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Disentangling the effects of the built environment on car ownership: A multi-level analysis of Chinese cities

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ABSTRACT

Reducing the reliance on car-based transportation is a common goal of academics and policy makers, one element of which is car-ownership. This paper contributes to our understanding of the links between socio-economic attributes, the built environment and car ownership. Based on a sample of 3480 individuals across China in 2012, this study examines the impacts of the built environment at both neighborhood and city levels on car ownership and its moderating effects on household income. The results indicate that built environment elements at both levels affect car ownership significantly, and while some elements mitigate the effects of household income on car ownership, others strengthen them. Thus, urban transportation policy should focus on the built environment at both the neighborhood and city levels and promote compact development for the sake of restraining car ownership and encouraging more sustainable modes of travel. Moreover, policy should not ignore the interaction effects between individual socio-economic attributes and the built environment, as their directions are heterogeneous.

1. Introduction

As more and more households have access to cars, traffic congestion and environmental pollution are becoming increasingly severe. It follows that to alleviate traffic congestion and protect the environment, reducing car use and promoting low-carbon travel have become a common goal in academia and policy circles. Considering that car utilization is, in large part, a consequence of car ownership (Kitamura, 1989; Zhao, 2013), exploring the factors affecting car ownership is an important first step in reducing car use and encouraging more environmentally sustainable modes of travel.

Although a number of urban planners and urban geographers have identified significant impacts of the built environment on car ownership, a recent controversy arose over the magnitude of the effects on distance traveled by car. Ewing and Cervero (2001, 2010) provided much evidence to prove that compact development makes people drive less, while Stevens (2017) found the impact of compact development is fairly small. Car ownership is one of the important indicators for reflecting travel mode option and daily travel (Clifton, 2017). Previous studies paid more attention to the built environment at the neighborhood level than at the city level, and few empirical studies have estimated their effects within the same framework (Ewing & Cervero, 2001, 2010). Furthermore, there is a persistent lack of evidence on whether the built environment at different levels moderates the relationship between individual socio-economic attributes and car ownership (Bhat & Guo, 2007). Lastly, most existing studies focused on individual cities, making it difficult to generalize their results to other cities due to the limited external validity (Cao & Cao, 2014).

This study contributes to the literature first by comprehensive considering both neighborhood and city scales built environment elements while examining their effects on car ownership. Second, for the first time, this study disentangles the moderating effects of built environment with individual socio-economic attributes. Moreover, the findings of this cross-city analysis are more generalizable. We conduct this study based on a sample of 3480 individuals across China from the China Labor-force Dynamics Survey (CLDS) project of 2012 and apply a multi-level model to address the problem of individual dependency in the same spatial unit. Our findings suggest that (1) city-level built environment needs to be integrated into studies of car ownership, we find that built environment elements at both city and neighborhood levels matter for car ownership; and (2), built environment elements also affect car ownership by either mitigating or strengthening the positive association between household income and car ownership.

In the next section, we review previous studies dealing with the relationships between the built environment and car ownership, then identify research gaps and introduce our theoretical framework.

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Section 3 describes data and methodology, followed by results and discussions in Section 4. We summarize the key findings and discuss their implications in Section 5.

2. Literature review and theoretical framework

2.1. Literature review

The links between disaggregated car ownership and built environment attributes have received significant attention (see Anowar, Eluru, & Miranda-Moreno, 2014). Among these attributes, scholars have explored the relationship between car ownership and density either at the neighborhood level (including the census tract and district level) (Bhat & Guo, 2007; Giuliano & Dargay, 2006; Soltani, 2005; Zegras, 2010) or at the city level (Dargay & Hanly, 2007). The results are similar: denser areas are associated with lower rates of car ownership. The explanation is that high density, often accompanied by mixed land use, tends to reduce trip lengths, encourage transit development thanks to higher potential patronage around each stop, and promote the use of non-motorized modes (Kenworthy & Laube, 1996). Conversely, empirical evidence suggests that the lower density developments associated with longer commute distances are positively associated with car ownership (Habib, 2014).

Evidence suggests that diversity of land use independently affects car ownership (Potoglou & Kanaroglou, 2008; Soltani, 2005; Van Acker & Witlox, 2010; Zegras, 2010). The majority of results point to increased land use diversity significantly reducing car ownership by making more destinations available within a short distance of an individual's home (Li & Zhao, 2017; Soltani, 2005). However, Cao, Mokhtarian, and Handy (2007) found neighborhood mixed land use may reduce car ownership only marginally. Senbil, Kitamura, and Mohamad (2009) and Ding, Wang, Liu, Zhang, and Yang (2017) found that mixed land use is positively related to car ownership in the Kuala Lumpur and Baltimore metropolitan areas respectively. They attributed this positive relationship to the proximity of a diversity of land use which reduces the cost of a single trip, thus increasing the likelihood of owing cars.

The link between car ownership and design is explored mainly at the neighborhood level and remains ambiguous. Some evidence points to pedestrian-friendly design, including sidewalks and overhead street lights, being associated with lower rates of car use (Cervero & Kockelman, 1997), as does the density of 4-way intersections for car ownership (Zegras, 2010). However, some studies also found an insignificant relationship between pedestrian-friendly design and car ownership (Soltani, 2005).

In terms of the linkage between car ownership and accessibility, research shows that car ownership decreases with high transit accessibility at the neighborhood level (Bhat & Guo, 2007; Caulfield, 2012; Chen, Gong, & Paaswell, 2008; Giuliano & Dargay, 2006; Potoglou & Kanaroglou, 2008; Salon, 2009; Zhang, Zheng, Sun, & Wang, 2017). Destination accessibility is usually measured at the city level. Some scholars found high job accessibility from one's residential location or proximity to the CBD is associated with a lower likelihood of car ownership (Chen et al., 2008; Huang, Cao, & Cao, 2016; Matas, Raymond, & Roig, 2009; Van Acker & Witlox, 2010; Wang & Lin, 2017; Zhang et al., 2017). Wang, Chai, and Li (2011) also found residents living in a suburban location are more likely to own cars in Beijing.

On the other hand, some studies focus on the relationship between city-level built environment and aggregated car ownership and found that dispersing land use at low density creates automobile dependence, but compact development in city center (i.e. transit-oriented development) helps reduce car ownership and automobile dependence (De Jong, Fox, Daly, Pieters, & Smit, 2004; Ewing & Cervero, 2010; Newman & Kenworthy, 1996, 2006). Moreover, Riley (2002) examined the positive impact of population growth on car ownership. Cao and Huang (2013) found city-level population density has negative effects on car ownership in Chinese cities, while Wu, Zhao, and Zhang (2016) and Yang, Jia, Liu, and Yin (2017) came to the opposite conclusion in Chinese metropolises. In terms of urban design, road area has positive effects on car ownership (Cao & Huang, 2013; Wu et al., 2016; Yang et al., 2017).

However, with respect to car ownership decisions, both aggregate and disaggregate studies found socio-economic attributes and demographics tend to play a more dominant role (Bhat & Guo, 2007; Dargay, 2007; Li & Zhao, 2017), especially household income in disaggregate studies (Bhat & Guo, 2007; Huang et al., 2016). Household income growth generally increases travel demand and travel distance, as well as car ownership rate (Nolan, 2010; Paulley et al., 2006). The number of adults and/or workers and/or young children in the household, as well as marital status was all found to be positively associated with car ownership (Chen et al., 2008; Dargay & Hanly, 2007; Matas et al., 2009; Nolan, 2010; Soltani, 2017). Some evidence points to an inverted U-shaped relation between the age of household head and car ownership (Matas et al., 2009), but car ownership was also found to monotonically increase (Chen et al., 2008) or decrease (Van Acker & Witlox, 2010) with age.

2.2. Theoretical framework

Based on the foregoing review, we identify three gaps which motivate this study. First, most previous studies on disaggregated car ownership focused on the built environment at the neighborhood level and only a few focused on the built environment at the city level. The impacts of neighborhood and city built environment on car ownership are seldom examined within the same framework comprehensively, to the best of our knowledge. Some scholars have discussed the role of built environment at both levels in influencing travel behaviors and believe city-level built environment has a higher effect on travel behaviors (Ewing & Cervero, 2001, 2010; Yang, 2008), but much less cross-scale studies focused on car ownership and they included only the distance to the city center in their estimation (Van Acker & Witlox, 2010; Wang & Lin, 2017; Zhang et al., 2017). Considering that individual travel purposes are diverse and destinations might be far beyond neighborhood areas, the determinants of car ownership should not be limited to single neighborhood-level or city-level built environment, thus we argue that the built environment at neighborhood and city levels need to be examined simultaneously and we should consider more factors from city-level built environment besides the distance to the city center.

Second, most previous studies identified individual socio-economic attributes, especially household income, as critical in shaping car ownership decisions (Bhat & Guo, 2007; Huang et al., 2016). However, few studies paid attention to how built environment elements moderate the effect of household income. In fact, built environment elements might strengthen or mitigate the effects of household income on car ownership. For example, high-income households might forgo car ownership if living in a neighborhood with transit within short distances.

Third, most previous studies on car ownership focused on a single city, yielding findings that might not be generalized to other cities. The impact of the built environment may vary in different cities, so evidence from one city may not be valid in another (Cao & Cao, 2014). Empirical studies based on cross-sectional samples of cities are needed to provide more general results.

Building on evidence from previous studies, the objectives of this paper are to examine the impacts of the built environment on car ownership at different geographical scales and how it moderates individual behaviors towards ownership in China. To effectively meet the objectives, we propose a theoretical framework summarized in Fig. 1. On one hand, we recognize the impacts of built environment elements on car ownership are hierarchical. Specifically, residents (individuals) live in neighborhoods nested within cities. Thus, we hypothesize that