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Activity and Transportation Decisions within Households

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Abstract

Households are often responsible for labour supply, time allocation, transportation and many other decisions. Yet, research in both economics and transportation was traditionally dominated by so-called unitary models that treat households as single decision-making units with a representative individual. This began to change with the development, in the field of Economics of the Family, of non-unitary models that recognize differences in household members preferences, and attempt to describe the joint decision making processes within households. Application of non-unitary models took off in the transportation literature with the special issues on modelling intra-household interactions edited by Bhat and Pendyala, 2005 [24] and Timmermans and Zhang, 2009 [113]. This chapter reviews the development of integrated models of household activity and transportation from the perspective of the Economics of the Family. These models have been applied to long-run decisions such as residential and workplace location and vehicle ownership, as well as short-run decisions including activity schedules, transport mode, and departure time. Non-unitary models go well beyond conventional discrete choice models by accounting for individual family members preferences, and within-family decision-making processes. The models feature new concepts specific to within-family interactions, including repeated interaction, bargaining, altruism, and Pareto optimality.

1. INTRODUCTION

Several disciplines have developed independent streams of research on household decision-making. They cover topics ranging from labour supply, time and task allocation, and residential and employment location choices, to transportation decisions such as vehicle ownership and mode choice. Until the late 1990s, the literature in these fields was dominated by so-called unitary models that treat households as single decision-making units with a unique decision-maker. Interactions within the household were not explicitly modelled, and the decision-making process was treated as a black box. Household interactions were either disregarded in models of activity-travel demand (see Srinivasan and Bhat, 2005 [106]), or introduced implicitly using explanatory variables defined at the household level. Explanatory variables such as household income, numbers of household members, workers and children, and household dummy variables (e.g., age, occupational status, and residential status) appear in Townsend, 1987 [114] and Golob and McNally, 1997 [51], among other studies.

Contrary to the premise of unitary models, in practice many household decisions involve more than one member and cannot be reduced to a single decision maker. Moreover, even if only one person makes decisions, they may be influenced, directly or indirectly, by the preferences or related choices of other household members (Timmermans and Zhang, 2009 [113]; Hensher, Ho and Beck, 2017 [60]). A growing body of theoretical and empirical research in fields ranging from labour economics to transportation demand is now taking explicitly into account interactions between household members and their resulting decisions. Most of this literature uses so-called collective models initially introduced by Chiappori, 1988 [33]. Collective models assume, explicitly or implicitly, that household members are engaged in a joint decision process that involves bargaining. Vermeulen, 2002a [117], 2002b [118] reviews the literature on collective (and unitary) models, and Timmermans, 2006 [111] describes models used in transportation research.

The distinction between discrete and continuous household decisions is at the core of these new theoretical and empirical developments. Discrete choices are made between a finite set of alternatives such as whether to work or not, how many vehicles to own, and where to work. Continuous choices are made over intervals (i.e., connected sets) such as how much to work, and how long to undertake an activity such as shopping. Van Soest, 1995 [116] proposes a discrete choice model of spouses' labour supply that disregards the negotiation process within the household. By contrast, collective models of time allocation and labour supply focus on this negotiation process in discrete (Vermeulen, 2006 [119]) or in continuous-discrete applications (Blundell et al., 2007 [28]).

The modelling of within-family interactions took off in the transportation literature with the special issues on modelling intra-household interactions edited by Bhat and Pendyala, 2005 [24] and Timmermans and Zhang, 2009 [113]. Bhat and Pendyala, 2005 [24] focus on contributions based on utility-maximizing models, whereas Timmermans and Zhang, 2009 [113] present works that "adopt diverse methodologies" such as group decision theory and micro-simulation approaches. A few contributions use experimental economics methods to compare the decisions taken by the husband alone, the wife alone, and the spouses together (see Bateman and Munro, 2005 [31], Beharry-Borg, Hensher and Scarpa, 2009 [32] and de Palma, Picard and Ziegelmeyer, 2011 [34]). However, they do not analyze the decision mechanism within couples. Picard, Dantan and de Palma, 2018 [93] and Chiappori, de Palma and Picard, 2018 [35] are among the few exceptions that do analyze the bargaining process in discrete family mobility decisions.

Two major streams of research use a discrete choice framework to model decision-making processes in multi-person households with explicit consideration of within-family interactions. The first stream is related to collective models and their discrete labour supply model applications. Section 2 briefly reviews this stream by explaining the difference between individual and family models, and providing a transition from unitary to collective models. The second research stream, presented in Sections 3 and 4, covers the transportation, activity-travel demand, and location choice literatures with intra-household interactions. Section 5 concludes.

Readers are cautioned that the review in this chapter is not comprehensive. Other than for the occasional mention, it does not cover techniques such as mathematical programming, agent-based microsimulation, activity-based network equilibrium models or other operations research methods. It does not cover econometric issues and data requirements. It also excludes some decisions related to transportation such as obtaining a driving license, and decisions related to holidays and long-distance travel. It also does not deal explicitly with travel by rail, air or maritime modes. Some of these topics are addressed within the scope of transportation by Chinh and Mulley (2015b) [62].

Section 2 reviews some of the main concepts that have been developed in the field of Economics of the Family, and discusses how they have been applied to major household decisions such as consumption and work. Readers who are either familiar with Economics of the Family, or interested only in household decisions related to activity demand and transportation, may wish to skip Section 2. For ease of reference, the main concepts cited in Sections 3 and 4 from Economics of the Family are identified in Section 2 with **bold** type.

2. INDIVIDUAL VERSUS FAMILY MODELS

Many family-related decisions cannot be adequately addressed using individual decision-making models. At one extreme are decisions involving the existence and structure of the family itself, such as marriage, divorce and how many children to raise. Other decisions such as workplace and residential location, automobile ownership, and retirement plans are long-run choices that affect all existing family members. Still other short-run and repeated choices induce (positive or negative) externalities on other household members. These include allocation of chores, who gets access to the family car, who escorts children to school and sports activities, etc. Research on Economics of the Family seeks to provide the best representation of the household decision-making process in these and many other instances. In the simplest models, the household is treated as a unique decision unit, whereas in more elaborate models each household member is characterized by specific preferences, and household decisions are determined by some process of aggregating or resolving heterogeneous preferences.

2.1. Individual choices about consumption and work

Traditionally, Economics of the Family describes household behaviour, focusing on choices concerning consumption and work. The household is described as a small production unit that combines domestic time with intermediate goods purchased on the market in order to produce commodities that household members consume. This approach has allowed economists to answer important questions related to major socio-demographic changes over the twentieth century, such as the change in domestic working hours (Gronau, 1977 [53]) and female labour supply, the growing divorce rate (Becker, Landes, and Michael, 1977 [16]), or the diminishing fertility rate (Becker and Lewis, 1973 [17]). The description of household behaviour draws on contributions from disciplines such as sociology, demography and ethnology (see Picard, 1999 [91]). The topics under study go far beyond consumption and work choices. However, until the late 1980s, the way that household decisions were represented in Economics of the Family was not very far from that of "traditional" models of consumption and labour supply, since these models generally neglect the multiplicity of decision-makers.

The traditional methodology used in Economics of the Family is straightforward. A single household utility function describes household preferences, taking as its arguments the quantity of goods consumed (including local amenities when location choices are at stake) and leisure time. This function is maximized subject to a unique budget constraint that aggregates the resources and expenses of all household members (and possibly a unique aggregated time constraint). Maximization of the utility function yields household demand functions. This procedure can be used to assess the effects of economic policies on individual behaviour and welfare. For example, Hausman, 1981 [58] estimates the effect of a variation in marginal taxation rates on hours worked, and measures the welfare cost of the US taxation system.

2.2. Unitary models in Economics of the Family

In **unitary models,** the household is treated as a single decision-maker and no attention is given to the complexity of the decision-making process or various possible types of transactions between family members. As Sen (1983 [102]) notes, in the unitary-models literature, household members are incorporated into a "glued together family". Following the seminal work of Becker (1965 [5]; 1973 [12]; 1974 [14]; 1991 [15]), more recent developments in Economics of the Family have broadened the classical research field to address new decisions such as marriage, numbers of children, education of children, and the allocation of tasks among household members.

In unitary models, elements of family structure such as the number of members and the presence of children are either totally ignored, or simply reflected in *ad hoc* equivalence scales. Furthermore, any conflicts that arise among members are disregarded. Indeed, unitary models neglect diverging interests among household members, and implicitly assume that members pursue consensual goals. This leads to a poor understanding of decision mechanisms and therefore resource allocation within the household. More specifically, unitary models have three drawbacks. First, they interpret empirical results incorrectly. For example, Lise and Seitz, 2011 [76] show that failing to consider changes in the intrafamilial distribution of consumption leads to a major overestimation of inequality growth since ~1970 in the UK. Recognizing this bias could lead to a re-evaluation of the change in intrafamilial distribution of consumption, and possibly changes in poverty-reducing policies. The second drawback is a biased assessment of how economic policies, such as a change in the income taxation system, affect the well-being of individual household members. Lundberg, Pollak and Wales, 1997 [55] illustrate the importance of these questions for family policy, and show that a shift of family benefits from the father to the mother during the 1970s in the UK was followed by a rise in the demand for women's and children's clothes. This empirical result is inconsistent with unitary models of the household, in which every member has the same objective function. The third drawback of unitary models is poor predictive power and biased evaluation of the behavioural effects of economic policies. The change in family benefits in the UK just mentioned is one example. Other examples related to transportation are given in Sections 3 and 4.

The implicit or explicit assumption in unitary models that households act as a unique decision-maker implies that household preferences can be represented by a unique utility function, maximized subject to a unique budget and time constraint. This is inconsistent with Arrow's impossibility theorem that a set of individuals does not behave in the same way as a single individual with standard or "rational" preferences.

Unitary models also implicitly assume that household member incomes are pooled together (the **income pooling** hypothesis), and their relative contributions do not affect household behaviour. Apps and Rees (2009) [4] dub this assumption "anonymity" in the sense that an increment in any member's income has the same effect regardless of who receives it.

The consensus model proposed by Samuelson, 1956 [99] provides some justification for this unitary description, but only under very restrictive and unrealistic assumptions. Becker, 1974 [7] makes another attempt to legitimize the unitary approach with his famous "rotten kid" theorem. The Theorem basically states that, if there is a **benevolent dictator** in the family, then all family members, even if they are selfish, act to maximize the same utility function as the benevolent dictator. The key assumption is that the benevolent dictator transfers money to each family member. All members then want to please the benevolent dictator in order to receive a larger transfer. However, Bergstrom 1989 [14] notes that the "rotten kid" theorem relies on arbitrary and unrealistic assumptions; especially the assumption about transfers. Moreover, assumptions and predictions of unitary models are often contradicted empirically. Cherchye et al. (2015) [31] provide a list. For example, income pooling has been rejected by Thomas 1990 [110] who shows that the relative contributions of men and women to household income do influence household decisions.

2.3. Collective models in Economics of the Family

Collective models and other within-household bargaining or "strategic" models aim to overcome the theoretical and empirical criticisms directed at unitary models of family decision-making. Strategic models are based on the theory of non-cooperative games (see, e.g. Ashworth and Ulph, 1981 [84], Leuthold, 1968 [75]). Strategic models are not reviewed in this chapter. In

collective models, pioneered by Chiappori 1988 [33], 1992 [34], household members are assumed to bargain with each other. The **bargaining process** may be either explicit (as in McElroy and Horney, 1981 [83] and Lundberg and Pollak, 1993 [78]), or implicit as in Chiappori, 1988 [33], 1992 [34].

Chiappori adopts the significant assumption that the bargaining process leads to **Pareto-efficient allocations** such that one household member cannot be made better off without leaving at least one other member worse off. (By contrast, non-cooperative games do not, in general, yield Pareto efficient outcomes unless members are sufficiently patient and willing to adopt cooperative strategies.) Pareto-optimality is a plausible assumption about household decisions insofar as family members, who interact repeatedly over long time periods, are able to find ways of reaching efficient outcomes. As Vermeulen (2002a) [117] remarks, Pareto efficiency is a "natural generalization" of utility maximization in the unitary model (as well as utility maximization by an individual). For the remainder of this chapter, the term "collective" is restricted to household decisions that are Pareto efficient. Family decisions that may or may not be Pareto efficient are referred to as "joint" decisions.

Collective models are very general in the sense that they do not rely on a specific bargaining process. Nor do they impose restrictions on individual preferences beyond the standard assumptions invoked in consumer theory. Indeed, they are more general since they can include not only personal consumption of goods and leisure, but also other individuals' consumption and leisure. Thus, positive or negative externalities arising from consumption and leisure decisions can exist. Following Chiappori (1992) [34], preferences over public goods within the family, such as housing, can be considered. Collective models can also accommodate different degrees of concern by family members for each other. In the case of **paternalistic preferences** (see Pollak, 1988) [95], members value the consumption of others without actually gaining satisfaction from each other's well-being. By contrast, with **caring preferences**, members derive utility directly from other members' utility. Cherchye et al. (2015) [31] show that by varying the degree of intrahousehold caring, a continuum of models can be generated, ranging from no cooperation to full cooperation and Pareto-optimality.

In collective models, household utility maximization can be solved by maximizing a weighted sum of individual utilities. The weights, often called **Pareto weights**, can be functions of prices, wages, non-labour incomes, work status and other determinants. In specific choice situations, weights can also be higher for individuals who have better information about the alternatives. Weights can be interpreted as reflecting the bargaining power of household members in the intrahousehold allocation process (O'Neill and Hess, 2014 [89]). A collective model reduces to a unitary model in three instances. First and trivially, if members have identical preferences. Second, if the welfare weights are fixed and do not change due either to exogenous shocks (e.g., to prices) or changes in household decisions such as residential location. Third, if there is a benevolent dictator who receives a welfare weight of 1, while other members receive a weight of 0. The dictator is benevolent in the sense of being either paternalistic or caring so that other household members are not left to survive at a subsistence standard of living.

Collective models explain household behaviour better than unitary models because they do not rely on assumptions such as income pooling, which are usually rejected empirically, as mentioned in the previous section. For example, using Russian panel data and nonparametric tests, Cherchye, De Rock and Vermeulen (2009) [32] find that consumption behaviour of couples is consistent with the collective model, but not the unitary model.

Another strength of collective models is that they account for the welfare of individual household members. Hence, they can be used to assess the redistributive effects of economic policies at the individual as well as household level. Indeed, under rather plausible assumptions, individual utility functions can be recovered from household behaviour and disentangled from bargaining power effects. Section 3 provides some examples. The capacity of collective models to evaluate economic policies offers promising research avenues, especially in the context of transportation policies and urban development.

It should be noted that collective models are not universally supported empirically (in this case, unitary models are not supported either). Contradictory evidence has been found by studies of several countries. For example, Dercon and Krishnan (2000), Dufflo and Udry (2004), and

Robinson (2012) conclude that households in, respectively, Ethiopia, Côte d'Ivoire, and Kenya, do not insure members against individual income shocks, in violation of Pareto efficiency.

Households may fail to reach Pareto-efficient outcomes if individual behaviour is imperfectly observed. For example, Jack, Jayachandran and Rao, 2018 [63] find evidence that individuals in urban Zambia overconsume water because other family members cannot accurately measure each person's consumption, and each person bears only a fraction of the monetary cost. Also, as noted in Section 4, households may fail to reach Pareto-efficient long-run decisions if members who benefit from individually favorable decisions cannot commit to later compensating others who are less fortunate. In this vein, Mazzocco, 2007 [81] rejects the hypothesis that household members in the U.S. can commit to future allocations of resources.

2.4. Labour supply models within the family

One of the main applications of the Economics of the Family is to labour supply. Models that feature two adults in a unitary model are used by Hausman and Ruud, 1984 [57]; Ransom, 1987 [97]; Bloemen, 1989 [26]; Kapteyn, Kooreman, and van Soest, 1990 [66]. In these studies, the spouses' work hours are treated as mixed discrete and continuous random variables. Van Soest, 1995 [116], Bingley and Walker, 1997 [25] and Keane and Moffitt, 1998 [68] were the first to use a discrete choice framework to study family labour supply, still in a unitary framework. This approach enhances tractability, and facilitates incorporating such complications as fixed costs of working, nonlinear income taxes, joint tax filing, unemployment benefits, restrictions on work hours, unobserved wage rates of non-workers, and random preferences. The models are estimated using simulated maximum likelihood, following Gourieroux and Monfort, 1993 [52].

van Soest's (1995) [116] approach is based on a unitary model that neglects the effect of policies on household member's bargaining powers, and — similar to references mentioned above — may therefore lead to bias in predicting changes in labour supply. Collective models of labour supply have been developed for two-earner households (e.g., Fortin and Lacroix, 1997 [45]; Moreau and Donni, 2002 [59]; Chiappori, Fortin, and Lacroix, 2002 [36]) using a continuous framework. A series of discrete-choice collective labour supply models have also been crafted.

Laisney, 2002 [50] integrates non-participation and nonlinear taxation. Vermeulen *et al.*, 2006 [120] develop a discrete choice collective model, and solve it using a procedure combining calibration and estimation. Blundell et al., 2007 [28] consider a model in which the man's labour supply is discrete, whereas the woman's labour supply is continuous. Vermeulen, 2006 [119] models female labour supply in a discrete choice framework considering male labour supply as given, and including non-participation and nonlinear taxation. Other discrete collective models of labour supply include Callan, Van Soest, and Walsh, 2009 [30]; Bloemen, 2010 [27]; Haan, 2010 [55]; Michaud and Vermeulen, 2011 [84]; and Pacifico, 2012 [90].

3. HOUSEHOLD DECISION-MAKING IN DAILY ACTIVITY AND TRANSPORTATION

3.1. Overview

Many of the applications of both Economics of the Family and discrete choice models to household decisions involving multiple decision-makers have been to decisions related to transportation. They include the so-called intra-household interaction and group decision-making models of transportation, activity-travel demand and location choices. One set of studies deals with long-term decisions such as residential and workplace location and vehicle ownership. A few of these studies are reviewed in Section 4. This section reviews studies that deal with short-term decisions such as task allocation, joint activity and travel participation, mode choice and carpooling.

Household activity and travel behaviour differ from individual behaviour in various ways that need to be modeled directly, and that have implications for policy design. As discussed below, models of individual travel behaviour may over- or under-predict important aspects of travel such as the numbers of person trips and vehicle trips. They can lead to biased estimates of key parameters such as values of travel time. And they can lead to over-optimistic forecasts of the effectiveness of travel demand management policies.

A number of points are worth making by way of introduction. First, since household members undertake many out-of-home activities together, they also either travel together, or synchronize their trips to meet up with others if they travel alone. This leads to coordinated travel patterns in terms of destination, trip timing and transport mode (Lai et al., 2019 [72]).

Second, people often value activity participation and travel differently depending on whether they are together or alone (Gupta and Vovsha, 2013 [54], de Palma, Lindsey and Picard, 2015 [40]). Eating at restaurants, going to movies and participating in many recreational and other activities, or simply staying at home, is generally more satisfying with family members (or other people) than alone. These differences in preferences can induce differences in behaviour. For example, people may travel further and engage in activities for longer when they are with others rather than alone (Bhat et al., 2013 [23]). Family members may also enjoy commuting together, which has implications when each person leaves home or returns from work (Picard, Dantan and de Palma, 2018 [93]).

Third, family members that travel together on complex tours are more likely to use a car because of the flexibility and speed it usually offers relative to public transport or non-motorized modes (Ho and Mulley, 2015a [61]). Travel by larger groups is also more likely to occur in larger vehicles (Bhat et al., 2013 [23]). While these vehicles may be energy-inefficient and heavily polluting, the monetary cost to the family may still be less than if each person pays transit fare. However, families with two or more members who work at different locations and/or at different times may find commuting together impractical. Furthermore, everyone cannot travel separately by car if there are more commuters than vehicles.

Fourth, models of individual travel behaviour may over- or under-predict the number of person trips, the number of vehicle trips, and the total distance traveled by a given family. For example, if members participate jointly in out-of-home activities that they would not undertake alone, the number of person trips will be under-predicted. Conversely, if family members travel together in one vehicle, the number of vehicle trips may be over-predicted. However, an appreciable fraction of intra-household ridesharing trips is made to transport one member to an activity such as a child to school. If the driver returns home, and then makes the trip again to fetch the person back, an additional return trip is generated and the number of vehicle trips will be under-predicted (Morency, 2007 [87]).

Fifth, family interactions can influence values of travel time. Individuals who make many carpooling, family-related maintenance and other non-work trips may be pressed for time, and have correspondingly high values of time (Schintler, 2001 [100]). Conversely, if traveling with other family members is enjoyable, values of time will be lower.

Sixth, the presence of children can have a marked effect on family activities and travel. Ferrying children to and from school and other activities creates additional trips and/or detours for parents. Indeed, the amount of car travel on behalf of school children has been increasing, as Fyhri et al., 2011 [48] document for a sample of countries in Northern Europe. Vovsha and Petersen, 2005 [126] investigate parental escorting behaviour and responsibilities. Weiss and Habib, 2018 [133] use a parallel constrained choices logit model, originally proposed by Gliebe and Koppelman, 2005 [50], to study the mode choices of students and commuting/escorting adults. According to Jia, Wang, and Cai, 2016 [65], many families in Singapore, where automobile ownership is expensive, buy a car mainly so that they can transport their children to and from school.

Finally, travel demand management policies such as public transit service improvements, congestion pricing, ridesharing incentives and alternative work hours may affect families differently from individuals. A number of studies have identified instances in which travel demand management policies are less effective with families. As noted above, the economies of scale and flexibility of family car travel militate against using public transit. Family members can also make trips on behalf of each other. For example, a worker who adopts a compressed workweek may discontinue taking trips after work because s/he no longer has the time. However, another household member may take the trip in his/her place so that total family travel does not decline (Scott and Kanaroglou, 2002 [101]). Latent demand may also emerge. For instance, introducing school bus service saves parents from dropping off children on the way to work, and gives them more time for other trips.

As Bhat et al. (2013) [23] point out, joint activity participation such as carpooling, escorting school children, and participating in out-of-home social activities requires individuals to synchronize their schedules in time and space. This coordination reduces their flexibility, and makes them less willing or able to respond to transportation control measures by eliminating, retiming or re-routing vehicular trips, or adapting in other ways. Vuk et al., 2016 [130] illustrate this rigidity using a model in which family members agree to spend time together in the evening at home. This commitment induces them to concentrate their trips from elsewhere back home during the PM rush-hour peak, and makes them unresponsive to peak-period tolls. Similarly, couples that carpool typically do it in both directions since the passenger for a morning carpool would either have to use public transport, or find another carpool arrangement with a non-household member (Gupta and Vovsha, 2013 [54]), unless the distance is short enough for walking to be practical. A policy designed to discourage driving in either the morning or the evening alone might then be ineffective since it would require both spouses to alter their travel plans in both directions.

3.2. Activity-travel demand models in individual and unitary models

Activity analysis is a leading methodology for studying daily or short-term activity and transportation decision-making. The activity-based approach is reviewed in Pinjari and Bhat, 2011 [94] and Vuk et al., 2016 [130]. Unlike the trip-based approach, it is naturally suited to modeling linkages between individuals in activity participation and travel decisions.

Activity-based studies address which activities household members conduct during a day or over several days; when, where, for how long, and by whom the activities are performed. Discrete choice modelling on these topics has been conducted by a number of authors. Gliebe and Koppelman, 2002 [49]; Scott and Kanaroglou, 2002 [101]; Vovsha, Petersen, and Donnelly, 2003 [127]; and Srinivasan and Bhat, 2006 [107] study the decision whether to participate in an activity independently or jointly with other household members. Gliebe and Koppelman, 2002 [49] study independent activity participation, allocation of time to joint activities, and the interplay between individual and joint activities. They use a proportional shares model in which the proportion of daily time spent in an activity is equal to the proportion of total daily utility derived from participating in it. Scott and Kanaroglou, 2002 [101] develop an ordered probit model of the number of non-work, out-of-home activity episodes in two-person households in which both, one, or neither of the members work. The three types of households exhibit different approaches to task allocations. Spouses that both work exhibit flexibility in order to accommodate the temporal constraints of their work schedules. Couples in which neither person works are inclined toward joint decision-making and participation in out-of-home maintenance activities. Finally, in one-worker households, the nonworking spouse takes on most of the out-of-home maintenance activities. If the couple owns only one vehicle, the nonworking spouse may have access to it during the day, and is accordingly more likely than the working spouse to engage in non-work, out-of-home activity.

A body of research has examined the allocation of household maintenance activities. An appropriate way to study this is with a discrete choice model embedded within a tour-based travel demand modelling system. One example is the discrete choice system of Vovsha, Petersen, and Donnelly, 2003 [126]; 2004a [127]; 2004b [128]; that forms the joint travel model component of the Mid-Ohio Regional Planning Commission. Another is the discrete choice system of Bradley and Vovsha, 2005 [29] that comprises part of the activity-based model of the Atlanta region. As part of their paper, Bradley and Vovsha, 2005 [28] survey the activity-travel demand literature in which either intra-household decision-making *is not* considered explicitly, or discrete choice model techniques are not used.

In addition to discrete-choice models, the literature on activity-travel demand has used seemingly unrelated regressions (SUR) and structural equation modelling (SEM) to account for household interactions (see Srinivasan and Bhat, 2005 [106]). Studies usually develop a SUR or SEM system of two or more equations corresponding to the time invested in activities by the household head and other members in consideration (i.e., spouse and/or children). These approaches are not reviewed here.

Various classifications of activity-travel demand models that account for interpersonal dependencies in households with multiple decision makers have been proposed. For instance, Timmermans, 2006 [111] adopts three categories: micro-simulation, rule-based, and utility-maximizing models. Micro-simulation models simulate a household member's daily activity-travel pattern using algorithms that replicate the observed patterns from data, including time constraints and actual decision-making outcomes. These models yield timing and sequence of activities schedules that account for household and personal characteristics (see, e.g., Pribyl and

Goulias, 2005 [96]). Rule-based models encompass multi-agent computational processes in which the individual activity-travel decisions reflect "if-then" decision tree structures regarding which activities, with whom, and for how long the activities are conducted (see, e.g., Arentze and Timmermans, 2004 [5]).

Timmermans divides his last category, utility-maximizing models, into models that use the discrete choice approach based on random utility models, and models that use the time allocation approach. Time allocation models are based on a group utility function. This function is a linear function of individual-specific terms, and interaction terms that comprise interactions between individuals in a multiplicative form. The household allocates member's time to activities in order to maximize the group utility subject to individual time constraints (see, e.g. Zhang and Fujiwara, 2006 [139]). Pinjari and Bhat, 2011 [94] summarize and contrast utility-maximization models and rule-based models that include agent-based modeling systems.

As noted above, the ultimate goal of activity analysis is to explain which activities a household conducts, as well as when, where, for how long, and by which household members. This is a daunting task given the number of possibilities. Consider just the decisions of which activities to undertake, and by whom. Following Bhat et al., 2013 [23], Let *M* denote the number of individuals in a household, and *K* the number of out-of-home activities. The number of composite activity patterns that the household can undertake (other than for doing nothing) is $2^{K\left(2^{M}-1\right)}-1$. This number can be extremely large. The simplest nontrivial case is a household with two members, call them A and B, and one possible activity. Each person can engage in the activity alone, and they can also do it together (T). There are seven possible activity patterns defined by who engages in them: {A}, {B}, {T}, {A,B}, {A,T}, {B,T}, {A,B,T}. (For example, {A,T} denotes the case in which person A participates alone, and person A and B also participate jointly on a separate occasion.) With two members and two activities, the number of combinations increases to 63. With three members and two activities, the number explodes to 16,384.

To determine which activities a household chooses to carry out, and for how long, it is necessary to consider the utility from each activity. The multiple discrete continuous extreme value (MDCEV) model of Bhat (2008) [22] does this by combining the discrete decision of whether to undertake a utility with the continuous decision of how long. The sub-utility function for each activity is given by a generalized variant of the translated constant elasticity of substitution (CES) utility function:

$$u_{hk}\left(d_{hk}\right)=\frac{\gamma_{hk}}{\alpha_k}\Psi_{hk}\left\{\left(1+d_{hk}/\gamma_{hk}\right)^{\alpha_k}-1\right\},$$

where d_{hk} is the duration of activity k undertaken by household h, Ψ_{hk} is a baseline measure of utility from the activity, γ_{hk} is a positive parameter, and $\alpha_k \leq 1$ determines the rate at which marginal utility diminishes or saturates with the duration of activity k. In the limit $\alpha_k \rightarrow 0$, the utility function reduces to a logarithmic form that yields a linear expenditure system in consumer theory:

$$u_{hk}\left(d_{hk}\right)=\gamma_{hk}\Psi_{hk}\ln\left(1+d_{hk}/\gamma_{hk}\right).$$

Parameter γ_{hk} now determines the rate at which marginal utility declines with activity duration. Larger values of γ_{hk} imply slower rates of decline. Parameters Ψ_{hk} and γ_{hk} can be written as functions of activity purpose, individual and household characteristics, and combinations of these variables. With the logarithmic function, total household utility from all activities is then

$$U_{hq}\left(d_h\right)=\sum_k \gamma_{hk}\Psi_{hk}\ln\left(1+d_{hk}/\gamma_{hk}\right),$$

where $d_h \equiv \left(d_{h1}...d_{hK}\right)$ is the vector of durations of all activities.

The MDCEV model allows the weights of individual household members to depend on the activity as well as the set of members involved. The model also has the advantage that the time intervals allocated by participants to a joint activity are automatically synchronized without enforcing equality with separate constraints.

In addition to which activities a household undertakes, and for how long, activity analysis aims to determine where, when and with whom household activity takes place. Vo et al. (2020) tackle this goal by adopting a time-dependent utility specification, broadly analogous to that of the MDCEV, to describe intrahousehold activity and travel decisions on congested road networks. The utility derived by individual i of household h from engaging in activity k at location s with group g of the members in household h during time interval t is given by

$$u_{ks}^{hig}(t) = \left(1+\alpha_{ks}^{hg}(t)\right)u_{ks}^{hi}(t).$$

Function $u_{ks}^{hi}(t)$ is the marginal utility derived by member *i* of household *h* from conducting activity *k* alone at location *s*. Parameter $\alpha_{ks}^{hg}(k)$ quantifies the additional utility the person derives from participating in the activity jointly with group *g* rather than alone.

Vo et al. (2020) use their model to derive two new network equilibrium concepts for travel on congested road networks. *Household-oriented network equilibrium* (HO) is a counterpart to conventional user equilibrium in which households maximize their utilities by making activity participation, mode, route and other decisions while disregarding the effects on other households. *Household-based system optimum* (HSO) is a counterpart to the conventional system optimum in which a planner maximizes total utility net of travel costs for all households in aggregate. Vo et al. (2020) note that the HO and HSO could entail higher total travel times than their conventional counterparts because households may engage in more activities than solo individuals as well as making additional pickup and drop-off trips. They also note that HO and HSO may entail less use of public transit since, as noted above, carpooling offers more flexible travel choices.

Vo et al. (2021) extend the model in Vo et al. (2020) by adding new at-home activities such as telecommuting, multiple public transport modes, in-vehicle crowding on public transport, and crowding externalities at out-of-home activity locations such as shopping. The model includes fear of infection while using public transport or engaging in activities in public places, which discourages these activities. Individuals are assumed to have perception errors of the benefits and costs of alternatives, which may be large in the case of infrequent and unfamiliar events such as COVID-19. Vo et al. (2021) formulate a mixed equilibrium of individual and household activity–travel choices in which some individuals maximize household utility, while others maximize their individual utilities.

3.3. Trip-timing decisions

As this review so far should make clear, the times at which household members undertake activities and travel are key dimensions of household behaviour. The time dimension needs to be modeled in order to understand how household members synchronize their activities and travel, and to predict how they respond to travel demand management and other policies. Activity scheduling is a central component of activity analysis, and it is featured in the work of Vo et al., 2020 [123]; 2021 [124] and similar studies. It is also the central element of the bottleneck model due to Vickrey, 1969 [121]; 1973 [122], and extended by Arnott et al., 1990 [6]; 1993 [7] and others, in which individuals choose when to travel by weighing the costs of traveling earlier or later than they like against extra travel time at peak times due to congestion delay. See Small, 2015 [104] for a review of the bottleneck model, and an empirical study of the trade-off by Vovsha and Bradley, 2004 [125].

While the bottleneck model has typically been used to study solo trips, some authors have used it to study carpooling, use of high occupancy vehicle lanes, and other settings in which two or more people travel together. A few have also recently applied the model to family-related trips. Four of them analyze the timing of commuting trips by a parent who drops a child off at school on the way to work. Jia, Wang and Cai, 2016 [65] assume that the school day begins at time t_1^* before the parents' common preferred arrival time at work, t_2^*. There is a single bottleneck located between home and school at which queuing delay occurs if the arrival rate of vehicles at the bottleneck exceeds its flow capacity. Travel onwards from the school to the workplace is congestion free. Jia et al. assume that parents and child have the same values of travel time, and incur the same unit costs (or disutility) of arriving early or late. Parents are altruistic, and attach the same weight to their child's costs as their own costs.

Jia et al. show that if work starts shortly after school (i.e., $t_2^* - t_1^*$ is small), the total travel costs of all parents and children together do not depend on the difference $t_2^* - t_1^*$. This contrasts with the case of solo travelers in which total costs decrease with the degree of heterogeneity in desired arrival times. The reason for this difference is that solo travelers can time their trips to best match their individual preferences. Those with an early t^* can depart earlier, and those with a later t^* can depart later. With families, self-selection in this way is not possible because families travel together at the same time, and all families are assumed to have the same preferences. Jia at al also show that if $t_2^* - t_1^*$ is large, total travel costs rise as $t_2^* - t_1^*$ increases further. This is because when school and work schedules differ greatly, children inevitably arrive at school late, and parents inevitably reach work early. Further differentiation in their schedules exacerbates the mismatch. These results illustrate the potential inconvenience of coordinating joint family activities or travel.

Liu, Zhang and Yang, 2017 [77] extend the model in Jia, Wang and Cai, 2016 [65] by assuming that solo individuals as well as families travel between the same origin and destination, and traverse the same bottleneck. In this setting, solo travelers and families can self-select into separate departure time intervals. Doing so tends to reduce total travel costs. Indeed, if $t_2^* - t_1^*$ is large enough, they can travel in disjoint intervals so that they do not interfere with each other at all. Moreover, holding the number of solo travelers and families constant, total (variable) travel costs can actually decrease with the proportion of families even though families comprise two people who each incur travel costs. This result illustrates the advantages of differentiating the schedules of independent travelers when travel creates congestion or other negative externalities.

Zhang et al., 2017 [138] examine a variant of the model in Liu, Zhang and Yang, 2017 [77] by assuming that the bottleneck is located downstream between the school and workplace, rather than upstream between homes and school. This modification results in different possible equilibrium departure-time patterns, but it is again optimal to differentiate school start and work start times. Other things equal, it is also beneficial to segregate children into separate schools or classes with different schedules, just as it may be useful to stagger work hours. He et al., 2021 [59] adopt yet another variant of the model with two bottlenecks: one upstream of the school, and the other downstream between the school and the workplace. Solo individuals start their trips at a different origin from families, and have to traverse only the downstream bottleneck to reach the same workplace as families. He et al., 2021 [59] show that in this more complicated setting, staggering school and work start times can (again) increase total travel costs.

The four papers just reviewed all consider family carpooling trips to school and work. de Palma, Lindsey and Picard, 2015 [40] use the bottleneck model to look instead at the trip-timing decisions of working couples without children. Spouses are assumed to derive utility from each other's presence at home. By increasing the value of time spent at home, this increases the opportunity cost of travel, and thus increases the value (i.e., cost) of time spent traveling. It also increases the disutility from arriving at work early, and decreases the disutility of arriving late, since time spent at work becomes less valuable relative to time spent at home. The first spouse to leave for work (assumed to be the man) imposes an externality on the other spouse (the woman) since his choice of departure time affects her utility while at home. Spouses are assumed to have paternalistic preferences. Following the collective model approach, each couple maximizes a weighted sum of the spouses' utilities. As the weight on the women's utility increases, men postpone leaving home, and then depart at a faster rate so that queuing delay at the bottleneck grows more quickly. Men that leave home later are worse off individually, but their wives are better off by an offsetting amount so that (consistent with equilibrium) the combined utility of every couple is the same. In aggregate, men end up worse off if arriving late at work is very costly. Women are more likely to benefit in aggregate, although (based on empirical estimates of trip-timing preferences) couples together are likely to be worse off.

A notable feature of equilibrium in the model is that schedule coordination by couples affects traffic congestion and aggregate well-being even though coordination occurs only within couples who each represent a negligible portion of total travel demand. The equilibrium is a simple instance of household-oriented network equilibrium (HO) due to Vo et al., 2020 [123], summarized above. Vo et al. remark (p.97) that "HO is intermediate between UE and HSO in that there is a certain coordination (i.e., only intra-household interactions) among travelers from the same household." However, as de Palma, Lindsey and Picard, 2015 [40] show, HO may not be intermediate between UE and HSO as far as equilibrium travel costs.

When family members enjoy each other's company, being together at home creates a sort of agglomeration economy. Agglomeration economies also exist at work, and they have been extensively studied by economists (see Mackie, Graham and Laird, 2011 [81], for a review). Fosgerau and Small, 2017 [46] combine the two types of agglomeration in a modified bottleneck model, and study morning commute trip-timing decisions. They show that agglomeration economies enhance the benefits of optimal congestion pricing, and that pricing can leave travelers better off even if they do not benefit from the use of toll revenues. This is unlike the bottleneck model without agglomeration economies in which travelers neither gain nor lose.

Together, the studies reviewed in this section illustrate how intra-household interactions can constrain trip-timing decisions and affect traffic congestion. They also illustrate how the benefits of policies such as staggering school hours, staggering work schedules and congestion pricing depend on the spatial pattern of travel demand and congestion, and travel preferences.

4. ACCESSIBILITY, LOCATION CHOICE AND VEHICLE OWNERSHIP

Section 3 reviewed the literature on short-term, repeated decisions on activity participation and transportation. This section shifts focus to long-term, infrequent choices about where to live and work, and vehicle ownership. Early studies in this stream include Abraham and Hunt, 1997 [1]; Freedman and Kern, 1997 [47]; Sermons and Koppelman, 2001 [103] and Waddell, 1996 [131].

Accessibility is an overriding consideration in making location-choice decisions. In the case of where to live, it can be as important as dwelling characteristics and neighborhood amenities. Accessibility to jobs is measured by the spatial proximity of the residence to the locations of prospective jobs. Accessibility to schools, shopping, recreational opportunities and other destinations also matters. Lee et al., 2010 [74] categorize accessibility measurement approaches into four groups: proximity-based as measured by travel time or distance, gravity-based as derived from a gravity model, the cumulative opportunities approach as a special case of the gravity-based measure, and the utility-based approach. See Lee et al, 2010 [74] for further details on this classification and references.

The utility-based approach allows disaggregated or individual-specific accessibility measures to be developed. If utility is additive in income, so that income effects are absent, and demand is described by a logit function, accessibility is measured by a log-sum term, which is a measure of consumers' surplus. See Ben-Akiva and Lerman, 1979 [19]; Srour et al., 2002 [108]; Waddell and Nourzad, 2002 [132]; and Zondag and Pieters, 2005 [140], among others. By Roy's identity, the derivative of the accessibility measure with respect to the price or cost of an alternative is the demand function for the alternative. The same property holds for the Generalized Extreme Value model. See Anderson, de Palma and Thisse, 1992 [2]; and de Palma and Kilani, 2007 [39] for details. If agents are assumed to be identical, the same measure of accessibility applies to all of them. If agents are heterogeneous, accessibility generally depends on individual or household characteristics, values of time and job preferences, as in Inoa, Picard, and de Palma, 2015 [63].

Accessibility has been studied in single and multiple-worker location choice models, and measured using different approaches. We review the corresponding literatures in the remainder of this section.

4.1. Accessibility measures in multiple worker location choice models

Studies of residential location choice have allowed accessibility measures to vary with socio-demographic characteristics, and to differ between multiple-worker and one-worker households. Timmermans et al., 1992 [112] examine the residential location choices of two-worker households. Abraham and Hunt, 1997 [1] employ a three-level nested logit model of residential location, workplace and mode choice with a system for weighting the contributions of different workers to the household utility. Freedman and Kern, 1997 [47] analyze residential and workplace location choices with a joint logit model where a two-worker household jointly chooses residential location and both spouses' workplaces to maximize household utility, subject to budget and time constraints. Sermons and Koppelman, 2001 [103] develop a multinomial logit model of residential location choice to study differences between males and females in sensitivity to commuting time for two-worker households.

In general, these studies show that females are more sensitive to commuting time and measures of accessibility than males. Demographic characteristics — such as presence of children, workplace status, and spouses' occupations and workplace locations — determine commuting time and accessibility, and thus location choices in a multiple worker household.

4.2. Individual-specific accessibility measures

Despite the variety of contributions to the study of location choice, little attention has been given to the influence of job type on accessibility to jobs, and therefore to the residential location and workplace choices of individuals with specific careers and job opportunities. The particular decision-making process that a household adopts depends on whether workplaces are chosen conditional on a current residential location, or whether the residence is chosen after jobs. Naturally, the situation can vary from family to family.

Inoa, Picard, and de Palma, 2015 [63] develop a three-level nested logit model that allows to study the interdependency of residential location and workplace choices, while accounting for differences in preferences for job types across individuals. Residential location is treated at the upper level choice, workplace at the middle, and job type at the lower level. With this nested structure, Inoa et al. 2015 [63] construct an individual-specific accessibility measure that corresponds to the expected maximum utility across all potential workplaces and job types. The choice of a particular workplace depends on the distribution of jobs by type, which are valued differently by different workers. An individual-specific log-sum measure of attractiveness to job types can be computed in the model, and used in the workplace location choice model. Using data from the Paris Region Census, they find that the individual-specific job type attractiveness measure is a more significant predictor of workplace location than the total number of jobs that researchers have sometimes used. Most importantly, the individual-specific accessibility measure is a major determinant of the residential location choice, and its impact on the residential location choice strongly depends on gender, age, education, and number of children for women.

In another study that also uses Paris data, Picard, de Palma and Dantan, 2013 [93] estimate two model specifications: one in which residence is chosen conditional on workplaces, and the other in which residence is chosen first. They limit their sample to two-worker households. The data show that commuting distances and travel times are significantly lower for women than for men, particularly for trips by public transit that women take proportionally more than men. For the model with endogenous residential location, the results suggest that women have more bargaining power than men with respect to residential location choice. Nevertheless, the results also indicate that the man has priority in using a car. Picard et al. [93] estimate a mode choice model for the independent and unitary versions of the model, and compare results with the collective model. The independent choice model performs badly in predicting mode choice for households with one car because it ignores the constraint that only one car is available.

Swärdh and Algers, 2010 [109], O'Neill and Hess, 2014 [89], and Beck and Hess, 2016 [10] conduct a series of studies on commuting distance and value of travel time (VOT) of couples in Sweden. As described in Swärdh and Algers, 2010 [109], stated preference questionnaires were issued to two-worker couples to measure how much each person valued travel time on their own commuting trip, and travel time on their spouse's trip. Each spouse was asked to make choices that affected their commuting time and salary as well as that of their partner. Respondents first made binary choices between the status quo and an alternative in which their own income and commuting time were both higher. Then they made additional choices in which income and commuting time differed for their partner, as well.

Two results from the study stand out. First, respondents reveal a higher marginal utility for their own wage than that of their spouse. Swärdh and Algers, 2010 [109] conjecture that respondents may have valued their own wage highly not only for its purchasing power, but also for the social status it provided and/or for the greater bargaining power it might give them within the household. Second, men attached a higher value to their spouse's commuting time than their own, whereas women valued commuting times roughly equally. Swärdh and Algers, 2010 [109] interpret this as supporting the household responsibility hypothesis of Turner and Niemeier, 1997 [115] that employed women tend to take on a majority of household responsibilities such as maintenance and transporting children to school, and thus face tighter time constraints than men.

O'Neill and Hess, 2014 [89] analyze the data further, and quantify the significant heterogeneity among respondents in their valuations of travel time and salary. Beck and Hess, 2016 [10] also determine that in the case of carpooling trips, the value of commuting time for the woman depends on whether she or her spouse drives.

Barwick et al., 2021 [8] estimate a joint residential location and travel mode choice for residents of Beijing. In the model, households choose housing based on their preference for housing attributes, neighborhood amenities, and ease-of-commuting for each working household member by one of six modes (walk, bicycle, bus, subway, car, and taxi). Work locations are treated as fixed. Consistent with the studies mentioned above of France and Sweden, females tend to live closer to their work locations than men. Similarly, Barwick et al., [8] find that households value commuting time more highly for women than men. They estimate that an average household is willing to pay ¥219,000 (about USD $35,000) more for a house in order to shorten the female member's work commute by 10 minutes. For the male, the corresponding figure is ¥185,000 (about USD $30,000).

Research on residential location has commonly used accessibility as an aggregated measure of ease of access to jobs or people in choice models where the household is treated as a single decision-making unit. By contrast, Chiappori, de Palma and Picard, 2018 [35] use a collective choice model to study the residential location choices of households with two working spouses while assuming that their workplace locations are predetermined. Individual utilities are assumed to be additively separable in a household public good (e.g., home) and private utility which depends on consumption minus transport costs. Using data from the 1999 General Population Census survey in the Paris Region, Chiappori et al. [35] jointly estimate the spouses' individual values of time and bargaining powers. They show that neglecting bargaining powers can lead to downward-biased estimates of values of time by up to 20 percent. To see how this can happen, suppose that the man has less bargaining power than his wife, and agrees to buy a house that is much closer to her job than his own. Accepting a long commute suggests that the man has a low value of time, whereas it may actually be quite high.

Chiappori et al. [35] also observe that, according to the collective model, households can reach Pareto-optimal residential location choices that minimize total household commuting costs (with appropriate adjustments for housing characteristics and neighborhood amenities). As just noted, this may result in one spouse having a much longer commute than the other. In principle, the imbalance could be compensated by making daily consumption and other short-run choices that favour the spouse with the longer commute. However, this requires a commitment on the part of the other spouse that may not be fulfilled (or that the spouse with the longer commute does not expect to be fulfilled). If commitment is not possible, a Pareto-efficient outcome may not be realized. Chiappori et al. [35] conduct a test of Pareto-optimality which yields ambivalent results, while a unitary model is clearly rejected. Lundberg and Pollak, 2003 [79] illustrate theoretically the possibility of Pareto-inefficient outcomes in a similar setting in which a couple has to decide whether to move to a different city where one spouse can earn a higher wage, but the other can earn less.

Individual accessibility depends not only on residential and workplace locations, but also on household vehicle ownership and personal bargaining power in gaining access to a vehicle. Picard, Dantan and de Palma, 2018 [93] study vehicle ownership and bargaining power empirically using data from the 1999 General Population Census in Paris Region. Their model treats residential and workplace locations as exogenous, and distinguishes between households with no car, one car, or two or more cars. Each spouse either drives or takes public transport. In one variant of their model, mode choice is estimated conditional on car ownership. The estimated Pareto weight for the woman depends on several family characteristics. It is significantly higher when only her husband has a temporary work contract, and slightly lower if only she has a temporary contract. Her weight is significantly higher if the household owns its home, and decreases slightly with the number of children in the family.

In another variant of the model, car ownership and mode choice are estimated jointly using a three-level nested model with a decision whether to own at least one car in the upper level, a decision whether to buy a second car in the middle level, and mode choice in the lower level. Picard et al. [93] simulate the effect of a policy reform that encourages one of the spouses to telecommute. The policy is implemented in the model by assuming that travel time to work is reduced to zero while leaving other aspects of the couple's lives unchanged. The proportion of families with two cars falls by nearly the same amount whether the man or the woman switches to telecommuting. Telecommuting by the woman leads to a greater reduction in the fraction of families with no car than when the man telecommutes. However, total travel distance by car falls much more if the man telecommutes. In large part, this is because men commute much further on average than women. The exercise illustrates how a policy can affect household vehicle ownership and usage decisions differently depending on which family member is directly impacted.

4.3. Time geographic accessibility measures

The literature on residential location has considered accessibility not only to jobs, but also to non-work activity opportunities. Activity–travel demand and task allocation models are concerned with the activity patterns of households and individuals over a full day (and even over a week, in the new activity-based time use data sets). Capturing non-work accessibility is therefore essential when modelling in-home and out-of-home activity patterns and trip chaining (Neutens et al., 2012 [88]). Accessibility measures adapted for these models can be found in the framework of time geographic measures of accessibility.

Hägerstrand, 1970 [56] introduced the concept of a time-space prism in order to describe the temporal and spatial constraints on individual activity participation and travel. Time-space prisms define the locations that an individual can reach within a given time interval or budget. The set of locations is referred to as the potential path area. A thorough study of time-geographic measures can be found in Miller, 1991 [85] and Kwan, 1998 [71]. Kim and Kwan, 2003 [69] review accessibility measures used in empirical settings derived from the time-space prism.

Time-geographic measures of accessibility have been used in only a few studies that employ discrete choice models of intra-household interactions. Lee et al., 2010 [74] develop a discrete choice residential location model that includes a disaggregated measure of accessibility to non-work activities (derived from the time-space prism framework), while also accounting for accessibility to jobs. Yoon and Goulias, 2009 [136], 2010 [137] develop a structural equations model of activity and time allocation that considers intra-household interactions where the accessibility measure used is based on time geography. They study households without children, and then households both with and without children. Using a time-geographic accessibility measure, Kitamura et al., 2001 [70] study the influence of travel patterns and residential location on car ownership. Ettema, 2006 [44] develops a discrete continuous Tobit model of activity participation and duration.

4.4. Interactions within extended families

The review thus far has limited attention to interactions within traditional families. In some countries, extended families spanning three or more generations and living in different places have an important role. Compton and Pollak, 2009 [37] analyze interactions within large families that live in different households. They describe and analyze the patterns of proximity and co-residence involving adult children and their mothers using data from the U.S. National Survey of Families and Households (NSFH) and the U.S. Census. They explore the hypothesis that the ability of family members to engage in intergenerational transfers of hands-on care requires close proximity or co-residence. They find that, in spite of the decline in intergenerational co-residence in the United States, most Americans still live within 25 miles of their mothers, and even closer for those with the lowest educational levels. Individual characteristics such as age, race and ethnicity affect both the probability of co-residence and close proximity, and their effects depend on gender and marital status, indicating the need to model the corresponding categories separately. Similar to Compton and Pollak, 2009 [37], Løken, Lommerud and Lundberg, 2013 [77] find that family ties influence the location decisions of young couples in Norway. On average, couples live closer to the husband's parents than to the wife's parents due to the low mobility of young men who lack a college degree.

Compton and Pollak, 2011 [37] further show that close geographical proximity to mothers or mothers-in-law has, in turn, a substantial positive influence on the labour supply of married women with young children. They argue that proximity increases labour supply through the availability of childcare. Their interpretation of availability is broad enough to include not only regular scheduled childcare during work hours, but also an insurance aspect of proximity (e.g., a mother or mother-in-law can provide irregular or unanticipated childcare). Using large American datasets, they find that the predicted probability of employment and labour force participation is 4-10 percentage points higher for married women with young children living in close proximity to their mother or their mother-in-law compared to those living further away.

5. CONCLUSION AND EXTENSIONS

This chapter has described some central ideas from the Economics of the Family, and selectively reviewed the literature in activity analysis and transportation where the ideas have been applied. The review illustrates the strengths of non-unitary or collective models, developed in the Economics of the Family, which embody concepts inherent to family interactions and decision-making such as negotiation, altruism, repeated interactions, and Pareto optimality.

Significant advances have been made in applying these models, but there is still a long way to go. As Bhat et al., 2013 [23] remark, the field is still developing. There is, as yet, little consensus on how household interactions should be modeled, how household utility functions should be constructed from individual member preferences (and even whether they can be aggregated), whether households can reach Pareto-optimal outcomes, what econometric methods should be used to estimate preferences, and other questions. The most appropriate modeling approach is likely to depend on the time-frame of the decisions, how important they are to a family, which members of the family are involved, whether potential outcomes are perceived as reasonably equitable, availability of transport alternatives, features of the urban environment, and so on. The potential influence of local and environmental factors is illustrated by a study of household time allocation by Kato and Matsumoto, 2009 [67], who obtain qualitatively different results for Tokyo, and the smaller Japanese city of Toyoma.

Much work remains to be done in integrating household decision-making into operational activity-based travel demand systems and dynamic traffic assignment models (Vo et al., 2020 [123]). Policy evaluation also becomes more challenging given the interactions between household members, and the interdependence of their utilities. For example, investments in infrastructure capacity or changes in pricing policy affect not only the individuals who use the facilities, but also other family members through short-run and long-run changes in activity participation, travel behaviour, and household budgets. Tackling these challenges will occupy researchers for years to come.

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