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Intra-household Decision Models of Residential and Job Location

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Abstract

Residential location decision is often a household joint decision involving several decision-makers. These different decision-makers usually have diverging preferences, especially in dual-earner households, when spouses work at different locations. Since about half a century, literature on residential location has studied in great detail the influence of socio-demographic characteristics (and in particular the differences between females and males or between multiple-worker and single-worker households). However, there is no research devoted to the within-family joint decision process leading to residential location decision (and work-place decisions). In the context of Paris Area, we analyze differences between spouses' values of commuting times and show that spouses' disparities in commuting decisions is a key element in the intra-household decision process. The single-worker household approach leaves aside by construction important intra-household considerations that influence commuting time and accessibility to jobs. We review different models useful to study intra-household decisions in dual-earner households. To do that, we base our analysis on the framework introduced by Chiappori, de Palma, Picard, and Inoa (2013), which applies the collective approach of household behavior(Chiappori, 1988; Chiappori, 1992) to describe residential location choice of dual-earner households. This collective approach has been used in several economic fields, but not in urban and transport economics so far. Furthermore, we argue that the framework developed by Inoa, Picard, and de Palma (2013), can also be adapted to analyze the joint residential and job location decisions in a two-worker household. The analysis is based on two accessibility variables (one for each spouse) embedded in a three-level nested Logit model which is used to study the interdependence of residential and workplace locations, while accounting for variation of preferences for job types across individuals.

Keywords: intra-household interaction, residential location, Paris region
JEL Codes: R21, R31, C35.

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1 Introduction

The residential and job location choice literature is dominated by models considering a single decision-maker in each household. In such early models, the analysis of joint decisions (such as residential location choices, involving monetary cost, but also emotional and time dimensions) are usually simplified by assuming away the within-household bargaining process. De facto, it is assumed that there is a single decision maker, who can be seen as a more or less benevolent dictator, to use the terminology introduced more than 30 years ago, by Gary Becker, the father of Economics of the Family.

In the economic literature, models considering a single decision-maker are usually referred to as "unitary models". Many researchers, especially in family economics, tend to criticize this assumption, questioning the hypothesis that the behavior of multi-person households can be described by a single decision-maker model satisfying the basic preference axioms (such as transitivity, for example). Incidentally, we know, since the Arrow impossibility theorem, the difficulty to aggregate preference within small groups.

In the context of residential location, it is highly probable that some intra-household bargaining process plays an important role in dual-earner households. Intra-household bargaining process refers to the negotiation process within the household with respect to joint decisions, such as residential location, use of the car (when there is a single car), or choice of a holiday location. In particular, in the context of residential location, each worker in the household has his own preferences and constraints depending on his own workplace, generally different from the workplaces of the other workers in the same household.

When there is more than one decision-maker in the household, a complex bargaining process usually takes place, and the resulting decisions would appear irrational if they were analyzed using a single decision-maker model. Since the 80's, economic literature has developed models analyzing the within-family bargaining process in other contexts such as labor supply or consumption. For example, Lundberg and Pollak (1993), developed a specific bargaining process in the presence of multiple interrelated decisions made by multiple decision-makers, whereas Chiappori (1988) developed the so-called "collective model". Collective models take account of the fact that multi-person households face joint decisions involving more or less altruistic members with specific preferences and constraints. In collective models, decisions are assumed Pareto-optimal in the sense that the solution of the bargaining process is on the Pareto frontier, that is, that it would not be possible to increase the well-being of one household member without decreasing the well-being of at least another member. Spouses jointly make decisions leading to a Pareto-optimal outcome, if it is not possible to make one spouse better-off without making the other spouse worse-off. Pareto-optimality can be bested empirically, and is usually verified. By contrast, the assumptions and/or conclusions of unitary models are usually rejected in multi-person households.

Recently, economists and transport researchers have worked on explaining the effect of intra-household variables on the choice of residential location and workplace (Waddell, 1996; Abraham and Hunt, 1997; Sermons and

Koppelman, 2001). Their analysis addressed the multiple-member household decisions, but not the multiple decision-maker problem, involving a within-household bargaining process. Overall, intra-household considerations remain limited in this literature; the theoretical and empirical contributions on the effect of intra-household variables on the residential location and workplace choices are scarce. In particular, there are no published contributions on within-household bargaining process in location decisions (with the exception of the ongoing research by Chiappori, de Palma, Picard, and Inoa (2013)).

Our objective in this chapter is to make a first step to bridge the gap between two strands of literature which developed independently up to now. The first one covers location choice models that consider more than one household member or worker, but a single decision maker. The second one focuses on the decision process in other contexts, when several decision makers have diverging preferences and constraints. The ultimate objective is to make a step forward in the analysis of joint mode choice and residential and job location choices in a dual-earner household.

Beyond the simple differentiation of location choice by socio-demographic characteristics, recent models dealing with family location decisions allow for the identification of differences between females and males, and between multiple-worker households and single-worker households. In the context of Paris Area, we analyze differences between spouses' commuting times, and we show that spouses' disparities in commuting is a key element in the intra-household decision process. The single-worker household approach might leave aside important intra-household considerations that influence commuting time and accessibility to jobs. As a consequence, the one-worker oriented location choice models may lead to misleading conclusions for dual-earner households.

We review here different models potentially useful to study intra-household decisions. We assess the framework introduced by Chiappori, de Palma, Picard, and Inoa (2013), which applies the collective approache of household behavior (Chiappori, 1988; Chiappori, 1992) to describe residential location choice of dual-earner households. In the context of a collective model (assuming Pareto-optimality), bargaining powers play an important role to measure the values of time of the two spouses.

We then argue that the framework introduced by Inoa, Picard, and de Palma (2013), could also be adapted to analyze residential and job location choices in a two-worker household. By accounting for two accessibility variables (one for each spouse), their three-level nested Logit model could be used to study the interdependency of residential location and workplace, while accounting for variation of preferences for job types across individuals. This could be performed both in single- and in two-worker households.

The outline of the chapter is briefly described below. Section 2 provides some background of the studies analyzing household behavior in multi-person households. We focus the literature specifically on residential location and mode choice studied in this chapter. Differences between female and male commuting time in Paris Region are presented in Section 3, which also analyzes the role of spouses respective travel times in a model of residential location that considers intra-household decisions, and explores original considerations in individual-specific accessibility measures. Section 4 discuss insights

for future work and concludes.

2 Literature review

The models we review here present the two literature strands which developed independently up to now. The transportation and location choice literature has mainly modeled the household as a single decision-making unit. Timmermans (2006) offers an extensive review on past research in the transportation literature, whereas Vermeulen (2002a); Vermeulen (2002b) reviews the work on unitary and collective household models in other contexts.

Different literature reviews and special issues have already been interested in the modeling of intra-household decisions in such contexts. Two special issues on modeling intra-household interactions, edited respectively by Bhat and Pendyala (2005) and by Timmermans and Zhang (2009), have become the main references in the transportation literature. The former focuses on utility-maximizing models, whereas the latter presents other methods such as micro-simulation approaches and group decision theory.

de Palma, Picard, and Inoa (2013) update the previous reviews of intra-household decision models in the transportation literature, and focus on discrete choice models. It differs from such earlier reviews by putting more emphasis on economics of the family and collective models of household behavior.

These reviews reveal that two general research streams have modeled independently multi-person households and intra-household decisions. On the one hand, there has been interesting research on within-family interactions on what can be broadly categorized as the transportation, activity-demand, and location literature, which paid no attention to the within-family bargaining process itself. On the other hand, household decision-making processes have been studied in depth in the Collective Model literature, but they paid no attention to residential location, workplace or other transport-related choices.

These two strands of literature differ not only with respect to their topics, but also with respect to the nature (discrete versus continuous) of the decisions analyzed. As a consequence, these two strands of literature used and developed totally different techniques. This distinction is at the core of new theoretical and empirical developments.

2.1 Family decisions in the transportation literature

The transportation and activity-demand literature heavily relies on discrete choice modeling and more occasionally on structural equation modeling and seemingly unrelated regressions (a system of equations, where the error terms are assumed to be correlated across equations), to explain the time invested in activities by the household members, as reported by Srinivasan and Bhat (2005). Furthermore, Timmermans (2006) classifies transportation and activity-demand works that consider intra-household decision-making into three categories: micro-simulation (simulation of a household member daily activity-travel pattern), rule-based ("if-then" decision tree structures) and utility-maximizing models (RUM and time allocation approaches).

The discrete choice models of intra-household decisions in the transportation, activity-demand, and location literature covers choices from the short

run to the long run decision context.

Contributions regarding the long term decision context includes choices of residential and job location, mobility, and car ownership as in Abraham and Hunt (1997); Freedman and Kern (1997); Sermons and Koppelman (2001); Waddell (1996).

Contributions regarding the short term decision context includes modeling (joint) activity and task allocation, travel, car sharing, and mode choice as in Wen and Koppelman (1999); Wen and Koppelman (2000); Gliebe and Koppelman (2002). Scott and Kanaroglou (2002); Vovsha, Petersen, and Donnelly (2003); Vovsha, Petersen, and Donnelly (2004a); Vovsha, Petersen, and Donnelly (2004b); Bradley and Vovsha (2005) work on discrete choice of maintenance activities allocation in tour-based travel demand modeling systems, as Srinivasan and Bhat (2005); Srinivasan and Bhat (2006) and others.

More details can be found in the special issues and reviews mentioned before: Bhat and Pendyala (2005); Timmermans (2006); Timmermans and Zhang (2009); de Palma, Picard, and Inoa (2013).

2.2 Intra-household decision process in the economic literature

Following the impetus originated from seminal work by Nobel Prize laureate Gary Becker (1965; 1973; 1974; 1974; 1991), recent developments in economics of the family, broadens the classical research field, which initially focused on fertility and labor supply, to new questions such as the marriage decision or choices related to the number of children, their education, and the allocation of tasks and time among household members.

When modeling household decisions, the household was traditionally considered as a single decision-maker, and the study of the decision-making process and of the transactions between family members were neglected, as discussed in de Palma, Picard, and Inoa (2013). These so called "unitary models" neglect the differences and potential conflicts between the interests of the different household members, and implicitly assume that household members pursue consensual objectives. This assumption leads to a poor understanding of decision mechanisms within the household, even when individual-specific variables (such as spouses' respective ages or education levels) are introduced in the model.

Collective models and other within-households bargaining models aim at answering the theoretical and empirical criticisms addressed to unitary models of family decision-making. They were developed in two major directions. "Strategic" models rely directly on the theory of non-cooperative games (see, e.g. Ashworth and Ulph (1981); Leuthold (1968)), while "collective" models proposed by Chiappori (1988); Chiappori (1992) rely on the basic assumption that the household decision process leads to Pareto-efficient allocations. The bargaining process may then be either explicit (as in McElroy and Horney (1981), or in Lundberg and Pollak (1993)), or non-specified (as in Chiappori (1988); Chiappori (1992)). In the latter case, the bargaining process is very general and not restrictive, only assuming Pareto-optimality. Pareto-optimality hypothesis seems natural for analyzing household decisions since family members, who interact over a long period, are probably able to find

mechanisms leading to efficient decisions.

As shown by Chiappori (1992), collective models can be used to study the welfare level of each household member, and therefore to analyze and measure in a consistent way the redistributive effects of any economic policy, not only at the household level but also at the individual level. More specifically, he showed that, under some rather plausible conditions, individual utility functions can be recovered from household behavior (and disentangled from bargaining power effects, whereas bargaining effects induce a bias in the measurement of preference parameters in unitary models).

The collective model introduced by Chiappori (1988); Chiappori (1992) was originally restricted to continuous decisions, because it relied on the first-order condition resulting from Pareto-optimality. The extension to continuous-discrete applications (Blundell, Chiappori, Magnac, and Meghir, 2007) is very recent because it implies complex technical developments. A few years before, Van Soest (1995) considered a discrete choice model of joint labor supply within the family, but it did not take into account the negotiation process within the household, and it did not test or impose the restrictions implied by the optimality of the joint decision. Vermeulen (2006) made another step to introduce discrete (female) labor supply, but his model does not impose Pareto-optimality of discrete labor supply decision.

3 Modeling intra-household decisions in two specific examples

An important issue in modeling residential and job location is the interdependence of these two decisions, both at the individual level and at the household level. It can be argued that the choice of residential location is made conditional on the workplace, or vice versa (Waddell, 1996). We can also argue that the choice of residential location is made in different time frames according to the life cycle of individuals. What households then consider in their joint location decisions, with a varying degree of importance along their life cycle, are the chances of each active member in the household to access a good job in each alternative location, which determines the accessibility to jobs of each household member, from any given residential location.

We present here an innovative perspective on the interdependence between residential location and workplace of spouses, taking into account the process of negotiation within the household, the travel time of each spouse, and the job accessibility for each spouse. For this we propose models of residential location to give clear answers to various theoretical and empirical issues concerning: the residential location conditional on workplaces and the joint choice of residential location and workplace of each spouse.

This work has allowed expanding and developing models that correct the bias in the individual value of time of spouses. This is achived by measuring separately the influence of explanatory variables on (1) the decision-making process within the household and (2) the value of time of spouses. The bargaining power is taken into account to analyze the effect of the commuting time of spouses to the household residential location choice. For more details on the modeling framework of the results developed below see Chiappori, de

Palma, Picard, and Inoa (2013).

3.1 Mode choice and spouses travel times

The differences between male and female observed travel times depend (1) on spouses endogenous joint mode choices, (2) on the distribution of male and female jobs over the region (marginal distribution of the destination of morning commuting trips), (3) on the distribution of dwellings over the region (marginal distribution of the origin of morning commuting trips), as well as (4) on the household joint residential and job location choices. The link between the marginal distributions of origins (home) and destinations (work place) and their joint distribution is partially explained by the spouses bargaining powers for location choice in the household. If the women's bargaining power is larger than the men's one, then the joint distribution of household residential location and spouses' job locations results in a reduction in woman's travel time compared to man's travel time.

In this section, we make a first step at disentangling the effects of these different sources, focusing on the relative reduction in actual women's and men's travel times (compared to all potential travel times) resulting from their respective bargaining powers.

Using data form the 1999 Census in Paris Region, we analyze the distributions of spouses' potential and actual travel times, and interpret their differences in the light of respective bargaining powers. Travel times are computed using the dynamic transport network model METROPOLIS (de Palma and Marchal, 2002). The Paris Region is composed by 8 "*départements*": Paris, 3 *départements* around Paris ("inner ring"), and 4 *départements* farther away ("outer ring"). The city of Paris accounts for 20 *arrondissements* that correspond to 20 communes. The region contains 10,724,748 inhabitants for a total of 4,510,369 households. Household location and workplace are observed only in a 5% sample. About half of the individuals in this 5% sample work, which represents 242,516 workers, among which 239,499 work in Paris area. We finally restrict our sample to couples in which both spouses live and work in the Paris Region, which leads to 60,798 dual earners households (the difference corresponds to singles and one worker families).

Commuting network distances and travel times in chosen alternatives are computed using individual information on actual residential location and workplace, and reported in Table 1, in our sample of 60,798 dual-earner households. These distances and travel times correspond to the actual, or observed commuting trips. The upper (resp. medium) part of the table reports distance and travel time information for women (resp. men), and the lower part of the table reports the average differences and tests the statistical significance of these differences.

In the chosen alternatives, women's commuting distances and travel times are shorter than men's. The average difference is 2.27 km and 5.67 minutes through the public transportation network, and 1.85 km and 2.23 minutes through the private car network. The standard errors are those of the average difference between female and male actual commuting distances and travel times. The t-Stats are the ratios of the Mean to Std Err columns. Under the null hypothesis that the male and female average distances and travel times

are equal, this statistic follows a Student distribution. For the 4 variables considered, the absolute values of the t-Stats are very large, and the null hypothesis is clearly rejected: actual commuting distances and travel times are significantly lower for women than for men.

This difference may come from two different phenomena: (1) the marginal distributions of dwellings (irrespectively of the male and female workplaces) is such that dwellings are on average closer to female jobs than to men jobs; (2) the distribution of dwellings conditional on female and male workplaces is such that, for a specific household, the dwelling is closer to the woman's workplace than to the man's workplace.

In order to quantify the first phenomenon, we randomly select 9 hypothetical residential locations for each household, independently from the husband and wife workplaces. To do so, we consider a uniform distribution over the 5 million dwellings of the region. Equivalently, we perform importance sampling of communes, with weights proportional to the number of dwelling in this commune (see Chapter 2.5 for more details on importance sampling). Following this strategy, we build a sample of dwelling locations independent from both spouses workplaces, and the distribution of these hypothetical dwellings is statistically identical to the marginal distribution of dwellings in the region. The resulting distances and travel times are reported in Table 2, which is built on a sample of 60,798*9=547,182 hypothetical (unchosen) alternatives for residential location. The structure of Table 2 is the same as the one of Table 1, except that the figures are now those of hypothetical travel times.

Table 1. Actual commuting distances and travel times

Variable	**Mean**	**Std Dev**	**Min**	**Max**
Women				
Network Distance (public, km)	13.151	13.973	0.25	134.73
Network Distance (private, km)	10.710	11.716	0.25	107.32
Travel time (public, minute)	42.574	34.936	1.00	384.56
Travel time (private, minute)	15.200	14.248	0.76	151.51
Men				
Network Distance (public, km)	15.417	15.047	0.25	134.73
Network Distance (private, km)	12.557	12.620	0.25	109.12
Travel time (public, minute)	48.242	36.732	1.00	384.56
Travel time (private, minute)	17.431	15.199	0.76	149.36
Difference (Women - Men)	**Mean**	**Std Err**	**t-Stat**	**p-value**
Network Distance (public, km)	-2.266	0.083	-27.21	$<$0.01%
Network Distance (private, km)	-1.847	0.070	-26.45	$<$0.01%
Travel time (public, minute)	-5.668	0.206	-27.57	$<$0.01%
Travel time (private, minute)	-2.231	0.084	-26.41	$<$0.01%

In the hypothetical case in which households would randomly choose a residential location independent from husband's and wife's workplaces, the

Table 2. Hypothetical commuting distances and travel times using the marginal distribution of dwellings

Variable	**Mean**	**Std Dev**	**Min**	**Max**
Women				
Network Distance (public, km)	31.712	21.177	0.33	182.33
Network Distance (private, km)	26.995	19.399	0.33	155.90
Travel time (public, minute)	86.200	50.193	1.32	564.52
Travel time (private, minute)	35.020	20.778	1.00	233.01
Men				
Network Distance (public, km)	31.154	20.813	0.35	182.33
Network Distance (private, km)	26.464	19.020	0.35	155.90
Travel time (public, minute)	84.844	48.704	1.40	564.52
Travel time (private, minute)	34.469	20.355	1.05	233.01
Difference (Women - Men)	**Mean**	**Std Err**	**t-Stat**	**p-value**
Network Distance (public, km)	0.558	0.0401	13.90	$<0.01\%$
Network Distance (private, km)	0.531	0.0367	14.46	$<0.01\%$
Travel time (public, minute)	1.356	0.0945	14.34	$<0.01\%$
Travel time (private, minute)	0.551	0.0393	14.01	$<0.01\%$

average commuting distances and travel times would be approximately multiplied by 2. Stated differently, the fact that households (partially) adjust their residential location choice to the spouses' workplaces divides by 2 the spouses commuting distances and travel times, compared to the hypothetical case in which they would randomly pick one of the existing dwellings. More interestingly, in this hypothetical situation, women's commuting distances and travel times would be slightly larger than men's travel times. This means that, on average, dwellings are marginally closer to male jobs than to female jobs. The fact that actual commuting distances and travel times are shorter for wives than for men according to Table 1 cannot come from the marginal distributions of dwellings and jobs because the relationship is reversed in Table 2, but it comes from the conditional distribution of dwellings given spouses workplaces. Stated differently, the endogenous household residential location favors wives rather than husbands, which suggests a larger bargaining power for women than men in the residential location choice. This result is also consistent with Abraham and Hunt (1997), who explained that the probability of moving is more strongly related to commuting distance for women than for men, which results in shorter commuting distance for women after a relocation.

Note also that the endogenous residential location reduces more actual travel time of women compared to men by public transit than by private car. Given that women have a stronger tendency than men to commute by public transit, this result suggests that households locate so as to favor woman's commuting by transit.

The fact that both dwellings and jobs are rather located in the center of the region divides by about 2 the distances and by about 2.5 the travel times

in comparison with the hypothetical situation in which dwellings and jobs would be uniformly and independently distributed among the communes. In this even more hypothetical case, the average distance between dwellings and jobs would be 66 km both through public and private networks, and it would represent an average travel time of 215 min by public transportation and 80 minutes by car.

The geographical distribution of actual commuting time for women and men by public transportation and private care are depicted in Figure 1 and Figure 2, respectively, by gender. The "Other" category corresponds to communes with no observed trip by the mode considered, for the gender considered. Actual commuting times in public transportation and private car are increasing functions of the distance to the center of the region, in which most of the jobs are concentrated. The difference in travel times between the outer ring and the central part of the region (Paris and inner ring) is more pronounced for public transportation than for private car, which reflects the fact that the public transportation network is concentrated in the center of the region and is poorly adapted to trips from the outer ring to the outer ring.

The geographical distribution of relative (woman-to-man) travel times depicted in Figure 3 shows that women work closer to their dwelling than men in the outer ring, whereas, for households living in Paris or in the inner ring, the husband's workplace is closer to the dwelling than the wife's workplace. This is consistent with the fact that men's jobs are concentrated in the core of the region, whereas female jobs are more uniformly spread over the region.

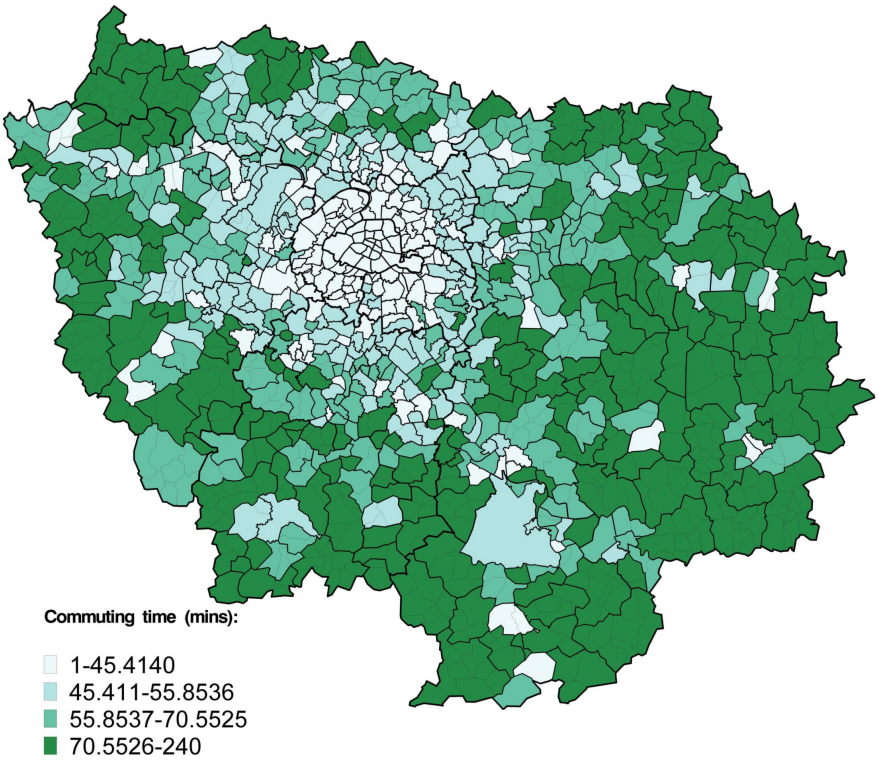
3.2 Car ownership and mode choice

Using the same sample as in Section 3.1, we estimate a multinomial logit model of residential location conditional on husband and wife workplaces, as a function of local dwelling price (per square meter, in log) and spouses' actual travel time, by mode and gender. Table 3 shows results of two different models. In the first model, the Value of Time (coefficient of the travel time variable) only depends on mode and gender. In the second model, the travel time variable is crossed not only with mode and gender, as in the first model, but also with the number of cars owned by the household.

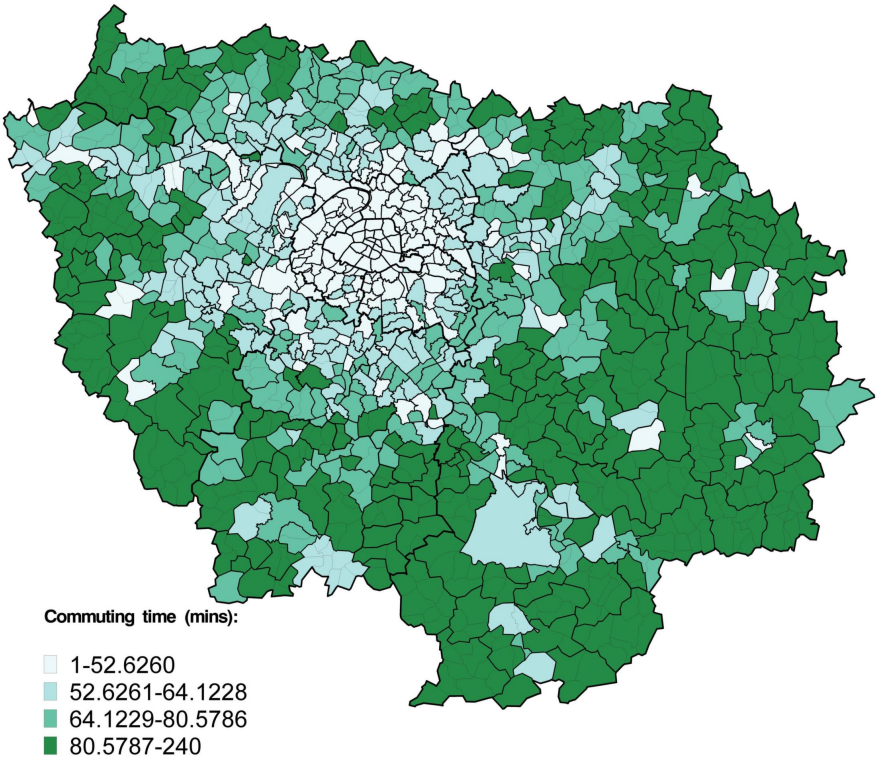
The Price has the usual negative sign and is highly significant in both models. According to the first model, household location is slightly more sensitive to woman's than man's travel time by private car (|-0.0212| is significantly larger than |-0.183|), but it is twice more sensitive to woman's than man's travel time by transit. The second model helps understanding such differences. Travel time by private car (both for husband and wife) has no influence on household location for households with no car, which is totally consistent. Households do not care how much time husband or wife would spend commuting by car, when they have no access to any car.

For each household, 9 unchosen alternatives are generated using importance sampling, alternatives corresponds to the 1300 communes of the Paris Region.

The difference between the coefficients of travel time by private car for the wife in households with 0 or 1 car is not statistically significant. For the husband, it is the difference between 1 and 2 cars which is not significant. This

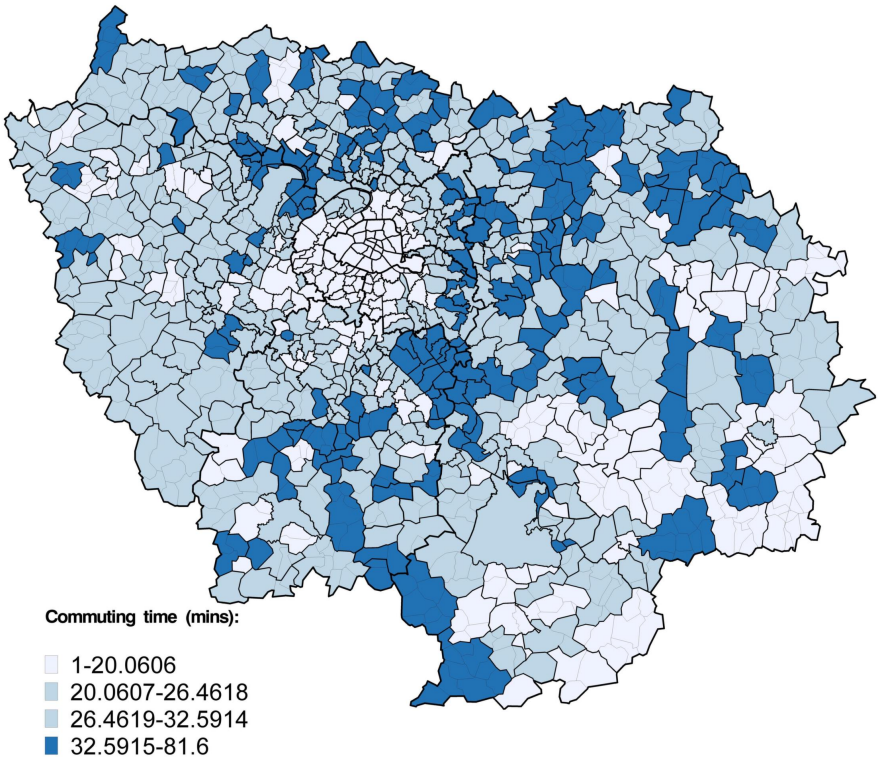


(a) Wife

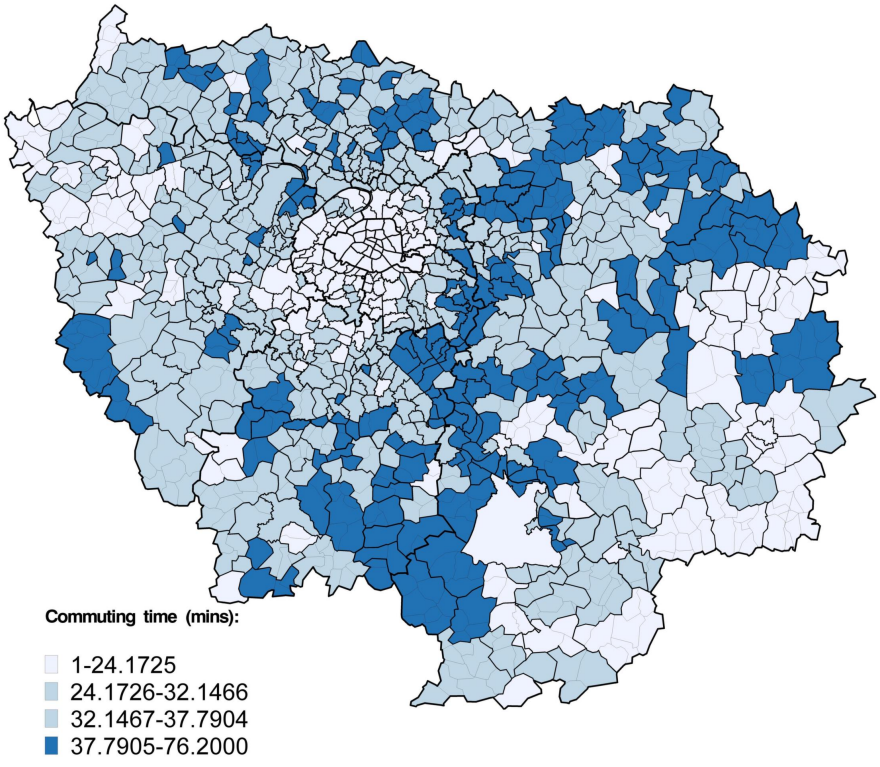


(b) Husband

Figure 1. Public transportation observed commuting times

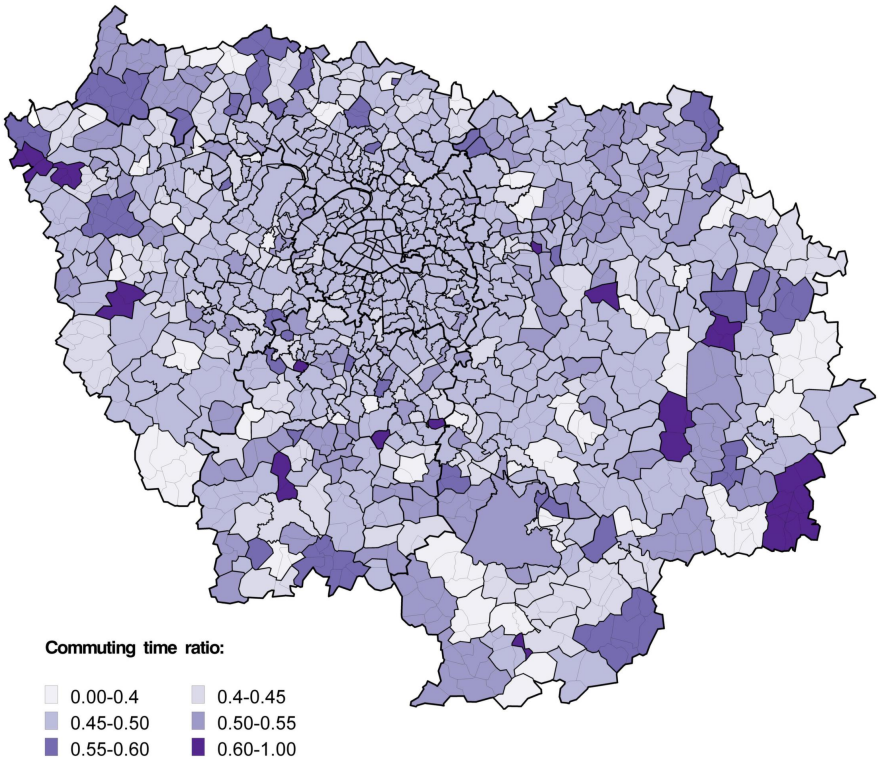


(a) Wife

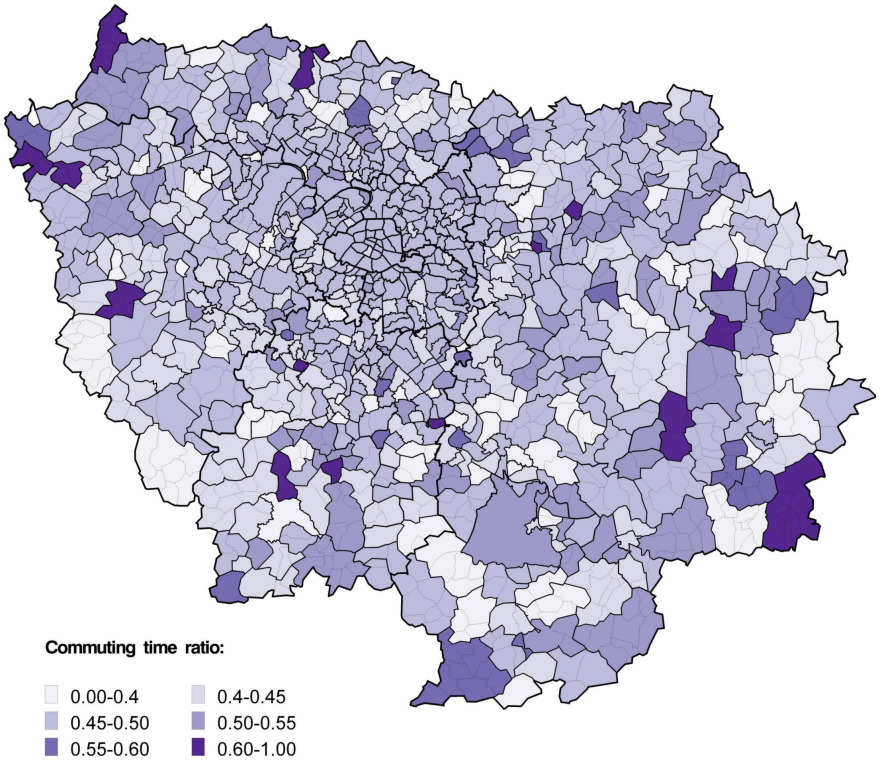


(b) Husband

Figure 2. Private vehicle observed commuting times



(a) Public transportation



(b) Private vehicle

Figure 3. Geographical distribution of relative travel times

Table 3. Residential location choice as a function of travel time

Parameter	Coefficient	Std Err	t Stat	Pr>|t|
Travel time by mode and gender				
Log(Price)	-3.7977	0.0314	-120.9	<.0001
Travel time (public transportation) Wife	-0.0325	0.0005	-69.59	<.0001
Travel time (public transportation) Husband	-0.0172	0.0005	-36.58	<.0001
Travel time (private car) Wife	-0.0212	0.0010	-21.68	<.0001
Travel time (private car) Husband	-0.0183	0.0010	-18.87	<.0001
Travel times by sex, mode, and number of cars				
Log(Price)	-4.0008	0.0323	-123.87	<.0001
Travel time (public transportation) Wife, no car	-0.0578	0.0023	-25.57	<.0001
Travel time (public transportation) Wife, 1 car	-0.0394	0.0007	-56.9	<.0001
Travel time (public transportation) Wife, 2 cars	-0.0233	0.0006	-36.07	<.0001
Travel time (public transportation) Husband, no car	-0.0414	0.0023	-17.84	<.0001
Travel time (public transportation) Husband, 1 car	-0.0232	0.0007	-33.31	<.0001
Travel time (public transportation) Husband, 2 cars	-0.0094	0.0007	-14.46	<.0001
Travel time (private car) Wife, no car	-0.0059	0.0048	-1.23	0.2191
Travel time (private car) Wife, 1 car	-0.0114	0.0014	-7.89	<.0001
Travel time (private car) Wife, 2 cars	-0.0319	0.0014	-22.97	<.0001
Travel time (private car) Husband, no car	-0.0075	0.0047	-1.58	<.0001
Travel time (private car) Husband, 1 car	-0.0169	0.0014	-11.89	<.0001
Travel time (private car) Husband, 2 cars	-0.0191	0.0014	-13.95	<.0001

means that the husband's commuting time by private car becomes relevant in residential location choice as soon as there is at least one car in the household. By contrast, the wife's commuting time by car becomes really relevant only when there is at least 2 cars in the household. This gives a strong indication that the husband has the priority to use the car to commute when there is competition between spouses for the use of the unique car.

The influence of travel time by public transportation on residential location is decreasing with the number of cars in the household, both for the wife and for the husband. This influence nearly disappears for men when there are two cars in the household, suggesting that the husband usually commutes by car and does not care about transit travel times when there are 2 cars in the household. These results are consistent with the fact that, on the one hand, public transportation is a substitute for private car when household members can easily reach a station, which is usually the case in Paris and inner ring, whereas it is a complement when individuals have to drive to the station in order to use public transportation. The fact that husband's transit commuting time plays virtually no role in residential location of two-car households, whereas the wife's transit commuting time still matters suggests that, when there are two cars in the household, men will anyway entirely commute by car, whereas wives may go to the station by car.

3.3 Couple residential location conditional on spouses workplaces

We now discuss the results obtained by Chiappori, de Palma, Picard, and Inoa (2013) in a structural collective model assuming that spouses workplaces are chosen before the residential location. In that case, like in Section 3.2, residential location depends on the spouses actual commuting times between

the current workplace and the potential residential locations contemplated. However, by contrast with the reduced-form model estimated in Section 3.2, we analyze here a structural model explicitly taking into account both spouses individual preferences and respective bargaining powers rather than mixing them in a household utility function which may or may not be consistent with collective rationality. To the best of our knowledge, this the only contribution to the literature that takes into account the role of the within-family decision process and spouses bargaining powers in a residential location.Picard, de Palma, and Dantan (2013) develop and estimate a one-step structural model to disentangle bargaining powers from spouses' values of time in a joint mode choice model. They find results similar to the results presented in this section concerning the determinants of the bargaining power. The other contributions such as Abraham and Hunt (1997); Beharry-Borg, Hensher, and Scarpa (2009) do consider the influence of individual characteristics on residential location choices, but the associated coefficients mix the influence of individual preferences and bargaining powers.

The objective here is to analyze the within-family decision process involving bargaining between members with diverging preferences , objectives and constraints. Spouses may or may not have diverging preferences concerning local amenities, and these preferences probably differ from the preferences of singles. The same individual will tend to enjoy bars and discos when he is single, and open spaces when he is married with children. Given this change in preferences of the same individual when he marries, it is not possible to disentangle respective bargaining powers and spouses' preferences for local amenities, and we will not try to do so. Instead, we consider a joint preference of the household for local amenities.

On the opposite, it is obvious that the husband preference for his own commuting time (let's call it Value of Time (VOT), although it is more complex when utility is not linear in travel time because then VOT is given by the local derivative of utility with respect to commuting time, and it varies with commuting time) is different from the wife's preference for the husband commuting time. The influence of the husband's commuting time on household residential location mixes (1) the role of the husband's VOT, which a priori depends only on the husband's individual characteristics and (2) the role of respective spouses bargaining powers, which a priori depends both on the husband and wife individual characteristics. Similarly, the influence of the wife's commuting time on household residential location mixes the role of the wife's VOT and of the respective spouses bargaining powers. As a result, neglecting spouses' respective bargaining powers leads to biased estimates of the values of time of the household members.

Chiappori, de Palma, Picard, and Inoa (2013) have developed a method to disentangle the bargaining power and the spouses VOTs, and to measure separately the influence of explanatory variables on the bargaining power and the value of time. They applied this method to the same data as in Sections 3.1 and 3.2. Each spouse's bargaining power is normalized to $1/2$ in the reference case (the two spouses are French and 20 years old), and the husband and wife bargaining powers always sum to 1, so that bargaining powers can be interpreted as percentages. Any increase in the woman's bargaining power

corresponds to a decrease of the same percentage for the husband's bargaining power. The econometric results show that the woman's age and man's nationality play a crucial role in determining bargaining power. The magnitude of the effects depends on the covariates considered, but some general patterns emerge. Each spouse bargaining power increases with age, but the increase is faster for the wife than for the man. Consider two equally old men. The wife of the first man is 10 years older than the wife of the second. Our estimates show that, in this case, the bargaining power of the first wife is 4.28% larger than that of the second woman. Consider now a third couple, in which the wife has the same age as the wife in the first couple, but the husband is 10 years older than the husband in the first couple. Then, the bargaining power of the husband in this third couple is 0.78% larger than that of the first husband. Consider now the first couple 10 years later. Each spouse is 10 years older and, as a result, the wife's bargaining power has increased more the the man's. As a consequence, the wife's bargaining power tends to increase over time (by 4.28%- 0.78%= 3.5% each 10 years).

The bargaining power of the husband is reduced by about 4.5% when he is foreign, whereas the wife's bargaining power does not significantly depend on her nationality.

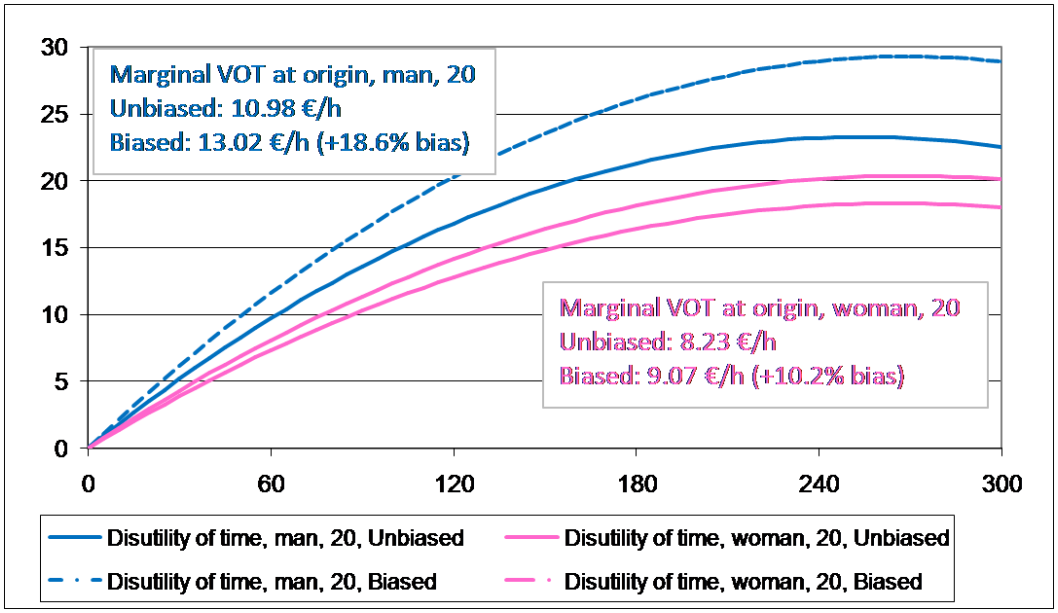
The econometric results of this model also show a large bias in the measurement of spouses' VOT when the bargaining power is not taken into account in a residential location model. For example, there is a 20% underestimation of the value of time for a 40-year-old French man, which becomes a 18% overestimation for a 40-year-old French man. For the wife, the VOT is always overestimated when the bargaining power is omitted, and the bias is 15% for a 40-year-old French woman and 10% for a 20-year-old French woman. There is an additional bias upwards in the measurement of the VOT of foreign men, when the bargaining power is omitted.

The commuting cost estimated in the model is a concave function of commuting time for each spouse. The value of time for a man (respectively woman) of 20 years old is about €11 (respectively €8) per hour at the origin (i.e. when the travel time tends to 0). The value of time is a decreasing function of age.

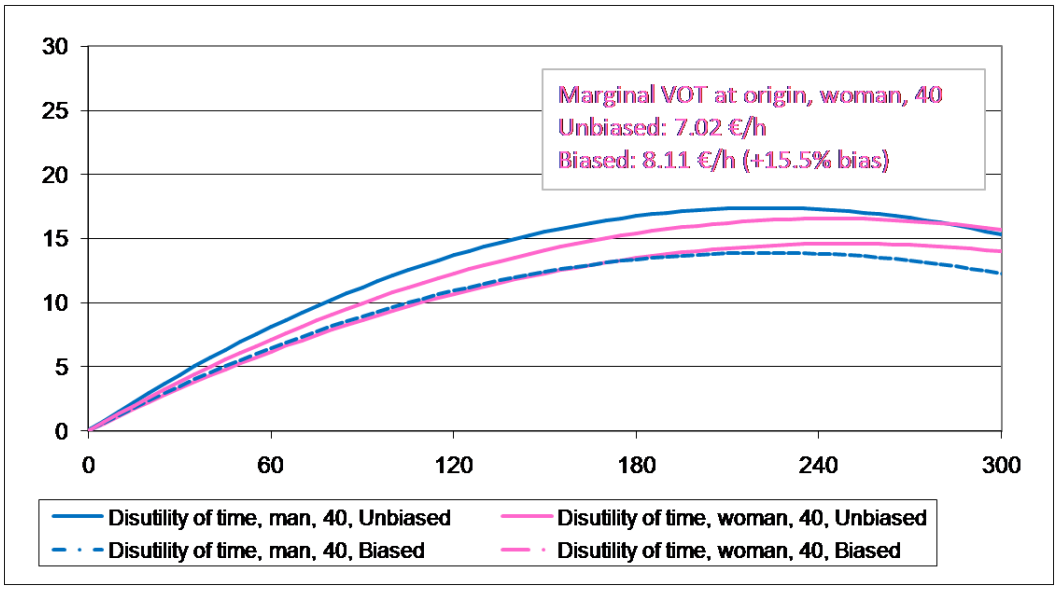
3.4 Accessibility in a residential location, workplace, and job type model in one- and two-worker households

We now discuss the extension to dual-earner households of the single or one-worker household structural model developed by Inoa, Picard, and de Palma (2013). By contrast to Sections 3.2 and 3.3, this model assumes that residential location is chosen before individual workplaces. This model analyzes a three-level nested logit model of residential location, workplace, and job type choice. Residential location is the upper-level choice, workplace the middle-level choice, and job type is chosen at the lower level.

The decision tree is fully consistent and rational: on one hand, workplace choice is anticipated at the upper-level residential location choice; on the other hand, the middle-level workplace choice is made conditional on the residential location actually chosen. This model allows defining and computing an individual-specific measure of attractiveness of geographical units, which takes



(a) Age 20



(b) Age 40

Figure 4. Baised and unbaised value of time

into account the local distribution of job types, and individual preferences for job types. This measure of attractiveness of geographical units is fully consistent with the model, from the theoretical and econometric points of view. It corresponds to a log-sum term going up the decision tree from the lower level to the middle level. Going one step up in the decision tree, we obtain an individual-specific measure of accessibility to jobs, which takes into account the heterogeneity in VOT and preferences for different job types captured in the measure of attractiveness of potential workplaces.

The model is estimated on single or one-worker households, using the same data as in Sections 3.1 to 3.3. At the lower level of the decision tree, preferences for job types depend on gender, education and number of children (for women only). The same variables also explain observed heterogeneity in the Values of Time at the middle level of the decision tree. At the upper level, observed heterogeneity in preferences for local amenities is even richer, with the introduction of profession of household dead, and household composition and income, crossed with the local distribution of the same characteristics, in order to reflect the tendency of households to locate close to similar households.

4 Conclusion

We have discussed in this article different models describing mode choice, residential location and workplace of the various members of a family, mainly the husband and wife, but more sophisticated models should also take into account the children. The key concept introduced in this chapter is the negotiation within the couple, that is to say, the decision-making process related to joint choices, such as the residential location, which is usually, but not always, unique in couples.

The tools we have discussed in this chapter are based on the work developed during recent decades in the field of economics of the family. They will revolutionize discrete choice models used in transport and urban economics, in the sense that the decisions are no more described as the outcome of a unique decision maker. Instead, in collective discrete choice models, the decisions depend on preferences and constraints of two individuals tied by economic, but also emotional ties. Discrete choice theory still has to be adapted to this new way of approaching the individual decisions. Current literature in transportation (Abraham and Hunt, 1997) has developed a few family decision models. However these models ignore the bargaining process within the family, as studied by family economists (Chiappori, 1988; Chiappori, 1992).

An objective of the research is to provide new tools for researchers in urban and transportation economics, as well as in engineering. In particular, we plan to provide collective choice models to the integrated transport and land use tool, UrbanSim. This article begins a search path that may be still very long and hopefully fruitful.

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