Commuting Time and Accessibility in a Joint Residential Location, Workplace, and Job Type Choice Model*

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Abstract

The effect of an individual-specific measure of accessibility to jobs is analyzed using a three-level nested logit model of residential location, workplace, and job type choice. This measure takes into account the attractiveness of different job types when the workplace choice is anticipated in the residential location decision. The model allows for variation in the preferences for job types across individuals and accounts for individual heterogeneity of preferences at each choice level in the following dimensions: education, age, gender and children. Using data from the Greater Paris Area, estimation results indicate that the individual-specific accessibility measure is an important determinant of the residential location choice and its effect strongly differ along the life cycle. Results also show that the job type attractiveness measure is a more significant predictor of workplace locations than the standard measures.

Keywords: residential location, location choice, nested logit, decision tree, Greater Paris Area.
JEL Codes: R21, C35, C51.

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1 Introduction

Residential location choice models have historically been estimated conditional on workplace, or vice versa. The first discrete choice models applied to residential location (Lerman, 1976; McFadden, 1978; Anas, 1981) borrowed from the Alonso-Muth-Mills literature on monocentric models, the assumption of exogenous determination of workplace location (Alonso, 1964; Muth, 1969; Mills, 1972). The interdependency between residential and workplace location was subject of interested during the late 70s, with the monocentric model extensions allowing simultaneous choice of workplace and residential location (Siegel, 1975; Simpson, 1980), and during the 80s, with the Linneman and Graves (1983) joint multinomial logit model on residence migration and job search.

The relevance of the exogenous workplace assumption in residential location choice models has been questioned from the early 90s following the empirical results of Waddell (1993). He obtained that a joint logit model of workplace, tenure and residence location outperformed a nested logit model of tenure and residential location choice conditional on workplace, using data of the metropolitan area of Dallas-Fort Worth (Texas, USA).

Subsequent applications and theoretical developments of residential location and workplace discrete choice models were made separately. On one hand, residential location choice models have been studied in relation, among other topics, with mobility or relocation (Clark and Davies Withers, 1999; Lee and Waddell, 2010), choice of travel mode (Eliasson and Mattsson, 2000), and accessibility (Ben-Akiva and Bowman, 1998). On the other hand, workplace location choice models have been mostly developed in the framework of aggregated travel models.

Explicit modeling of both residence and workplace choice can be then found within the multi-worker household discrete choice literature. In this field, researchers have been mainly interested in studying the influence of spouses' earnings and commuting time on the choice of the household residential location and spouses' specifics job locations (Freedman and Kern, 1997; Abraham and Hunt, 1997). Aditionally,Waddell et al. (2007) developed a discrete choice model of joint residence location and workplace adapting methods of market segmentation for one-worker households. Doing so, no a priori assumption has to be made on the exogenous choice (workplace first and residence after or vice versa) and the probability of making one choice before the other is determined as a function of the household characteristics.

It is important to highlight the literature on topics related to residential and workplace location, ranging from mobility and job uncertainty to risk and context on discrete choice models. Readers can survey the work of Crane (1996) and Kan (1999; 2002) for insights on modeling the effect of job changes on residential mobility, mobility expectation and commuting behavior. Introducing risk in discrete choice models is a relatively new area of interest among researchers. de Palma et al. (2008) offers a review on the implications of risk and uncertainty on the framework of discrete choice models and gives recommendations on its implementation. A recent research strand in choice models is pushing for the consideration of the effects of context on the process leading to a choice. For a review and illustration of *process and context* in choice models readers are referred to Ben-Akiva et al. (2012).

Commuting time is one of the main determinants of residential location. Household and workplace location are strongly interdependent choices because they jointly determine commuting time. The joint decision of residential location and workplace can be modeled as a two-stage decision process. In this decision process the second stage will be made conditional on the first stage; and the second stage will be anticipated in the first stage decision. For instance, households not only will choose a workplace conditional on their current residential location (second stage), but they will also consider the future changes on workplaces when choosing their residential location (first stage). In this configuration, actual travel time is relevant for explaining the workplace location choice (Levine, 1998; Abraham and Hunt, 1997) and accessibility measure is suitable for explaining the residential location choice (Anas, 1981; Ben-Akiva and Bowman, 1998; Levinson, 1998).

The recurrent question is: which decision is made first? Is it the choice of workplace or the choice of residence? The extent to which workplace location will depend on residential location, or conversely, varies along household's life cycle and depends on the dwelling and labor market rigidities, the diffusion of jobs, and the demographic and socioeconomic characteristics of households (Waddell, 1993; Waddell et al., 2007). The most widely used approach to model sequential decision-making processes in a (residential, workplace, mode) choice framework is to use discreet choice models. This will be the approach used here. Discreet choice models allow to study the location decision choice interdependency (nested models) and to model residence (and workplace) choice as a trade off among locational attributes that can vary across sociodemographic segments, as described in Sermons and Koppelman (2001) and Bhat and Guo (2004).

Despite the variety of contributions to the study of residential location, little has been said regarding the influence of job type attractiveness on the accessibility to jobs and therefore on the residential location and workplace choice when individuals are considered forward-looking. A three-level nested logit model is developed here, allowing to study, within a behavioral framework (RUM), the interdependency of residential location and workplace, while accounting for variation across individuals on the preferences for job types. In this model residential location is the upper level choice, and workplace location and job type are the middle and lower level choices, respectively. This nested structure allows to build an individual-specific accessibility measure, which corresponds to the expected maximum utility across all potential workplace locations (middle level). When considering accessibility to jobs, the choice of a particular workplace location is influenced by the relative distribution of jobs of the same type of the worker. Modeling the job type choice (lower level) allows for the computation of an individual-specific measure of attractiveness to job types (log-sum variable) that is used in the workplace location choice model.

In the next section, a three-level nested logit is developed to model the residential, workplace and job type choices. In this model, residential location and workplace choices are assumed to be dependent through the generalized cost of commuting. However, workplace and job type choices are supposed to be independent; all jobs of the same type located at a particular workplace are statistically equal. The data, the empirical methodology and the results are analyzed in Section 3 and 4. Finally, Section 5 concludes with comments on implications for urban models and future work.

2 Econometric Framework

The econometric framework for empirical analysis relies on a model that outlines a choice structure describing how individuals decide upon their residence location, workplace, and job type. Consider an individual denoted by n. She chooses a residential location i, a workplace j and a specific job l of type k in a set denoted by $\mathcal{E}_n$. Her utility U_n is then equal to:

$$U_n(l,k,j,i) = U_n^T(l,k) + U_n^W(j) + U_n^R(i) - C_n^{WR}(j,i) \quad \forall \quad (l,k,j,i) \in \mathcal{E}_n, \quad (1)$$

where $U_n^T(l,k)$, $U_n^W(j)$, and $U_n^R(i)$ denote, respectively, the utility specific to job l of type k, the utilty specific to the (job) location j, and the utility of living in (residential) location i. The term $C_n^{WR}(j,i)$ captures the generalized commuting cost between residential location i and workplace j.

The model concentrates on two major choices: the selection of a job, including its type and location, and the choice of residence. These choices are analized by a three-stage model solved by backward induction (See Figure 1). At the lower level, individual n chooses a specific job l of type k, conditional on workplace j and residential location i. At the middle level, individual n chooses a workplace j, conditional on residential location i and anticipating job l of type k. Finally, at the upper level individual n chooses a residential location i, anticipating the work related choices (j,k,l).

Figure 1 about here

Imposing additive separability between the deterministic and stochastic components of the utility, $U_n(l,k,j,i)$ can be decomposed as:

$$\begin{aligned} U_n(l,k,j,i) = {} & V_n^T(k) + \varepsilon_n^0(l) + \varepsilon_n^1(k) + V_n^W(j) + \varepsilon_n^2(j) \\ & + V_n^R(i) + \varepsilon_n^3(i) - C_n^{WR}(j,i) \qquad \forall \quad (l,k,j,i) \in \mathcal{E}_n. \end{aligned} \quad (2)$$

The utility $U_n^T(l,k)$ provided by job l of type k, in (1), is decomposed into a deterministic term $V_n^T(k)$ depending on type k and two random terms depending, respectively, on type k and job l. The term $V_n^T(k)$ represents the intrinsic preferences of individual n for job type k. A deterministic term specific to the utility of performing a specific job l could be added if job characteristics could be observed. This would add a level into the tree. The random terms, $\varepsilon_n^0(l)$ and $\varepsilon_n^1(k)$ represent, respectively, the idiosyncratic preference of individual n for the specific job l, and for the job type k.

The deterministic terms $V_n^W(j)$ and $V_n^R(i)$ measure respectively, the intrinsic preference for working in j and living in i. The choices of residence location and workplace are de facto related through the generalized commuting cost $C_n^{WR}(j,i)$ and cannot be assumed independent.

The random terms $\varepsilon_n^2(j)$ and $\varepsilon_n^3(i)$ correspond to the idiosyncratic preference of individual n for working in j and living in i. This corresponds to the unobserved heterogeneity of preferences. The random terms $\varepsilon_n^\bullet(\bullet)$ are assumed independent from each other for a given individual n and independent across individuals. An additional random term could be considered explicitly for the generalized commuting cost but it would be then impossible to disentangle it from $\varepsilon_n^2(j)$.

2.1 Lower Level Choice: Job Type

We assume that the preference of individual n for a specific job l of type k is independent from the job location. The preference is, for example, dependent on the expected wage, the number of working hours and other working conditions. All these characteristics significantly vary across job types and depend on individual characteristics such as gender, education or age, but there is no reason why they should depend on workplace or household location. This explains why $V_n^T(k)$ and $\varepsilon_n^0(l)$ do not depend on i or j.

As a result, the choice between the various jobs located in j only depends on individual characteristics and job types, and is not affected by local observed or unobserved characteristics of workplace and/or residential location. Indeed, using equation (2), the probability that individual n living in i prefers a job l of type k to a job l' of type k', both located in j, reduces to:

$$\begin{aligned}&\mathbb{P}\left(U_n(l,k,j,i) > U_n(l',k',j,i)\right)\\ =&\,\mathbb{P}\left(V_n^T(k)+\varepsilon_n^0(l)+\varepsilon_n^1(k) > V_n^T(k')+\varepsilon_n^0(l')+\varepsilon_n^1(k')\right).\end{aligned}$$

Let $\mathcal{T}_{kj}$ denote the set of jobs of type k available to an individual n choosing (job) location j; from utilities (1) and (2), the utility of job type $U_n^T(l,k)$ can be expressed as:

$$U_n^T(l,k) = V_n^T(k) + \varepsilon_n^0(l) + \varepsilon_n^1(k) \qquad \forall \ (l,k) \in \mathcal{T}_{kj}, \tag{3}$$

where $V_n^T(k)$ stands for the systematic preference of individual n for a job of type k, reflecting the observed heterogeneity in preferences for job types. Moreover, $\varepsilon_n^0(l)$ and $\varepsilon_n^1(k)$ capture respectively, the stochastic preferences of individual n for a specific job l and for a job type k (unobserved heterogeneity in preferences for job types). These errors are distributed so that $\max_{l,k\in\mathcal{T}_{kj}} U_n^T(l,k)$ is type I extreme value distributed with scaling factor μ^1. Therefore, the probability that individual n chooses a given job l of type k among all jobs available in j is then:

$$\mathbb{P}_n^1(l,k) = \frac{\exp\left(\dfrac{V_n^T(k)}{\mu^1}\right)}{\displaystyle\sum_{l,k'=1,\ldots,K\in\mathcal{T}_{k'j}} \exp\left(\dfrac{V_n^T(k')}{\mu^1}\right)} \qquad \forall \ (l,k) \in \mathcal{T}_{kj} \tag{4}$$

The choices of workplace and job type are assumed to be independent. Indeed, for the econometrician, all the jobs l of same type k and same location j are statistically identical and are only interdependent through the number of jobs of each type in location j labeled as N_{kj}. Since all the N_{kj} jobs of the same type k located in the same workplace j offer the same expected utility and therefore have the same probability, the probability that individual n chooses job type k (with $N_{kj} > 0$) among all jobs types available in j is:

$$\begin{aligned}\mathbb{P}_n^1(k) &= \frac{N_{kj}\exp\left(\dfrac{V_n^T(k)}{\mu^1}\right)}{\displaystyle\sum_{k'=1,\ldots,K;N_{k'j}>0} N_{k'j}\exp\left(\dfrac{V_n^T(k')}{\mu^1}\right)} \\ &= \frac{\exp\left(\dfrac{V_n^T(k)+\ln(N_{kj})}{\mu^1}\right)}{\displaystyle\sum_{k'=1,\ldots,K;N_{k'j}>0} \exp\left(\dfrac{V_n^T(k')+\ln(N_{k'j})}{\mu^1}\right)} \qquad \forall \ \ k \in \mathcal{T}_{kj}\end{aligned} \tag{5}$$

Note that allowing μ^1 to vary across individual types (and then be denoted by μ_n^1) amounts to considering heteroscedasticity in the unobserved heterogeneity of preferences for job types. Probability (**??**) then becomes:

$$\mathbb{P}_n^1 (k \in \mathcal{T}_{kj}) = \frac{\exp\left(\delta_n^1 + \delta_n^0 \ln (N_{kj})\right)}{\sum\limits_{k'=1,\ldots,K,N_{k'j>0}} \exp\left(\delta_n^1 + \delta_n^0 \ln \left(N_{k'j}\right)\right)}, \tag{6}$$

with $\delta_n^0 = \dfrac{1}{\mu_n^1}$ and $\delta_n^1 = \dfrac{V_n^T (k)}{\mu_n^1}$. This amounts to normalizing the scaling factor μ_n^1 of the lower level choice.

2.2 Middle Level Choice: Workplace Location

Solving by backward induction, workplace location is the middle choice of the three-level nested logit developed here. Let $\mathcal{L}$ denote the set of all potential (residential or workplace) locations. These locations are assumed available for each individual both for working and for living, so $(j, i) \in \mathcal{L}^2$. Considering the decision tree imposed here, an individual n will choose a workplace j conditional on her current residential location i, therefore actual travel time is relevant for explaining workplace location and the generalized travel cost, $C_n^{WR}(j, i)$, is considered in the middle level choice.

Using the assumptions above, from equation (1), the utility of workplace location j, can be expressed as:

$$U_n^W (j) - C_n^{WR} (j, i) = V_n^W (j; X_n, Z_j) - C_n^{WR} (j, i) + \varepsilon_n^2 (j) \quad \forall \ j \in \mathcal{L}, \tag{7}$$

where $V_n^W (j; X_n, Z_j)$ represents the measured utility of workplace j for an individual living at i.The utility of a workplace depends on individual characteristics X_n, and local amenities of workplace location, Z_j. Moreover, $C_n^{WR}(j, i)$ captures the generalized cost of commuting between residence location i and workplace j.

The error term $\varepsilon_n^2 (j)$ represents the residual preference of individual n attributable to workplace j, this error term is distributed so that $\max\limits_{j \in \mathcal{L}} U_n^W (j) + C_n^{WR}(j, i)$ is type I extreme value distributed with scale parameter μ_n^2 specific to individual n (See the discussion about μ_n^1 below equation (5)). The probability of choosing workplace location j is then:

$$\mathbb{P}_n^2(j) = \frac{\exp\left(\dfrac{V_n^W(j; X_n, Z_j) - C_n^{WR}(j,i) + S_n(j)}{\mu_n^2}\right)}{\sum_{j' \in \mathcal{L}} \exp\left(\dfrac{V_n^W(j'; X_n, Z_{j'}) - C_n^{WR}(j',i) + \varepsilon_n^2(j') + S_n(j')}{\mu_n^2}\right)} \quad \forall \ j \in \mathcal{L}, \tag{8}$$

where the term $S_n(j)$ is what we call the measure of attractiveness of locations j.that is, the expected utility resulting from the choice of the best job type conditional on working in location j; This terms corresponds to:

$$S_n(j) = \mu_n^1 \ln\left(\sum_{k'=1,\dots,K; N_{k'j}>0}^{K} \exp\left(\frac{\delta_n^1 + \delta_n^0 \ln\left(N_{k'j}\right)}{\mu_n^1}\right)\right). \tag{9}$$

The term $S_n(j)$ is defined here as the measure of attractiveness of locations j.

2.3 Upper Level: Residential Location

Let the utility of a residential location i depend on the individual characteristics affecting preferences (X_n), the attributes of location i (Z_i), and the dwelling price $p(i)$. The utility of living in residential location i (see equation (1)) is assumed to be:

$$U_n^R(i) = V_n^R(i; X_n, Z_i) - \beta_n p(i) + \varepsilon_n^3(i) \quad \forall \ i \in \mathcal{L}. \tag{10}$$

The residual term $\varepsilon_n^3(i)$ account for the residual preference of individual n for residence location i. It expresses unobserved location attributes, variation in individual tastes, and model misspecification. In addition, this residual term is distributed so that $\max_{i \in \mathcal{L}_i} U_n^R(j)$ is type I extreme value distributed with scale parameter μ_n^3. The probability of choosing residential location i is then:

$$\mathbb{P}_n^3(j) = \frac{\exp\left(\dfrac{V_n^R(i; X_n, Z_i) - \beta_n p(i) + LS_n(i)}{\mu^3}\right)}{\sum_{i' \in I} \exp\left(\dfrac{V_n^R(i'; X_n, Z_{i'}) - \beta_n p(i')\, LS_n(i')}{\mu^3}\right)} \quad \forall \ i \in \mathcal{L}. \tag{11}$$

where $LS_n(i)$ is defined as the expected maximum utility across all potential workplaces:

$$LS_n(i) = \mu_n^2 \ln \left(\sum_{j' \in J_i} \exp \left(\frac{V_n^W(j'; X_n, Z_{j'}) - C_n^{WR}(j', i) + \varepsilon_n^2(j') + S_n(j')}{\mu_n^2} \right) \right), \tag{12}$$

reflecting the the individual-specific accessibility to jobs from residential location i.

3 Data

The econometric framework is empirically tested using data on the Ile de France Region (IDF). The exhaustive census data on households is available for the last French General Census in 1999. In this census, residential location is observed for 100% of the regional population; this is about 11 inhabitants or 5 million households. The central city of Paris accounts for about 2 million people. Workplace and job type is observed for a 5% sample of the working population (around 240,000 people in 1999).

Location is observed at the commune level. The commune is the smallest administrative unit used in France, and the one we use in this paper. The IDF region is composed by 1300 communes, of which 20 form the central city of Paris. The 1300 communes are grouped into 8 departments or districts, central Paris being one of them. The inner ring or close suburbs is composed by 3 districts, while the outer ring or far way suburbs is composed by 4 districts (See Figure 3 in Appendix).

The study area exhibits spatial disparities in the supply of jobs. In particular, outer ring communes have little or none job supply. Almost 25% of the 1300 communes (almost entirely in the outer ring) are very small communes in terms of number of jobs (See Figure 4 in Appendix). Small adjacent communes were grouped following a simple pairwise aggregation strategy until the total number of jobs by grouped communes (from 2 to 20 communes) was at least 100. As a result, 950 grouped or pseudo-communes with 100 jobs or more were obtained and are used as unit of location choice in this paper.

Based on these 950 pseudo-communes, exhaustive census data was aggregated and location attributes were calculated. Average prices for dwelling (per m^2) by type and tenure were estimated for all communes by hedonic regression using the

Cote Callon prices for communes with more than 5,000 inhabitants (287 communes). Readers can survey the work of de Palma et al., 2007 for a detailed analysis on the location attributes of the Greater Paris Area.

Finally, MODUS OD matrices of travel time for public transportation were obtained from the DRIEA. OD matrices of travel time for private car were computed using the dynamic transport network model METROPOLIS (de Palma, Marchal, and Nesterov, 1997).

3.1 Sample Categorization

We consider individual heterogeneity of preferences at the age, education, gender and children dimensions for all choice levels. Total sample size is 239,499 working persons that live and work in the Ile de France Region. In order to capture the more mobile part of the population to better study accessibility, a person is considered young if she has less than 35 years old.

Categories by education and children (for women) where defined by previously studying the results of multinomial logit models of the influence of both dimension on the choice of job types. For education, categories were defined by elementary, secondary, undergraduate and graduate education levels. For the children dimension, a woman is categorized as having children if she has at least one child of 11 years old or less. Consequently, total sample is divided in 24 categories (See Table 1).

Table 1 about here

4 Results

The results of the econometric framework of residential location, workplace and job type outlined in Section 2 are presented in the following pages. Before doing so, several points are worth noting. First, the nested logit is estimated sequentially by backward induction. Consequently, the first choice estimated is the job type choice, then the workplace choice and finally the residential location choice.

Second, important sampling of alternatives is used in the location choice models. For each household, seven unchosen alternatives are generated, where the sampling weight is proportional to the number of jobs or dwellings in the commune.

Third, it is important to point out that we have no information regarding the dwellings' and workplaces' (intrinsic) characteristics. This implies that all housing units or workplaces located in a particular commune are considered to be statistically identical; and therefore providing the same expected utility and the same odds of being selected by a specific worker. By adding a size measure term (of number of dwellings or jobs, respectively) into the expected utility, consistent estimates of the local amenities coefficients can be obtained (McFadden, 1978).

Finally, in empirical terms the decision tree presented in Section 2 changes marginally. Indeed, the decision tree grows in the upper part because empirically we have to distinguished residential location alternatives by tenure status and dwelling type (See Figure 2). Therefore, 4 different residential location choice models need to be estimated. Here, the residential location choice is restricted to one-worker households and bargaining considerations are left for future work.

Figure 2 about here

Overall, two main conclusion arise from the following estimated models. First, the job type attractiveness measure is a more significant predictor of workplace locations than the usual (total number of jobs) measure. Second, the individual-specific accessibility measure is an important determinant of the residential location choice, and its impact strongly differ with respect to the population mobility.

4.1 Job Type Choice

A multinomial logit (MNL) model for each of the 24 categories is estiamated. This is, 24 different MNL choice models for the following job types: blue collar, employee, intermediate, manager and independent.

This choice level allows us to calculate a measure of attractiveness that is therefore the log-sum of job types. That is to say, the log of the sum of the number of jobs by type, weighted by the individual-specific probability to choose a particular job type. This measure varies then between job locations and between individual characteristics. We have mapped the calculated job type attractiveness of workplaces in Figures 6 and 5 by gender and education in the Appendix.

The results of the MNL model of job type are presented in Table 2. The reference job type is the blue collar and the estimated coefficients by job type are almost all strongly significant. The measure of goodness of fitness presented in the last column of Table 2 suggests that the explanatory power increases with education for men. The less-educated men accept any job and are randomly assigned to jobs such as blue collar, employee or independent types. The most educated men only accept jobs of the manager, intermediate and independent types. The effect of education is more ambiguous for women. Conditional on age and children, what most influences the decision to work or not for a woman is the education rather than the choice of job type.

Table 2 about here

4.2 Workplace Location Choice

As explained in the Econometric Framework Section, the workplace location choice of a pseudo-commune is considered to depends on its job type attractiveness (a individual-specific measure calculated in the job type choice model) and the commuting travel time of individuals. For this second choice level, MNL models are estimated separately for each of the 24 categories described. The results of the 24 workplace location choice models are presented in Table 3.

Table 3 about here

In the "Attractiveness" column of Table 3 the association between the measure of attractiveness and the workplace location is explored. The estimated coefficients indicate that the most educated and older men are more sensitive to the job type attractiveness of the workplace than the younger and less educated. Women (especially the more educated) are less sensitive than men to the job type attractiveness.

Columns "Travel time" and "(Travel time)^2" allow for a quadratic specification of travel time . The results suggest that the workplace location utility is decreasing and concave in travel time for each of the 24 groups. The value of time depends then on age, education, gender and children.

In order to explore further the gain of using a job type attractiveness measure, 24 workplace location choice models were estimated using a size measure (log number of jobs) instead of the measure of job type attractiveness chosen in this paper, while keeping the quadratic specification of travel time. The last column of Table 3 presents the difference between the Likelihood Ratio (LR) of the workplace location choice model estimated with the attractiveness measure and the LR of a the models estimated with the size measure. Results indicate that the measure of attractiveness (specific to each individual) is a better predictor of the workplace location choice than the size measure commonly used (log of the number of jobs).

Accessibility differs between groups, because local employment prospects and the value of time differ across groups. This choice level allows us to develop an accessibility measure specific to each individual: the log-sum of workplace locations. That is to say, the expected maximum utility of all job opportunities. This measure varies between residential location of households and individual characteristics. The calculated measure of accessibility to jobs has been mapped in Figures (7) and (8) by gender and education in the Appendix. Difference of accessibility are particularly strong as the education level of individual increases (See Figure 8).

4.3 Residential Location Choice

The results presented in Tables 5 and 6 are limited to households with only one worker. In households with more workers, the choice of residential location and workplace is modified by the negotiation process within the household. Bargaining considerations are left for future work. The localization model is estimated separately by tenure (owner and renter) and type of dwelling (house and flat). Simple size by tenure and dwelling type is presented in Table 4.

Tables 4, 5, and 6 about here

In the last row of Tables (5) and (6) the measure of goodness of fit is presented. The explanatory power is higher for owners than for renters. This is consistent with the fact that purchasing decisions are much more developed or matured (and therefore less random) than renting decisions. Similarly, the explanatory power is higher for the choice of houses than for the choice of flats. This result is consistent with the rotation rates, which are higher for renters than for owners, and for houses than for flats. Location decisions are more thoughtful when it regards the longer term.

From the accessibility and transport coefficients estimated and presented in Table 5, when comparing between ownership status and dwelling types, owners are more sensitive to accessibility than tenants; and sensitivity to accessibility is more pronounced for households living in apartments than for those living in a house. These results are consistent with considerations of life cycle and geographical distribution of houses and flats. In the early stages of the life cycle, when jobs are less stable and when households do not have children yet, households usually rent a flat strategically located in relation to potential jobs. At later stages of the life cycle, when employment stabilizes and couples have children, households buy houses that are usually far away (and less accessible) in the suburbs. In the decision-making process of choice of residence, the more the households move through their life cycle, the more they are willing to sacrifice accessibility to jobs to access to ownership and gain in residence space.

The numbers of subways and suburban train stations (RER and SNCF suburban trains) only attract households who rent a flat. For other households, the effect is ambiguous or insignificant, which is logical in a one-worker household sample.

The results of the influence of price in the residential location choice can be found in the lower rows of Table 5 . For households with an average income, the price has a negative impact on the probability of location, with the exception of households that rent a house (that are a very small sample). The negative effect of price decreases with income, and may be positive for the richest households.

To test for the influence of residences located on the different geographical zones of the Paris Greater Area, regional dummies are considered. All things being equal, a flat in the outer ring has a lower probability of being selected, and conversely a house in the outer ring has a higher probability to be chosen. Similarly, flats located in a Planned City have greater probability of being selected, while being located in a Planned City will not influence the choice of location for houses. All things being equal, a flat in Paris has a lower probability of being selected, which may seem surprising at first sight. However, this can be explained by the fact that the reasons why Paris attracts households are already taken into account by other explanatory variables in the model (number of subway stations and accessibility to jobs are particularly favorable for Paris).

The fourth group of explanatory variables taken into consideration and the last group presented on Table 5 are the local taxes variables. The effect of the residence tax (for ownership and tenancy) and property taxes (for ownership) is ambiguous.

Higher taxes have a direct negative effect, but they are usually associated with local services (such as child care center or streets amenities, not measured here), which exert an attractive effect.

In the second table of results of the residential location choice model (Table 6), shows the estimated result of the influence of land use and local amenities, and population composition variables. As expected, the probability of choosing a commune increases with the density for households who choose a flat, and decreases for those who choose a house, as well as for ownership with respect to tenancy. The other usual local amenity variables present the expected coefficient signs.

Variables related to social diversity exert a particularly strong effect on location choices: households are attracted by households with similar characteristics regarding age, size and income per capita. House owners are more attracted by communes with a high percentage of foreigners, which can be explained by the fact that the (rich) foreigners who settled in the Paris Greater Area tend to buy a dwelling close to their compatriots. Moreover, beyond a threshold, the percentage of foreigners (rather poor) can be seen as a negative characteristic, but the communes' concerned generally have little owners. For renters, the percentage of foreigners has a positive effect, which decreases with the greater levels of education.

5 Conclusion

The choices between residential location, workplace and job type are modeled here. An interesting econometric framework is developed to study the interdependency between the residential location and workplace. This framework provides a way to compute individual-specific measures that are very relevant for public policy analysis: accessibility to jobs, travel time and value of time, and job type attractiveness.

The three-level nested logit model proposed allows for a new concept of accessibility to jobs that takes into account the individual-specific job type attractiveness, and the heterogeneity in the preferences in the education, age, gender, and children dimensions.

The econometric analysis shows that the job type attractiveness measure is a more significant predictor of workplace locations than the usual (total number of jobs) measure. Empirical results also show that the individual-specific accessibility measure is an important determinant of the residential location choice, and its impact strongly differ with respect to the population mobility.

The model developed here bridges the gap between micro-simulation and general equilibrium urban models. In one hand, micro-simulation urban models ignore the joint nature of the residential location, workplace, and job type decision. On the other hand, general equilibrium urban models consider only limited heterogeneity. Empirical results draw the attention to the pertinence of considering residential location, workplace, and job type all together and allowing for greater heterogeneity, especially when individual-specific accessibility, attractiveness, and travel time measures are calculated for policy study.

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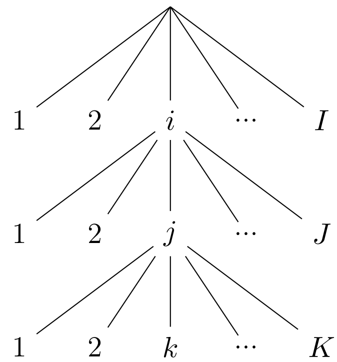
Figure 1: Three-level Nested Structure of Residential Location, Workplace, and Job Type Choice



3. Upper Level:
Residential Location

2. Middle Level:
Workplace

1. Lower Level:
Job Type

Figure 2: Three-level Nested Structure of Residential Location, Workplace, and Job Type Choice; Segmentation by Tenure and Dwelling Type

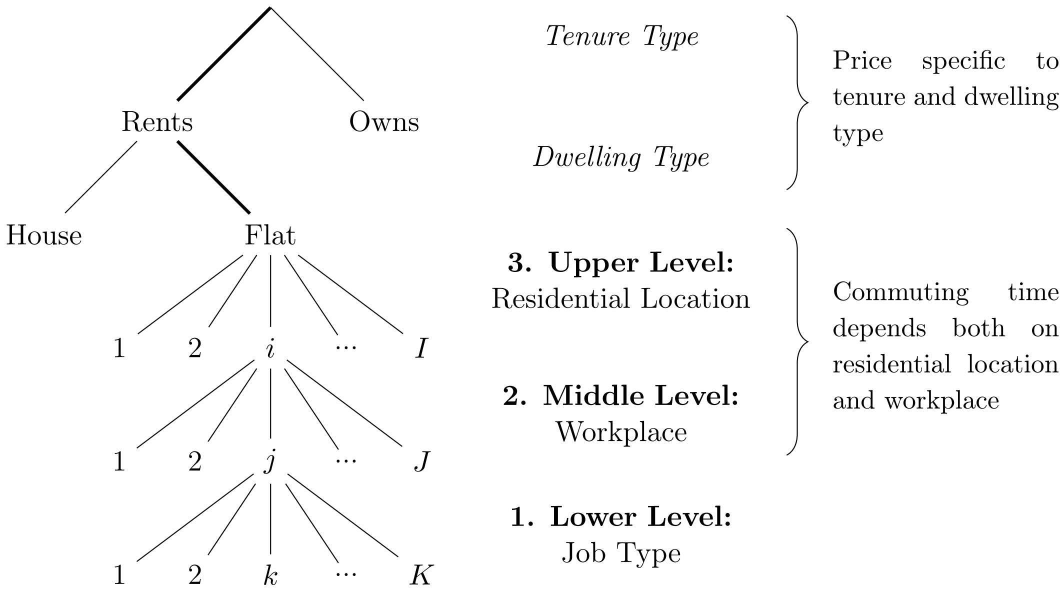


Table 1: Sample Size per Category

	Men		Women			
	Young	Old	Young		Old	
Education			With Children	Without Children	With Children	Without Children
Elementary	18,270	36,813	5,002	7,700	5,974	25,577
Secondary	8,551	12,750	2,950	5,883	3,402	11,251
Undergraduate	10,441	10,234	3,354	9,569	3,145	7,791
Graduate	11,091	17,279	2,478	8,549	3,165	8,280

Note: Total sample size of 239,499 working persons. Categorization by sex, age, children, and education resulted in 24 subsamples. For the purpose of this paper, a person is considered young if she has less than 35 years old. Also, a woman is categorized as having children if she has at least one child of 11 years old or less.
Source: General Population Census for the Paris Region. INSEE, 1999.

Table 2: Job Type Choice Model

Groups	Job Type Preferences (Reference: Blue Collar)					ρ^{2}[1]
	Size Measure	Independent	Managerial	Intermediate	Employee	
Men						
Young						
Elementary	0.8222‡	-1.5332‡	-3.2529‡	-1.7087‡	-1.3610‡	0.30
	(0.0251)	(0.0452)	(0.0490)	(0.0244)	(0.0231)	
Secondary	0.8643‡	-0.9413‡	-1.704‡	-0.3940‡	-0.3618‡	0.16
	(0.0365)	(0.0709)	(0.049)	(0.0323)	(0.0342)	
Undergraduate	0.9574‡	0.0309‡	0.2486‡	1.2597‡	0.4337‡	0.21
	(0.0389)	(0.0792)	(0.0436)	(0.0387)	(0.0432)	
Graduate	0.8261‡	0.9085‡	2.9593‡	1.5861‡	0.5015‡	0.44
	(0.0398)	(0.0990)	(0.0646)	(0.0676)	(0.0748)	
Old						
Elementary	0.8063‡	-0.3283‡	-1.9485‡	-1.0148‡	-1.3334‡	0.13
	(0.0158)	(0.0249)	(0.0221)	(0.0152)	(0.0171)	
Secondary	0.8032‡	0.7045‡	0.3025‡	0.4639‡	-0.3486‡	0.07
	(0.0275)	(0.0479)	(0.0311)	(0.0302)	(0.0354)	
Undergraduate	0.7389‡	1.2021‡	1.5406‡	1.3041‡	-0.3058‡	0.19
	(0.0324)	(0.0627)	(0.0425)	(0.0435)	(0.0548)	
Graduate	0.5935‡	1.8790‡	3.1703‡	1.0478‡	-0.3125‡	0.50
	(0.0296)	(0.0653)	(0.0521)	(0.0574)	(0.0708)	
Women						
Young						
With Children						
Elementary	0.8421‡	-0.6579‡	-2.5086‡	-0.5056‡	1.3346‡	0.47
	(0.0652)	(0.1252)	(0.1372)	(0.0638)	(0.0515)	
Secondary	0.7735‡	0.0085‡	-0.6206‡	1.2581‡	2.1184‡	0.40
	(0.0983)	(0.1903)	(0.1344)	(0.0990)	(0.1000)	
Undergraduate	0.8730‡	0.7312‡	1.5153‡	3.1667‡	2.6266‡	0.37
	(0.0933)	(0.2398)	(0.1554)	(0.1472)	(0.1515)	
Graduate	0.9575‡	1.3300‡	4.1252‡	3.4052‡	1.9893‡	0.42
	(0.0884)	(0.3437)	(0.2526)	(0.2540)	(0.2623)	
Without Children						
Elementary	0.8540‡	-0.6294‡	-2.0835‡	-0.4047‡	1.3296‡	0.45
	(0.0511)	(0.0981)	(0.0921)	(0.0501)	(0.0423)	
Secondary	0.7288‡	-0.5234‡	-0.4125‡	1.1887‡	2.1063‡	0.41
	(0.0679)	(0.1480)	(0.0889)	(0.0699)	(0.0708)	
Undergraduate	0.7167‡	0.0124‡	1.1669‡	2.9215‡	2.7596‡	0.37
	(0.0585)	(0.1543)	(0.0914)	(0.0854)	(0.0885)	
Graduate	0.8210‡	0.8320‡	3.6721‡	3.2444‡	2.3833‡	0.34
	(0.0479)	(0.1790)	(0.1230)	(0.1236)	(0.1265)	
Old						
With Children						
Elementary	0.7458‡	-0.5445‡	-1.8243‡	-0.3663‡	1.2783‡	0.40
	(0.0549)	(0.1019)	(0.0919)	(0.0556)	(0.0474)	
Secondary	0.7786‡	0.8059‡	0.6396‡	1.9021‡	2.2070‡	0.30
	(0.0823)	(0.1628)	(0.1123)	(0.1018)	(0.1044)	
Undergraduate	1.1452‡	1.6729‡	1.9197‡	3.0693‡	1.8303‡	0.34
	(0.0860)	(0.2038)	(0.1495)	(0.1447)	(0.1513)	
Graduate	0.6183‡	1.6659‡	4.1522‡	3.0145‡	1.6371‡	0.45
	(0.0775)	(0.2467)	(0.2030)	(0.2064)	(0.2173)	
Without Children						
Elementary	0.8646‡	0.1262‡	-1.1662‡	-0.1209‡	1.2035‡	0.32
	(0.0250)	(0.0432)	(0.0355)	(0.0259)	(0.0231)	
Secondary	0.8230‡	1.3394‡	1.1889‡	2.2136‡	2.1471‡	0.24
	(0.0415)	(0.0855)	(0.0644)	(0.0610)	(0.0628)	
Undergraduate	0.8785‡	1.6054‡	2.2571‡	3.0564‡	1.8847‡	0.29
	(0.0515)	(0.1233)	(0.0950)	(0.0936)	(0.0980)	
Graduate	0.3816‡	1.6216‡	4.1368‡	2.9735‡	1.9107‡	0.41
	(0.0484)	(0.1428)	(0.1217)	(0.1241)	(0.1300)	

[1] ρ^2 is a measure of goodness of fit defined as the percentage increased in the log-likelihood function above the value taken at zero parameters.
‡ Significant at the 1% level, † Significant at the 5% level, * Significant at the 10% level

Table 3: Workplace Location Choice Model

Groups	Explanatory Variables: Attractiveness	Travel Time	(Travel Time)^2	ρ^{2}[1]	ΔLR[2]
Men					
Young					
Elementary	-0.0468‡	1.2532‡	-8.4221‡	0.48	-7.0
	(0.0108)	(0.1247)	(0.1907)		
Secondary	0.0634‡	1.7142‡	-8.3713‡	0.38	-1.0
	(0.0141)	(0.1581)	(0.2418)		
Undergraduate	0.0511‡	1.4170‡	-7.0682‡	0.28	6.0
	(0.0102)	(0.1360)	(0.2034)		
Graduate	0.1277‡	1.2599‡	-5.8953‡	0.21	114.6
	(0.0104)	(0.1231)	(0.1741)		
Old					
Elementary	0.0381‡	1.7761‡	-8.7578‡	0.43	1.0
	(0.0076)	(0.0794)	(0.1227)		
Secondary	0.2090‡	1.9071‡	-8.3928‡	0.33	-6.0
	(0.0119)	(0.1288)	(0.1966)		
Undergraduate	0.1510‡	1.8766‡	-7.7952‡	0.29	25.0
	(0.0132)	(0.1365)	(0.2049)		
Graduate	0.2904‡	1.6935‡	-7.1091‡	0.25	272.0
	(0.0119)	(0.1101)	(0.1549)		
Women					
Young					
With Children					
Elementary	0.0425*	0.5459†	-7.9755‡	0.53	-2.0
	(0.0227)	(0.2412)	(0.3928)		
Secondary	0.1970‡	-0.2243	-6.2741‡	0.42	0.1
	(0.0287)	(0.2921)	(0.4595)		
Undergraduate	0.1619‡	-0.4822*	-5.8000‡	0.39	6.8
	(0.0227)	(0.2767)	(0.4285)		
Graduate	0.1078‡	-0.3486	-4.9114‡	0.30	13.9
	(0.0204)	(0.3014)	(0.4424)		
Without Children					
Elementary	0.0648‡	0.5082†	-7.8432‡	0.51	-4.0
	(0.0174)	(0.1986)	(0.3055)		
Secondary	0.2283‡	0.2109	-6.7998‡	0.42	-1.0
	(0.0217)	(0.2116)	(0.3177)		
Undergraduate	0.2453‡	0.3424†	-6.0165‡	0.32	25.0
	(0.0157)	(0.1512)	(0.2248)		
Graduate	0.1120‡	0.5039‡	-5.3448‡	0.25	45.1
	(0.0129)	(0.1484)	(0.2122)		
Old					
With Children					
Elementary	0.1761‡	0.5775‡	-8.1457‡	0.54	-7.0
	(0.0244)	(0.2244)	(0.3590)		
Secondary	0.3019‡	-0.0683	-6.9683‡	0.46	2.5
	(0.0280)	(0.2860)	(0.4470)		
Undergraduate	0.1893‡	0.2121	-6.9253‡	0.42	13.3
	(0.0190)	(0.2815)	(0.4258)		
Graduate	0.2033‡	-0.4168	-5.3695‡	0.35	20.2
	(0.0293)	(0.2838)	(0.3988)		
Without Children					
Elementary	0.1462‡	0.6924‡	-8.2738‡	0.55	-28.0
	(0.0102)	(0.1083)	(0.1699)		
Secondary	0.2961‡	0.3529†	-7.2969‡	0.45	23.0
	(0.0145)	(0.1560)	(0.2371)		
Undergraduate	0.1576‡	0.6057‡	-7.1502‡	0.41	20.0
	(0.0149)	(0.1754)	(0.2578)		
Graduate	0.1705‡	0.6792‡	-6.6626‡	0.36	22.0
	(0.0300)	(0.1684)	(0.2355)		

[1] ρ^2 is a measure of goodness of fit defined as the percentage increased in the log-likelihood function above the value taken at zero parameters.
[2] ΔLR is the difference between the Likelihood Ratio (LR) of the workplace location choice model estimated with the attractiveness measure and the LR of a model estimated with the size measure (total number of jobs): $\Delta LR = LR_{attractiveness} - LR_{size\ measure}$
‡ Significant at the 1% level, † Significant at the 5% level, * Significant at the 10% level. Standard errors in parenthesis.

Table 4: Sample Size by Tenure and Dwelling Type

	Dwelling Type[1]		
Tenure	Flat	House	Total
Owner	17,047	16,121	33,168 (37.96%)
Tenant	51,104	3,095	54,199 (62.04%)
Total	68,151 (78.01%)	19,216 (21.99%)	87,367 (100%)

[1]All the detached-single unit and semi-detached dwellings are defined as "houses", otherwise the dwellings are defined as "flats".

Note: Sample size of 87,367 one-worker households living and working in the Greater Paris Area.

Source: General Population Census for the Paris Region. INSEE, 1999.

Table 5: Residential Location Choice Mode, I

	Buy		**Rent**	
	Apartment	**Single Dwelling**	**Apartment**	**Single Dwelling**
Accessibility and Transport				
Accessibility to Jobs (IV)	0.3024‡	0.0727†	0.4029‡	0.236‡
	(0.0428)	(0.0369)	(0.0236)	(0.0789)
Suburban Train × High-Income	0.0199‡	0.0161*	0.0368‡	0.0291
	(0.0064)	(0.0088)	(0.0054)	(0.0217)
Suburban Train× Middle-Income	0.000662	-0.0649‡	0.0176‡	-0.0449†
	(0.0066)	(0.0109)	(0.0038)	(0.0214)
Suburban Train× Low-Income	-0.006209	-0.0303	0.0161 ‡	-0.0724‡
	(0.0099)	(0.0195)	(0.0040)	(0.0257)
Subway × High-Income	0.004628	-0.0620‡	0.0355‡	-0.0633‡
	(0.0031)	(0.0059)	(0.0022)	(0.0129)
Subway× Middle-Income	0.004678	-0.0953‡	0.0197‡	-0.0596‡
	(0.0033)	(0.0083)	(0.0018)	(0.0120)
Subway × Low-Income	-0.009174†	-0.0818‡	-0.000154	-0.0417‡
	(0.0043)	(0.0141)	(0.0019)	(0.0125)
Prices				
AvgPrice × High-Income	1.2159‡	-0.0929	-1.3917‡	2.1822‡
	(0.1686)	(0.1387)	(0.1552)	(0.5123)
AvgPrice × Middle-Income	-0.4729‡	-0.2054	-2.4401‡	0.8922*
	(0.1954)	(0.1556)	(0.1354)	(0.4823)
AvgPrice × Low-Income	-0.8661‡	-0.6162**	-3.4165‡	0.959*
	(0.2082)	(0.2578)	(0.1293)	(0.5184)
Regional dummies				
Paris Dummy	-0.4969‡		-1.0269‡	
	(0.0585)		(0.0377)	
Outer Ring Dummy	-0.0972‡	-0.0391	-0.4347‡	0.3993‡
	(0.0370)	(0.0305)	(0.0214)	(0.0739)
Planned City Dummy	0.3938‡	-0.0374	0.0619‡	0.0351
	(0.0436)	(0.0356)	(0.0234)	(0.0780)
Local Tax Rates				
Residence Tax × High-Income	0.0388‡	0.0221‡	-0.0295‡	-0.002156
	(0.0060)	(0.0040)	(0.0038)	(0.0113)
Residence Tax × Middle-Income	0.0538‡	-0.001725	-0.003713	-0.003324
	(0.0056)	(0.0045)	(0.0026)	(0.0101)
Residence Tax × Low-Income	0.0587‡	-0.006367	0.0148‡	0.000731
	(0.0072)	(0.0081)	(0.0026)	(0.0122)
Ownership Tax × High-Income	-0.0382‡	-0.003597†		
	(0.0029)	(0.0016)		
Ownership Tax× Middle-Income	-0.0180‡	0.0119‡		
	(0.0024)	(0.0017)		
Ownership Tax × Low-Income	-0.0181‡	0.0151‡		
	(0.0032)	(0.0032)		
Observations	17,047	16,121	51,104	3,095
ρ^2	0.0598	0.2166	0.0553	0.1639

‡ Significant at the 1% level, † Significant at the 5% level, * Significant at the 10% level. Standard errors in parenthesis.

Table 6: Residential Location Choice Model, II

	Buy		Rent	
	Apartment	Single Dwelling	Apartment	Single Dwelling
Land Use and Local Amenities				
Density	0.0140‡	-0.0750‡	0.0171‡	-0.0688‡
	(0.0018)	(0.0048)	(0.0012)	(0.0085)
%Noise (Surface)	0.1883	-0.3433‡	-0.0697‡	-0.567†
	(0.1281)	(0.1080)	(0.0719)	(0.2577)
%Water (Surface under)	0.1042	-2.4388‡	0.9928‡	-0.6122
	(0.3065)	(0.3524)	(0.1760)	(0.7749)
%Water × Children Dummy	0.3851	1.1099	0.0808	2.5462†
	(0.8023)	(0.7161)	(0.3673)	(1.2991)
% Priority Schools (Surface)	-0.0604	-0.1178‡	-0.0780‡	0.1463
	(0.0458)	(0.0435)	(0.0239)	(0.0995)
% Priority Schools × Children Dummy	0.2551‡	-0.1348*	0.4531‡	-0.0265
	(0.0856)	(0.0793)	(0.0375)	(0.1559)
%Educational Buildings (Surface)	0.5175	-11.1408‡	0.6231†	-5.9683‡
	(0.5074)	(1.1641)	(0.3163)	(2.1469)
%Education × Children Dummy	-0.0755	-0.3048	3.3991‡	-8.0326†
	(1.5100)	(1.6933)	(0.6295)	(3.2130)
Neighborhood Composition				
%Foreign HHs	8.2979‡	8.5187‡	5.2350‡	6.499‡
	(0.5791)	(0.5381)	(0.2352)	(0.9758)
%Foreign HHs × Below Secondary	3.8826‡	0.5979	3.0045‡	1.7406
	(0.6095)	(0.5024)	(0.2824)	(1.1303)
%Foreign HHs × Undergraduate	0.2241	-0.4024	0.1871	-1.4373
	(0.4228)	(0.4236)	(0.2254)	(0.9273)
%Foreign HHs × Graduate	-1.2090‡	-1.3881‡	-1.7355‡	-2.066†
	(0.4242)	(0.4690)	(0.2397)	(1.0649)
% High-Income HHs × High-Income	1.3133‡	2.6800‡	-0.0670	1.3933‡
	(0.2497)	(0.1951)	(0.1718)	(0.4723)
% Low-Income HHs × Low-Income	-0.9021†	-0.5987	0.3802†	0.8118
	(0.4337)	(0.5595)	(0.1920)	(0.8369)
% Middle-Income HHs × Middle-Income	-1.5340†	2.8920‡	1.6014‡	0.7312
	(0.6313)	(0.4131)	(0.3068)	(0.8124)
% of 1person HHs × 1 person HH	4.1973‡	-1.1671‡	4.2715‡	0.9202
	(0.1804)	(0.3930)	(0.1063)	(0.5751)
% of 2 persons HHs × 2 persons HH	-1.3139	2.1214‡	-0.1747	-1.2891
	(0.8264)	(0.6843)	(0.4722)	(1.5166)
% of 3+ persons HHs × 3+ persons HH	0.1882	3.3951‡	1.2337‡	2.9105‡
	(0.2002)	(0.2091)	(0.1093)	(0.4280)
% Young HHs × Young HH	2.4149‡	-3.7586‡	4.2568‡	-1.0913
	(0.5182)	(0.8446)	(0.2343)	(0.9658)
% Middle-age HHs × Middle-age HH	-0.6212‡	1.7560‡	-0.2820*	-0.2946
	(0.2408)	(0.2383)	(0.1492)	(0.4910)
% Old HHs × Old HH	3.6486‡	2.3031‡	1.5554‡	1.5386*
	(0.3758)	(0.3067)	(0.2951)	(0.9104)
Observations	17,047	16,121	51,104	3,095
ρ^2	0.0598	0.2166	0.0553	0.1639

Note: HH= Household Head
‡ Significant at the 1% level, † Significant at the 5% level, * Significant at the 10% level. Standard errors in parenthesis.

Appendix:
Area of Study, Attractiveness and Accessibility Measures

Figure 3: Greater Paris Area (1,300 Communes)

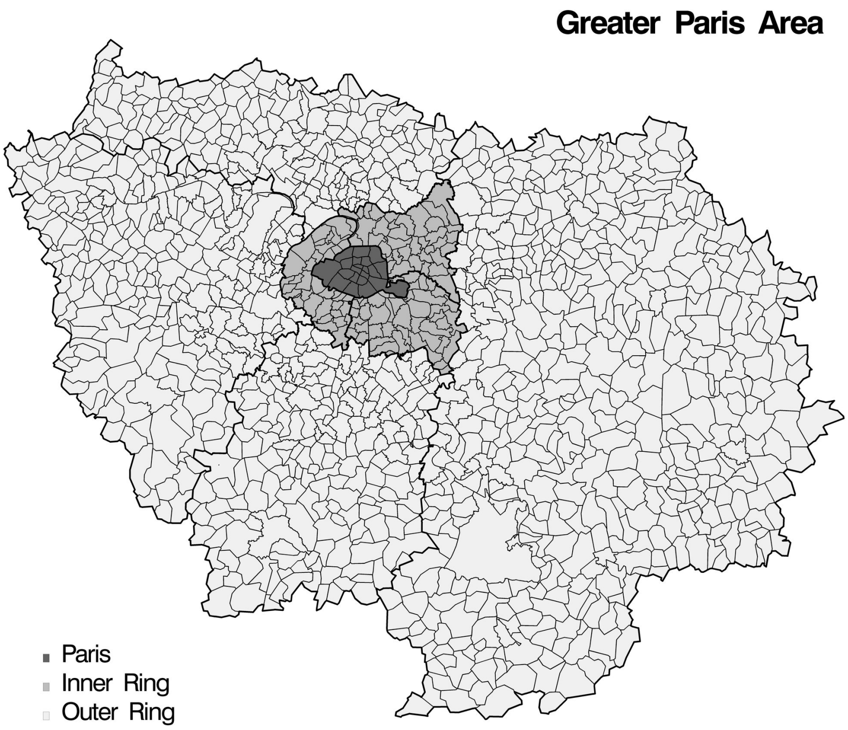
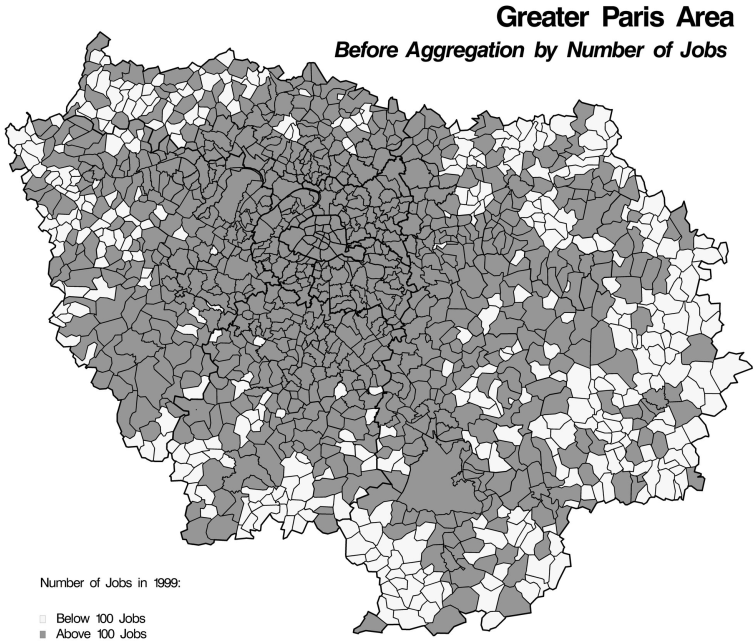


Figure 4: Aggregation of Small Adjacent Communes by Number of Jobs (950 Pseudo-Communes with More than 100 Jobs)



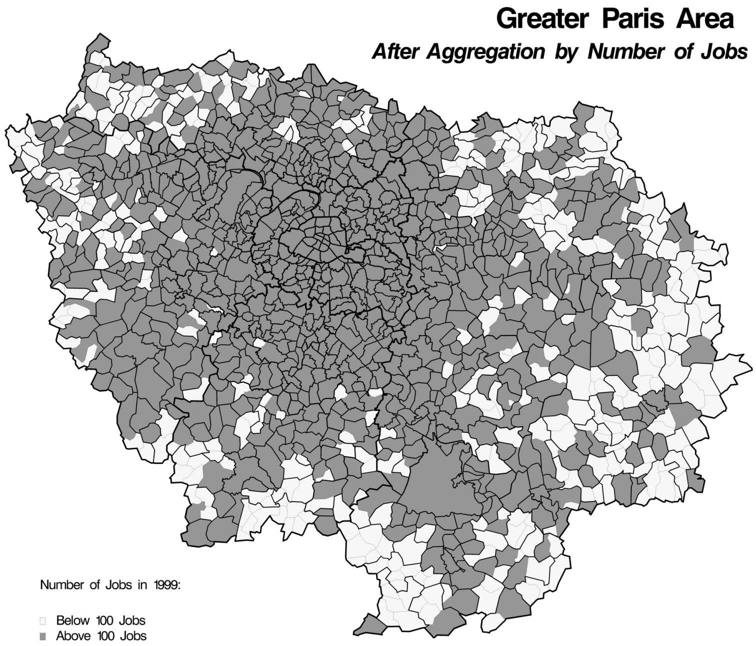


Figure 5: Attractiveness of Communes for Workers by Gender

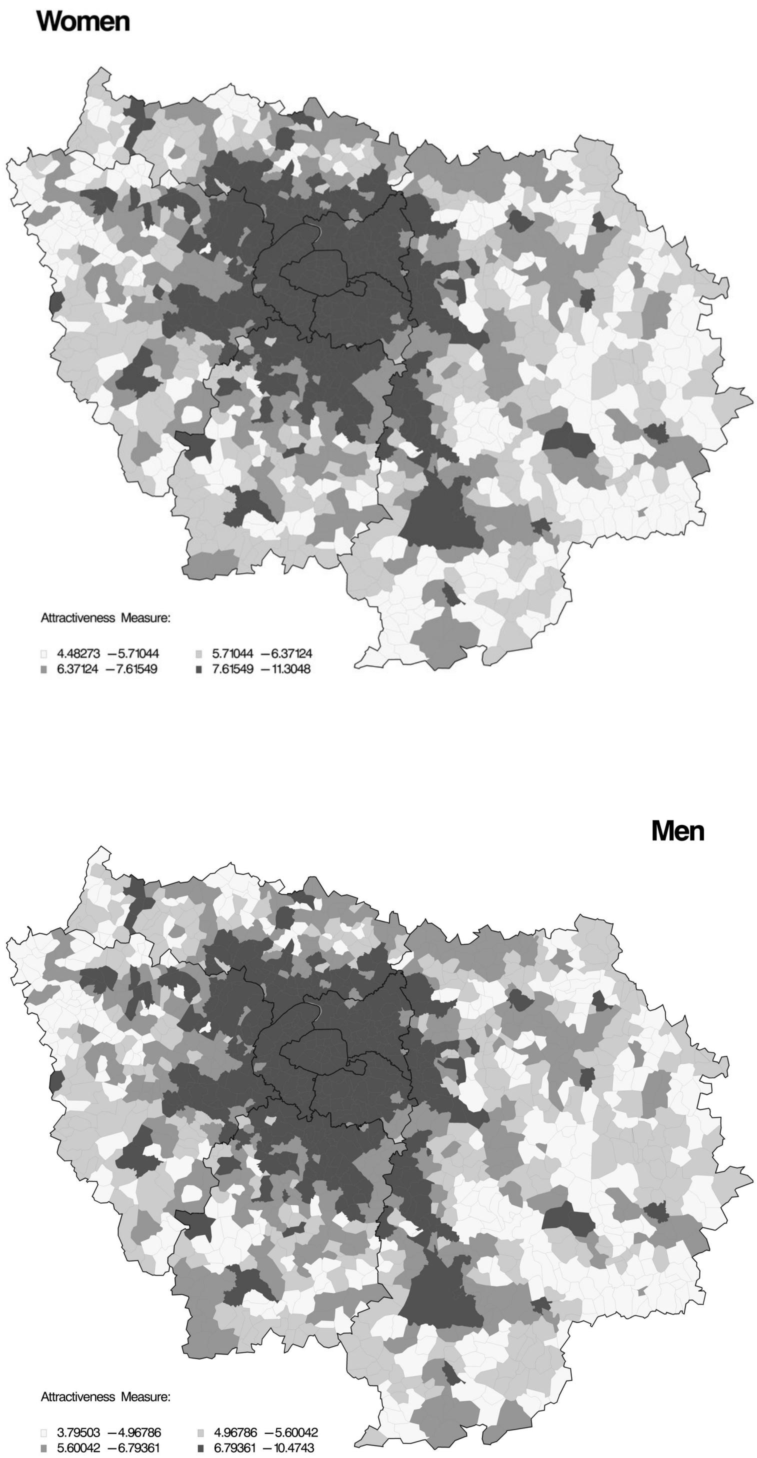


Figure 6: Attractiveness of Communes for Workers by Education Level

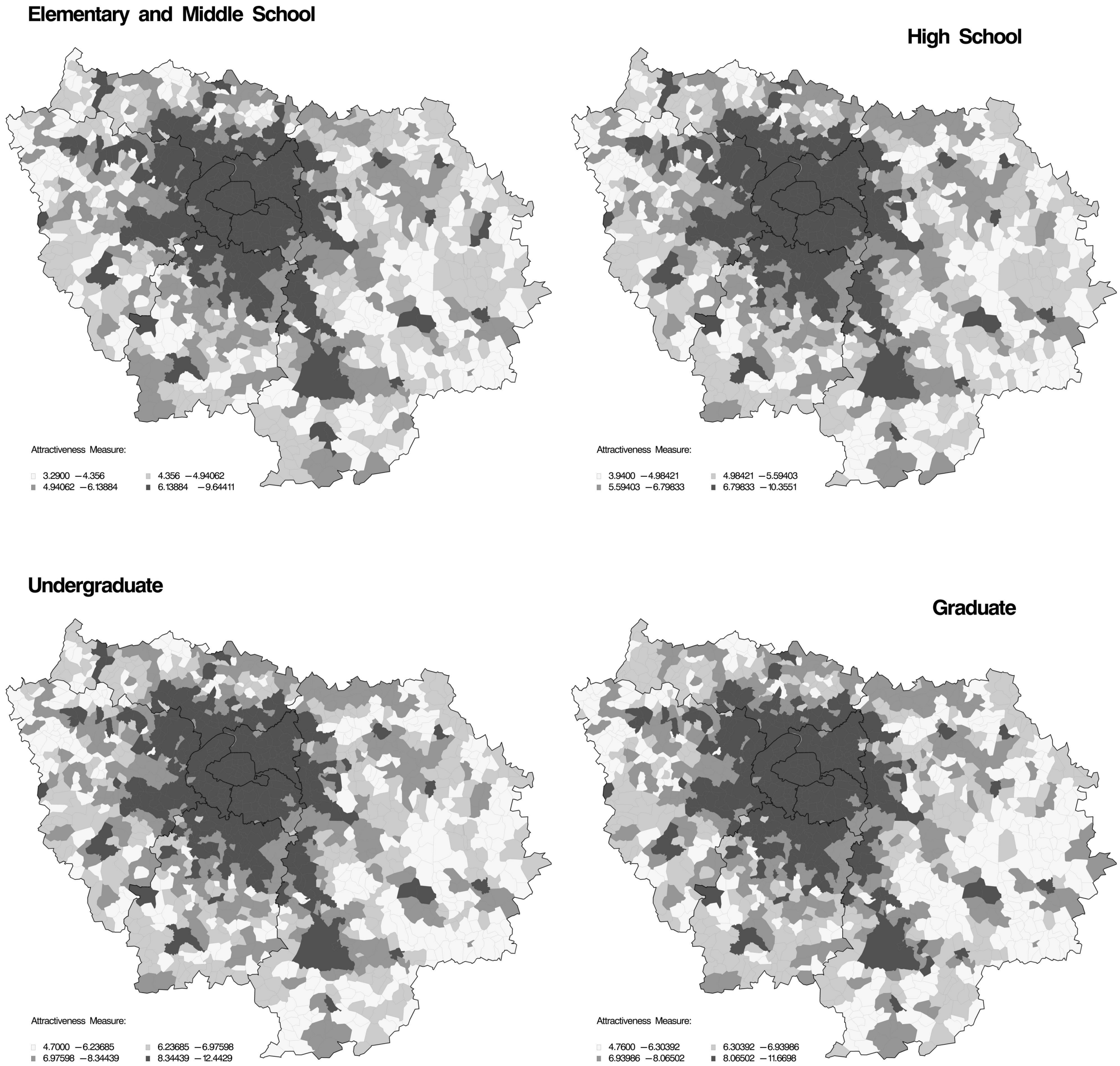


Figure 7: Accessibility to Jobs by Gender

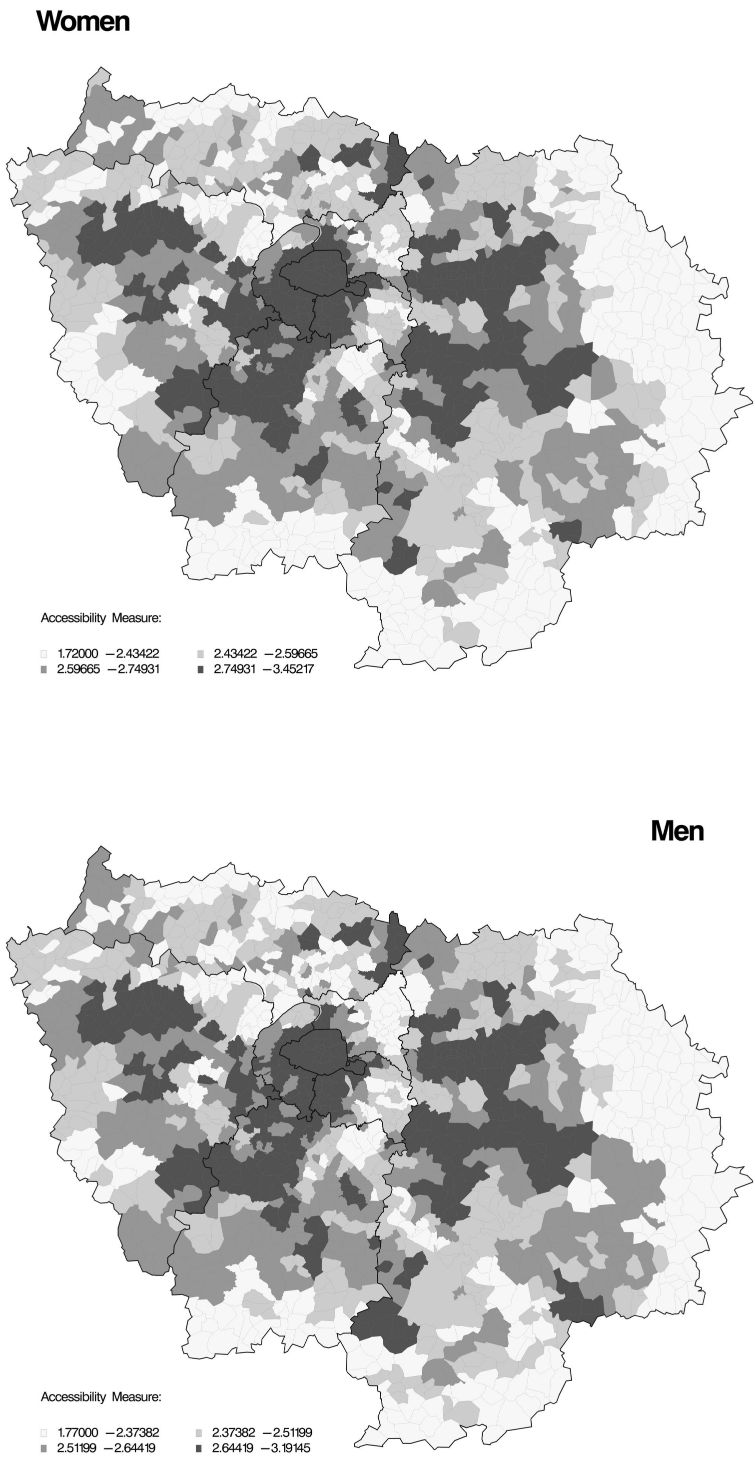


Figure 8: Accessibility to Jobs by Education Level