found higher income households are less likely to use transit, and several studies have found positive relationships between income and vehicles owned.

An important aspect of the household characteristics is the idea of residential self-selection and attitudes. In other words, people who walk and use transit in certain neighborhoods do so because they chose to live in such neighborhoods, and thus they may be more influenced by their own attitudes than by the built environment, although the built environment enables these activities. Levine, Inam, and Torng (2005) showed that there is an undersupply of neighborhoods that can support transportation choice, and more people probably would select into them if there were a sufficient number. Authors have also found that attitudes may change over time (Handy, Cao, & Mokhtarian, 2005) and that there are variations in the influence of attitudes versus the built environment (e.g., the decision to walk vs. the frequency of walking; Cao, Handy, & Mokhtarian, 2006).

Measuring the Built Environment for Travel Influences

Boarnet et al. (2011) and others (Hamidi et al., 2016) note several studies that show the importance of using individual data rather than aggregate data, to avoid ecological fallacy or aggregation bias. Ganning (2017) emphasizes this in her extensive critique of the LAI developed by CNT for HUD.

In terms of built-environment measures, Boarnet et al. (2011) found residents in Southern California near high numbers of businesses were more likely to walk to those businesses that were either in their nearest commercial center or corridor. Haas et al. (2013) found that seven neighborhood characteristics, rather than four, increased the predictability of their model, particularly for VMT, but less so for auto ownership, including two measures of density, two measures of transit, two measures of walkability, and one measure of employment access. Further, their seven neighborhood variables combined had greater explanatory power than did the four household characteristics combined.

The geographic scale also matters. For instance, in the Boarnet et al. study (2011) in Southern California (referenced above), residents within a quarter mile of their neighborhood's commercial center walked at much greater rates than those who lived within the one-mile linear corridor areas extending from a commercial center. Renne, Tolford, Hamidi, and Ewing (2016) and Scheer, Ewing, Park, and Khan (2017) demonstrated the importance of specifying the detailed land uses near transit, and Holtzclaw et al. (2002) used the zip-plus-four geographic scale. Chatman's (2013) study on whether transit-oriented development needs the T may have identified another factor beyond the neighborhood scale by adding a measure of subregional density.

Studies have identified that residents living near transit are approximately 5 times more likely to commute by transit than is the average resident worker in the same city (Cervero & Seskin, 1995;

Lund, 2003). Yet transit use varied significantly by type of transit and by region, as well as whether there was good pedestrian connectivity to the station. Proximity to a station was not a sufficient predictor by itself.

Interactions Between Transportation and Housing Costs

The housing/transport trade-off is a long-studied theory in urban economics (Alonso, 1964; Deka, 2015; Kain, 1961; Mills, 1972; Muth, 1969). Recently, Wang and Immergluck (2019) used the LAI data for more than 300 U.S. metro areas to determine the interaction between location affordability and household recovery from the foreclosure crisis. They found that high location affordability contributed to recovery (a decline in foreclosure rates) in high-density central cities in strong- and weak-market metro areas and in suburbs of boom–bust metro areas, but not in suburbs of strong and weak markets. They recommend adding denser affordable housing near transit and more affordable housing and sustainable infrastructure in suburbs to increase the (presently limited) supply of, and benefits from, locational affordable places. This furthers the research on the shortage of location-affordable places (Leinberger, 2008; Levine et al., 2005). Walter and Wang (2016) note the difficulty for households needing HUD-approved housing given the need to find a supply of affordable housing plus HUD-defined opportunities plus good neighborhood conditions, all in the same place. Several other studies have found the shortage of walkable and transit-served neighborhoods places them out of reach for low- and moderate-income households since the high demand raises housing values (Bereitschaft, 2019; Wardrip, 2011). Further, existing affordable and (tax credit) expiring housing is at risk in walkable areas where buildings are beginning to appreciate (Lens & Reina, 2016). Tremoulet, Dann, and Adkins (2016) report the ability of Housing Choice Voucher participants to stay in Portland, Oregon, was good as they could more likely live in location-affordable places, but the H + T index may be misleading in that it might be lower because of low transport costs, but the ability to be approved to live in one of the higher cost housing units in a low-transportation cost area might be impossible.

Hartell (2017) found that high rates of auto-mobility and estimated rates of foreclosure and mortgage default share a positive significant relationship, and thus transport cost burdens could be a relevant factor in shaping housing outcomes. But she notes that high housing and transport expenditures also could reflect a household's propensity to spend money. Similarly, Deka's (2015) analysis of the CES showed that homeowners of single-family detached homes spent more on both housing and transport, whereas households in older single-family and attached homes spent less on transport. He asserts the former could be a suburban lifestyle preference (Talen, 2001), whereas the latter may be because of the more walkable urban form found near older housing.

Methods and Data

Our analysis consisted of two parts based on a single data set. First, we examined differences in household transportation and housing expenditures to look for patterns across income and urban form types. This was followed by multivariate analysis using OLS regression models to predict household transportation expenditures using measures of urban form, transit access, and household characteristics.

Data

To ascertain the effect of both urban form and household dynamics on transportation expenditures, we use block group-level data from the 2015 PSID (Panel Study of Income Dynamics, Restricted Use Data, 2015). The PSID is the longest running household survey in the world. Beginning in 1968, the PSID includes a nationally representative sample of families. In the 2015 sample, there were 9,048 families distributed across the United States. This data set is maintained by the Institute for Social

Research at the University of Michigan. We use data from the public family file in addition to restricted files on geospatial location, urban and rural designations, and vehicle ownership. These data allow us to characterize the neighborhoods in which respondents live by matching the block group ID of the family unit (household) to other block-group variables constructed by CNT and in the 2012–2017 American Community Survey from the U.S. Census. We include several household variables from the PSID in our analysis, including transportation expenditures, family income, family size, number of adults, number of children or other dependents, number of working adults, home expenditures, vehicle ownership, and total travel time to and from work for the head of household and spouse.

We eliminated 1,044 cases that were missing data or had extreme outliers, including 43 families that were not georeferenced; 51 families spending $50,000 or more annually on transportation (including one spending $244,000); 567 families who did not report transportation expenditures; an additional 80 families that reported zero or negative income; 190 families who reported zero or negative housing expenditures; and 112 families who spent more than 200% of their income on housing. This left us with 8,004 households. Whereas the zero and negative cases were sizable to eliminate, most of the zero values appeared to be a nonresponse or issues of data validity, not an actual reported expenditure. We also wanted to focus on households with positive incomes and at least some housing and transportation expenditures that were in broadly typical ranges. The households in our remaining sample were similar to the complete sample in terms of family types and sizes, income ranges, and geographic distribution across urban form types.

The urban form and household variables are our independent variables that we test against our dependent variable, household transportation expenditures. We sum several transportation-related expenditures reported in raw dollars to obtain total annual transportation expenditures, including vehicle loan(s), lease payments, down payments, insurance, repair and maintenance costs, gas, parking, public transit, taxis, and carpooling.

Instead of including a measure of total family members within the household for our OLS models, we delineate the number of household adults, number of working adults, and number of children and dependents. As other studies have found, the household size, and particularly the presence of children and adults who commute, has a positive effect on transportation expenditures.

We also control for total home expenditures, which combines several housing costs including mortgage and loan payments or rent, property tax, insurance, and utilities. We also include total travel time to and from work (measured in minutes) to account for the relationship between commute distance and total transport expenditures, since commutes are a routine and consistent trip.

Both housing and transport expenditures are compared with total annual family income, which we include as a percentage of the household's regional AMI. This is a continuous variable we calculated from the absolute value of their total reported income (including income supports) and the regional median income to recognize the differences in the cost of living across regions.

Last, we include a measure for vehicle ownership. Given the direct link between vehicle ownership and transportation expenditures, we use this measure in our descriptive tests and to test our model with and without this variable. Because the purpose of this article is to identify the effects of urban form and household dynamics on differences in transportation expenditures, we wanted to test the differences in other expenditures before including one of the most expensive costs within transport expenditures.

We then match the PSID block group for each family with block-group data from CNT's H + T Index data set for 2015, including the Transit Connectivity Index (TCI), Transit Access Shed (TAS) jobs, job gravity, gross household density, and block density. The TCI measures the quantity, frequency, and density of transit in the block group by tallying the number of transit routes and their frequency in one-eighth-mile rings around stops that intersect the block groups. Because of the positively skewed distribution of TCI and the necessity of retaining the large share of U.S. block groups that have zero transit service in our analysis, we included a square root-transformed TCI variable. Job gravity, or employment access, is a measure of the distance to all jobs within a 63-mile radius from each block group using a gravity model (distance squared to every other block group). It is significantly correlated with gross household density, block density, and the mix of jobs by industry. Given this strong association and other studies that find job density is a proxy for nearby retail and other amenities, we did not include a separate measure for access to good and services, such as land-use entropy, employment mix, or distance to retail and grocery stores. The TAS jobs variable measures, for each transit stop in a block group, the number of jobs accessible by transit within 30 minutes based on a quarter-mile buffer around the transit stops within or near a block group, and allows for one transfer. Gross household density is the total number of households (from the Census) divided by the land area in the census block group. The block density is the number of Census blocks, which are polygons, in a block group divided by the total land area (in acres) of the block group. The block area is gross and is not net of internal features that may affect the walkability of an area, such as water or an internal set of pathways. In CNT's tests of this variable as a proxy for walkability, they found strong relationships with intersection density and block perimeter and concluded it was a strong proxy for walkability and intersection density in their final models. Table 1 lists the summary statistics for these variables.

Methods

Creating Urban Form Clusters and Income Bins, and Comparing Groups

The families in the 2015 PSID sample live in 7,154 block groups across all 50 states and the District of Columbia. To answer our first question regarding the representativeness of the sample for U.S. households and urban characteristics, we compared the distribution of all U.S. block groups with the PSID block groups across four neighborhood types: urban, midurban, suburban, and rural (see Table 2). To create these four neighborhood types, we used two processes. First, we used the two-step k-cluster method in SPSS, with four clustering variables that represented four of the D variables: gross household density, transit connectivity index (distance to transit), job gravity (diversity of land uses and access to destinations), and block density (intersection density).[1] We categorized these urban form clusters as urban, midurban, and suburban/rural. We then combined two sources that classify counties along an urban–rural continuum: the size of the largest city in a county and the U.S. Department of Agriculture (USDA) 2013 Rural–Urban Continuum Codes based on metro-area size and adjacency, total population, and density (U.S. Department of Agriculture, 2013). Specifically, we categorized block

Table 1. Descriptive statistics for urban form variables and household dynamics.

	Mean	Minimum	Maximum	*SD*	*N*
Total transportation expenditures (DV)	$9,130	$3.22	$49,331	$7,278.26	8,004
Urban form					
- Job gravity	29,505	28	1,571,701	77,548	8,004
- TAS jobs	97,600	0	3,292,775	251,673	8,004
- TCI (square root)	1.24	0	9.33	1.40	8,004
- Gross household density	3.32	0	206.79	8.71	8,004
- Block density	0.10	0	1.11	0.12	8,004
Household dynamics					
- Total family income as % of AMI	138%	1%	9211%	168%	8,004
- Full-time working adults	0.58	0	2	0.48	8,004
- Household adults	1.84	1	7	0.76	8,004
- Household children and dependents	0.79	0	10	1.17	8,004
- Total travel time for all workers (min)	48.43	0	420.0	50.26	7,533
- Total housing expenditures	$12,943	$12	$103,584	$9,013	8,004
- Car ownership (yes/no)	0.9	0	1	.30	8,004

Note. SD = standard deviation; *DV* = Dependent Variable; *AMI* = Area Median Income; *TAS* = Transit Access Shed; *TCI* = Transit Connectivity Index

Table 2. Comparison of block group distribution across urban forms: United States compared with the PSID.

Urban form block group types by geography	United States	PSID
Total block groups	217,184	7,154
Urban	5,753 (2.6%)	111 (2%)
Midurban	52,776 (24.3%)	1,451 (20%)
Suburban	154,223 (71%)	5,361 (75%)
Rural	4,430 (2%)	231 (3%)
Block group types by states	51	51
Urban	22 (59%)	10 (20%)
Midurban	5 (100%)	48 (94%)
Suburban	51 (100%)	51 (100%)
Rural	41 (80%)	32 (63%)
Block group types by county	3,221	1,134
Urban	48 (1%)	16 (1%)
Midurban	1,378 (43%)	219 (19%)
Suburban	2,497 (78%)	997 (86%)
Rural	643 (20%)	137 (11.9%)
Population in block group types	316,515,021	16,918,008
Urban	8,187,140 (2.6%)	216,056 (2.0%)
Midurban	64,762,569 (20.5%)	2,389,856 (14.0%)
Suburban	238,871,782 (75.5%)	13,940,431 (82.0%)
Rural	4,693,530 (1.5%)	371,665 (2.0%)

Note. PSID = Panel Study of Income Dynamics. The counts for the PSID sample include 9,000 families in 7,154 block groups, including the cases we removed because of missing household data.

groups as rural if they were in counties in which the population is less than 10,000, and the USDA classified the county as completely rural. This resulted in 231 block groups, which we subtracted from the suburban/rural group to create a separate rural category.

Urban form clusters allowed us to look at household housing and transportation expenditures for different income groups in different urban form contexts. Expenditures for housing, transportation, and H + T were calculated as absolute values (dollars) and as a share of household income (see Table 3). We tested for significant differences between household expenditures in each urban form cluster for each income bin and housing tenure type using the Kruskal–Wallis test for one-way analysis of variance. To test for other possible influences on expenditures by urban form, such as the types of households who tend to live in urban versus suburban areas, and assumptions about where households without vehicles live, we ran additional descriptive statistics by the four urban form types for detailed household characteristics (Table 6) and vehicle ownership (Table 7).

Regression Model to Predict Household Transportation Expenditures

To ascertain the effects of urban form and household dynamics on transportation expenditures, we tested two OLS regression models predicting household transportation expenditures for PSID families. The models consider the actual dollar amount of transportation expenditures as the dependent variable.[2] We first tested the use of a multilevel model by estimating the intraclass correlations, but the results indicated that the OLS approach was more appropriate. We use clustering of households and robust standard errors to control for heteroscedasticity, which we present in parentheses below the coefficients in Table 8. We also test for multicollinearity by computing a mean variance[3] for each model and present the results along with the R^2 values.

We present two full regression models (see Table 8). Model 1 does not include car ownership, whereas Model 2 does.[4] Although we know that car ownership is a strong predictor of transportation expenditures, testing models with and without it allowed us to examine the share of overall transportation costs saving that can be attributed to reduced car ownership. The two models are otherwise identical and include multiple indicators of urban form and household characteristics known to influence travel behavior. Urban form variables include TAS jobs, TCI, gross household density, and block density. The family dynamics variables include income as a percentage of AMI, number of adults employed full time, the number of adults within the household, the number of dependents and children under the age of 18, total travel time to and from work, and annual home expenditures. We also include a measure for rural communities to test its independent effect on transportation expenditures.

Results

Is the PSID Representative of the United States?

The distribution indicates that the PSID oversamples households in suburban locations (see Table 2). Specifically, the PSID has a slightly lower share of urban block groups (by 0.6%) and midurban block groups (by 4.3%), and larger shares of suburban block groups (by 4.5%) and rural block groups (by 1%) than exist in the United States. When translated to block groups by state, PSID families live in urban block groups in 10 of the 51 states, whereas the urban block group type exists in 22 states in the United States. By county in the PSID, only 16 have urban block groups, which is 2% of the PSID sample, but there are 48 counties in the United States with the urban block group type. Last, the sum of the total population living in the urban and midurban block groups that are in the PSID sample is much lower than the percentage of the actual population of the United States in these types of block groups (16% in PSID compared with 23.1% nationally). Whereas this comparison makes it clear that a small share of places in the United States have an urban form, it also suggests that these types of neighborhoods are underrepresented in the PSID, and thus there may be limits in generalizing the effects of compact urban forms from research with the PSID data to all areas of the United States. Although the numbers of urban and midurban block groups were large enough for most of our statistical tests, they do not necessarily represent the range of characteristics in both urban form and household characteristics that exist in these types of places (e.g., urban places with moderately priced housing, or midurban places with lower household density but frequent transit), as we explain via our discussion of the results in Table 3.

The comparison of households and block-group characteristics between the U.S. and PSID samples indicates that the PSID block groups are similar to the average of all U.S. block groups of each type in terms of block density, average commuters per household, and mean household size. But for other characteristics that are important in this study, the mean square root of the TCI is higher in the PSID sample for each type, yet lower overall because of the overrepresentation of suburban and rural locations. Similarly, job gravity and gross household density are also higher in each of the types in the PSID sample, but the overall average is lower, and the maximums are not as great in each type within the PSID. On the other hand, the percentage of rental housing units is higher in each type and overall in the PSID. On the income measures, the PSID has much higher urban mean incomes, but lower mean incomes in the other urban form type and overall. The mean household size is close for the midurban, suburban, and rural types, and overall, but is much lower than the household sizes for urban areas in the entire United States. Unfortunately, when we attempted to disaggregate across urban forms by family type, race, ethnicity, and education levels, the cell sizes in urban areas were too low. We conclude, therefore, that the PSID is a uniquely rich data set for examining individual transportation expenditures at a fine-grained geographic scale, but it must be used cautiously with these differences in mind.

A frequent critique of location affordability is that there are only a handful of metro areas in the United States where transit is good enough to allow for lower levels of VMT and car ownership (see, e.g., Smart & Klein, 2018, who note just six such metro areas). To test this critique, we matched the 162 urban block groups to their corresponding counties and census core-based statistical areas (CBSAs). This analysis indicated that the urban block groups were spread across 29 CBSAs, 48 counties, and 22 states (see Table S1 in the supplemental online material for the complete list). These urban block groups include large and medium-sized urban areas, as well as smaller college or university towns like Champaign-Urbana, Illinois, and Madison, Wisconsin. When we further limited the urban areas to those with sufficient levels of urban infrastructure within our urban type—places with block and job densities and TCI scores close to the mean of our urban places—there were nine

Table 3. Mean comparisons of urban form and household dynamics between all U.S. Census block groups and block groups in the PSID by four place types (American Community Survey (ACS) 5-year estimates, 2015).

	Urban		Midurban		Suburban		Rural		Total	
Urban Form	U.S.	PSID	U.S.	PSID	U.S.	PSID	U.S.	PSID	U.S.	PSID
Block density										
Mean	0.32	0.33	0.25	0.27	0.06	0.06	0.01	0.02	0.11	0.11
Minimum	0.004	0.11	0.004	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	2.11	1.05	1.54	1.11	0.27	0.32	0.26	0.30	2.11	1.11
TCI (Square Root)										
Mean	5.92	6.27	2.61	2.99	0.68	0.77	0.01	0.07	1.28	1.25
Minimum	1.10	3.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	10.00	9.33	7.39	6.68	3.54	3.44	1.81	2.39	10.00	9.33
Job Gravity										
Mean	252,739	441,766	46,709	61,265	14,226	14,897	1,019	1,572	32,305	27,720
Minimum	6,705	61,025	375.00	1,091	7.67	188.88	7.74	29.00	7.67	28.50
Maximum	1,603,273	1,571,702	249,263	264,554	174,703	119,233	5,300	71,426	1,603,273	1,571,702
Gross household density										
Mean	48.6	54.37	6.33	7.14	1.30	1.49	0.06	0.13	3.80	3.32
Minimum	0.00	4.09	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	533.20	206.79	44.10	38.66	18.3	16.18	2.30	3.22	533.00	206.79
% rental units (%)										
Mean	77.00	73.00	51.00	57.00	29.99	33.00	24.00	27.00	36.00	38.00
Minimum	0.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	91.00	100.00	100.00
Household Variables										
Median income ($)	61,715	69,461	53,481	44,825	61,517	57,700	42,071	41,644	59,190	52,598
Mean no. commuters	1.12	1.11	1.16	1.09	1.14	1.15	0.92	0.94	1.14	1.14
Mean household size	2.43	2.11	2.70	2.70	2.66	2.70	2.43	2.43	2.66	2.68

Note: For both the U.S. and PSID, the mean is for all households in the block group according to the American Community Survey (ACS) 2015 5-Year estimates.

Table 4. Mean differences in expenditure on housing and transportation by income and urban form for PSID renter households, as measured by absolute costs and percentage of income (*N* = 3516).

Income (% of AMI)	Urban form	Housing cost	Transport cost	H + T cost	Housing (%)	Transport (%)	H + T (%)
35% AMI	Rural (11)	$6,564	$3,582	$10,146	61	31	92
	Suburban (427)	$7,213	$3,880	$11,093	69	37	106
	Midurban (282)	$7,763	$2,746	$10,509	67	24	91
	Urban (19)	$9,567	$2,799	$12,366	74	24	98
	Total (739)	$7,474	$3,415	$10,889	68	32	100
	p value	.254	.000***	.250	.767	.000***	.010**
65% AMI	Rural (13)	$5,813	$5,563	$11,376	29	28	57
	Suburban (610)	$9,441	$5,929	$15,370	37	23	61
	Midurban (260)	$10,258	$4,845	$15,103	35	17	52
	Urban (27)	$11,919	$3,878	$15,796	36	11	47
	Total (910)	$9,696	$5,553	$15,249	37	21	58
	p value	.000***	.001**	.180	.047*	.000***	.000***
95% AMI	Rural (19)	$7,829	$5,187	$13,016	24	17	41
	Suburban (454)	$10,901	$7,814	$18,715	26	19	46
	Midurban (184)	$11,290	$7,162	$18,452	24	15	39
	Urban (21)	$15,633	$5,019	$20,652	29	10	39
	Total (678)	$11,067	$7,477	$18,544	26	18	44
	p value	.000***	.001***	.002**	.008**	.000***	.000***
135% AMI	Rural (18)	$8,750	$7,435	$16,185	18	16	33
	Suburban (412)	$12,244	$10,071	$22,315	21	17	38
	Midurban (110)	$14,301	$8,809	$23,110	21	13	34
	Urban (21)	$16,090	$5,708	$21,798	21	8	29
	Total (561)	$12,680	$9,576	$22,255	21	16	37
	p value	.000***	.001***	.008**	.495	.000***	.001***
200% AMI	Rural (24)	$8,661	$12,088	$20,749	11	15	26
	Suburban (472)	$15,206	$12,363	$27,569	15	13	28
	Midurban (101)	$19,109	$10,983	$30,092	16	9	25
	Urban (31)	$29,170	$7,948	$37,119	17	5	22
	Total (628)	$16,273	$11,913	$28,186	15	12	27
	p value	.000***	.000***	.000***	.000***	.000***	.002**
Total	(3,516)	$11,144	$7,252	$18,397	35	20	55

Note: AMI = Area Median Income; H+T = combined housing and transportation expenditures; *p<=.05, ** p<=.01, ***p<=.001.

CBSAs in the PSID data, but 20 CBSAs across 19 states in the United States.[5] In these areas, 46% of the PSID households did not own a car and 45% owned just one. The 20 CBSAs with these urban thresholds include midsized metro areas, such as Baltimore, MD, Detroit, MI, Denver, CO, Miami, FL, Minneapolis, MN, Philadelphia, PA, Pittsburgh, PA, Portland, OR, and Seattle, as well as the often cited large metro areas (e.g., New York, NY, Chicago, IL, San Francisco, CA, Boston, MA and Washington, DC, among others; see Supplemental Tables S2 and S3 for a full list of the 29 metro areas with urban block groups and the 20 that meet the higher thresholds).

Do Household Expenditures Vary by Urban Form, and Is There Evidence of a Housing/Transport Trade-Off?

Income is one of the most influential predictors of travel behaviors, including transportation costs, with marked differences by income level (Raphael & Rice, 2002; Sanchez, Shen, & Peng, 2004; Shen, 2000). With this in mind, we grouped the households into five bins based on their income as a percentage of their region's 2015 AMI, as noted earlier, from 35% AMI to 200% or more of AMI. These five bins allowed for finer-grained analysis by income, which is necessary because we expect expenditure patterns to vary across income groups. Using these income bins and urban form types, we queried the rents and home ownership expenditures to answer two questions. First, do expenditures on transport vary by urban form; and, second, is there evidence of a housing/transport trade-off by urban form?

Table 5. Mean differences in expenditure on housing and transportation by income and urban form for PSID owner households, as measured by absolute costs and percentage of income (*N* = 4,297).

Income (% of AMI)	Urban form (N)	Housing cost	Transport cost	H + T cost	Housing (%)	Transport (%)	H + T (%)
35% AMI	Rural (8)	$3,897	$6,703	$10,599	37	61	97
	Suburban (144)	$6,414	$5,213	$11,627	59	52	112
	Midurban (44)	$8,419	$4,416	$12,835	71	36	107
	Urban (0)						
	Total (196)	$6,761	$5,095	$11,856	61	49	110
65% AMI	Rural (16)	$5,667	$5,832	$11,498	31	36	68
	Suburban (350)	$8,820	$6,154	$14,974	33	24	58
	Midurban (83)	$11,159	$6,100	$17,259	37	20	57
	Urban (4)	$6,587	$4,322	$10,909	19	13	33
	Total (433)	$9,117	$6,117	$15,234	34	24	58
95% AMI	Rural (23)	$6,426	$6,304	$12,730	21	22	43
	Suburban (453)	$10,652	$7,657	$18,308	25	19	44
	Midurban (52)	$15,470	$7,949	$23,419	31	16	47
	Urban (4)	$11,545	$5,091	$16,636	25	10	35
	Total (532)	$10,947	$7,607	$18,554	25	18	44
135% AMI	Rural (31)	$9,222	$7,998	$17,221	18	17	35
	Suburban (603)	$12,343	$9,587	$21,930	20	16	36
	Midurban (85)	$13,125	$8,423	$21,548	19	12	32
	Urban (5)	$11,904	$7,922	$19,826	16	11	26
	Total (724)	$12,298	$9,371	$21,669	20	16	35
200% AMI	Rural (122)	$11,317	$13,763	$25,080	12	16	28
	Suburban (2,037)	$18,427	$13,503	$31,930	14	11	26
	Midurban (213)	$20,836	$11,880	$32,716	15	9	24
	Urban (20)	$18,538	$8,513	$27,051	12	5	17
	Total (2,392)	$18,280	$13,330	$31,610	14	11	26
Total	Total (4,297)	$14,873	$10,818	$25,691	21	16	37

Note. Because of the small sample size in some cells, we did not run ANOVA/Kruskal–Wallis tests on these data.

The overall distribution of housing and transportation costs from urban to midurban to suburban to rural is as expected, with reported transportation expenditures across all five income groups highest for PSID households in suburban, rural, and midurban locations, and lowest for households in urban block groups. Also as expected, we observed higher mean housing expenditures in urban areas and lower expenditures in suburban areas. We tested the significance of observed differences in expenditures for renter households in each income group across urban form types using a Kruskal–Wallis test for differences.

These patterns of transportation expenditures remained true for both renter (Table 4) and owner (Table 5) households, but the housing expenditure pattern was different for owner households (Table 5), with the highest housing expenditures in midurban block groups. Because of the small sample of owner households in urban block groups (*n* = 33) and because of additional complexities of homeowner expenditures (mortgages, maintenance, paid-off or inherited properties, etc.) we focus most of our interpretation on Table 4, with renter households.

Differences between urban and suburban transportation expenditures for renter households ranged from $1,081 for those earning 35% or less of AMI to $4,363 for those who earn 135% of AMI and $4,415 for those earning more than 200% of AMI. It is also important to look at these differences as a share of income. To illustrate, if the suburban dwellers with the lowest incomes in the PSID had the same transportation costs as those in urban areas, the savings would represent, on average, 9% of their income.

Including housing costs, we see that for the income bin closest to the regional median income (95% AMI), rental housing costs are significantly different across urban form types and higher in more urban locations ($15,633 in urban, $11,290 in midurban, $10,901 in suburban, and $7,829 in rural locations). When looking at housing cost as a share of income, these differences are less apparent

(29% in urban, 24% in midurban, and 26% in suburban, and 24% in rural areas), indicating that as housing costs increase in urban areas, so do incomes.

Findings of combined housing and transportation costs for renters largely support the hypothesis of a beneficial H + T trade-off, with housing expenditures increasing and transportation expenditures decreasing in each income bin from suburban to rural or midurban to urban. Combined housing and transportation costs (H + T) are also consistently lower in more urban locations, except for the lowest income bin where the lowest costs are in the midurban locations.

We know that household characteristics other than income also influence travel expenditures. For example, households in urban areas may spend less on transportation because of the types of households that tend to live in these areas (e.g., singles or couples with few or no children). Our data show a smaller mean family size in urban areas, although the number of adult workers per household is similar across urban form groups: 1.2 to 1.4 (see Table 6 for additional descriptive statistics of the sample). These differences make multivariate analysis necessary to further unpack patterns and relationships.

We also examined patterns in vehicle ownership to understand the role of this variable across urban form and income groups. Table 7 shows that there are people across all incomes and all neighborhood types who live without a car, although there are fewer with higher incomes in more suburban and rural locations.

Multivariate Analysis

Model 1 (see Table 8) predicted approximately a quarter of the variation in household transportation expenditures (R^2 = 0.271). Household characteristics had the largest effect, with transportation costs increasing significantly with family income, with home expenditures as a percentage of income, and with the number of working adults, total adults, and children/dependents. Aside from housing

Table 6. Demographic differences by urban form among PSID families used in this study (*N* = 8004).

Variable	Urban (*N* = 151)	Midurban (*N* = 1441)	Suburban (*N* = 6118)	Rural (*N* = 291)	Total (*N* = 8004)	*p* value
Mean family income	$93,697	$60,072	$78,039	$65,858	$74,662	***
Median family income	$65,487	$40,500	$58,100	$56,607	$55,089	***
Mean family size	1.86	2.48	2.68	2.76	2.63	***
Mean number of children	0.34	0.73	0.81	0.91	0.79	***
Mean number of full- and part-time adult workers	1.21	1.26	1.37	1.39	1.35	***
Mean work hours (household head)	38.75	32.78	34.79	37.10	34.59	***
Mean work hours (spouse)	9.91	11.18	15.43	16.61	14.60	***
Mean total commute time (for all adults)	61.80	47.04	48.68	42.60	48.43	**
Mean number of vehicles	.66	1.23	1.91	2.32	1.78	***
Mean food expenditure	$9,543	$7,058	$7,977	$7,135	$7,811	***
Mean education expenditure	$2,535	$1,249	$1,431	$705	$1,393	*
Mean child-related expenditure	$540	$433	$624	$342	$577	*
Mean health expenditure	$2,861	$2,535	$3,875	$3,665	$3,606	***

*$p \leq .05$. **$p \leq .01$. ***$p \leq .001$.

Table 7. Vehicle ownership by income and urban form among PSID households.

Income	Urban		Midurban		Suburban		Rural		Total	
(% AMI)	Mean vehicle	% no vehicle	Mean vehicle	% no vehicle	Mean vehicle	% no vehicle	Mean vehicle	% no vehicle	Mean vehicle	% no vehicle
35	0.35	65	0.55	54	0.85	32	1.37	11	0.75	41
65	0.53	50	1.04	23	1.42	13	1.48	10	1.31	16
95	0.60	52	1.23	16	1.55	5	1.73	2	1.47	8
135	0.77	42	1.55	6	2.02	2	2.24	4	1.94	3
200	0.84	35	1.99	2	2.46	0	2.81	0	2.40	1
Total	0.66	46	1.23	22	1.91	7	2.32	3	1.78	11

Table 8. Ordinary least squares regression with robust standard errors.

Variable	Model 1	Model 2
TAS jobs	− 0.000	0.000
	(0.001)	(0.000)
TCI (square root)	− 493.406***	− 223.497*
	(97.941)	(90.511)
Gross household density	− 1.767	5.634
	(10.687)	(9.084)
Block density	− 2,653.982***	− 2,515.814***
	(628.496)	(586.263)
Family income as % of AMI	790.702**	737.474**
	(305.648)	(266.714)
Full-time working adults	908.380*** (154.021)	720.358***
		(143.221)
Total household adults	1,670.612***	1,479.118***
	(112.002)	(105.998)
Children and/or dependents	337.832***	372.217***
	(64.292)	(60.870)
Total travel time	16.768***	17.287***
	(1.759)	(1.668)
Home expenditures as % of income	− 0.113***	0.089***
Rural area	(0.021)	(0.020)
	− 224.660	102.323
	(409.480)	(407.465)
Car ownership		5,683.278***
		(158.873)
Constant	2762.083***	− 1,966.130***
	(251.338)	(218.073)
Mean VIF	1.73	1.69
R^2	0.271	0.320
N	7,533	7,533

Note. Robust standard errors are given in parentheses.
*$p < .05$. **$p < .01$. ***$p < .001$.

expenditures, the number of adults within the household yielded the largest effect on transportation expenditures. Within this sample, each additional adult household member increases transportation expenditures by over $1,600 on average.

Controlling for these household characteristics, two of our four urban form variables were significant. Higher block density was associated with lower transportation expenditures. For every unit increase in block density, a household spent $2,654 less on transportation. This is reduced only slightly in Model 2 when car ownership is added as an independent variable. Better transit access, as captured by square root-transformed TCI, was also associated with lower transportation expenditures in Model 1. For every 1-point increase in square root-transformed TCI, a household would save about $500. To put this in perspective, the mean square root of TCI is 2.3 in midurban block groups and 5.4 in urban block groups. That difference in TCI would, therefore, represent a savings of approximately $1,550 between the average urban location and the average midurban location, controlling for other variables.

Including car ownership in the model (Model 2) increases R^2 to 0.320. The effect of transit access is cut by more than half; however, TCI loses some of its significance in the model, reducing the statistical level of confidence from 99% to 90%. This suggests that only a portion of the effect of the built environment and transit access on transportation expenditures can be explained by car ownership. This means some households may be overly reliant on car ownership as the primary means of transportation even when other options are available. However, as an independent explanation, higher levels of TCI are associated with lower levels of transportation expenditures.

The effect sizes of some of the household variables were also mitigated with the addition of car ownership, including family income, full-time working adults, household adults, and housing expenditures. In contrast, the effect size of the number of children and dependents as well as total travel time both increased slightly with car ownership. In effect, both car ownership and car use likely increase with more children and dependents and either longer commutes or more than one regular commuter. Specifically, we find that a 1-unit increase (1 minute) in total commute time increases transportation costs by approximately $17 annually. We also find home expenditures as a percentage of family income have a positive effect on transportation expenditures. We find that a 1-unit increase in the share of housing expenditures as a percentage of family income increases total transportation expenditures by approximately 0.01%. This is likely related to the income effects on both, as well as lifestyle preferences (Deka, 2015). Our proxy for rural areas had no effect across either model. Taken together with the other results, it is clear that both urban form and household characteristics are strongly associated with transportation expenditures.

Discussion

The results from our analysis of individual-level data at the block-group level, in both statistical tests for differences and OLS regression, show that the combination of household characteristics, urban form, and transit access significantly affect transportation expenditures. Consistent with the location affordability literature, household characteristics appear to have larger effects on transportation expenditures than urban form does, although urban form and transit access remain significant after controlling for household characteristics and contribute to substantial savings on transportation expenditures.

Our exploration of housing and transportation expenditures (H + T) across four distinct urban form categories and five income bins supports the argument that lower transportation costs help offset higher housing costs. This relationship is evident for all income bins except those earning 35% of AMI or less. Our regression analysis also shows that urban form and transit access are associated with lower transportation costs, even when controlling for several household characteristics, including income, children, workers, adults, housing expenditures, and commute time. Although one of the best predictors of transportation expenditures is car ownership—households that own an automobile spend approximately $5,584 more than those that do not—we find that the effects of block density and transit access remain significant and represent a meaningful cost savings even after controlling for car ownership. In other words, households with cars may still be able to reduce their transportation expenditures, likely because they are not limited to car travel for all their trips or because they are traveling shorter distances.

In sum, even with several positive associations with household dynamics variables, we find an enduring effect of two key urban form variables on transportation costs. This underscores the need to fully unpack, at a fine geographical scale, the detailed household and built-environment dynamics that influence transportation affordability. These details can provide more guidance to planners and policymakers regarding where and how to invest scarce public dollars for affordable housing and the supporting urban infrastructure. Specifically, these findings can help to inform the following two related issues.

Supporting Urban Households with the Lowest Incomes

The expected H + T trade-off for renters appears to hold up except for households with the lowest incomes (35% AMI or less). This highlights the need for further interventions to support this population, which has likely been the hardest hit by rising urban housing prices as new rental construction focuses on the high-end market and cities continue to lose lower cost rental units (Harvard Joint Center for Housing Studies, 2020). Research has shown when households spend most of their money on housing and transportation, they may struggle to afford other necessities, let alone get ahead (Lipman, 2005). Interventions should include increasing the supply of deeply subsidized affordable housing in location-efficient urban locations; regulating unfair housing practices such as landlord exploitation of vulnerable renters (i.e., those with poor credit or rental histories) and evictions, which makes it harder for renters to find housing in accessible or amenity-rich locations where competition is greater (Desmond, 2016); providing free or greatly reduced public transit fares, which some cities and regions have already implemented; and implementing other mobility options, including new options such as demand-responsive transit and subsidized ridesharing, affordable car sharing, and, for some, carefully designed car subsidization programs that consider the total cost of car ownership and operations and incorporate energy-efficient electric and hybrid vehicles (Murphy & Feigon 2016; Pendall, Blumenberg & Dawkins, 2016).

Addressing the Suburbanization of Poverty, Metropolitan Growth, and Patterns of Disinvestment and Segregation

Households with lower incomes continue to move to suburban locations where they may find lower housing costs but face higher transportation costs because of longer distances to work, shop, recreate, visit friends, and attend school. Indicative of this process, our analysis of PSID data shows that the households with the lowest incomes were in midurban locations. Many of these midurban locations are older inner-ring suburbs that have experienced disinvestment and lack the fiscal resources to support these new residents. At the same time, regions face high and underfunded cost estimates to repair and expand roads because of years of auto-centric outward growth (Makarewicz, Adkins, Frei, & Wennink, 2019). As one solution, some regions have developed programs to target growth and infrastructure to these older areas where new investments in sidewalks, transit, jobs, and infill housing can leverage existing infrastructure and an affordable housing stock, thereby increasing the livability of these areas (e.g., the San Francisco region's Priority Development Areas and the Atlanta, Georgia, region's Livable Centers Initiative).

This research supports the theory behind such programs for relatively lower density urban areas and higher density midurban areas. In addition to lower incomes, these areas already have block densities much higher than those of suburban areas (0.25 in midurban areas compared with 0.06 in suburban ares), but lack the household density, transit access, and job access observed in urban locations (see Table 3 and supplemental tables). With additional investments in transit access, walkability, and planning aimed at increasing the density of housing and jobs, these areas could become more location efficient over time. Moreover, the preservation and substantial addition of diverse housing types and tenure options can help to improve the location affordability of these places, providing individuals and families with cost savings over their life cycles as their housing needs change (2016). Zoning that allows greater densities and second units, and the use of inclusionary zoning, among other land-use regulations, may help create these diverse types and at the same time create more resilient neighborhoods that support transportation mode choice (Wang & Immergluck, 2019). The urban form changes in the last few decades in the metropolitan areas of Seattle, Portland, Minneapolis, and Washington, DC, with the introduction or expansion of rail transit systems, are evidence that investments in transit and walkability can support greater job and household density that leads to lower transportation expenditures.

Conclusion

In this study we have shown that findings from Smart and Klein (2018), which challenged the importance of location affordability, may be overstated and based, in part, on methodological shortcomings. By using more appropriate measures and a finer-grained geographic scale, and looking at differences across multiple urban forms and income groups, we have shown that household transportation expenditures of families in the PSID are significantly and meaningfully influenced by the urban form and transit accessibility of the block groups in which they live. Location-efficient places in which households can save money on transportation are not confined to large cities on the coasts, but rather are distributed across 29 Metropolitan Statistical Areas (MSAs) across the United States. Our findings largely support the H + T and location affordability hypotheses, with the notable exception that transportation savings accruing to the lowest income households in urban areas are not enough to offset higher urban housing costs, especially as a share of their income.

In a finding relevant to other researchers, we also determined that the PSID is fairly representative of households from all 50 states and income brackets, but that its undersampling of households in urban and midurban block groups limits our ability to further stratify the sample, such as by tenure, educational attainment, or race and ethnicity. Despite this caution, the block-group data from the PSID retains value in providing a uniquely rich examination of household transportation expenditures at a fine-grained geographic scale.

These results make the case that households in location-efficient places do, on average, benefit through total transportation cost savings, which at least partially offsets higher urban housing costs. Our more nuanced findings across urban form and income groups suggest regionally coordinated efforts with solutions tailored to the local context. For example, it appears that the group least likely to offset higher housing prices with transportation savings in the most urban areas are those making less than 35% of AMI. Specific housing interventions are necessary to make these location-efficient places affordable to households with low and very low incomes. Meanwhile, families with low and moderate incomes in midurban locations may be more likely to find more affordable rental housing but may find transit access lacking. In these places, a focus on preserving existing affordable housing while increasing transit access, jobs, mixed uses, and household density may be more appropriate.

Taken together, these findings suggest that measures of location affordability should continue to be used in planning and policy discussions, although with continued refinement. As Ganning (2017, p. 820) notes, it is "commendable and just" to include measures of access to opportunity in the discussion of housing affordability, and the measure of LE is a step forward, even if the current measure is problematic. Future research could use the PSID or other individual-level data, such as data on occupations or special samples from the NHTS (Hamidi et al., 2016), and these could be paired with more detailed urban form variables, such as grocery stores and other nonwork destinations, data on the quality and comfort of transit, and a growing array of walkability measures. These future studies should build on the approach in this study, those by CNT, and other recent studies in the United States (Hamidi et al., 2016; Wang & Immergluck, 2019), Buenos Aires (Guerra et al., 2018), Iran (Isalou et al., 2014), and elsewhere that measure and show how LE improves location affordability.

Notes

1. These four variables resulted in a high score on the silhouette measure of separation and cohesion (about 0.6 on a scale of −1 to +1), which indicates the cases within each cluster are close to each other and there is distance between the clusters. We specified three clusters to correspond to categories of urban form and to ensure a sufficient sample size (Norusis, 2011).
2. We also considered modeling transportation as a share of family income. However, transforming the dependent variable in this manner would introduce significant endogeneity into the model since some of the other controls are also a function of income. Taken together with the possible omitted variable bias introduced if car ownership is not included as a possible control, we rely on the actual dollar of transportation expenditures to mitigate possible correlation with the error term.
3. We also tested for multicollinearity issues across individual variables, given concerns around correlation between several of our predictors. However, we did not find evidence to suggest that we have issues of collinearity between our explanatory variables.
4. We also had the number of cars owned by each household. Approximately 89.35% of households own at least one vehicle. With a range from 0 to 10 vehicles, the mean is 1.71. Given our results, we use a dummy variable for vehicle ownership instead of the actual number for each household. The models yielded similar results to the one provided in this article.
5. We defined these as block densities at or above 0.3, square root-transformed TCIs greater than or equal to 5, and job densities greater than or equal to 100,000.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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