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1 Introduction

There is substantial literature on modelling individual residential location choices. We restrict here our attention to some key aspects discussed below, which remain overlooked in the litterature.

First, the set of decisions related to residential location in a multiperiod setting typically involve a very large number of alternatives. At a given date, a choice entails several dimensions: where to locate, which dwelling types and which tenure status. A fine tuned demand analysis of housing choices, would consider dozens of small geographical units for potential locations, at least two tenure types (own or rent) and at least two dwelling types (apartment or house).

Another aspect is: who makes residential location related decisions. Recent litterature (see Picard & Chiappori (2011), de Palma et al. (2013)) shows that accounting for intra-household negotiation processes provide a new understanding about how residential location choices may result from consensus reached by household members. Most of research work is yet based on unitary household approaches that consider there is a single decision maker in the family.

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Another point is about the dynamics of these choices. One may reasonably assume that a household optimises over its lifecycle the path of decisions about labour supply, goods/services and floor space by dwelling type consumptions, tenure statuses (Di Salvo & Ermisch (1997)), where to locate dwellings, whether housing is used as a financial asset and whether it is left for bequest to heirs (Arrondel & Lefebvre (2001)). All these decisions are subject to per-period financial constraints.

Also, housing markets are segmented but interacting with each other and with other markets such as the labour market, transport activity and land development. Prices are not always sufficient to clear the markets. Most models do not question equilibrium, or consider only partial equilibria. There are relatively few spatial general equilibrium or micro-simulation models with both heterogeneous agents and markets.

Data requirements would be very stringent if one would carry out a complete analysis at a very fine level of analysis. In general, one uses several statistical sources and data merging procedures to prepare samples. The types of model and their focus are often adjusted to available data.

The importance of transportation costs has been pointed out by Weisbrod et al. (1980), Anas & Chu (1984), Waddell et al. (2007), Lee & Waddell (2010), inter alia. They focused on the induced effects of the transportation market on residential location choices. Accessibility to and from a residential location greatly affects households choices.

Quigley (1985), Nechyba & Strauss (1998), Brueckner et al. (1999) focus on the effects local amenities and neighbourhood to explain the choice of a specific location. They show how extrinsic attributes of dwellings play a significant role in spatial distribution of housing demand and on the corresponding market prices. Bureau & Glachant (2010) find that market prices of owned dwellings are sensitive to their surrounding environment.

de Palma & Lefevre (1985), Ben-Akiva & de Palma (1986) recognized that transaction costs and moving costs may affect the dynamics of location choices since they increase the duration of stay at one location. Any fiscal distorsion that increases market price (either temporarily or permanently) needs to be compensated by either a longer stay period to return on investment or larger streams of income. Duration of stay at one location is inversely proportional to the levels of transaction prices and moving costs effective in the housing market. As a consequence, households that rent a dwelling are more mobile than households that purchase a dwelling, because of lesser transaction costs.

de Palma et al. (2007) recently showed that existence of capacity constraints in housing supply changes considerably location choices.

Analysis of choices of dwelling and tenure types have also been subject to several analysis, e.g. Ioannides & Rosenthal (1974), Henderson & Ioannides (1986), Mills (1990), Cho (1997), Skaburskis (1999). They discussed the effects on individual demand functions of the dwelling attributes (such as number of rooms, presence of garden/balcony, age of the building, etc..). They mainly discuss the effects of intrinsic characteristics and how they may differ across socioeconomic and demographic groups. McFadden (1977), Weisbrod et al. (1980), Thisse (2010), Dantan et al. (2010), Dantan & Picard (2010) also discussed in a more general way existing tradeoffs that may have consequence on location choices, including differences across individuals with different socioeconomic characteristics.

Linneman & Wachter (1989), Zorn (1989), Brueckner (1997), Gobillon & Le Blanc (2004), discussed the dynamics of housing expenditures of homeowners in presence of credit rationing. He shows how the latter may not only affect the demand for floor space but also the choice of a tenure type (for a given demand of floor space) and less directly the choice of a dwelling type (since, on average, consumed floor space is larger for houses than for apartments).

In this paper, we propose a theoretical microeconomic model to analyze residential choices of households in a dynamic context with perfect information. The decision maker is a household. We do not envisage intra-household negotiation between members. We consider that the household lives two periods. Addressing simultaneously economic choices of residential location, dwelling and tenure and their dynamics, while accounting for interaction with transportation market, with demand for local amenities, and with financial investment constraints represent the main focus of the paper.

At the beginning of each period, household is endowed with a per-period utility function that depends on the level of amenities, the level of floor space, and the level of consumption of a composite good. It is faced with continuous and discrete decisions: choices of optimal quantity of floor space, consumption level of an outside composite good, and the choices of residential location, tenure and dwelling types. Indeed, these choices are subject to budget and technical constraints. In our model, borrowing is allowed in the first period, but not in the second one: no debt can be left when at the beginning of a third period. We also assume that the interest rate is higher when borrowing for a dwelling than when saving/borrowing on the money market (this is a form of credit imperfection). We do not consider any selection mechanism: every household can borrow money for housing purpose. Transaction costs apply to real estate (acts made by notaries or lawyers but also local taxes). We consider existence of moving costs whenever changing home location in the second period. Of course, transportation costs affect the choices of households. Another feature of our model is the introduction of a bequest motive. The household leaves a bequest to heirs at the end of his/her lifecycle for altruistic reasons, which enters in the third period utility. The bequest consists in money and/or in real estate.

The household program is to maximise the sum of discounted flows of utility over its lifecycle subject to an inter-temporal budget constraint. The problem can be solved in two preliminary steps, then by backward induction. First, we compute for each combination of locations, tenure and dwelling types, optimal demands for floor space and consumption of a composite good. Second, we derive the associated indirect utility functions. The household chooses the combination of locations (hence levels of amenities), tenure and dwelling types that maximises its utility. The levels of optimal (continuous) demands adjust to these optimlal (discrete) choices.

We detail our theoretical model in Section 2. We discuss the mathematical formulation and related solutions of the household optimisation program. We choose functional forms which lead to analytically tractable theoretical model of intertemporal utility maximization. We study the effects of the most relevant ingredients of residential location choices: demand for local amenities, financial constraints (pay-down requirement, borrowings and savings), housing and goods/services prices, income, transaction costs, transportation and moving costs.

In Section 3, we then turn to an empirical application. We present data in the first subsection. Our main data source is the 2006 French Housing Survey, which comprises a short retrospective survey back to 2002. We focus on the population living in Paris region during these years. Due to lack of statistical information about precise locations of dwellings, we restrict our analysis to the dynamics of tenure and dwelling types choices given location choices. Also, since the survey is based on revealed preferences, we need to buid conterfactuals and impute values of the attributes of unchosen alternatives. To this extent, we use data on credit from the survey and from the Côtes Callon. The latter provides average observed market prices by tenure type for 2002 and 2006. We also address the problem of missing information about precise locations of dwellings: we only have information about the "département" (large French administrative unit) where households live. Therefore we cannot compute any reliable transportation costs. The moving costs are accounted for through a dummy variable indicating whether the household moved between 2002 and 2006. In a second subsection, we propose an econometric specification of the theoretical model accounting for data availability and identification constraints. Our approach is based on random utility maximization. It takes the form of a Nested Logit choice model, see for example McFadden (1977), Train (2003). We discuss estimation results in the third subsection.

We conclude in a last section and argue that our theoretical model can be used as a building block for detailed analysis of residential location choices.

2 A microeconomic model of residential choices

We consider a household living 2 periods $j \in \{1, 2\}$. A bequest B is transmitted to heirs at period 3. At the beginning of each period, the household has to choose its dwelling location, its dwelling type, its tenure type, and the levels of consumption of floor space, composite good, and local amenities. The latter are actually not really chosen but instead determined by residential location choices.

2.1 Household preferences

At the beginning of every period $j \in \{1, 2\}$, a household obtains utility u from consumption of floor space Q, local amenities x, and a composite good C (excluding dwelling). We define by $u_j(x_j, C_j, Q_j)$ the household utility in period j. We assume that $u_j(\cdot)$ is strictly increasing and quasi-concave in its arguments.

The utility of a household over its lifecycle is measured at the beginning of the first period. It is defined as the discounted sum period-specific utilities plus the level of bequest B left to heirs at period 3 (bequest is transmitted once the household disappears). We denote by $\beta \in [0, 1]$ the discount factor. The resulting intertemporal utility function $U(\cdot)$ is defined as

$$\begin{aligned} &U(x_1, C_1, Q_1, x_2, C_2, Q_2, B) = \\ &\quad u_1(x_1, C_1, Q_1) + \beta u_2(x_2, C_2, Q_2) + \beta^2 \gamma_2 \ln(B) \end{aligned} \tag{1}$$

and we further assume that $u_j(\cdot)$ has a Cobb-Douglas mathematical formulation

$$u_j(x_j, C_j, Q_j, B) = \psi_j(x_j) + \alpha_j \ln(C_j) + (1 - \alpha_j) \ln(Q_j), j \in \{1, 2\}. \tag{2}$$

If the household does not change dwelling in period 2, floor space consumption is determined once for all in period 1, i.e. $Q_2 = Q_1$. We assume that the level of consumed amenities may change over time whenever location is the same. The intertemporal utility function simplifies to

$$\begin{aligned} &U(x_1, C_1, Q_1, x_2, C_2, Q_1, B) = \\ &\quad u_1(x_1, C_1, Q_1) + \beta u_2(x_2, C_2, Q_1) + \beta^2 \gamma_2 \ln(B) \end{aligned} \tag{3}$$

2.2 Budget constraints

Choices of household are made under finite budget constraints. Before writing explicitly the inter temporal budget constraint of the household, we need first to define further notations. For each period $j \in \{1, 2\}$, we assume that tenure type (k_j) corresponds to either owning (o_j) or renting (r_j), dwelling type (d_j) corresponds to either house (h_j) or flat (f_j), and location corresponds to a predetermined geographical zone l_j in a region that is divided into L mutually exclusive units.

Let $\pi_t^{k_j, d_j, l_j}(x_{j,l_j})$ be the price (per unit of surface) in period $t \in \{1, 2, 3\}, t > j$, of a dwelling located at l_j that is occupied by the household in period j. Whatever d_j, k_j or l_j, the household is faced with additional transaction costs when considering dwelling consumption. These are of two types. The first applies only once to the transaction itself when purchasing or renting a dwelling, often under the form of a proportional tax rather than a lump sum. Let $\mu_j^{k_j, d_j, l_j} > 0$ be this unit tax level. The second applies to the occupation of the dwelling and is recurrent over time as long as the dwelling is occupied. It mainly models local taxes. Let then $\kappa_j^{k_j, d_j, l_j}$ be the unit tax level.

Prices of the composite good are defined as $p_j, j \in \{1, 2\}$[1].

[1] Note that it means that prices of the composite good does not differ across zones in the considered region.

The household is endowed a strictly positive level of (exogenous) income R_j at the beginning of each period $j \in \{1,2\}$. As household members have to participate in out-of-home activities, e.g. work or education, $D_j\left(x_{j,l_j}, y_j\right) > 0$ is a transportation cost in period j for a residential location l and a set of locations to be reached $y_j, j \in \{1,2\}$[2].

Let also S_j model monetary savings at period $j \in \{1,2\}$. For $j = 2$, it corresponds to the level of monetary bequest left to heirs, and we assume that $S_2 \geq 0$. When $j = 1$, it can be either positive or negative. If positive, the return on money savings is $r_j > 0, j \in \{1,2\}$. We assume that the household can borrow money only during the first period (out of two) of its lifecycle. It is excluded to leave debts to heirs. If money is borrowed in period $j = 1$, the household contracts a loan that has to be reimbursed during the second period $j = 2$. The interest rate of the loan is τ_1. We assume that $\tau_1 > r_1$. If money is borrowed for housing purpose, as the household must pay down a fraction $\rho \in [0,1]$ of the total dwelling price, only the remaining portion has to be reimbursed in period 2. By convention, $\rho = 1$ when dwelling is rented in period 1 (no borrowing is allowed for renting), and $\mu_j^{r_j,d_j,l_j} = 0$.

There is yet one component to consider. When household makes the choice to change dwelling in period 2, moving costs affecting the budget constraint may occur. We model them by $\Delta\left(x_{1,l_1}, x_{2,l_2}\right) \geq 0$. By convention, these costs are equal to zero when not changing dwelling.

The budget constraint for the first period is then

$$\begin{aligned} &p_1 C_1 + \left[\left(1 + \mu_1^{k_1,d_1,l_1}\right)\rho + \kappa_1^{k_1,d_1,l_1}\left(x_1\right)\right]\pi_1^{k_1,d_1,l_1}\left(x_{1,l_1}\right) Q_1 + S_1 = \\ &\quad R_1 - D_1\left(x_{1,l_1}, y_1\right) \end{aligned} \tag{4}$$

The budget constraint in period 2 is more involved:

$$\begin{aligned} &p_2 C_2 + \left[\left(1+\tau_1\right)\left(1 + \mu_1^{k_1,d_1,l_1}\right)\left(1-\rho\right)\right]\pi_1^{k_1,d_1,l_1}\left(x_{1,l_1}\right) Q_1 \\ &+ \left[1 + \mu_2^{k_2,d_2,l_2} + \kappa_2^{k_2,d_2,l_2}\left(x_{2,l_2}\right)\right]\pi_2^{k_2,d_2,l_2}\left(x_{2,l_2}\right) Q_2 + S_2 \\ &= \left(1+r_1\right) S_1 + R_2 - D_2\left(x_{2,l_2}, y_2\right) - \Delta\left(x_{1,l_1}, x_{2,l_2}\right) \\ &+ \pi_2^{o_1,d_1,l_1}\left(x_{1,l_1}\right) Q_1 \mathbb{I}_{1\frown 2}, \end{aligned} \tag{5}$$

where $\mathbb{I}_{1\frown 2}$ is a dummy variable indicating that dwelling bought in period 1 may be sold in period 2.

[2]Note that y_j is a vector when many household members work and/or when considering other locations than workplaces. Note also that x is an argument of the transportation cost function as presence of public transport or any special transport infrastructure may be considered as amenities for location l_j and may have effect on the level of transportation costs.

We can combine equations 4 and 5 to obtain the intertemporal budget constraint:

$$\begin{aligned}&(1+r_1)\,p_1C_1+p_2C_2+S_2\\&+\left\{\begin{array}{l}\left(1+\mu_1^{k_1,d_1,l_1}\right)\left[\rho+\frac{\left(1+\tau_1^{k_1,d_1,l_1}\right)(1-\rho)}{1+r_1}\right]\\+\kappa_1^{k_1,d_1,l_1}\left(x_{1,l_1}\right)\end{array}\right\}(1+r_1)\,\pi_1^{k_1,d_1,l_1}\left(x_{1,l_1}\right)Q_1\\&+\left(\left(1+\mu_2^{k_2,d_2,l_2}\right)+\kappa_2^{k_2,d_2,l_2}\left(x_{2,l_2}\right)\right)\pi_2^{k_2,d_2,l_2}\left(x_{2,l_2}\right)Q_2\\&=(1+r_1)\left(R_1-D_1\left(x_{1,l_1},y_1\right)\right)+R_2-D_2\left(x_{2,l_2},y_2\right)\\&-\Delta\left(x_{1,l_1},x_{2,l_2}\right)+\pi_2^{o_1,d_1,l_1}\left(x_{1,l_1}\right)Q_1\mathbb{I}_{1\frown 2}\end{aligned} \tag{6}$$

This general constraint further simplifies when considering specific series of discrete residential choices. For instance:

- if $k_j=r_j$ then $\rho=1$, $\tau_1=0$, $\mu_j^{r_j,d_j,l_j}=0$;
- if $l_1=l_2$ then $d_1=d_2$, $Q_2=Q_1$, and $\Delta\left(x_{1,l_1},x_{2,l_1}\right)=0$ by convention.

2.3 Bequest function

The dwelling(s) transmitted at the beginning of period 3, if any, were necessarily bought previously. For $j=1,2$, we denote by $\mathbb{I}_{j\frown 3}$ the dummy variable indicating that a dwelling is bought in period j and transmitted to heirs at period 3. The total value of the bequest evaluated in period 3 is therefore:

$$B=\pi_3^{o_1,d_1,l_1}\left(x_{1,,l_1}\right)Q_1\mathbb{I}_{1\frown 3}+\pi_3^{o_2,d_2,l_2}\left(x_{2,l_2}\right)Q_2\mathbb{I}_{2\frown 3}+(1+r_2)\,S_2, \tag{7}$$

2.4 Characterization of the solution

Consider now that the household is able to compute optimal demands and derived indirect utility function for each possible trajectory of discrete decisions. It would then compares the levels of utility of every possible series of decisions and it selects the one that maximizes its utility. As modellers, we want to define more precisely these optimal demands and indirect utility functions so as to develop a structural framework.

We proceed in two steps to solve the problem of the household. We consider in a first step that the household chooses one of the possible trajectories of discrete residential choices, i.e. location, tenure and dwelling types. Given prices and budget resources, its problem is then to determine its optimal demands for floor spaces Q_1 and Q_2 and other consumption expenditures C_1, C_2 plus a potential level of savings S_2 due to bequest behaviour so as to maximize an intertemporal utility function subject to budget constraints.

We however have to account for two key decisions. The first regards whether to move from one dwelling to another in between period 1 and period 2. The second regards whether to leave housing or savings as bequest to heirs. Combination of both does not give the same maximization program.

In a second step, once obtained optimal demands and savings, thus the associated indirect utility function, and still considering that the household is maximizing its utility function, the optimal series of discrete choices is the one that corresponds to the conditional (to discrete residential choices) indirect utility function that reaches the largest level.

2.4.1 On bequest composition

As already stated, the solution of the problem depends on the composition of the bequest, which in turn depends on whether markets are perfect. We make some proposition accounting only for tenure type but extension to account simultaneously for tenure and dwelling types would just introduce more complexity without improving understanding of our baseline assumptions.

Definition 1. *Full perfection holds if*

- $r_1 = r_2 = \tau_1 \equiv r$
- $\mu_1^{o_1} = \mu_2^{o_2} = 0$
- $\kappa_1^{o_1}(x_1) = \kappa_2^{o_2}(x_2) \equiv \kappa$
- $\pi_j^b(x_j) = \pi_j^r(x_j)\,,\ j = 1,2$
- $(1 + r_t)\,\pi_t^b(x_j) = \pi_{t+1}^b(x_j)\,,\ j = 1,2,\ t = 1,2.$

In order to simplify notations, we define implicit prices :

$$
\begin{aligned}
\Pi^0_{Q_1} &= \left\{ \left(1 + \mu_1^l\right)\left[(1 + r_1)\,\rho + (1 + \tau_1)(1 - \rho)\right] + (1 + r_1)\,\kappa_1^l(x_1) \right\} \pi_1^l(x_1) \\
\Pi^0_{Q_2} &= \left[\left(1 + \mu_2^l\right) + \kappa_2^l(x_2) \right] \pi_2^l(x_2) \\
\Pi^0_{C_1} &= (1 + r_1)\, p_1 \\
\Pi^0_{C_2} &= p_2 \\
\Pi^0_{S_2} &= 1
\end{aligned}
\tag{8}
$$

Lemma 1. *Full perfection implies that the relative implicit prices in the bequest equation are equal to the relative prices in the intertemporal budget constraint:*

$$\frac{\Pi^0_{Q_1}}{\pi_3^b(x_1)} = \frac{\Pi^0_{Q_2}}{\pi_3^b(x_2)} = \frac{1}{(1 + r_2)}$$

Proof. The result is straightforward by applying the simplifications implied by full perfection in Equations (6) and (7). □

Lemma 2. *Under full perfection, and with no budget constraints ($S_1 \gtrless 0$), at the optimal solution, the household is indifferent between renting and buying, and the bequests are transmitted indifferently as real estate or money. The problem reduces to the maximization of a standard Cobb-Douglas function*

$$C_1^{\alpha_1} Q_1^{1-\alpha_1} C_2^{\beta\alpha_2} Q_2^{\beta(1-\alpha_2)} S_2^{\beta^2\gamma_2}$$

under the simplified intertemporal budget constraint:

$$(1+r)\,p_1C_1 + p_2C_2 + S_2 + (1+r)\,(1+\kappa)\,\pi_1^l\,(x_1)\,Q_1 + (1+\kappa)\,\pi_2^l\,(x_2)\,Q_2 \\ = (1+r)\,[R_1 - D_1\,(x_1,y_1)] + [R_2 - D_2\,(x_2,y_2) - \Delta\,(x_1,x_2)]\,.$$

Proof. Indifference between renting and buying results from the absence of budget constraints associated with the conditions $\pi_j^b\,(x_j) = \pi_j^r\,(x_j)\,,\ j = 1,2$ and $\mu_1^b = \mu_2^b = 0$. Lemma 1 implies that real estate has exactly the same value whether is is transmitted as real estate or sold at period 2 (or at period 1 when relevant), and the corresponding value is transmitted to heirs as a monetary bequest S_2. We can therefore assume that dwellings are rented at both periods, and only a monetary bequest is transmitted. □

Proposition 1. *There exists exactly one form of bequest, entailing either real estate (bought either in first or in second period), or money if and only if the three ratios* $\frac{\Pi^0_{Q_1}}{\pi_3^b(x_1)} \neq \frac{\Pi^0_{Q_2}}{\pi_3^b(x_2)} \neq \frac{1}{(1+r_2)}$.

Proof. According to Lemma 1, when the three ratios are equal, interior solutions with composite bequest (entailing both real estate and money) are optimal. The reciprocical part proceeds by contradiction. Consider an optimal solution denoted by $\{C_1^*, Q_1^*, C_2^*, Q_2^*, S_2^*\}$. Assume, without loss of generality, that $\frac{\pi_3^b(x_1)}{\Pi^0_{Q_1}} > 1 + r_2$ Assume further $\mathbb{I}_{1\frown 3} = 1$ and $S_2 > 0$. Consider an infitesimal change $\Delta > 0$ such that Q_1^* is replaced with $Q_1^* - \frac{\Delta}{\Pi^0_{Q_1}} < Q_1^*$ and C_1^* is replaced with $C_1^* + \frac{\Delta}{(1+r_1)p_1}$. The total cost of this infinitesimal change is zero, so intertemporal utility remains unchanged. Consider an additional change such that S_2^* is replaced with $S_2^* + \frac{\Delta\pi_3^b(x_1)}{(1+r_2)\Pi^0_{Q_1}}$ and first period consumption of composite good becomes

$$C_1^* + \frac{\Delta}{(1+r_1)p_1} - \frac{1}{(1+r_1)p_1}\frac{\Delta\pi_3^b(x_1)}{(1+r_2)\Pi^0_{Q_1}} = C_1^* + \underbrace{\left(1 - \frac{\pi_3^b\,(x_1)}{(1+r_2)\,\Pi^0_{Q_1}}\right)}_{<0 \text{ since } \frac{\pi_3^b(x_1)}{\Pi^0_{Q_1}} > 1+r_2}\frac{\Delta}{(1+r_1)p_1} < C_1^*.$$

The total cost of this additional infinitesimal change is zero, so intertemporal utility remains unchanged. The second change moves the total bequest back to its initial value (here, we use $\mathbb{I}_{1\frown 3} = 1$). The combination of these two infinitesimal changes leaves intertemporal utility, total bequest value, and second-period utility unchanged. As a result, it leaves first-period utility unchanged. This is in contradiction with the decrease in both C_1 and Q_1, since $u_1\,(\cdot)$ is increasing in its arguments. Similarly, considering $Q_2^* \to Q_2^* - \frac{\Delta}{\Pi^0_{Q_1}} < Q_2^*$ and $C_2^* \to C_2^* + \frac{\Delta}{p_2}$ proves that $\frac{\pi_3^b(x_2)}{\Pi^0_{Q_2}} > 1 + r_2$, $\mathbb{I}_{2\frown 3} = 1$ and $S_2 > 0$ cannot hold simultaneously. Finally, a similar infinitesimal change in Q_1^*, C_1^*, Q_2^* and C_2^* leaving both total bequest and total cost unchanged proves that $\frac{\pi_3^b(x_2)}{\Pi^0_{Q_2}} \neq \frac{\pi_3^b(x_1)}{\Pi^0_{Q_1}}$, $\mathbb{I}_{1\frown 3} = 1$ and $\mathbb{I}_{2\frown 3} = 1$ cannot hold simultaneously. □

Proposition 1 implies that, under perfect foresight, the case in which the household owns and transmits to heirs both the dwelling where it lives in period 1 and the dwelling where it lives in period 2 cannot be optimal when the relative (implicit) price of these two assets is not the same in period 2 and in period 3, which constitues a systematic imperfection in real estate markets in Paris region. It happens that, in our dataset, this case represents less than 1% of the sample. This low percentage is consistent with unanticipated changes in personal or professional situation over the life cycle (such unanticipated changes are ignored in lour model).

2.4.2 Optimal series of discrete choices

Another result of our model is that, once solved the intertemporal optimization program, the indirect utility functions for every sequence of tenure and dwelling types write using only two different mathematical formulations:

$$\bar{V}_{l_1,l_2,d_1,d_2,k_1,k_2} = \Omega_{l_1,l_2,d_1,d_2,k_1,k_2} - \lambda^0_{Q_1} \ln\left(\Pi_1^{l_1,d_1,k_1}\right) - \lambda^0_{Q_2} \ln\left(\Pi_2^{l_2,d_2,k_2}\right) + \lambda \ln\left(W\left(x_1, x_2\right)\right)$$

for movers and

$$\bar{V}_{l_1,l_1,d_1,d_1,k_1,k_2} = \Omega_{l_1,l_1,d_1,d_1,k_1,k_2} - \lambda^1_{Q_1} \ln\left(\Pi_1^{l_1,d_1,k_1} + \Pi_2^{l_1,d_1,k_2}\right) + \lambda \ln\left(W\left(x_1, x_1\right)\right)$$

for non movers where

- $\lambda^0_{Q_1} = (1-\alpha_1) + \beta^2\gamma_2 \mathbb{I}_{1\frown 3}$,
- $\lambda^0_{Q_2} = \beta(1-\alpha_2) + \beta^2\gamma_2 \mathbb{I}_{2\frown 3}$,
- $\lambda^1_{Q_1} = (1-\alpha_1) + \beta(1-\alpha_2) + \beta^2\gamma_2 \mathbb{I}_{1\frown 3}$
- $\lambda = 1 + \beta + \beta^2\gamma_2$
- Ω's are functions of the possible choices, the exogenous variables, and the parameters of U

The optimal series of discrete choices is solution of

$$\max\left(\max_{l_1,l_2,d_1,d_2,k_1,k_2}\left(\bar{V}_{l_1,l_2,d_1,d_2,k_1,k_2}\right), \max_{l_1,l_1,d_1,d_1,k_1,k_2}\left(\bar{V}_{l_1,l_1,d_1,d_1,k_1,k_2}\right)\right) \tag{9}$$

3 Application

We present in this section a probabilistic discrete choice to analyze dynamics of tenure and dwelling types *given locations*. We focus on the population of inhabitants that lived and may have moved within the Paris region in 2002 and 2006.

3.1 Data

Empirical implementation of our theoretical model is data demanding in that we need to have available at least longitudinal disaggregate data but not only.

Our main data source is the 2006 French National Housing Survey (FNHS). It reports observed housing choices of French households during this year and it briefly reports those made in 2002. For these two years, we also observe socioeconomic and demographic characteristics of these decision makers. We however point out that available information is somewhat limited for year 2002.

As the 2006 FNHS is a revealed preference survey, we don't have any information about unchosen alternatives. We therefore need to complement this survey by drawing statistical information from other data sources, especially regarding housing prices. To this extent, we will use 2003 and 2007 Côtes Callon.

Furthermore, it appears that some of the attributes of all the likely alternatives, especially as it regards local amenities, are not described. As it regards our problem, we see mainly two demanding requirements: information about prices by location, dwelling and tenure types, and information about local amenities by location.

3.1.1 Sample formation

We have initially 6988 observations. When we look at combinations of tenue and dwelling types at these dates, we observe that only 5 of them appears enough significant. They are written italics in table 1.

Table 1: Matrix of tenure and dwelling types in 2002 and 2006

	Dwelling types (2002, 2006)				
Tenure types (2002, 2006)	(h,h)	(h,f)	(f,h)	(f,f)	Total
Move, (o,o), keep	23	9	10	16	58
Move, (o,o), resell	*53*	*14*	*44*	*46*	*157*
Move, (o,r), keep	3	17	1	14	35
Move, (o,r), resell	7	10	4	17	38
No move, (o,o)	*1440*	*0*	*0*	*967*	*2407*
No move, (o,r)	33	0	0	19	52
Move, (r,o)	*25*	*6*	*133*	*170*	*334*
Move, (r,r)	*18*	*41*	*60*	*809*	*928*
No move, (r,o)	25	0	0	35	60
No move, (r,r)	*171*	*0*	*0*	*2748*	*2919*
Total	1798	97	252	4841	6988

o: own, r: rent; h: house, f: flat; (,) is defined as (type in 2002 , type in 2006)

Move, No move: change home or not, Keep, resell: keep formerly owned home or resell it

For the rest of our application, we will not consider choice situations where a household moves in between 2002 and 2006 and keep its owned dwelling that served as a residence in 2002 whatever its new tenure type. We also won’t the choice situation where a household changes tenure type from owner to renter. Finally, we won’t consider the situation where a household may become owner of the dwelling it was renting in the former period: there is an obligation to change dwelling.

We virtually have 5 sequences of tenure types by 4 sequences of dwelling types but, by natural constraint, we have to remove 4 of them. We then have 16 choice situations. We observe that our 6745 remaining observations greatly favours non moving choices. Only 1419 observations (21.04%) concern moving households. We also observe that:

- shift in tenure type from rental to ownership if closely related to households that move from an apartment to a house. The reciprocal exists but it is not that much important;
- move and ownership at both periods is often associated to a non change in dwelling type;
- house renting is not a very usual choice.

3.1.2 Attributes of unchosen alternatives

As already stated, the 2006 FNHS is a revealed preference survey. We only have description of what has been done but not what may have been done. As we want to parametrize and estimated a probabilistic choice model, one important task is to reconstruct pertinent variables that describe attributes of unchosen alternatives. For other reasons, we also have missing data that describe characteristics of some households. We can use some secondary tables of the 2006 FNHS but it is not enough: we need to draw additional information from other data sources. Data imputation is made using standard statistical techniques and developing a series of auxiliary descriptive models. We discuss and present them in this subsubsection.

First of all, we remind the reader that we don’t have accurate information about locations of dwellings. We only have locations at the “département” level, a very large administrative geographical unit (there are only 8 département for the region we consider). Even though we stated that we present a model of dwelling and tnure types given locations, we would have prefered to have available these variables at least to be able to compute less roughly housing prices for unchosen alternatives. This is not the case and, as a result:

- we are not able to compute any transportation cost or accessibility indicator;
- housing prices that we will compute for unchosen alternatives will be at the “département” geographical scale.

In order to reconstruct housing prices, we firstly need some external baseline data. We will use 2003 and 2007 Côtes Callon (data collected during years 2002 and 2006), which provide average housing prices for apartments and houses in several locations of the region and for different levels of comfort and quality of the dwellings. We compute weighted average housing prices for apartments and houses at the "département" level". Weights are drawn from the 2006 census of population and consider only age of the building. We also assume that these weights did not change in between 2002 and 2006 so that we use them to obtain our necessary housing prices for year 2002.

Secondly, we also need to convert both purchasing and renting prices to some comparable unit. To this extent, we will convert purchasing prices to "pseudo" renting prices. We will base our analysis on the "mortgage" table of the 2006 FNHS that regards housing loans that were contracted by French inhabitants of the Paris region (disregarding our sample selection) for the dwelling they purchased earlier and currently live in. Using an auxiliary regression model, we then will be able to impute missing information about mortgage level, pay-down fraction and interest rate for household that actually chose to rent.

Another point is about how to deal with non moving households when reconstructing variables of choice alternatives that imply it to move from one location to another. Here again, we have to constrain our approach. A brief look at the data shows that about 71.20% of moving households stay in the same "département". Another look at the 2006 Census of population also shows that many households keep rather conservative in their choices of new residence place. For our model, we will then assume that if a non moving household would have chosen to change dwelling in between 2002 and 2006, it would then have been in the same "département".

We now list what we assumed to reconstruct housing prices for every considered household in our sample:

- non moving households would have chosen the same "département" if they had chosen to change dwelling
- for owners, we assume for each dwelling type that the renting price is given by the corresponding average rental price per square metre at the level of "département" computed from Côtes Callon;
- for renters, we proceed in 3 steps:
  - we draw for each dwelling type the average purchasing price per square metre at the level of "département";
  - we impute how much, how long, and at which interest rate would be a mortgage to buy the dwelling. To impute the values of these variables, we adjust a hierarchical simultaneous equation system by full information likelihood method. We use the "mortgage" table of the 2006 FNHS that regards housing loans that were contracted by French inhabitants of the Paris region for the dwelling they purchased earlier and currently live in. Our specification is rather simple: we assume that the mortgage amount is function of income per capita, age of the household head, and household size. Mortgage duration is function of the ratio between

mortgage amount and total household income. Mortage interest rate is function of mortgage duration and a year-specific variable. Quality of fit is rather good for a such simple system and estimates are along with intuition. We obtain that mortgage amount is an increasing function of income per capita and follows a U-shape with respect to age of household head. It is also an increasing function of household size. Duration of a mortgage is and increasing function of the ratio between amount and income. Naturally, interest rate decreases in between 2002 and 2006 and is a decreasing function of the duration. Estimates are reported in table 2.

Table 2: Mortgage-related system of equations

Log. of amount equation		
Label of variable	Estimate	T-stat.
Intercept	6.66	6.68
Log. of income per capita	0.62	6.84
Age of household head	-0.10	-6.67
Age of household head squared	0.001	5.81
Log. of household size	0.27	4.03
Log. of duration equation		
Intercept	2.59	259.80
Log. of ratio between amount and total income	0.16	24.28
Log.of interest rate equation		
Intercept	3.57	7.77
$\mathbb{I}^a$: year 2002	0.21	6.27
Log. of duration	-0.91	-5.23
Number of observations	1628	
Overal ρ^2	0.78	

^{a}: $\mathbb{I}$: dummy variable

- we then impute how much would be the monthly reimbursement amount for renters in our sample (as already stated, we need to make comparable housing purchasing and monthly rental prices per square meter). To this extent, we use simple financial mathematics. We assume that household i buy a dwelling of type k in location l by means of a mortgage. An amount equal to $(1-\rho_i)\,\pi$ per square meter is borrowed over a period of T_i years at an annual interest rate of τ_i. ρ_i is the fraction of down payment and $\pi_{k,l}$ is the purchasing price per square meter. The monthly expenditure in housing per meter square is defined as the fixed monthly reimbursement $C_{i,k,l}$:

$$C_{i,k,l} = \frac{\tau \pi_{k,l}}{1-(1+\tau)^{-T}}. \tag{10}$$

We finally merge these imputed values with these related to the revealed choices of households. We now have available a set of housing prices for every observed and likely housing choice of all households.

3.1.3 Income and wealth

We also miss 2002 income levels. Actually, we have 2006 income levels but some observations are also missing. We proceed as it is often done in many applications to impute missing values of this variable for year 2006. We fit a type II Tobit model (also known as generalized Tobit model). The first part of the model consists in explaining non reporting of the income variable by some households. The second part of the model consists in explaining the levels of incomes of households using only the subset of observed income levels and correcting for this sample selection bias. Estimates are reportted in table 3.

Table 3: Imputation of income variable

Label of variable	Estimate	T-stat.
Selection equation		
Intercept	0.84	33.02
$\mathbb{I}^a$: household head is an active worker	0.33	11.94
$\mathbb{I}$: household head is unemployed	-0.14	-3.99
$\mathbb{I}$: household head is retired	0.36	12.11
Log. of 2006 income equation		
Intercept	7.14	148.47
Log. of age of household head	0.48	39.21
Log. of household size	0.48	81.34
$\mathbb{I}$: household head is an active worker	0.91	68.16
$\mathbb{I}$: household head is unemployed	0.04	2.54
$\mathbb{I}$: household head is retired	0.54	34.53
$\mathbb{I}$: household lives in Paris	0.02	1.50
$\mathbb{I}$: household lives in Seine-et-Marne	0.14	6.93
$\mathbb{I}$: household lives in Yvelines	0.23	10.63
$\mathbb{I}$: household lives in Essonnes	0.16	8.71
$\mathbb{I}$: household lives in Hauts-de-Seine	0.11	6.15
$\mathbb{I}$: household lives in Seine-Saint-Denis	-0.13	-7.89
$\mathbb{I}$: household lives in Val de Marne	0.06	3.22
$\mathbb{I}$: household lives in Val d’Oise	0.07	3.82
Standard deviation of error term	0.58	272.49
Correlation of error terms	-0.00	-0.00
Overall ρ^2	0.58	

^{a}: $\mathbb{I}$: dummy variable

Here again, we use a simple specification of the model. Goodness-of-fit of the model is not as good as we would expect but we use these results to impute both missing values of income R for years 2006 and 2002. The latter is made using part of socio-demographic information we have available at this year in the survey. Of course, we implicitely assume that the relation between the dependent variables and the exogenous variables stays constant over the $2002 - 2006$ period.

We finally compute wealth as $R_{2002} + \frac{R_{2006}}{1+r}$ where r is defined as the interest rate of a risk-free monetary asset. In our application, it is defined as a 4 years investment in the french "livret A":

$$(1+r)^4 = \prod_{t=2002}^{2005} (1+i_t) \tag{11}$$

where $i_t, t = 2002, \cdots, 2005$, are drawn from data of "Banque de France".

3.1.4 Transportation and moving costs

We don't have any accurate measurement of these variables in data. We also are limited as it regards locations of dwellings. Furthermore, we don't have any information about automobile ownership and use at the household level. Finally, there is nothing about travel behaviour of households. There is no possibility to compute variables that regard transportation costs or moving costs.

3.2 Model specification

We now turn to the econometric specification of our probabilistic discrete choice model.

3.2.1 Choice set

The first step is to elaborate a little bit more on the structure of the choice set we consider. We focus here on dynamics of dwelling and tenure types at two spaced dates. There exists several ways to nests the different dimensions of our choice set. We assume the following. Firstly, dwelling type for year 2002 is chosen. Then, tenure type for year 2002 is chosen. In between 2002 and 2006, the choice to move or not is made. In year 2006 is made again the choice of a tenure type and then a dwelling type. We may have privileged the choice of a dwelling type prior to the choice of a tenure type or even other combination of the sequence of choices. The search of the most relevant combination is left aside for future research work. Figure 1 summarizes the nesting structure of choices we consider for our application.

3.2.2 Indirect utility functions

Because of missing statistical information, proxy variables, measurement errors, and because we only observe choices, we assume that the indirect utility function for household i are continuous random variables

$$V_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,2},t_{i,1},t_{i,2}} = \bar{V}_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,2},t_{i,1},t_{i,2}} + \epsilon_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,2},t_{i,1},t_{i,2}}$$

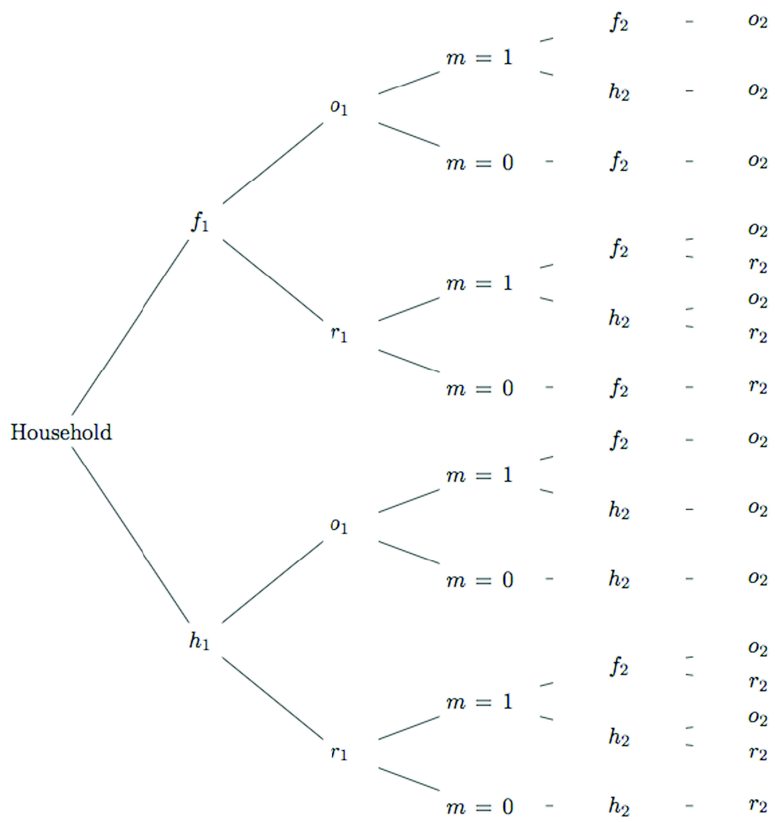

Figure 1: Sequence of choices

and

$$V_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,1},t_{i,1},t_{i,1}} = \bar{V}_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,1},t_{i,1},t_{i,1}} + \epsilon_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,1},t_{i,1},t_{i,1}}$$

We also assume that parameters of the utility function (α's and γ) are function of the characteristics of the household (here, household size)

3.2.3 Probabilistic formulation

ϵ's enter additively and are independent from observed variables. For each observed household, they are distributed with a GEV distribution, $\boldsymbol{\epsilon}_i \rightarrow F(\boldsymbol{\epsilon}_i) = \exp(-H(\boldsymbol{\epsilon}_i; \boldsymbol{\sigma}))$. The choice probabilities are defined as

$$\Pr(x_{i,1}, x_{i,2}, d_{i,1}, d_{i,2}, t_{i,1}, t_{i,2}) = \exp\left(\bar{V}_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,2},t_{i,1},t_{i,2}}\right) \frac{\partial H\left(\exp(\bar{\mathbf{V}}_i); \boldsymbol{\sigma}\right)}{\partial \exp\left(\bar{V}_{i,x_{i,1},x_{i,2},d_{i,1},d_{i,2},t_{i,1},t_{i,2}}\right)} H\left(\exp\left(\bar{\mathbf{V}}_i\right); \boldsymbol{\sigma}\right)^{-1} \tag{12}$$

H is chosen to satisfy the nested structure of choices as presented in figure 1. It takes the form of a 5-level Nested Logit model. There are effects of lower choices in the tree on related upper choices ("logsum", i.e. effect of maximum expected utility of a subsequent choice on current choice). We refer the reader to McFadden (1977), Ben-Akiva & Lerman (1985), Train (2003) for explicit formulation of these choice probabilities.

3.3 Results

The model is estimated by maximum likelihood method. Estimates are reported in tables 4 and 5. We observe several significant effects, all along with theory and common practive.

It is found that household is sensitive to floor space consumption ($1-\alpha$'s coefficients) and that this sensitivity increases with household size. We also remark that the ratio of periodic sensitivities is larger than 1, as expected, meaning that there exists a strictly positive (and lower thatn 1) discounting factor. There also exists a significant bequest effect as scaled γ is found to be positive. Accumulating assets, whatever they take the form of money or housing, increases household's level of utility. We are however not sure whether it directly regards heirs or future period of the household as we did not control for lifecycle effects. Anyway, data shows that there exists a positive effect in accumulating assets for future periods of life, whichever they regards the household or its heirs.

Results also show that there are different effects of socio-economic and demographic characteristics on dynamics of delling and tenure types. Income has a positive effect on the probability to choose a house instead of an apartment. It also has a positive effect on the probability to move, i.e. to change dwelling, over time. This is not surprising as it the relative contribution of moving costs are then lesser and that the relative larger purchasing power favours consumption of more space and a more private type of dwelling (no direct up and down neighbours).

We also observe that the structure of a household and its evolution affects the sequence of dwelling and tenure types. Actually, it is found that work status of the household head change the way housing is consumed. If he/she retires in the second period then he/she anticipated a lowering of his/her household income and then privileges the choice to own in the first period and then stay in the same dwelling. If he/she is unemployed in the second period, he/she prefers to rent in both period and move to another dwelling. Any choice that involves ownership in either the first or the second period is ranked down. If he/she is unemployed in both period, then renting the same dwelling both periods is favoured. We also observe that if he/she is a student in 2002 and then work in 2006, what is favoured is renting during the first period and then buying in the second period.

When there is a change in workplace or job type of any household member, the probability to move is increasing. Such a result is along with the fact that the household looks at minimizing transportation costs. We also find that a variation of the household size has an asymmetrivcal effect on the probability to move: an increase of the size favours change of dwelling but a decrase of size does not affect significantly the proability to move.

Finally, All the same, there is a “natural” trend in prefering to consume flat rather than houses.

Table 4: Estimates of the discrete choice model

Label	Est.	T-stat.
Intercepts:		
dwelling type is house in 2002, same dwelling in 2002 and 2006[b]	-0.94	-3.48
dwelling type is house in 2002, move[c]	-1.26	-3.96
dwelling type is house in 2006, move[d]	-1.30	-3.18
move	-1.71	-4.89
HH head works in 2002 and is unemployed in 2006, effects on[a]:		
own in 2002 and 2006 and move	-2.76	-4.49
own in 2002 and 2006 and stay	-2.00	-9.93
rent in 2002 and own in 2006 and move	-0.94	-2.84
rent in 2002 and 2006 and move	0.16	1.77
HH head works in 2002 and is retired in 2006, effects on[a]:		
own in 2002 and 2006 and move	0.00	0.01
own in 2002 and 2006 and stay	0.72	4.73
rent in 2002 and own in 2006 and move	0.35	1.53
rent in 2002 and 2006 and move	-0.26	-1.29
HH head is unemployed in 2002 and works in 2006, effects on[a]:		
own in 2002 and 2006 and move	-2.67	-3.01
own in 2002 and 2006 and stay	-1.75	-5.16
rent in 2002 and own in 2006 and move	-1.48	-2.20
rent in 2002 and 2006 and move	0.07	0.57
HH head is unemployed in 2002 and in 2006, effects on[a]:		
own in 2002 and 2006 and stay	-0.87	-4.95
rent in 2002 and own in 2006 and move	-1.43	-2.13
rent in 2002 and 2006 and move	-0.12	-1.02
HH head is retired in 2002 and in 2006, effects on[a]:		
own in 2002 and 2006 and move	-1.12	-2.78
own in 2002 and 2006 and stay	0.58	5.50
rent in 2002 and own in 2006 and move	-1.19	-3.36
rent in 2002 and 2006 and move	-0.63	-3.03
HH head is student in 2002 and works in 2006, effects on[a]:		
own in 2002 and 2006 and stay	-2.23	-3.22
rent in 2002 and own in 2006 and move	0.37	1.23
rent in 2002 and 2006 and move	0.61	2.67

Looking now at the inclusive values, i.e. “logsum effects”, these are all in line with theoretical constraint that ensure that the probabilistic model actually derives from random utility maximization. They all exhibit existence of “within-nest” substitution patterns.

Table 5: Estimates of the discrete choice model, cont’d

Label	Est.	T-stat.
Income:		
dwelling type is a house in 2002[e]	0.09	5.54
dwelling type is a house in 2006 [f]	0.17	3.08
move[g]	0.08	2.44
HH member other than HH head (re)starts working, effect on prob. to move[h]	0.01	0.14
Change in job and or workplace of any HH member, effect on prob. to move[h]	0.37	3.21
HH member other than HH head stops working, effect on prob. to move[h]	-0.16	-2.59
Decrease in HH size in between 2002 and 2006, effect on prob. to move[i]	0.04	0.80
Increase in HH size in between 2002 and 2006, effect on prob. to move[i]	0.73	3.30
$1 - \alpha_1$ scaled:		
baseline	0.61	2.69
per additional HH member	0.20	3.18
$\beta\,(1 - \alpha_2)$ scaled:		
baseline	0.43	3.56
per additional HH member	-0.06	-2.23
$\beta^2\gamma_2$ scaled:		
baseline	0.29	5.14
per additional HH member	-0.02	-2.48
logsum: dwelling type choice in 2006 on prob. to move, own in 2002	0.51	3.98
logsum: dwelling type choice in 2006 on tenure type choice in 2006, rent in 2002, move	0.55	8.77
logsum: choice to move on dwelling type choice in 2002	0.69	7.14
logsum: dwelling type choice in 2002 on tenure type choice in 2002	0.86	11.21

[a]: reference: HH head works in 2002 and 2006 and HH rents the same dwelling over both period; [b]: reference is flat, same dwelling in 2002 and 2006
[c]: reference is flat in 2002 and move; [d]: reference is flat in 2006 and move
[e]: reference is flat in 2002; [f]: reference is flat in 2006;[g]: reference is stay
[h]: reference is no modification in job or workplace for every HH member; [i]: reference is no modification of HH structure

4 Conlusion

We developed a structural microeconomic framework to analyze simultaneously several aspects of the dynamics of residential choices: location, dwelling, and tenure. We accounted for intertemporal budget constraints while allowing for bequest motives. Our analytical formulation is tractable for empirical matters, and we therefore proposed an econometric formulation of the approach by using a nested-Logit probabilistic choice models. We discussed demanding and stringent data requirements to implement it.

Our work may however be further extended in several ways. First, the model may be extended to a multi-period maximization program. Second, the assumption about perfect information and perfect foresight of market variables is questionable. The approach may be formulated as a dynamic discrete choice model with forward-looking economic agents. We also think that using estimated parameters from the econometric model would provide a better basis to perform simulation of an urban system equilibrium.

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