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Influence of land use and street characteristics on car ownership and use: Evidence from Jinan, China

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ABSTRACT

This study examines the effects of land use and street characteristics on household car ownership and use, based on a travel survey of 2540 households in 104 neighborhoods of Jinan, China. We performed two-step instrumental variable models, composed of a multinomial logistic model predicting the car ownership in the first step and a double-hurdle model predicting the car traveling distances in the second step with the use of car ownership as a mediating variable. It is found that parking supply, neighborhood permeability and street design influence car ownership. Most land use and street variables along dimensions of density, diversity and design, as well as the proximity to regional transport infrastructures, influence either the participation probability or the distance travelled by car. Overall, our study points to the importance of strategic urban planning favoring bus rapid transit development, mixed land uses, human friendly streets and restrictive parking to reduce car dependency in rapidly motorizing Chinese cities.

1. Introduction

In many cities of the developing world, car ownership levels are increasing rapidly thanks to urban sprawl, economic growth, rising incomes and strong car purchase intentions among residents (Pucher et al., 2007; Belgiawan et al., 2014). Meanwhile, an explosive growth of car use is taking place in these cities, evident from the travel mode shifting to cars from other modes (i.e., transit, walk and cycle) as well as longer car travel distances in families (Darido et al., 2013; Pourbaix, 2011; Cervero, 2013; Guerra, 2014). The combination of these trends has triggered a series of negative consequences at the local level, such as traffic congestion, road accidents, air pollution and heavy financial burdens for expanding and maintaining large-scale transportation infrastructures. At the global level, current motorization paths make developing countries the main contributor to the growth of transport-related energy consumption and greenhouse gas emissions (GHG), imposing great pressures on the fight against world-wide energy crisis and climate change (Sperling and Clausen, 2002; Figueroa et al., 2013; Lyu et al., 2015).

To address the aforementioned challenges, promoting urban development patterns that can reduce car dependency have gained wide interests among policy makers and scholars (Cervero, 2013). From a theoretical perspective, people choose their vehicle ownership and travel patterns to maximize the derived net utility, and the built environment can influence both travel costs (disutility) and potential activity realization benefit at destinations (positive utility) (Crane, 1996; Maat et al., 2005).

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While cities in US and Europe are largely built up with structures and mobility cultures established already, cities in the developing world like China are still experiencing rapid urbanization and shaping their spatial forms, a trend likely to continue for decades (UN DESA, 2010; Wang and He, 2015). If empirical evidences confirm that the influence of the built environment on travel behavior does exist in the developing cities, there would be a much larger scale-up potential for them than developed countries to intervene in the form of urban development in order to purposefully influence travel behaviors and outcomes.

Unfortunately, literature on the relationship between built environment and travel behavior has mainly focused on cities in the developed countries. Since urban development strategies such as new urbanism, smart growth, compact cities and transit oriented development (TOD) are mostly originated from US and Europe, advocating and implementing those strategies in the context of developing-world cities is subject to transferability concerns. For example, empirical precedents in Santiago de Chile suggest that residential density can assert little influence on car use (Zegras, 2010). For China, the very few research precedents were limited by crude measurement on built environment and/or relatively small sample size of neighborhoods due to data availability, making policy implications inconclusive and difficult to be generalized. Furthermore, previous research in the developing world focused mostly on the land use of neighborhoods but rarely quantified the physical form of streets. Thus they failed to separate the potential effect of street characteristics on household car ownership and use.

This paper aims at filling the gap described above using a travel survey of 2540 households from 104 neighborhoods in Jinan, China. We endeavor to shed light on answers to following questions. What neighborhood characteristics are associated with car ownership and use after controlling for socio demographics and residential self selection in the rapidly urbanizing context of Jinan? How big are the impacts of built environment on car ownership and use respectively? Do street characteristics impose an independent impact on car ownership and use? This research, to our knowledge, presents one of the first efforts of developing integrated household car ownership and use models for a Chinese city and at the same time quantifying the effect of built environment at a decent level. The remainder of this paper is organized as follows. The next section reviews previous studies on the relationships between the built environment and car ownership and use. Section 3 describes data and variables used in this study. Section 4 presents the modeling approach. Section 5 discusses results. Section 6 concludes with the key findings and policy implications.

2. Literature review

In the past decades, numerous studies have been conducted in the developed countries using empirical data and a wide variety of methodological approaches to explore the relationship between built environment and travel (including car ownership and use). Earlier studies were featured of comparative analysis as they directly compared aggregate data of travel patterns across different neighborhood settings (Cervero and Gorham, 1995; Dagang and Loudon, 1995; Friedman et al., 1994). Yet findings using this approach were challenged of the failure in separating effects of individual neighborhood form attributes or in filtering out confounding socio demographic factors such as income (Handy, 1996). To address such challenges, disaggregate multivariate regression analysis has become the mainstream of analytical approach. Depending on the type of dependent variables (e.g., car traveling distance being continuous versus car ownership being discrete), ordinary least square regression (OLS), logistic regression (LOGIT), TOBIT regression and other modeling techniques were employed to directly control for confounding effects.

More recently, scholars paid much attentions to the potential self-selection and endogeneity problems associated with the disaggregate regression analysis. Simply put, for example, if residents who have a priori preferences for owning and using cars choose neighborhoods that permit these preferences to be expressed, some of the observed association of built environment with travel behavior may not attribute to the causal effects of built environment per se, and results may be biased due to omitting unobserved variables (e.g., attitudes) in the regression (Kitamura et al., 1997; Kahn and Morris, 2009). Accordingly, advanced approaches such as instrumental variable models, sample selection models, joint discrete choice models, structural equations models, and/or models using longitudinal/attitude data were further developed and applied in the literature (for detailed discussions and comparisons of these modeling techniques, see Mokhtarian and Cao, 2008).

Across different methodological approaches and geographies in the developed-world cities, the academy has reached a general consensus; that is, built environment, socio demographics and attitudes all can influence the car ownership and use to some extent, although the significance and magnitude of effects from certain built environment factors can vary a lot (for a comprehensive review, see Ewing and Cervero, 2010). Influencing socio demographic factors include household size, income, age, education and employment status (Holtzclawet al., 2002; Bhat and Guo, 2007; Guo, 2013; Keller and Vance, 2013; Cao and Cao, 2014). Attitudes such as residential and travel preferences can also play an important role on car ownership and use (Kitamura et al., 1997; Schwanen and Mokhtarian, 2005; Cao et al., 2006). As of the influencing disaggregated built environment elements, they were generally grouped into dimensions of density, diversity, and design, the so-called 3Ds (Cervero and Kockelman, 1997). Specifically, higher densities are associated with lower car ownership and less car use in distance and time, a strong effect revealed by many studies (Cervero and Kockelman, 1997; Holtzclaw et al., 2002; Dargay and Hanly, 2004; Hammadou et al., 2008; Kitamura et al., 1997; Schwanen et al., 2004; Stead, 2001; Keller and Vance, 2013). Diversity, measured by the degree of balance across various land use types and often taking forms of an entropy index or a job/housing ratio, is found to be negatively associated with car ownership and use (Boarnet and Sarmiento, 1998; Ewing et al., 1994; Frank and Pivo, 1994; Kockelman, 1997; Van Acker and Witlox, 2010; Zhang et al., 2012; Keller and Vance, 2013;