Geography and social networks in transportation mode choice

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A B S T R A C T

In this paper we explore the effects of social influence on travel behavior and utilize an instrumental variables approach to address the potential endogeneity related to similarities in the choice environments of socially connected individuals. We expect individuals to use a mode of transportation that is used by others in their social network. However, other factors important to mode choice, such as commute characteristics or transit access, may influence multiple members of a social network at the same time. Thus it is necessary to estimate the effects of social influence while taking into account the potential effects of shared environmental characteristics. We hypothesize that social influence is relevant to transportation mode choice, even when accounting for shared environmental characteristics among members of a social network. We explore this hypothesis, utilizing survey data collected from a sample of university students, in Davis California. The survey collected information about respondents' social networks, the transportation mode choices of their social contacts, and geographic information for the respondent and their social network. We estimate models using instrumental variables measuring neighborhood characteristics of the social contacts. Results provide evidence that social processes are important to travel behavior, even when accounting for similarities in behavior that may be attributed to similar choice environments.

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1. Introduction

Traditional models of transportation mode choice usually rely on a rational model of decision-making where individual actors assess the benefits and cost of their transportation alternatives. In contrast, a growing number of transportation researchers are investigating the social processes that affect transportation decision-making, such as processes occurring within the social networks in which individuals are embedded. Social networks serve as a foundation for multiple social processes, including cooperation, resource sharing and social influence. Evidence shows social networks provide access to opportunities; for example collaboration (i.e. Freeman, 1984) and employment (Granovetter, 1973), through network connections. In this study we focus on social influence, whereby the knowledge, behaviors, or opinions of one individual affect those of others to whom they are socially connected. Social influence is linked to many behaviors, including academic achievement (Sacerdote, 2001), civic engagement (Klofstad, McClurg, and Rolfe, 2009) and health (Koehly and Loscalzo, 2009). Given the widespread importance of social influence and other processes related to social networks, it is no surprise that social networks are gaining greater attention in travel behavior research and policy.

Here we empirically analyze whether individual mode choice is affected by the mode choices of social contacts, which could occur via

several possible social influence mechanisms. One mechanism occurs when social networks serve as pathways for information sharing; for example individuals may seek information about telecommuting, from their friends and colleagues who already telecommute (Wilton, Páez, and Scott, 2011). Social relationships can also reinforce social norms for particular modes of transportation. For example, bicycling may be more accepted or expected within some communities (Goetzke and Rave, 2011), households, or social networks. Lastly, social relationships provide channels for persuasion, where the behaviors of social network members change an individual's preference for a particular mode of travel. All of these social influence mechanisms can produce a positive correlation between the mode choice of an individual, and the choices of that individual's social network contacts.

Empirically detecting social influence is challenging due to various endogeneity issues where unmeasured variables create a positive correlation between the behaviors of the individual and their network members. In travel behavior, the most important endogeneity occurs when socially connected individuals live in the same neighborhood, or face similar commute circumstances (though in different neighborhoods). It is possible that similarities in commute environment, rather than social influence, causes similarities in behaviors. This *shared environment* problem is particularly relevant to social influence in transportation since we expect geographic factors such as commute distance, land use characteristics, and infrastructure to be important in mode choice. Further, scholars have demonstrated that both geographic or neighborhood mode use (Pike, 2014; Dugundji and Walker, 2005; Goetzke,

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2008) and social influences (Scott, Páez, Dam, and Wilton, 2012; Wilton et al., 2011) are relevant in travel behavior. In this paper we employ statistical models that estimate the effect of social influence in transportation mode choice, while accounting for shared environment within social networks.

2. Background: social networks and travel behavior

Social networks have recently emerged as an important area of inquiry in transportation behavior and policy research (for a review see Maness, Cirillo, and Dugundji, 2015). Travel behavior research related to social networks is primarily focused on two related areas; how social networks affect activity schedules (Van den Berg, Arentze, and Timmermans, 2010), trip generation, and travel demand (Carrasco, Hogan, Wellman, and Miller, 2008 and Carrasco and Miller 2006 and 2009, Larsen, Urry, and Axhausen, 2008; Mok, Wellman, and Carrasco, 2010) and how social relationships influence travel behavior (Goetzke, 2008; Wilton et al., 2011; Pike, 2014).

Manski (1993) identifies several challenges related to the study of social influence, including difficulty distinguishing between endogenous effects: effects related to social influence, and correlated effects: effects of similar institutional contexts or shared environment. In the remainder of this section we discuss the social influence research and the contributions of this study; namely, we present an empirical estimation of endogenous effects, referred to as *social influence*, in transportation mode choice. The social networks utilized in our analysis are formed using identifiable social interactions, and we address endogeneity related to correlated effects, or *shared environment* among socially connected individuals.

2.1. Social network definitions

There are two main areas of research on social influence and travel behavior; one area focused on aggregate social interactions, where connections between individuals are assumed when individuals live near one another, share socio-economic traits, or may otherwise be grouped aggregately by a relevant characteristic. The other main area of social influence in travel behavior is focused on social interactions that are identifiable or explicit. Respondents may be asked to identify individuals with whom they share a specific type of relationship; for example, "list the names of five close friends." Identifiable relationships may also be elicited by asking respondents to indicate the nature of their relationships with all others in a specific network, such as their network of colleagues.

The influence of identifiable social networks and neighborhood networks likely operate in different ways. In a previous study, results indicate identifiable network connections are more relevant in the decision to bike, while neighborhood networks are more relevant in the decision to take the bus (Pike, 2014). The majority of studies on social influence in transportation mode choice utilize aggregate social interactions and represent social networks as neighborhoods or other broadly defined social groups. However, there are many examples of identifiable social interactions in activity-based travel research (for example Carrasco et al., 2008; Larsen et al., 2008).

2.2. Social influence and travel behavior

Studies of social influence using aggregate social network interactions have demonstrated effects of social context on individual behavior. For example, college students are more likely to bike, when higher proportions of their neighbors bike (Wang, Akar, and Guldmann, 2015), and an individual's choice to use transit is influenced by neighborhood transit use (Goetzke, 2008). Goetzke (2008) points out that such network effects may be attributed to both a social effect, but also to effects on the perception of the service; as more people in a neighborhood use transit the perception of safety and quality are likely to

improve, and lead to even more use. Further, social reference groups defined geographically and socioeconomically are relevant to choices between multiple modes of transportation (Dugundji and Walker, 2005); several formulations of reference group variables are explored and found to improve model outcomes, when compared to frameworks that do not account for spatial and social interdependencies. In another example of aggregate network effects, bicycling mode share in German cities can be attributed to a city-level cultural component characterized as a social network effect (Goetzke and Rave, 2011); however, the effect is relevant for shopping and recreational trips but not for travel to school or work. Their findings show limited importance of infrastructure in bicycle mode share and suggest bicycle programs would benefit from promoting bicycle culture (Goetzke and Rave, 2011).

The second branch of the literature explicitly measures social networks as groups of individuals with identifiable social connections. Wilton et al. (2011) find interactions with co-workers at work and a workplace culture around telecommuting are among the social factors relevant in the decision to telecommute. Scott et al. (2012) also find that social effects play a role in the decision to telecommute and that relationship strength affects the extent of social influence. In this study the most important mechanism of social influence is information and advice from contacts who already telework (Scott et al., 2012). Social influence may also occur when connected individuals affect one another's knowledge or preferences through discussion (Axsen and Kurani, 2011).

2.3. Social influence and endogeneity

Endogeneity of the variables representing social influence is a challenge common to all of this research (Manski, 1993). Endogeneity problems include social selection effects where individuals develop relationships with people who are similar to them, or who are likely to share their travel preferences, and reciprocal causality where the travel behavior of the focal individual influences the travel behavior of their network contacts. Most important to this study, is the shared environment effect where both the individual and the social network are influenced by the same environmental and contextual variables. Endogeneity in social influence related to transportation mode choice is explored in a number of studies (For example, Goetzke and Weinberger, 2012; Walker, Ehlers, Banerjee, and Dugundji, 2011, and Dugundji and Walker, 2005). Endogenous neighborhood effects have been addressed using spatial autocorrelation models (for example, Goetzke and Andrade, 2010), as well as instrumental variables approaches (such as Goetzke and Rave, 2011, and Goetzke and Weinberger, 2012).

We extend the use of instrumental variable approaches to investigate social influence in identifiable social networks; we define social influence in terms of the mode use of contacts with identifiable social relationships. We collected information about the residential locations of respondents' social contacts; therefore we are able to address endogeneity related to correlated effects by using geographically defined instrumental variables. Another concern in this research is the possibility of joint mode choice decision-making between socially connected individuals when they live within the same household. Because our sample is made up of students, household joint mode choice decisions are likely to differ from the joint mode-choice decisions expected of families. In particular, we expect household members to use the same mode choice in most cases; as they likely travel to and from campus together, or establish household behavioral norms, as opposed to splitting up household tasks such as child transport, that we might expect in households of families (for example see Srinivasan and Bhat, 2005). To explore the possibility of within household joint decision making all of the analyses presented here were conducted including and excluding household members from the social networks of respondents.