Projet ANR-14-CE22-0006

ELITISME

ELITISME WORKING PAPER SERIES

ANR-ELITISME-2018-002

Couple Residential Location and Spouses Workplaces

Pierre-André Chiappori, André de Palma, Nathalie Picard

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

Labex MME-DII
Modèles Mathématiques et Économiques de la Dynamique, de l'Incertitude et des Interactions

UNIVERSITÉ de Cergy-Pontoise

ÉCOLE POLYTECHNIQUE UNIVERSITÉ PARIS-SACLAY

ENS CACHAN

université PARIS-SACLAY

Couple Residential Location and Spouses' Workplaces[1]

Pierre-André Chiappori[2], André de Palma[3], Nathalie Picard[4],

May 22, 2019

[1]The authors would like to thanks for the fundings from the European Commission, project SustainCity and from the French agency, ANR, project Elitisme. Amine Naouas helped us in running the first estimations and preparing the initial data set. Julien Monardo provided usefull comments.

[2]Columbia University, Department of Economics, 420 West 118th St., New York, NY 10025, USA. Email: pc2167@columbia.edu

[3]École Normale Supérieure Paris-Saclay, CREST, 61 avenue du Président Wilson, 94230 Cachan Cedex, France. Email: andre.de-palma@ens-paris-saclay.fr

[4]Université de Cergy-Pontoise, THEMA, 33 boulevard du Port, 95011 Cergy-Pontoise Cedex, France. Email: nathalie.picard@u-cergy.fr, ignacio.inoa@u-cergy.fr

Abstract

The transport and urban economics literatures typically rely on 'unitary' representations of the household, therefore disregarding the role of spouses' bargaining powers in the decision process. This misspecification generally leads to biased measures of the values of time. We elaborate a new method to provide an unbiased measure of the value of time. More specifically, using census data on Paris Region, we are able to disentangle bargaining power from the values of time of spouses for the residential location choices. We show that the nationality of the couple, their education level, as well as the age difference between spouses, play a crucial role in determining bargaining power.

Keywords: urban economics, residential location, collective models, bargaining power, transportation cost.

JEL Codes: R21, R23, D13.

1 Introduction

Urbanization all over the world represents one of the most important phenomenons in our societies. In many developed countries more than 50 percent of households live in urban areas. In developing countries, urbanization is extremely fast. Not surprisingly, there is growing interest in understanding how large urban areas function and how they can be better managed. Residential mobility is an essential component to understand the dynamics of urban development, together with job location, automobile ownership and other major mobility decisions (starting with Lerman 1976 and McFadden, 1978). Residential location has attracted attention of researchers for decades, not only in urban economics (with the monocentric and polycentric model, Fujita and Thisse, 2013) but also in the transportation fields (see the handbook of de Palma et al. 2011). These approaches have given rise to a wide set of large scale tools, such as dynamic disequilibrium models (UrbanSim, Waddell, 2002), micro-simulation models (such as Simmobiliy, developed by Ben-Akiva and coauthors) or general equilibrium models relying on perfect foresight (Anas and Arnott, 1994). For a recent survey on transportation and mobility, see Proost and Thisse (2018). These tools, however, systematically rely on a *single decision maker assumption.* In other words, models that specifically analyze residential location almost uniformly ignore intra-household issues, and (implicitly) assume that the decisions are made by a single individual, the household head.[1] An assumption of this type, however, raises several problems. One the one hand, it amounts to ignoring some of the most important (and interesting) aspects of household economics. In general, incentives to choose a specific residential location may differ between husband and wife: they may have different tastes for amenities and more importantly different job locations (and therefore different commuting times). Location decisions are infrequent, consequential, and costly to reverse; as such, they are very likely to reflect power relationships within the household in a fundamental way. Secondly, urban location models that ignore intra-household bargaining will typically be misspecified; in particular, the impact

[1] A few authors in the transport literature (Bhat and Pendyala, 2005, and Timmermans and Zhang, 2009) have been aware that individual decision making models provide an incomplete approach and have made a first step to model joint decisions. However, their approaches do not rely on fully rational models involved in a family bargaining process and thus remains rather far from the standard economic models used in the economics of the family literature (see Browning, Chiappori and Weiss, 2014).

of husband's and wife's transportation costs on the location they choose may be estimated with a bias, which may in turn affect the cost-benefit analysis based on these estimates and the corresponding policy recommendations. For instance, observing an individual living far from their work place will, in such a 'unitary' framework, mechanically translates into a low estimated value of this person's time. Yet, an alternative (and arguably more plausible) interpretation is possible; namely, if the location decision is made collectively, it may be that this person has a low bargaining power.

All in all, it seems likely that the final decision is not driven only by the spouses' constraints or preferences, but also by the distribution of power within the household. Even casual empiricism suggests that, typically, location choices involve complex, intra-family decision processes. Most families include several active individuals, whose respective workplace locations can be expected to play a key role in the household decision. In fact, within family economics, deciding on a residential location is commonly given as an example of complex, intra-family issue in which individual bargaining powers, as related to the characteristics of each household member, are likely to play a crucial role (see for instance Lundberg and Pollak, 2003).

The goal of the present paper is precisely to propose a more realistic description of decision making, and to explore how such reconsiderations could improve modelling and possibly change the basic estimates of these models, as for the estimation of the value of time.[2] The main innovation of our paper, thus, is to concentrate on the intra-household residential location decisions made *collectively* instead of individually (taking as fixed the other long term decisions). Specifically, we provide a non unitary analysis of location decisions, based on a collective representation of household decision processes. In our model, location choice depends not only on the spouses' respective transportation costs, but also on their respective bargaining powers. In particular, an individual may experience long commutes to his/her working place either because his/her value of time is low *or* because his/her bargaining position within the household is weak - or any combination of these two effects.

We first show that a model of this type can be estimated on actual (revealed preference) data. Next, we take a specific formulation to a rich data

[2] In a related framework, Picard, Dantan and de Palma (2018) have recently studied mode choice decisions with the couples. Using a collective model, they show that mode choice (who is using the car if there is a single car) and conditional on both spouse using the same car, who is driving, depends on the bargaining power of each spouse. Mode choice is not explicitely described in this paper.

set about residential location of French couples living and working in the Paris area. Our conclusions are clear-cut: we find that bargaining aspects play a statistically significant role in these decisions. Consequently, an estimation based on a unitary specification would be misspecified, and we show they lead to biased results (specifically, biased values of time). In addition, we identify several variables that influence each spouse's bargaining power. In particular, we find that the spouses' nationalities and education levels, as well as the age difference between them, play a crucial role in determining respective weights in the decision process.

The model is described in the next section. We then discuss the econometric specification. Section 4 considers identification issues. Data are described in Section 5 and results are provided in Section 6. Section 7 concludes.

2 The Household Location Model

2.1 Framework

We consider a multi person household, in which both the husband (denoted by the superscript m) and the wife (denoted by f) are working and receive a total income y. Throughout the article, we consider the workplace locations of both spouses as given, and analyze the residential location decision conditional on them; more on this below. This setting, which is discussed in the next subsection, seems particularly relevant for an empirical work on French data, given the relative rigidity of the French labor market. At any possible dwelling location, spouses enjoy the consumption of dwelling characteristics and local amenities, denoted by a vector Z. Location also affects individual commuting times t^g and the corresponding commuting costs function $c^g(t^g)$, $g = m,\ f$. This function is positive and strictly increasing in the commuting time. Finally, spouses also consume other commodities. Since, in the data set we use, nothing is known about individual consumptions, we simply assume that the corresponding commodities are publicly consumed in the household, and intervene in the spouses' utilities through the same, additive term. In practice, individual utilities are therefore assumed additively separable, of the form:

$$U^g = V(Z, y, P) - c^g(t^g),\ g = m,\ f,$$

where $V(Z, y, P)$ is the indirect utility corresponding to the household's consumption; this depends on the local amenities associated with housing consumption, on household's income y, and on the price of housing P. This formulation reflects the cross-sectional nature of our analysis, whereby the prices of all commodities (except housing) do not vary over the sample: the corresponding consumptions can be aggregated into a single, Hicksian composite good, the price of which can be normalized to 1.[3]

2.2 Timing and commitment

In our model, the household's decision process is in three stages. First, spouses each choose their job (and the corresponding job location); in the second stage, they choose a dwelling location, and the corresponding housing price; lastly, they decide on the consumption of other goods. Given the nature of our data, we cannot address the first decision; therefore we concentrate on the second one, that is on the choice of a dwelling location conditional on each individual's workplace location.

As emphasized by Lundberg and Pollak (2003), commitment issues play a crucial role in location decisions. Under full commitment, for instance, the first stage choices will entail commitment on the future dwelling location; say, a spouse who really wants to take some new job may accept, as a counterpart, to incur a larger fraction of the transportation costs. However, the existing literature emphasizes the difficulties involved in implementing and enforcing such long term commitments. Our approach, therefore, is mostly agnostic. That is, we allow the conditional choice of residence, given the spouses' workplace locations, to be the outcome of a second period renegotiation. In particular, we are interested in analyzing the impact of the spouse's respective bargaining powers on the final location decision.

In practice, we therefore consider the household's negotiation process at the beginning of stage 2. Following the collective approach, we do not assume a specific bargaining framework; instead, we consider a general, collective formulation that captures two basic insights, namely (i) that the outcome is Pareto efficient at stage 2, i.e. in an 'interim' sense, and (ii) that any variable ('distribution factor' in the collective terminology) that affects a spouse's bargaining power may influence the final outcome through its impact on the Pareto weights.

[3] One could, in principle, consider individual, private consumptions as well. In practice, however, in the absence of exclusive goods, such a model would be only partly identified (see for instance Chiappori and Ekeland, 2009) - hence our more parsimonious choice.

The household location decision, then, maximizes the weighted sum

$$\begin{aligned} W^c\left(Z,y,P,t^m,t^f,\mu\right) &= (1-\mu)\left[V\left(Z,y,P\right)-c^m\left(t^m\right)\right]+\mu\left[V\left(Z,y,P\right)-c^f\left(t^f\right)\right] \\ &= V\left(Z,y,P\right)-(1-\mu)\,c^m\left(t^m\right)-\mu c^f\left(t^f\right). \end{aligned} \quad (1)$$

It is crucial to note that the Pareto weights μ and $1-\mu$, $\mu \in [0,1]$ reflect the spouses's respective weights in the negotiation; they therefore depend on all variables that may influence the members' bargaining powers.

3 Econometric specification

3.1 The parametric form

The Pareto weight μ measures the woman's bargaining power. In the parametric specification, we assume the following formulation for the couple's utility of public goods:

$$V\left(Z,y,P\right)=\sum_k \nu_k\left(y,X^m,X^f,X^c\right)Z_k-\nu_P\left(y\right)\ln P, \quad (2)$$

where X^m, X^f and X^c respectively denote characteristics of the husband, the wife and the household (not specific to any spouse, such as marital status or number of children). It is here assumed that the price elasticity depends on household income, through the ν_P function. The ν_k function denotes the couple's marginal utility for dwelling (or location) characteristic Z_k. The dependence of ν_P and ν_k functions on income and/or individual/household characteristics reflects heterogeneity of preferences.

Individual commuting costs are assumed to be quadratic functions of commuting times:

$$c^g\left(t^g\right)=a^g\left(X^g,X^c\right)t^g+b^g\left(X^g,X^c\right)\left(t^g\right)^2,\ g=m,f, \quad (3)$$

with $a^g\left(X^g,X^c\right)$ and $b^g\left(X^g,X^c\right)$ measuring individual-specific value of time. Note that the marginal value of time is either increasing or decreasing (i.e. the commuting cost function is either convex or concave), depending on the sign of $b^g\left(X^g,X^c\right)$. A linear formulation is assumed for $a^g\left(X^g,X^c\right)$ and $b^g\left(X^g,X^c\right)$:

$$\begin{aligned} a^g\left(X^g,X^c\right) &= a_0^g+\textstyle\sum_k a_k^g X_k^g+\sum_l a_l^g X_l^c, \quad g=m,f \\ b^g\left(X^g,X^c\right) &= b_0^g+\textstyle\sum_k b_k^g X_k^g+\sum_l b_l^g X_l^c, \quad g=m,f. \end{aligned} \quad (4)$$

Finally, we use a linear formulation for the Pareto weight:

$$\mu = \mu_0 + \sum_k \left(\mu_k^f X_k^f + \mu_k^m X_k^m \right) + \sum_l \mu_l^c X_l^c. \tag{5}$$

As usual, μ_0 is not identified (and welfare irrelevant) and can be normalized to 1/2. Note that variables (if any) from the vector X_k^m, X_k^f, X_k^c entering Equation (5) but not Equation (4) can be considered as distribution factors (see Chiappori, Fortin and Lacroix, 2002).

Therefore, the negotiation for household location conditional on workplaces solves the following program (see Equation (1)):

$$\max_{\left(P,Z,t^m,t^f\right)\in\mathcal{A}} \left\{ V\left(Z,y,P\right) - \left(1-\mu\right) c^m\left(t^m\right) - \mu c^f\left(t^f\right) \right\},$$

where $\mathcal{A}$ denotes the set of feasible allocations $\left(P, Z, t^m, t^f\right)$, corresponding to available locations.

Using parametric specifications (1), (2), (3) and (4), we get for the welfare function to maximize:

$$\begin{array}{l} W^c\left(Z,y,P,t^m,t^f,\mu\right) = \\ \sum_k v_k\left(y,X^c,X^m,X^f\right) Z_k - v_P\left(y\right)\ln P \\ -\left[1/2 - \sum_k \left(\mu_k^f X_k^f + \mu_k^m X_k^m\right) - \sum_l \mu_l^c X_l^c\right] \bullet \\ \left[\begin{array}{c} \left\{a_0^m + \sum_k a_k^m X_k^m + \sum_l a_l^m X_l^c\right\} t^m \\ + \left\{b_0^m + \sum_k b_k^m X_k^m + \sum_l b_l^m X_l^c\right\} \left(t^m\right)^2 \end{array}\right] \\ -\left[1/2 + \sum_k \left(\mu_k^f X_k^f + \mu_k^m X_k^m\right) + \sum_l \mu_l^c X_l^c\right] \bullet \\ \left[\begin{array}{c} \left\{a_0^f + \sum_k a_k^f X_k^f + \sum_l a_l^f X_l^c\right\} t^f \\ + \left\{b_0^f + \sum_k b_k^f X_k^f + \sum_l b_l^f X_l^c\right\} \left(t^f\right)^2 \end{array}\right] \end{array}.$$

3.2 The stochastic setting

Turning to the stochastic specification, we denote by γ the vector of parameters $\mu_l^c, \mu_k^g, a_k^g, b_k^g, a_l^g, b_l^g,\ g = m, f$, and we consider a finite number of alternative locations j, referred later on as 'pseudo communes' (and broadly corresponding to a US county although in general much smaller). The parametric specification of the stochastic utility of alternative location j for household with characteristics y and $X = \left(X^m, X^f, X^c\right)$ is:

$$W_j^c + \varepsilon_j^c = W\left(P_j, Z_j, t_j^m, t_j^f; \gamma, y, X\right) + \varepsilon_j^c =$$
$$\sum_k v_k\left(y, X^m, X^f, X^c\right) Z_{k,j} - v_P(y) \ln P_j$$
$$-\left[1/2 - \sum_k \left(\mu_k^f X_k^f - \mu_k^m X_k^m\right) - \sum_l \mu_l^c X_l^c\right] \bullet$$
$$\left[\left\{a_0^m + \sum_k a_k^m X_k^m + \sum_l a_l^m X_l^c\right\} t_j^m + \left\{b_0^m + \sum_k b_k^m X_k^m + \sum_l b_l^m X_l^c\right\} \left(t_j^m\right)^2\right]$$
$$-\left[1/2 + \sum_k \left(\mu_k^f X_k^f - \mu_k^m X_k^m\right) + \sum_l \mu_l^c X_l^c\right] \bullet$$
$$\left[\left\{a_0^f + \sum_k a_k^f X_k^f + \sum_l a_l^f X_l^c\right\} t_j^f + \left\{b_0^f + \sum_k b_k^f X_k^f + \sum_l b_l^f X_l^c\right\} \left(t_j^f\right)^2\right] + \varepsilon_j^c. \tag{6}$$

The residual terms ε_j correspond to omitted variables, specification errors (from the econometrician) and optimization errors (from the household). They are assumed to be i.i.d. accross couples, with standard Gumble distribution, which leads to a Multinomial Logit formulation. If J denotes the total number of alternatives j (pseudo communes), then the probability for the couple c to choose the commune j is given by the Multinomial Logit formula (see, McFadden, 2001):

$$\Pi_j^c = \frac{\exp\left(W_j^c\right)}{\Sigma_{j'=1}^J \exp\left(W_{j'}^c\right)}. \tag{7}$$

It is well known that, in the multinomial logit model with additive random utility linear in the parameters, the likelihood function is quasi concave (see, McFadden, 1974), so the maximization of the likelihood is straightforward. However, Equation (6) is not linear in the components of the γ vector, and the likelihood function proves to be very difficult to maximize directly. In the next Section, we provide a tractable procedure to handle this estimation.

4 Parametric Estimation

We propose a two-step estimation procedure based on a minimum distance estimator. In the first step, we estimate the unconstrained parameters, while in the second step, we take account of the constraints (specified later on) using the minimum estimator method summarized in Subsection 4.2.

4.1 Reduced Form and Structural Parameters

The first step consists in developing Equation (6) in order to get an expression linear in the new parameters, β, to be estimated. These new parameters are defined more precisely below.

Developing Equation (6) leads to terms quadratic in γ, multiplied by terms quadratic in X, denoted by XX, multiplied by $t_j^m, t_j^f, \left(t_j^m\right)^2$ and $\left(t_j^f\right)^2$, respectively:

$$\begin{aligned} W\left(P_j, Z_j, t_j^m, t_j^f; \gamma, y, X\right) &= \sum_k v_k\left(y, X^m, X^f, X^c\right) Z_{k,j} - v_P(y) \ln P_j \\ &+\beta_1(\gamma) XX \cdot t_j^m + \beta_2(\gamma) XX \cdot \left(t_j^m\right)^2 \qquad (8) \\ &+\beta_3(\gamma) XX \cdot t_j^f + \beta_4(\gamma) XX \cdot \left(t_j^f\right)^2 . \end{aligned}$$

These quadratic functions, and especially the vector of parameters to be estimated, $\beta(\gamma) = (\beta_1(\gamma), \beta_2(\gamma), \beta_3(\gamma), \beta_4(\gamma))$, are detailed in Subsection 4.3 for two examples and the final specification. The right-hand side of Equation (8) is of the form:

$$\begin{aligned} \tilde{W}\left(P_j, Z_j, t_j^m, t_j^f; \tilde{\beta}, y, X\right) &= \sum_k v_k\left(y, X^m, X^f, X^c\right) Z_{k,j} - v_P(y) \ln P_j \\ &+\tilde{\beta}_1 XX \cdot t_j^m + \tilde{\beta}_2 XX \cdot \left(t_j^m\right)^2 \\ &+\tilde{\beta}_3 XX \cdot t_j^f + \tilde{\beta}_4 XX \cdot \left(t_j^f\right)^2 . \end{aligned}$$

The vector $\beta(\gamma)$ belongs to a set $\mathcal{S}_C$ of constrained parameters, while $\widetilde{\beta}$ is extended to an unconstrained set $\mathcal{S}_U$, with $\mathcal{S}_C \subset \mathcal{S}_U$; and $\tilde{\beta}_k = \beta_k(\gamma)$ $(k = 1, 2, 3, 4)$ on $\mathcal{S}_C$.

Let $D_C = \dim \mathcal{S}_C$ denote the number of structural parameters (dimension of the γ vector) and $D_U = \dim \mathcal{S}_U$ denote the number of elements of the unconstrained $\tilde{\beta} = \left(\tilde{\beta}_1, \tilde{\beta}_2, \tilde{\beta}_3, \tilde{\beta}_4\right)$ vector. Note that the function $\tilde{W}\left(P_j, Z_j, t_j^m, t_j^f; \tilde{\beta}, y, X\right)$ is defined for $\tilde{\beta} \in \mathbb{R}^{D_U}$. Therefore, the likelihood function is defined over the unrestricted set $\mathcal{S}_U = \mathbb{R}^{D_U}$; the unconstrained vector $\tilde{\beta} \in \mathbb{R}^{D_U}$ is estimated using a standard maximum likelihood technique. Moreover, there exists a one to one mapping between the set $\mathbb{R}^{D_C}$ of structural parameters γ and the set $\mathcal{S}_C$ of *constrained* parameters $\beta = (\beta_1, \beta_2, \beta_3, \beta_4)$.

4.2 Minimum Distance Estimator

The second step, the minimum distance estimator, consists in minimizing the distance between the estimated unconstrained vectors of parameters $\hat{\beta} \in \mathcal{S}_U$, and their constrained counterparts $\beta(\gamma) \in \mathcal{S}_C$. This distance is weighted by the inverse of the variance-covariance matrix, V, estimated for $\hat{\beta}$. We therefore wish to solve the following problem:

$$\underset{\beta \in \mathcal{S}_C}{Min} \left[\left(\hat{\beta} - \beta \right)^t V^{-1} \left(\hat{\beta} - \beta \right) \right],$$

or equivalently:

$$\underset{\gamma \in \mathbb{R}^{D_C}}{Min} \left[\left(\hat{\beta} - \beta(\gamma) \right)^t V^{-1} \left(\hat{\beta} - \beta(\gamma) \right) \right].$$

The solution of this problem is denoted by γ^*, and the optimized objective function is denoted by

$$\chi^2 = \left(\hat{\beta} - \beta(\gamma^*) \right)^t V^{-1} \left(\hat{\beta} - \beta(\gamma^*) \right).$$

Under the null hypothesis of Pareto optimality and correct functional specification of bargaining power and spouses utilities, $\beta \in \mathcal{S}_C$ and the χ^2 statistic has a chi-squared distribution with $D_U - D_C$ degrees of freedom. Under the alternative assumption, household location is not optimized in the medium run. Household location then depends on the same variables XX, but $\beta \notin \mathcal{S}_C$ is not Pareto-optimal, the value of χ^2 is statistically larger. The χ^2 statistic can therefore be used to test partial medium-term Pareto optimality of household location.

It is important to point out that the reduced form and structural estimations have different convergence properties. Likelihood is quasi-concave in $\tilde{\beta}$, so the estimation of the unrestricted $\tilde{\beta}$ parameters is straightforward by maximum likelihood. By contrast, the minimization of the distance between the unconstrained $\hat{\beta}$ parameters and the constrained parameters $\beta(\gamma)$ is less well behaved, and exhibits several local minima. We therefore used a numerical optimization algorithm in order to find the global minimum of the distance function.

It is theoretically possible to compute an asymptotic variance for γ, based on the delta method, but the sample size proved to be too small to rely on an asymptotic estimator given the non linearity of the problem. Therefore, we choose to rely on a bootstrap technique to compute the variance of the structural parameters. We carried out 200 bootstrap replications and computed the mean, the variance and the 95% confidence interval of the estimated structural parameters.

4.3 Empirical Specification

We illustrate our methodology with two simple examples before turning to the final, more involved, specification.

4.3.1 One Continuous Variable for Each Spouse: Age

We begin illustrating our minimum distance estimator approach with only one continuous variable used to explain both the bargaining power and the Value of Time. For example, with the age of each spouse (A^m for the husband's age and A^f for the wife's age)[4] the structural model is written as follows:

$$\begin{aligned} & W\left(P_j, Z_j, t_j^m, t_j^f; \gamma, y, X\right) = V\left(Z, y, P\right) \\ & -\left[\tfrac{1}{2} - \mu_1 A^m - \mu_2 A^f\right] \bullet \left[\left\{a_0^m + a_1^m A^m\right\} t^m + \left\{b_0^m + b_1^m A^m\right\} (t^m)^2\right] \\ & -\left[\tfrac{1}{2} + \mu_1 A^m + \mu_2 A^f\right] \bullet \left[\left\{a_0^f + a_1^f A^f\right\} t^f + \left\{b_0^f + b_1^f A^f\right\} (t^f)^2\right]. \end{aligned}$$

There are therefore 10 structural parameters, whereas the estimated model comprises 20 parameters (see Appendix 8.1.1):

$$\begin{aligned} & W\left(P_j, Z_j, t_j^m, t_j^f; \gamma, y, X\right) = V\left(Z, y, P\right) \\ & +\beta_{10} t^m + \beta_{11} A^f t^m + \beta_{12} A^m A^f t^m + \beta_{13} A^m t^m + \beta_{14} (A^m)^2 t^m \\ & +\beta_{20} t^f + \beta_{21} A^m t^f + \beta_{22} A^m A^f t^f + \beta_{23} A^f t^f + \beta_{24} (A^f)^2 t^f \\ & +\beta_{30} (t^m)^2 + \beta_{31} A^f (t^m)^2 + \beta_{32} A^m A^f (t^m)^2 + \beta_{33} A^m (t^m)^2 + \beta_{34} (A^m)^2 (t^m)^2 \\ & +\beta_{40} (t^f)^2 + \beta_{41} A^m (t^f)^2 + \beta_{42} A^m A^f (t^f)^2 + \beta_{43} A^f (t^f)^2 + \beta_{44} (A^f)^2 (t^f)^2. \end{aligned}$$

In this case, the unconstrained parameters belong to the unconstrained space $\mathcal{S}_U = \mathbb{R}^{20}$, whereas the constrained parameters $\beta(\gamma)$ belong to a constrained space $\mathcal{S}_C$ which is isomorphic to the structural parameters space,

[4] More precisely, $A^g = (Age^g - 40)/10,\ g = m, f$. With this specification, $\mu = \mu_0 = 1/2$ when both spouses are 40 years old, which is more relevant than normalizing to $\mu = 1/2$ when both spouses are just born (0 years old). The division by 10 is just to multiply associated parameters by 10 (and multiply by 100 parameters associated with age squared), in order to get parameters not too close to 0, which can be interpreted in terms of marginal changes when one spouse is 10 years older.

here $\mathbb{R}^{10}$. Equating the terms of the two polynomials leads to a system (S) of 20 equations. This system leads to 10 independent constraints and 10 equations allowing to express the structural parameters as functions of the estimated parameters.

4.3.2 One Dummy Variable for Each Spouse: Nationality

We now illustrate the case in which only one dummy variable is used to explain the bargaining power. If we use, for example, the nationality of each spouse (foreigner or not), that is N^m for the husband's nationality and N^f for the wife's nationality, the main difference with the previous case is that, for dummy variables N^g, $g = m, f$, we have: $(N^g)^2 = N^g$. We still have 10 structural parameters, but we now have 16 estimated parameters (see Appendix 8.1.2 for the identification rule):

$$\begin{aligned} W\left(P_j, Z_j, t_j^m, t_j^f; \gamma, y, X\right) &= V(Z, y, P) + \beta_{10}t^m + \beta_{11}N^f t^m + \beta_{12}N^m N^f t^m \\ &+\beta_{13}N^m t^m + \beta_{20}t^f + \beta_{21}N^m t^f + \beta_{22}N^m N^f t^f + \beta_{23}N^f t^f \\ &+\beta_{30}(t^m)^2 + \beta_{31}N^f(t^m)^2 + \beta_{32}N^m N^f(t^m)^2 + \beta_{33}N^m(t^m)^2 \\ &+\beta_{40}(t^f)^2 + \beta_{41}N^m(t^f)^2 + \beta_{42}N^m N^f(t^f)^2 + \beta_{43}N^f(t^f)^2. \end{aligned}$$

We now turn to the final specification chosen.

4.3.3 Final Specification

In Table (1), the three left colums list the potential explanatory variables and their level of definition (HouseHold or individual); the five right columns correspond to the different components of the γ vector and the variables (lines) with a "x" have been tested for inclusion in the corresponding component. The check marks (✓) indicate the variables retained in the final model, based on their significance level. We tested several specifications for the education, profession and number of children by age category variables: four education categories (secondary, undergraduate and graduate), six profession categories (independent, managerial, intermediate and employee), and four age categories for the children (from 0 to 3, 4 to 6 and 7 to 11 years old). Graduate education was the only significant category both for the man and the woman. The independent job category was significant for both geders, whereas the "managerial or intermediate" job category was significant for the man only. Finally, the significant age category fot children was $4 - 11$.

Different variables were tested to explain bargaining power and values of time of spouses. These are listed in Table (1). The variables with a check mark (✓) are included in the final specification. We tested several categories for the education (secondary, undergraduate and graduate), profession (self-employed, managerial, intermediate and employee) and number of children variables. Graduate education and self-employed profession were the significant categories for both the man and the woman; the managerial and intermediate categories combined together were significant for the man only. Finally, three age categories were tested for the number of children: from 0 to 3, 4 to 6 and 7 to 11 years old. The pooled age category from 4 to 11 years old was significant for woman's Value Of Time. Marital status and tenure status were also tested to explain bargaining power, but they appeared to have no significant efffect on bargaining power, *ceteris paribus*.

	Level		Bargaining Power	Value Of Time			
				Male		Female	
	HH	indiv	μ	a^m	b^m	a^f	b^f
Age		x	x	x✓	x	x✓	x
Age difference		x	x✓				
Education		x	x	x✓	x	x✓	x
Educ. comparison		x	x✓				
Profession		x	x	x✓	x✓	x✓	x✓
Nationality		x	x	x✓	x	x✓	x
Nat. comprison		x	x✓				
Part-time work		x		x✓	x	x✓	x
# children	x					x✓	x
Marital status	x		x				
Tenure status	x		x				

Table 1: Potential and selected determinants of bargaining power and values of time

Different variables can influence either the bargaining power μ, or the values of time $a^g(.)$ and $b^g(.)$, $g = m, f$. We find that three variables significantly affect the bargaining power of spouses and were chosen for the final specification: the nationality of the spouses (two dummy variables: French woman married to a foreign man and foreign woman married to a French man), the age difference of the couple (woman age - man age), and the education of the spouses (two dummy variables: woman more educated than her partner and vice-versa).

Six variables significantly affect the values of time (VOT) of the man and the woman: age, nationality, education (graduated), profession (self-employed, middle and senior management), part time job, and number of children from 3 to 11 years old. Table (2) presents the notations for the final selection of variables.

The upper part of Table (2) describes the variables selected in the final bagaining power specification, whereas the lower part describes the variables selected in the final Value Of Time specification. Variables with a double chack (✓✓) are included in the specification of the quadratic term (coefficients of $(t^m)^2$ and $(t^f)^2$.

We tested different specifications for these variables. Based on these tests, the squared specification of age was chosen only for the VOT of the man; the middle and senior management profession significantly affect the VOT of the man only, and the number of young children (3 to 11 years old) affect the VOT of the woman only.

Notation	Bargaining Power		Variable
N_1	✓		(French woman,Foreign man)
N_2	✓		(French man,Foreign woman)
D	✓		Age difference (woman-man)
M^f	✓		f more educated than m
M^m	✓		m more educated than f
	Value Of Time		Individual Variable
	Man	Woman	(g index omitted)
A	✓	✓	Age
A^2	✓		Age squared
N	✓	✓	Nationality (Foreigner dummy)
E	✓	✓	Graduate
C_1	✓✓	✓✓	Independent
C_2	✓		Manager or intermediate
P	✓	✓	Part time
k		✓	Number of children $4-11$

Table 2: Notation for selected determinants of bargaining power and values of time in the final specification

The final specification of the structural model is therefore written as follows:

$$
\begin{aligned}
& W\left(P_j, Z_j, t_j^m, t_j^f; \gamma, y, X\right) = V(Z, y, P) \\
& \quad - \left[\tfrac{1}{2} - \mu_1 N_1 - \mu_2 N_2 - \mu_3 D - \mu_4 M^f - \mu_5 M^m\right] \bullet \\
& \quad \left[\begin{array}{l} \left\{a_0 + a_1 A^m + a_2 \left(A^m\right)^2 + a_3 N^m + a_4 E^m + a_5 C_1^m + a_6 C_2^m + a_7 P^m\right\} t^m \\ \quad + \left\{b_0^m + b_1^m C_1^m\right\} \left(t^m\right)^2 \end{array}\right] \\
& \quad - \left[\tfrac{1}{2} + \mu_1 N_1 + \mu_2 N_2 + \mu_3 D + \mu_4 M^f + \mu_5 M^m\right] \bullet \\
& \quad \left[\begin{array}{l} \left\{a_0^f + a_1^f A^f + a_3^f N^f + a_4^f E^f + a_5^f C_1^f + a_7^f P^f + a_8^f K\right\} t^f \\ \quad + \left\{b_0^f + b_1^f C_1^f\right\} \left(t^f\right)^2 \end{array}\right].
\end{aligned}
$$

This final specification comprises 24 structural parameters and the estimated model comprises 108 parameters. The specification of the estimated model as well as the identification rule can be found in Appendix 8.1.3. It takes into account the dependence between the variables used in the specification of the bargaining power and those used in the specification of the commuting cost function. For example, $N_1 = (1 - N^m) N^f$, which implies that $N_1 N^f = (1 - N^m) \left(N^f\right)^2 = (1 - N^m) N^f = N_1$. Furthermore, $N_1 N^m = (1 - N^m) N^f N^m = 0$.

5 Data

5.1 Data source

In this paper we use the last French General (exhaustive) census survey conducted in Paris Region in 1999.[5] The Paris Region (11 million inhabitants in 1999) contains 1,300 *communes* (municipalities). Inside Paris, a commune corresponds to an arrondissement (there are 20 arrondissements in Paris, and 2.1 million inhabitants in 1999). Given that one fourth of the 1,300 communes contain a too small number of inhabitants and job positions, we grouped small adjacent communes of the same commuting or transportation zone, in line with the Paris region transportation zones, to end up with 725 *pseudo-communes*. The census data was aggregated from the original 1,300 communes to the 725 pseudo-communes and the prices and local amenities variables were computed at this aggregated level. This

[5] Since then, the methodology for data collection has changed, and only a fraction of the population (about 20%) is observed each each year.

aggregation reduces the potential errors in the computation of travel times. Origin-Destination matrices, or O-D matrices of travel time by public transportation were estimated from the regional transportation planning department transport model MODUS.[6] O-D matrices of travel time by private car were computed using the dynamic transport network model METROPOLIS (see de Palma, Marchal and Nesterov, 1997). The computation of the equilibrium in this dynamic model relies on the O-D matrix of number of individuals living in location i, and working at location j.

Household and workplace location locations are observed at the commune level in a 5% sample representative of the working population. Since our focus is on bargaining over commuting times, we restrict the sample to couples in which both spouses work, ending up with a sample of $60,798$ households containing two-earner couples. For each household, we consider subsets of alternatives according to the importance sampling method (see Ben-Akiva and Lerman, 1985). Each subset contains the chosen alternative plus 9 unchosen alternatives (pseudo-communes) randomly generated. The weights are proportional to the number of dwellings in the pseudo-commune, for the dwelling type (flat versus house) and tenure status (renter versus owner) of the household considered. We thus consider four real-estate sub-markets and do not assume that prices clear the market.

5.2 Descriptive statistics

Descriptive statistics presented in Table (3) will help us to draw a picture of the typical two-earner couple living and working in Paris region. In this typical couple, the woman is two years younger than her husband, namely 39 versus 41 years old. Most of the couples (86%) are composed of two French spouses. Both spouses have the same education level in 59% of the couples in our sample, whereas the woman is more educated than the man in 22% of the couples. In our sample, 24% of the men have a blue collar job and 25% of the women have a part time job. Finally, the average number of children (of all ages) of the two-earner couples is 1.29.

[6]MODUS, defined by the Paris, Ile-de-France urban planning agency, IAU-IDF.

		Man	Woman
Age	Mean	41.48	39.41
	Std Dev	9.49	9.30
Natio-nality	French	54,085	54,810
		88.96%	*90.15%*
	Foreign	6,713	5,988
		11.04%	*9.85%*
Prof-ession	Indep-endent	5,182	1,886
		8.52%	*3.10%*
	Manager	17,413	10,747
		28.64%	*17.68%*
	Interme-diary	15,392	17,381
		25.32%	*28.59%*
	Emp-loyee	8,190	27,257
		13.47%	*44.83%*
	Blue Collar	14,621	3,527
		24.05%	*5.80%*
Educ-ation	Elemen-tary	32,123	28,757
		52.84%	*47.30%*
	Secon-dary	8,161	10,222
		13.42%	*16.81%*
	Under-graduate	7,022	10,033
		11.55%	*16.50%*
	Graduate	13,492	11,786
		22.19%	*19.39%*
Job Type	Part Time	2,302	15,179
		7.79%	*24.97%*
	Full Time	58,496	45,619
		96.21%	*75.03%*

		Couple
Educ. comparison	Woman more Edu.	13,425
		22.08%
	Man more Edu.	11,578
		19.04%
	Same Edu. level	35,795
		58.88%
Nationality Mix	Both French	52,523
		86.39%
	(French W. Foreign M.)	1,562
		2.57%
	(Foreign W. French M.)	2,287
		3.76%
	Both Foreigners	4,426
		7.28%

		Mean	Std Dev
Age Diff.	W.-M.	-2.07	4.84
Number of Children	All ages	1.29	1.10
	0 to 3	0.20	0.44
	4 to 6	0.18	0.41
	7 to 11	0.29	0.56

Table 3: Descriptive Statistics

6 Results

6.1 Reduced form estimation

The first step of our minimum distance approach consists in the estimation of the unconstrained parameters ($\hat{\beta} \in \mathcal{S}_U$) of the residential location choice model (given spouses' workplaces) using a Multinomial Logit Model (MNL).

We consider two types of dwellings: flat versus house and two different tenure status: renter versus owner. We assume that each household is associated to one of the four combinations of dwelling type and tenure status. Therefore, there are 4 dwelling sub-markets denoted by s (renting flat, renting house, owning a flat and owning a house, i.e. $s = 1...4$), and we add the upper-level index s to the expected utility of the couple, $W_j^{c,s}$ defined in Equation (6).

We have no information regarding the dwellings intrinsic characteristics. As a result, all housing units i of the same type s located in a particular location j (pseudo-commune) are considered to be statistically identical, and to provide the same expected utility $W_i^{c,s} = W_j^{c,s}$ to a given couple c, $c = 1 \ldots 60,798$.

Let D_j^s represent the number of dwellings of type s in location j. Then $I^s = \sum_{j=1}^{J} D_j^s$ represents the total number of dwellings of type s in the whole region. The probability that household c of type s chooses a specific dwelling i is given by:

$$\Pi_i^{c,s} = \frac{\exp\left(W_i^{c,s}\right)}{\sum_{i'=1}^{I^s} \exp\left(W_{i'}^{c,s}\right)},$$

and it is the same for all the D_j^s dwellings of type s located in j. Therefore, the probability $\Pi_j^{c,s}$ that household c of type s chooses location j is (see also Ackerberg and Rysman, 2018) :

$$\begin{aligned} \Pi_j^{c,s} &= D_j^s \Pi_i^{c,s} = \frac{D_j^s \exp\left(W_j^{c,s}\right)}{\sum_{j'=1}^{J}\left(\sum_{i' \text{ in } j'} \exp\left(W_{i'}^{c,s}\right)\right)} = \frac{D_j^s \exp\left(W_j^{c,s}\right)}{\sum_{j'=1}^{J}\left(D_{j'}^s \exp\left(W_{j'}^{c,s}\right)\right)} \\ &= \frac{\exp\left(W_j^{c,s} + \log\left(D_j^s\right)\right)}{\sum_{j'=1}^{J} \exp\left(W_{j'}^{c,s} + \log\left(D_{j'}^s\right)\right)}. \end{aligned} \tag{9}$$

In the above equation, the coefficient of the $\log\left(D_j^s\right)$ variable is equal to 1, and the variance of the residuals is to be estimated.

In practice, however, we shall use a slightly more general form by introducing a coefficient for the $\log\left(D_j^s\right)$ variable. Indeed, the vector of coefficients associated to $W_j^{c,s}, \log\left(D_j^s\right)$ and the standard deviation of the residuals is identified only up to a multiplicative constant. Here, we assume, as is usually done, that the variance of the residuals is equal to $\pi^2/6$; as a consequence, the coefficient of $\log\left(D_j^s\right)$ may not be equal to 1. In addition, alternatives for each household were generated using importance sampling. Importance sampling improves the efficiency of estimates, and usually induces a bias in the coefficients, which can be corrected by adding a $\log\left(D_j^s\right)$ term, with a coefficient to be estimated (see Ben-Akiva and Lerman, 1985 for details). Finally, households may have specific preferences for the size of the pseudo commune, and the coefficient associated to $\log\left(D_j\right)$ is to be estimated. As a result, the coefficient of $\log\left(D_j\right)$ reflects a mix of these 3 effects (size effect in Equation 9, correction for importance sampling, preferences for pseudo commune size), and there is no way to disentangle these 3 effects. Therefore we will not attempt to interpret this coefficient, which appears in the first block of Table (1).

We now turn to the results of the MNL estimation of the $\hat{\beta} \in \mathcal{S}_U$ parameters. The estimated coefficients of the 108 parameters corresponding to the unconstrained model are not presented here and they would be difficult to interpret given the large number of interaction terms. Our MNL choice model contains not only these 108 parameters, but also all the determinants of the residential location choice, that is, local amenities, neighboring effects or prices included in the $V\left(Z, y, P\right)$ function. Among all these variables, only the price is specific to type s, and we decided to estimate price coefficients specific to each type s. For all other amenity variables, we decided to impose the same coefficients for the four types, in order to reduce the total number of coefficients to be estimated.

Table (1) and Table (2) provide the estimation results concerning local amenities and price. Given the number of variables and the resulting size of the tables, results of the MNL estimations are presented in the Appendix. The McFadden's likelihood-ratio index (ratio of the log likelihood with intercepts only and the log likelihood with all the explanatory variables) of the MNL estimation is 61.18% , which is large for a MNL model. This indicates that the choice of residential location is well explained by the explanatory variables included in the model.[7]

In the second block of Table (1), we find evidence that, when couples move, they have a strong tendency to stay within the same *département*, which explains the highly significant positive coefficient for the dummy variable 'Same department as the reference (1990)'. This dummy variable indicates that the alternative considered is located in the same department

[7]It should however be remebered that, in discrete choice models, this pseudo R-squared measure cannot be interpretated as the proportion of the variation of utility that can be explained by the local amenities, commuting times and other explanatory variables, as it would be the case in a linear model.

as the pseudo-commune in which the couple lived in 1990, i.e. year of the previous census. The second line in this block indicates that, ceteris paribus, households are not attracted by Paris. The negative coefficient for the 'Paris' dummy is not surprising since most of the characteristics attracting people in Paris are already taken into account by the local amenities variables such as the number of rail and subway stations or neighborhood composition.

The third block of Table (1) shows that the preference for pseudo-communes with more rail stations increases with the number of cars owned by the household. This is consistent with the fact that, in Paris region, personal car is a complement rather than a substitute to RER and suburbs train. Indeed, people who commute using such medium distance public transport tend to connect to the stations by car. By constrast, the fourth block of Table (1) shows that the preference for pseudo-communes with more subway stations decreases with the number of cars owned by the household. This is consistent with the fact that people who commute by subway typically don't use a car.

The negative coefficient of the '%Noisy Area' in the fifth block of Table (1) indicates that, as expected, households tend to be repelled by a noisy environment. By contrast, households enjoy living in close to forests, water or cultural spaces. Large families (with more than 2 children) also enjoy living close to parks, whereas the probability that a couple without children or with only one child locates in a pseudo-commune is a decreasing function of the fraction of the pseudo-commune covered by parks. This last result may reflect an eviction effect. It may also reflect the specific case of 'Bois de Boulogne' and 'Bois de Vincennes', which cover a large fraction of the land of the corresponding communes.

The sixth and seventh blocks of Table (1) shows that rich households are less sensitive to dwelling prices that poor or middel-income households. Price elasticity even becomes positive above some income threshold specific to each real estate submarket. For example, this threshold is $\exp(3.4151/3.675) = 2.5327$, meaning that households which are at least 2.5 times richer than the average Parisian household prefer living in more expensive locations, probably because they prefer neighbours able to afford living there (in a way which is not captured by variables described in Table (2)). Globally, owners are more sensitive to prices than renters, and households that are looking for a flat are more sensitive to prices than those looking for a house.

Table (2) provides the parameter estimates of neighborhood effects and globally show a string taste for social homogamy. The first block of Table (2) shows that French households (HHs) tend to avoid communes with a large fraction of foreigners and this avoiding behavior increases with the education of household head (HHH). Furthermore, foreign households tends to prefer locations with more foreigners, except if HHH is at least undergraduate. This means that not only the more educated French households dislike foreign neighbors but also that the most educated foreigners avoid other foreigners.

Similarly, the third block of Table (2) shows that low-income households dislike low-income neighbors, whereas wealthier households prefer neighbors with the same income profile. The fourth block of Table (2) shows that couples without children prefer neighbors without children and symmetrically, couples with children prefer neighbors with children.

Finally, the fifth block of Table (2) shows that households prefer communes where they will find households of the same age and this preference intensifies with age.

6.2 Structural model estimation

The second step of our minimum distance approach consists in minimizing the distance between the estimated unconstrained vectors of parameters $\hat{\beta} \in \mathcal{S}_U$, and their constrained counterparts $\beta(\gamma) \in \mathcal{S}_C$ as explained in Section 4.2. The minimization of the distance between the unconstrained and the constrained parameters is achieved using a numerical optimization algorithm in order to find the global minimum of the distance function. We carried out 200 bootstrap replications and computed the mean, the variance, and the confidence interval of the estimated structural parameters. The mean value of the test statistic is 424.44, which is very large for a χ^2 distribution with 83 degrees of freedom ($108 - 24 - 1 = 83$), so the null hypothesis is clearly rejected. However, this result holds for a given set of explanatory variables and optimality is very much rejected when the bargaining power coefficients are not taken into account. The distributions of the distance statistics when considering bargaining power or not are presented in Table (4). In this case, the mean value of the test statistic goes up to $33,72121$ which clearly shows that neglecting the bargaining power leads to biased measures of values of time. The value of time is a key component in any mobility or residential location study. A a consequence, these biases for the value of time that we have proved empirically are likely to have severe consequence in many applications, and in particular for cost-benefit analysis studied. The magnitude of these biases remain to be quantified.

	Structural model	
	With Bargaining Power	Without Bargaining Power
Bootstrap replications	200	200
Minimum distance	278.518	26,213.476
Maximum distance	630.192	34,819.876
Mean distance	424.440	33,721.209
Std Dev of distance	60.823	830.577

Table 4: Distribution of the Distance Statistic

Results of our empirical specification are presented in Table (5) for the bargaining power estimates and in Table (6) for the estimates of the values of time. Each spouse's bargaining power is normalized to 1/2 in the reference case (couple with the same nationality, no age difference, and equally educated), 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.

	Estim.	Av. BS	Std Err	t-Stat	95% CI Inf	95% CI Sup
μ_1 (French W., Foreign M.)	3.837	3.716	1.618	2.372	0.707	5.669
μ_2 (Foreign W., French M.)	-7.178	-7.249	2.182	-3.290	-10.928	-4.187
μ_3 (Age difference)	0.128	0.113	0.083	1.530	-0.055	0.209
μ_4 (Woman more Edu.)	4.478	4.245	0.980	4.568	2.507	5.703
μ_4 (Man more Edu.)	-3.146	-3.526	0.684	-4.600	-4.746	-2.562

Table 5: Bargaining Power Estimates (expressed in percentage)

The estimation results presented in Table (5) show that the spouses' age, education difference, and the nationalities play a crucial role in determining the bargaining power. The magnitude of the effects depends on the covariates considered, but some general patterns emerge. The bargaining power of the women increases if she is French and married to a foreigner and decreases if she is foreigner and married to a French. Considering two French women, one is married to a non-French husband and the second married to a French one, our estimates show that, all other things being equal, the bargaining power of the wife in the first couple is around 3.84% larger than that of the wife in the second couple. By contrast, considering two French men, one married to a non-French wife and the second to a French wife, our estimates show that, all other things being equal, the bargaining power of the wife in the first couple is around 7.18% smaller than that of the wife in the second couple.

Consider now two men of the same age; the wife of the first man is ten years older than him, while the second's has the same age as him. Our estimates show that, all other things being equal, the bargaining power of the first wife is around 1.28% larger than that of the wife in the second couple. The fact that the bargaining power of the wife increases if she is older than her husband reflects the additional experience she has acquired with age.

Moreover, the bargaining power of the wife increases if she is more educated than her husband. Considering two equally educated men, assuming that the wife of the first man is more educated than the wife of the second, our estimates show that, all other things being equal, the bargaining power of the first wife is around 4.48% larger than that of the second wife. Conversely, if a man is more educated than his wife, then her bargaining power will be smaller of about 3.14%.

We turn now to the results of the parameter estimates of the commuting cost variables presented in Table (6). Almost all the variables are significant at a 5% level. The value of time is a decreasing function of age for the men. As expected, foreigners value less than French men their commuting time. Men with graduated education will value 0.790 more their commuting time than the less educated men. Men working independently will attach more value to their commuting time than the others (except for managerial and intermediate jobs). Note that this is the only variable that significantly affect the value of time in a quadratic fashion. This could be easily explained by the fact that this line of work requires much more commuting (mostly by private car) than all the others. However, it is the man working as managers or holding and intermediate job that attach more value to their commuting time, it's estimate amounts to 6.337, which is the variable with the strongest effect for men in our results. Finally, men working part time ascribe more value to the commuting time.

We now turn to study the estimates for the value of time of the women. Women with graduated education will value 2.196 more their commuting time than the less educated women. Note that this effect is almost three times more important for graduate women than for graduate men. As for the men, women working independently will attach more value to their commuting time than the others and as above this is the only variable that significantly affects the value of time in a quadratic fashion. Women working part time ascribe more value to the commuting time than the other women and those that have children from 4 to 11 years old attach less value to their commuting time than the other mothers.

		Estim.	Av. BS	Std Err	t-Stat	95% CI Inf	95% CI Sup
t^m	a_0^m Constant	7.921	7.925	0.154	51.504	7.645	8.177
	a_1^m Age	-0.676	-0.667	0.060	-11.264	-0.775	-0.577
	a_2^m Age^2	0.280	0.279	0.059	4.784	0.157	0.358
	a_3^m Nationality	-0.585	-0.584	0.112	-5.237	-0.807	-0.410
	a_4^m Graduate	0.790	0.776	0.194	4.062	0.388	1.049
	a_5^m Self-Empl.	1.614	1.611	0.164	9.863	1.315	1.843
	a_6^m Manager, Inter.	6.337	6.310	0.525	12.060	5.521	7.168
	a_7^m Part-Time	1.246	1.240	0.308	4.041	0.612	1.655
$(t^m)^2$	b_0^m Constant	-2.237	-2.266	0.064	-35.207	-2.377	-2.191
	b_1^m Self-Empl.	-2.479	-2.453	0.366	-6.774	-3.338	-1.994
t^f	a_0^f Constant	10.317	10.358	0.152	67.826	10.049	10.582
	a_1^f Age	0.256	0.250	0.060	4.255	0.145	0.344
	a_3^f Nationality	2.011	1.957	0.238	8.439	1.541	2.362
	a_4^f Graduate	2.196	2.198	0.142	15.440	1.894	2.409
	a_5^f Self-Empl.	3.339	3.444	0.765	4.367	2.113	4.498
	a_7^f Part-Time	0.360	0.356	0.115	3.127	0.204	0.525
	a_6^f Children 4-11	-0.042	-0.054	0.069	-0.601	-0.156	0.031
$(t^f)^2$	b_0^f Constant	-1.833	-1.838	0.042	-43.883	-1.930	-1.777
	b_1^f Self-Empl.	-0.754	-0.763	0.291	-2.590	-1.244	-0.334

Table 6: Commuting Cost Structural Parameters Estimates

Commuting cost is an increasing and convex function of commuting time (Utility is decreasing and concave) for both spouses. Figures presented in the Appendix show curves of the disutility of time for different examples. These figures show that neglecting the bargaining power would lead to inaccurate values of time of the man and the woman. When comparing the results, values of time would be underestimated, for instance, by around 7.1% for a woman married to a foreigner, like in Figure (2), or by 11.7% for a woman more educated than her husband, like in Figure (3), at one hour of commute.

7 Conclusions

The main purpose of this paper was to construct and estimate a model of location decision based on a non unitary representation of household residential location behavior and choice. Specifically, we provide a non unitary framework in which decisions reflect not only individual preferences and costs, but also the distribution of bargaining power within the household. Bargaining power has been omitted so far in the urban economics and transport literature. We show that such a model can be identified on existing data, and that the shift from a unitary to a collective formalization deeply affects the estimation of key parameters. In particular, in standard approaches in the transport literature, which neglect issues related to respective bargaining powers, introduce several bias for the computation of the values of time of the man and of the woman. These biases have important consequences (in particular for Cost-Benefit Analysis studies), which remain to be quantified.

We offer a new method that provides an unbiased measure of the values of time. More specifically, using census data on Paris region, we were able to disentangle bargaining power from the values of time of spouses. In particular, we find that the spouses' nationalities and education levels, as well as the age difference between them, play a crucial role in determining respective weights in the decision process. Lastly, and from a more methodological perspective, our approach investigates the application of collective models in the context of discrete choices. As such, we hope it can lead to further progress in other areas of household behavior.

Clearly, several other decisions in the couple, need a similar treatment. For example, departure time decisions in the commuting trip, residential location together with mode choice and car ownership, tenure choices are interrelated decisions, which are the outcome of bargaining within the couple. They all have a strong spatial component that they share with the model presented in this paper.

References

ACKERBERG, Daniel A. and Marc RYSMAN. 2018. Unobserved product differentiation in discrete choice models: estimating price elasticities and welfare effects, RAND Journal of Economics (forthcoming).

ANAS, Alex and Richard ARNOTT. 1994. The Chicago prototype housing market model with tenure choice and its policy applications. Journal of Housing Research, 23-90.

BHAT, Chandra R. and Ram PENDYALA. 2005. Modeling intra-household interactions and group decision-making. Transportation, 32(5), 443-448.

BEN-AKIVA, Moshe E. and Steven LERMAN. 1985. Discrete choice analysis: theory and application to travel demand. MIT press.

BROWNING, Martin, Pierre-André CHIAPPORI and Yoram WEISS. 2014. Economics of the Family. Cambridge University Press.

CHIAPPORI, Pierre-André. Rational household labor supply. 1988. Econometrica, 63-90.

CHIAPPORI, Pierre-André. 1992. Collective labor supply and welfare. Journal of political Economy, 100(3), 437-467.

CHIAPPORI, Pierre-André, Bernard FORTIN and Guy LACROIX. 2002. Marriage market, divorce legislation, and household labor supply. Journal of political Economy, 110(1), 37-72.

CHIAPPORI, Pierre-André and Ivar EKELAND. 2009. The Microeconomics of Efficient Group Behavior: Identification 1. Econometrica, 77(3), 763-799.

DE PALMA, André, Robin LINDSEY, Emile QUINET and Roger Vickerman (eds.). 2011. A handbook of transport economics. Edward Elgar Publishing.

DE PALMA, André, Fabrice MARCHAL and Yurii NESTEROV. 1997. METROPOLIS: Modular system for dynamic traffic simulation. Transportation Research Record: Journal of the Transportation Research Board, 1607, 178-184.

FUJITA, Masahisa and Jacques-François THISSE. 2013. Economics of agglomeration: cities, industrial location, and globalization. Cambridge university press.

GOURIEROUX, Christian, Alain MONFORT and Alain TROGNON. 1985. Moindres carrés asymptotiques. In : Annales de l'INSEE. Institut national de la statistique et des études économiques. 91-122.

KODDE, David A., Franz, C. PLAM and Gerard PFANN. 1991. A. Asymptotic least-squares estimation efficiency considerations and applications. Journal of Applied Econometrics, 5(3), 229-243.

MCFADDEN, Daniel. 1974. The measurement of urban travel demand. Journal of public economics, 3(4), 303-328.

LERMAN, Steve. 1976. Location, housing, automobile ownership, and mode to work: a joint choice model. Transportation Research Record, 610, 6-11.

MCFADDEN, Daniel. 1978. Modeling the choice of residential location. Transportation Research Record, 673.

MCFADDEN, Daniel. Economic choices. 2001. American economic review, 91(3), 351-378.

LUNDBERG, Shelly and Robert POLLAK. 2003. Efficiency in marriage. Review of Economics of the Household, 1(3), 153-167.

PICARD, Nathalie, Sophie DANTAN and André DE PALMA. 2018. Mobility decisions within couples. Theory and Decision, 84(2), 149-180.

PROOST, Stef and Jacques-François THISSE. 2015. Cities, Regional Development, and Transport. National Research University, Higher School of Economics.

TIMMERMANS, Harry JP and Junyi ZHANG. 2009. Modeling household activity travel behavior: Examples of state of the art modeling approaches and research agenda. Transportation Research Part B: Methodological, 43(2), 187-190.

WADDELL, Paul. 2002. UrbanSim: Modeling urban development for land use, transportation, and environmental planning. Journal of the American planning association, 68(3), 297-314.

8 Appendix

8.1 Identification rules

8.1.1 One continuous variable for each spouse : Age

The system to be solved is:

$$(S):\left\{\begin{array}{lcl}
\beta_{10} & = & -\frac{1}{2}a_0^m \\
\beta_{11} & = & \mu_2 a_0^m \\
\beta_{12} & = & \mu_2 a_1^m \\
\beta_{13} & = & \frac{1}{2}a_1^m + \mu_1 a_0^m \\
\beta_{14} & = & \mu_1 a_1^m \\
\beta_{20} & = & -\frac{1}{2}a_0^f \\
\beta_{21} & = & \mu_1 a_0^f \\
\beta_{22} & = & \mu_1 a_1^f \\
\beta_{23} & = & \frac{1}{2}a_1^f + \mu_2 a_0^f \\
\beta_{24} & = & \mu_2 a_1^f \\
\beta_{30} & = & -\frac{1}{2}b_0^m \\
\beta_{31} & = & \mu_2 b_0^m \\
\beta_{32} & = & \mu_2 b_1^m \\
\beta_{33} & = & \frac{1}{2}b_1^m + \mu_1 b_0^m \\
\beta_{34} & = & \mu_1 b_1^m \\
\beta_{40} & = & -\frac{1}{2}b_0^f \\
\beta_{41} & = & \mu_1 b_0^f \\
\beta_{42} & = & \mu_1 b_1^f \\
\beta_{43} & = & \frac{1}{2}b_1^f + \mu_2 b_0^f \\
\beta_{44} & = & \mu_2 b_1^f
\end{array}\right.$$

8.1.2 One dummy variable for each spouse : Nationality

The system to be solved is:

$$
(S):\left\{\begin{array}{lcl}
\beta_{10} & = & -\frac{1}{2}a_0^m \\
\beta_{11} & = & \mu_2 a_0^m \\
\beta_{12} & = & \mu_2 a_1^m \\
\beta_{13} & = & \frac{1}{2}a_1^m + \mu_1 a_0^m + \mu_1 a_1^m \\
\beta_{20} & = & -\frac{1}{2}a_0^f \\
\beta_{21} & = & \mu_1 a_0^f \\
\beta_{22} & = & \mu_1 a_1^f \\
\beta_{23} & = & \frac{1}{2}a_1^f + \mu_2 a_0^f + \mu_2 a_1^f \\
\beta_{30} & = & -\frac{1}{2}b_0^m \\
\beta_{31} & = & \mu_2 b_0^m \\
\beta_{32} & = & \mu_2 b_1^m \\
\beta_{33} & = & \frac{1}{2}b_1^m + \mu_1 b_0^m + \mu_1 b_1^m \\
\beta_{40} & = & -\frac{1}{2}b_0^f \\
\beta_{41} & = & \mu_1 b_0^f \\
\beta_{42} & = & \mu_1 b_1^f \\
\beta_{43} & = & \frac{1}{2}b_1^f + \mu_2 b_0^f + \mu_2 b_1^f
\end{array}\right.
$$

8.1.3 Final Specification

The final specification comprises 24 structural parameters and the estimated model comprises 108 parameters.

$$
\begin{aligned}
U^c \;=\; & V(P,Z) + \beta_{10}t^m + \beta_{11}A^m t^m + \beta_{12}(A^m)^2 t^m + \beta_{13}N^m t^m + \beta_{14}E^m t^m \\
& + \beta_{15}C_1^m t^m + \beta_{16}C_2^m t^m + \beta_{17}P^m t^m + \beta_{18}N_1 t^m + \beta_{19}N_1 A^m t^m + \beta_{110}N_1(A^m)^2 t^m \\
& + \beta_{111}N_1 E^m t^m + \beta_{112}N_1 C_1^m t^m + \beta_{113}N_1 C_2^m t^m + \beta_{114}N_1 P^m t^m \\
& + \beta_{115}N_2 t^m + \beta_{116}N_2 A^m t^m + \beta_{117}N_2(A^m)^2 t^m + \beta_{118}N_2 E^m t^m \\
& + \beta_{119}N_2 C_1^m t^m + \beta_{120}N_2 C_2^m t^m + \beta_{121}N_2 P^m t^m + \beta_{122}D t^m + \beta_{123}D A^m t^m \\
& + \beta_{124}D(A^m)^2 t^m + \beta_{125}D N^m t^m + \beta_{126}D E^m t^m + \beta_{127}D C_1^m t^m \\
& + \beta_{128}D C_2^m t^m + \beta_{129}D P^m t^m + \beta_{130}M^f t^m + \beta_{131}M^f A^m t^m + \beta_{132}M^f (A^m)^2 t^m \\
& + \beta_{133}M^f N^m t^m + \beta_{134}M^f E^m t^m + \beta_{135}M^f C_1^m t^m + \beta_{136}M^f C_2^m t^m + \beta_{137}M^f P^m t^m \\
& + \beta_{138}M^m t^m + \beta_{139}M^m A^m t^m + \beta_{140}M^m (A^m)^2 t^m + \beta_{141}M^m N^m t^m \\
& + \beta_{142}M^m C_1^m t^m + \beta_{143}M^m C_2^m t^m + \beta_{144}M^m P^m t^m \qquad (10) \\
& + \beta_{20}t^f + \beta_{21}A^f t^f + \beta_{22}N^f t^f + \beta_{23}E^f t^f + \beta_{24}C_1^f t^f + \beta_{25}P^f t^f + \beta_{26}K t^f \qquad (11) \\
& + \beta_{27}N_1 t^f + \beta_{28}N_1 A^f t^f + \beta_{29}N_1 E^f t^f + \beta_{210}N_1 C_1^f t^f + \beta_{211}N_1 P^f t^f \\
& + \beta_{212}N_1 K t^f + \beta_{213}N_2 t^f + \beta_{214}N_2 A^f t^f + \beta_{215}N_2 E^f t^f + \beta_{216}N_2 C_1^f t^f \\
& + \beta_{217}N_2 P^f t^f + \beta_{218}N_2 K t^f + \beta_{219}D t^f + \beta_{220}D A^f t^f + \beta_{221}D N^f t^f \qquad (12) \\
& + \beta_{222}D E^f t^f + \beta_{223}D C_1^f t^f + \beta_{224}D P^f t^f + \beta_{225}D K t^f \qquad (13) \\
& + \beta_{226}M^f t^f + \beta_{227}M^f A^f t^f + \beta_{228}M^f N^f t^f + \beta_{229}M^f C_1^f t^f \\
& + \beta_{230}M^f P^f t^f + \beta_{231}M^f K t^f + \beta_{232}M^m t^f + \beta_{233}M^m A^f t^f + \beta_{234}M^m N^f t^f \\
& + \beta_{235}M^m E^f t^f + \beta_{236}M^m C_1^f t^f + \beta_{237}M^m P^f t^f + \beta_{238}M^m K t^f \\
& + \beta_{30}b_0^m (t^m)^2 + \beta_{31}N_1 (t^m)^2 + \beta_{32} (t^m)^2 + \beta_{33}D (t^m)^2 + \beta_{34}M^f (t^m)^2 \qquad (14) \\
& + \beta_{35}M^m (t^m)^2 + \beta_{36}C_1^m (t^m)^2 + \beta_{37}N_1 C_1^m (t^m)^2 + \beta_{38}N_2 C_1^m (t^m)^2 \\
& + \beta_{39}D C_1^m (t^m)^2 + \beta_{310}M^f C_1^m (t^m)^2 + \beta_{311}M^m C_1^m (t^m)^2 \\
& + \beta_{40} \left(t^f\right)^2 + \beta_{41}N_1 \left(t^f\right)^2 + \beta_{42}N_2 \left(t^f\right)^2 + \beta_{43}D \left(t^f\right)^2 + \beta_{44}M^f \left(t^f\right)^2 \qquad (15) \\
& + \beta_{45}M^m \left(t^f\right)^2 + \beta_{46}C_1^f \left(t^f\right)^2 + \beta_{47}N_1 C_1^f \left(t^f\right)^2 + \beta_{48}N_2 C_1^f \left(t^f\right)^2 \\
& + \beta_{49}D C_1^f \left(t^f\right)^2 + \beta_{410}M^f C_1^f \left(t^f\right)^2 + \beta_{411}M^m C_1^f \left(t^f\right)^2
\end{aligned}
$$

The system to be solved is:

$$
(S):\left\{
\begin{array}{lll}
\beta_{10} & = & -\frac{1}{2}a_0^m \\
\beta_{11} & = & -\frac{1}{2}a_1^m \\
\beta_{12} & = & -\frac{1}{2}a_2^m \\
\beta_{13} & = & -\frac{1}{2}a_3^m \\
\beta_{14} & = & -\frac{1}{2}a_4^m \\
\beta_{15} & = & -\frac{1}{2}a_5^m \\
\beta_{16} & = & -\frac{1}{2}a_6^m \\
\beta_{17} & = & -\frac{1}{2}a_7^m \\
\beta_{18} & = & +\mu_1 a_0^m \\
\beta_{19} & = & +\mu_1 a_1^m \\
\beta_{110} & = & +\mu_1 a_2^m \\
\beta_{111} & = & +\mu_1 a_4^m \\
\beta_{112} & = & +\mu_1 a_5^m \\
\beta_{113} & = & +\mu_1 a_6^m \\
\beta_{114} & = & +\mu_1 a_7^m \\
\beta_{115} & = & +\mu_2 a_0^m \\
\beta_{116} & = & +\mu_2 a_1^m \\
\beta_{117} & = & +\mu_2 a_2^m \\
\beta_{118} & = & +\mu_2 a_4^m \\
\beta_{119} & = & +\mu_2 a_5^m \\
\beta_{120} & = & +\mu_2 a_6^m \\
\beta_{121} & = & +\mu_2 a_7^m \\
\beta_{122} & = & +\mu_3 a_0^m \\
\beta_{123} & = & +\mu_3 a_1^m \\
\beta_{124} & = & +\mu_3 a_2^m \\
\beta_{125} & = & +\mu_3 a_3^m \\
\beta_{126} & = & +\mu_3 a_4^m
\end{array}
\right.
\begin{array}{lll}
\beta_{127} & = & +\mu_3 a_5^m \\
\beta_{128} & = & +\mu_3 a_6^m \\
\beta_{129} & = & +\mu_3 a_7^m \\
\beta_{130} & = & +\mu_4 a_0^m \\
\beta_{131} & = & +\mu_4 a_1^m \\
\beta_{132} & = & +\mu_4 a_2^m \\
\beta_{133} & = & +\mu_4 a_3^m \\
\beta_{134} & = & +\mu_4 a_4^m \\
\beta_{135} & = & +\mu_4 a_5^m \\
\beta_{136} & = & +\mu_4 a_6^m \\
\beta_{137} & = & +\mu_4 a_7^m \\
\beta_{138} & = & +\mu_5 a_0^m \\
\beta_{139} & = & +\mu_5 a_1^m \\
\beta_{140} & = & +\mu_5 a_2^m \\
\beta_{141} & = & +\mu_5 a_3^m \\
\beta_{142} & = & +\mu_5 a_5^m \\
\beta_{143} & = & +\mu_5 a_6^m \\
\beta_{144} & = & +\mu_5 a_7^m \\
\beta_{20} & = & -\mu_0 a_0^f \\
\beta_{21} & = & -\mu_0 a_1^f \\
\beta_{22} & = & -\mu_0 a_3^f \\
\beta_{23} & = & -\mu_0 a_4^f \\
\beta_{24} & = & -\mu_0 a_5^f \\
\beta_{25} & = & -\mu_0 a_7^f \\
\beta_{26} & = & -\mu_0 a_8^f \\
\beta_{27} & = & -\mu_1 a_0^f \\
\beta_{28} & = & -\mu_1 a_1^f
\end{array}
\begin{array}{lll}
\beta_{29} & = & -\mu_1 a_4^f \\
\beta_{210} & = & -\mu_1 a_5^f \\
\beta_{211} & = & -\mu_1 a_7^f \\
\beta_{212} & = & -\mu_1 a_8^f \\
\beta_{213} & = & -\mu_2 a_0^f \\
\beta_{214} & = & -\mu_2 a_1^f \\
\beta_{215} & = & -\mu_2 a_4^f \\
\beta_{216} & = & -\mu_2 a_5^f \\
\beta_{217} & = & -\mu_2 a_7^f \\
\beta_{218} & = & -\mu_2 a_8^f \\
\beta_{219} & = & -\mu_3 a_0^f \\
\beta_{220} & = & -\mu_3 a_1^f \\
\beta_{221} & = & -\mu_3 a_3^f \\
\beta_{222} & = & -\mu_3 a_4^f \\
\beta_{223} & = & -\mu_3 a_5^f \\
\beta_{224} & = & -\mu_3 a_7^f \\
\beta_{225} & = & -\mu_3 a_8^f \\
\beta_{226} & = & -\mu_4 a_0^f \\
\beta_{227} & = & -\mu_4 a_1^f \\
\beta_{228} & = & -\mu_4 a_3^f \\
\beta_{229} & = & -\mu_4 a_5^f \\
\beta_{230} & = & -\mu_4 a_7^f \\
\beta_{231} & = & -\mu_4 a_8^f \\
\beta_{232} & = & -\mu_5 a_0^f \\
\beta_{233} & = & -\mu_5 a_1^f \\
\beta_{234} & = & -\mu_5 a_3^f \\
\beta_{235} & = & -\mu_5 a_4^f
\end{array}
\begin{array}{lll}
\beta_{236} & = & -\mu_5 a_5^f \\
\beta_{237} & = & -\mu_5 a_7^f \\
\beta_{238} & = & -\mu_5 a_8^f \\
\beta_{30} & = & -\frac{1}{2}b_0^m \\
\beta_{31} & = & +\mu_1 b_0^m \\
\beta_{32} & = & +\mu_2 b_0^m \\
\beta_{33} & = & +\mu_3 b_0^m \\
\beta_{34} & = & +\mu_4 b_0^m \\
\beta_{35} & = & +\mu_5 b_0^m \\
\beta_{36} & = & -\frac{1}{2}b_1^m \\
\beta_{37} & = & +\mu_1 b_1^m \\
\beta_{38} & = & +\mu_2 b_1^m \\
\beta_{39} & = & +\mu_3 b_1^m \\
\beta_{310} & = & +\mu_4 b_1^m \\
\beta_{311} & = & +\mu_5 b_1^m \\
\beta_{40} & = & -\mu_0 b_0^f \\
\beta_{41} & = & -\mu_1 b_0^f \\
\beta_{42} & = & -\mu_2 b_0^f \\
\beta_{43} & = & -\mu_3 b_0^f \\
\beta_{44} & = & -\mu_4 b_0^f \\
\beta_{45} & = & -\mu_5 b_0^f \\
\beta_{46} & = & -\mu_0 b_1^f \\
\beta_{47} & = & -\mu_1 b_1^f \\
\beta_{48} & = & -\mu_2 b_1^f \\
\beta_{49} & = & -\mu_3 b_1^f \\
\beta_{410} & = & -\mu_4 b_1^f \\
\beta_{411} & = & -\mu_5 b_1^f
\end{array}
$$

Table 1: Results of the Multinomial logit: local amenities (I)

Parameter	**Estimate**	**Std Error**	**t Value**	**Pr > |t|**
1. **- log(Nb Houses Owned)* Own* House**	-0.0528	0.0174	-3.04	0.0024
log(Nb Flats Owned)* Own * Flat	-0.0358	0.0179	-2	0.0459
log(Nb Houses Rented)* Rent *House	-0.0465	0.044	-1.06	0.2906
log(Nb Flats Rented)* Rent * Flat	-0.039	0.0137	-2.86	0.0043
2. **- Same department as in 1990)**	2.6743	0.0173	154.66	<.0001
Paris	-1.279	0.0442	-28.97	<.0001
3. **- Nb Rail Stations* No Car**				

Table 2: Results of the Multinomial logit: local amenities (II)

Parameter	**Estimate**	**Std Error**	**t Value**	**Pr > |t|**

[1] Priority education zones (*Zones d'éducation prioritaires*).

[2] HHs accounts for Household.

[3] HHH accounts for Household Head.

8.2 Reduced form estimations

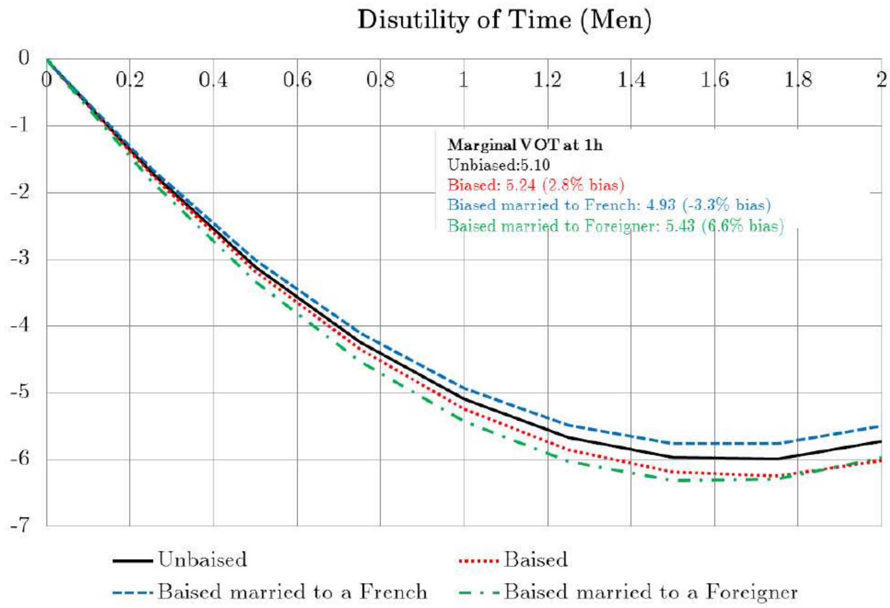

Figure 1: Disutility of commuting time for men, by nationality of wife

8.3 Magnitude of bias in VOT

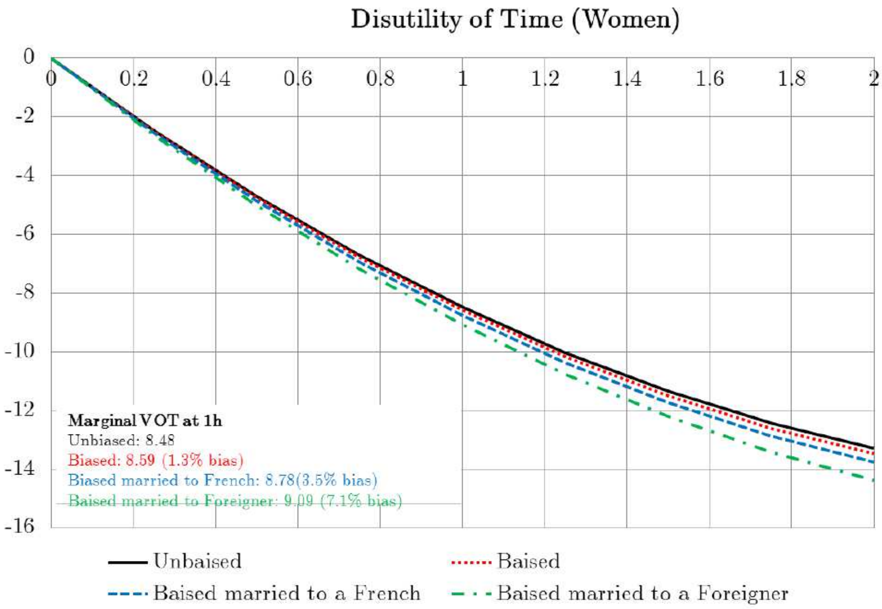

Figure 2: Disutility of commuting time for women, by nationality of husband

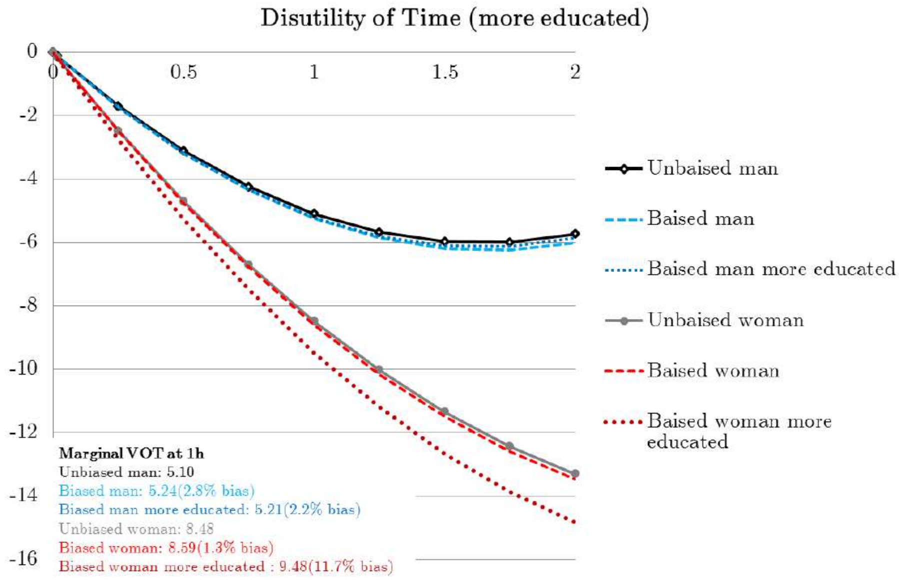

Figure 3: Disutility of commuting time, by gender and education