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Modeling individual travel behaviors based on intra-household interactions☆

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ABSTRACT

This paper investigates how individual activity–travel behaviors are influenced by interactions between household members in making decisions about their daily trips. Traditional discrete choice models mainly incorporate individual decision-making mechanisms ignoring the household context. In reality, each household member's travel choice often depends on the decision of the other members. We propose a new estimation method that assumes each travel decision depends on intra-household interactions. Using Bayesian estimation we develop a spatial multivariate tobit specification that allows for each individual facing a set of potential destinations to take into account the willingness to travel of other household members. Using a unique dataset containing more than 67,000 trips made by more than 3500 individuals in the area of Greater Cincinnati, we show that depending on the purpose of the trip, household members do interact and accommodate their travel decisions with respect to other household members.

1. Introduction

There is growing evidence that the behavior of decision-making units is influenced by the choices of peers. Trying to disentangle the role played by the characteristics and behaviors of others in influencing an individual's choices remains one of the main avenues of research in many disciplines. Different social interaction models have been developed across many fields, such as psychology, sociology, and economics, to understand the explicit structure of social networks of family, friends, and colleagues. The influence that social factors may have on transportation behaviors has also been recently analyzed (Dugundji et al., 2008; Zhang et al., 2009). Here we are interested in approaches for which activity–travel behavior is not regarded as independent across members of the same household (Kato and Matsumoto, 2009). This paper uses trip and activity based analysis to offer a new perspective on how individual travel choice behavior within a household could influence other members' decisions. Based on the seminal work of Brock and Durlauf (2001), discrete choice models typically characterize social interaction through rational expectations (see Lee et al., 2014 and Lin, 2014 for a detailed review of rational expectation under binary choice models). This paper proposes a modeling framework that incorporates trip decisions as latent utilities that interact additively with other household members' utilities. Similar to the traditional linear-in-means models, we develop simple stability conditions (as defined in Lee, 2007), avoiding complex contraction mapping properties to define the rational expectation equilibrium.

In the case of household mobility, the members of a household often consider the preferences of each other member when making choices. Interaction with other household members will be at the origin of trip decision even if only one individual takes the responsibility for most activities. Therefore, it is necessary to propose a modeling approach that accommodates such decision-making mechanisms for each member of the household. Since daily trip activities are likely correlated, logit models are inappropriate due to their independence of irrelevant alternatives characteristic. We implement a multivariate tobit that allows for dependence between the types of daily activities for each individual, while controlling for observed and unobserved individual and household characteristics as well as socioeconomic factors for each location.

The goal of the present study is to analyze interactions among household members when making decisions about their daily trips and the effect of such interactions on individual travel behavior. Based on Bramoullé et al. (2009), we introduce a spatial econometric specification in order to capture the influence of other household members'

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decisions. Specifically, we use a spatial lag structure that identifies members of the same household and allows each individual's latent utility to be influenced by the other household members' trip choices. We analyze a unique dataset of more than 67,000 trips taken over three days by 3509 individuals belonging to 1481 households sampled from the Greater Cincinnati area. As described in Lee (2007), estimates of group interaction might suffer from the presence of unobservable factors that could affect all members of the same household. Instead of using the traditional fixed effects model, we implement the correlated random effects approach (Chamberlain, 1984) and avoid the incidental parameters problem. The purpose of introducing the influence of unobservable factors along with peer effects is not only to account for additional heterogeneity but also to achieve greater understanding of motives underlying travel choice behavior. This allow us to disentangle direct effects arising from a change in one's own characteristics from indirect or spillover effects associated with a change in the other household members' characteristics. Results reveal that the endogenous peer effect coming from other household members is a primary factor for shopping and school related activities.

The remainder of this paper is organized as follows. Section 2 presents a brief review of household choice models on activity–travel behavior. Section 3 proposes a household choice model incorporating household decision-making mechanisms and addresses the econometric specification of the spatial multivariate tobit. Section 4 describes the dataset. Empirical results are presented in Section 5 followed by an analysis of the marginal effects in Section 6. Section 7 concludes.

2. Literature review

Over the last three decades, many studies have attempted to determine and analyze the actual and potential activity participation of persons and households. The early literature has given considerable attention to the conceptualization of the intra-household behavior of individuals. While theoretical models were operating at the micro-level, empirical analyses were focusing primarily on activity-based travel demand models using zone-based data. This changed at the beginning of the 1990s with the development of the spatial analytic capabilities of GIS along with the increased availability of micro-level data. Researchers became more interested in the spatial character of many decision-making processes, increasing their efforts toward the development of techniques robust to spatial dependence (Qu and Lee, 2013) or peer effects (Lin, 2014).

As many geographers and behavioral economists have argued, an individual's choices are correlated with the choices of others (Srinivasan and Athuru, 2005). A number of recent studies (Bramoullé et al., 2009; Blume et al., 2011; Vovsha et al., 2004) have analyzed peer effects and provided a better understanding on how to identify the main drivers of correlation between outcomes of individuals who interact together. Based on the seminal work of Manski (1993), a distinction was made between contextual effects (i.e., influence of exogenous peer characteristics), endogenous effects, (i.e., influence of peer outcomes) and unobserved correlated effects coming from individuals in the same reference group who tend to have similar behaviors because of their common environment. As reviewed by Kim et al. (2014), empirical studies in transportation based on peer effects and group decision-making theories have been conducted over a long period of time. Focusing on interaction between children and their parents, Kato and Matsumoto (2009) have proposed a time-allocation model to analyze household activity using a utility-maximization model under the constraints of time and monetary budgets. Zhang et al. (2009) explicitly incorporated group decisions into household travel behavior models using different types of group utility functions to aggregate individual utilities into a household utility. They showed that intra-household interactions are statistically related with household decisions by household members. All individuals were assumed to be homogenous with respect to their values of time and utility perception. This assumption was later relaxed to incorporate the interaction between household activity–travel schedules. In fact, Bhat et al. (2013) extended the Multiple Discrete Continuous Extreme Value model as a time allocation tool, to control for different combinations of individual as well as joint activities across household members. However, this approach did not explicitly allow for multiple instances of the same activity. With help of individual travel data, there has been a growing body of research on modeling joint travel activities (Ho and Mulley, 2015). The number of joint travel undertaken by the adult household members is highly dependent on the number of children. The mode shares for individual travel are also significantly different from the mode shares for joint travel (Kang and Scott, 2011). Modeling joint activities is an essential part of individual travel behaviors since they differ by transport modes and trip purposes, and the number of family, etc. For example, Srinivasan and Bhat (2005) showed that the travel distance and activity participation duration is usually longer for joint activities relative to individual activities.

Travel behavior has also been intensively linked to built environment. Many studies found density to be negatively associated with car ownership, car use and travel distances. For example, based on the travel data in Belgium, Van Acker and Witlox (2011) found that densely built neighborhoods are associated with lower car use and shorter commuting distances. A similar result that high density development appears to encourage non-motorized travel has been found by Tracy et al. (2011) in Buffalo, New York. Despite these advancements the underlying framework considers only single trips. This limitation prevents exploring the effect of density on tour complexity (i.e., the number of stops per tour). It is highly possible that denser built environment will lead to more complex tour and people may switch travel mode within a single tour. Policymakers and urban transportation researchers have always been trying to understand and exploit the relationship between travel behavior and land use (Tracy et al., 2011; Cervero and Kockelman, 1997; Kockelman, 1997; Boarnet and Crane, 2001; Naess, 2009). In particular, Cervero (2002) weighted the influences of different land-use factors when computing the parameter for the overall effect of land use of household travel behavior. A recent study by Shay and Khattak (2012) modeled the relationship between land use and travel behavior at the personal level while most studies are based on aggregated data at the large geographic unit such as the census tract, traffic analysis zone (TAZ), or the metropolitan.

Despite the importance of intra-household interactions, household and neighborhood context, previous empirical studies of individual travel behaviors have not considered simultaneous relationships among individuals, households, and neighborhood. The scope and degree of intra-household interactions on empirical findings concerning individual travel behaviors still remain overlooked.

3. Theoretical framework

There is a large variety of theoretical and empirical studies arguing for the possibility that social interactions could enter directly into the utility function. The recent literature on household decision-making processes views the family or household as a collection of individuals with their own preferences. As detailed in Del Boca and Flinn (2012), household members are often modeled as behaving strategically with respect to one another given their time and resource constraints. Because of its attractiveness and equilibria that are often unique, non-cooperative models are often used.

The baseline model of social interactions analyzes the joint behavior of individuals who are members of a household r of size n_r. Following Liu et al. (2011), we define by $N_r = \{1, \ldots, n_r\}$, a finite set of members belonging to the same household structure w_r $(r = 1, \ldots, R)$, where R represents the total number of household. Total number of individuals is defined by $n = \sum_{r=1}^{R} n_r$.

All members within the same household have some interactions and influence each other's travel decision, but we assume each household is