Micro-simulation model of municipality network in the Auvergne case study

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PRIMA working paper

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1 INTRODUCTION

How do European rural areas evolve? Some tend to decrease dramatically, as in the Netherlands or in the United Kingdom, where the urban areas tend to spread all over the country. Their population can also be drastically depleting through a large rural exodus, as observed in for instance France, Bulgaria or Croatia in the first part of the last Century. They can also keep steady population densities occupied in leisure services offered to urban people and agriculture with various proportions of inhabitants commuting to the cities for their work. Better understanding these evolutions is what the PRIMA simulation model presented in this report is interested in[1].

Indeed, the objective is to simulate the evolution of demographics and activities in the rural municipalities through a micro modelling approach. In the literature, the evolution of the rural municipalities is attributed to several dynamics. The most cited is what is called the residential economy (Blanc and Schmitt 2007; Davezies 2009) which argues that rural areas dynamics is linked to the money transfers between production areas and residence locations. These money transfers are fro instance performed by commuters, or by retirees who move from the urban to the rural areas. Indeed migrations from urban to rural areas are also considered as a very important strand for rural areas evolution (Perrier-Cornet 2001). The residential economy studies particularly how an increasing local population (and money transfers) increases the employment in local services. The geographic situation plays also a role in the municipality evolution (Dubuc 2004).

To summarise, the literature stresses out the importance of:

- The different types of mobility between municipalities: commuting, residential mobility (short range distance), migration (long range distance) (Coulombel 2010);
- the local employment offer generated by the presence of the local population;

These two aspects have to be properly taken into account in our model, since our objective is to study through simulations the dynamics of rural areas. Obviously, it appears also essential to model the demographic evolution of the municipality considering the strands explaining the local natural balance.

To model both the demography and different types of mobility, we consider a social simulation micro modelling (Gilbert and Troitzch 2005). Micro modelling includes three different approaches: cellular automata, microsimulation and agent-based models.

A cellular automaton involves a finite number of cells on a grid. Each cell has a finite number of states. The state of a cell changes depending on a function taking into account the state of the neighbouring cells.

The microsimulation (Orcutt 1957) is initially a projection at the individual or micro level of some aggregated data in order to assess the heterogeneity of the impact of a policy. Then, more recently, the microsimulation started to include dynamics and it now considers individuals that change their state according to probabilistic laws independently from each other. Only undirected interactions through the environment (constraints on job or dwelling offers for example) are taken into account in the microsimulation approach (Bourguignon and Spadaro 2006; Moeckel et al. 2003; Morand et al. 2010; O'Donoghue 2001). Cellular automata and microsimulation are often used to simulate the land use and land cover change (Ballas et al. 2005, 2006; Ballas et al. 2007; Brown et al. 2006; Coulombel 2010; Moeckel et al. 2003; Rindfuss et al. 2004; P.H. Verburg et al. 2002; P.H. Verburg et al. 2004; P. H. Verburg et al. 2006). Microsimulation alone is the most frequent formulism used in demography modelling (INSEE 1999), (Holme et al. 2004), (Turci et al. 2010) (Morand et al. 2010).

The last micro modelling approach considers individuals, each interacting with the others and with her environment. We adopted this approach in the IMAGES project (Deffuant and al. 2001; Deffuant et al. 2002; Deffuant et al. 2005; Deffuant et al. 2008) for example where it has been particularly interesting for gathering different aspects of the complex problem of agri-environmental measure adoption, and the viewpoint of stakeholders. Many other researches point out the interest of agent-based approaches (Bousquet and Le Page

[1] The PRIMA project (PRototypical policy Impact on Multifunctional Activities in rural municipalities) has been funded by the EU 7th Framework Programme (ENV 2007-1), contract n° 212345 – https://prima.cemagref.fr

2004; Brown and Robinson 2006; Fontaine and Rounsevell 2009; Parker et al. 2003) (Fontaine and Rounsevell 2009). They have noticed *this type of model is particularly well suited for representing complex spatial interactions under heterogeneous conditions and for modelling decentralized, autonomous decision making* (Parker et al. 2003). Moreover (P.H. Verburg et al. 2004) in their review of current models of land use and land cover change underline the need of *a new generation of land use models that better address the multi-scale characteristics of the land use system* and spatial interactions. They suggest that agent based approaches have good assets to address this challenge. However, (Parker et al. 2003) also emphasise the challenge of the level of abstraction: "*Whatever the goal of modelling efforts, balancing the utility of abstraction against the need to include the critical components of the system under study is a major challenge of modelling*". Aged based models can also address some complex individual dynamics, largely unknown and for which no data are available, such as the residential location decision (Coulombel 2010). Parker et al. also stress that "*The lack of validation of most current land use models makes it impossible to properly assess the performance of these models. Validation would enable to inform policy makers and other users of model results, on the uncertainties in the model outcomes and help the modeller to assess the suitability of the model for a particular situation and provide ideas to improve the model".*

Then trying to develop an approach which is as close to the data as we can, we decide to use mainly microsimulation even if we had to include a few heuristic rules for some state transitions that make the model close to the agent based spirit in some of its dynamics.

To sum-up, the model implements virtual individuals, members of households located in municipalities and their state transitions corresponding to demographic and changing activity events: birth, finding a partner, moving, changing job, quitting their partner, retiring, dying … The virtual municipalities offer jobs and dwellings which constrain the possible state transitions.

Two sets of cruxes can be identified in the model:

- The individual dynamics which determine the needs for residence and qualifications for different jobs; Thus, the model includes individual's position on the labour market, the fact she is a job seeker or not, the distance between work and residence places in case of mobility, or simply the residence location for retirees or students.

- The dwelling and the job offers are exogenously defined by scenarios, except for jobs in proximity services. Indeed, we derive the number of jobs in proximity services offered in a municipality from the size of the municipality, using an appropriate statistical model. The change of number of jobs in proximity services tends therefore to enhance the growth or the depletion of municipalities. This is important because we are interested in understanding better the dynamics leading to the development or, on the contrary, to the decline and possible disappearance of municipalities and settlements.

Being strongly data-driven, this type of model is generally dedicated to a particular case study. The PRIMA project had the initial objective to model six different European rural regions. They differ a lot in their culture, their regulations and the available data. Thus, as a modelling approach, we adopt a compromise (Deffuant et al. 2006) between abstract modelling and totally data-driven modelling. Here we present the model which has been designed for the French case study, and from which we derived a more general model that has been applied on the other case studies of the PRIMA project.

The next section is entirely dedicated to the model and sub-models presentation.

2 THE PRIMA MODEL

We have adopted a micro-modelling approach. The presentation of the model globally follows the requirements of the ODD (Overview, Design concepts, and Details) framework (Grimm et al. 2006). Indeed, this recently updated protocol (Grimm et al. 2010) has proved its utility to describe properly complex individual-based models, for example in (Polhill et al. 2008).

2.1 PURPOSE

The purpose of the model is to study how the population of rural municipalities evolves. We assume that this evolution depends, on the one hand, on the spatial interactions between municipalities through commuting flows and service, and on the other hand, on the number of jobs in various activity sectors (supposed exogenously defined by scenarios) and on the jobs in proximity services (supposed dependent on the size of the local population).

2.2 ENTITIES, STATE VARIABLES AND SCALES

The model represents a network of municipalities and their population. The distances between municipalities are used to determine the flows of commuting individuals (for job or services). Each municipality comprises a list of households, each one defined as a list of individuals. The municipalities also include the offers of jobs, of residences and their spatial coordinates. Here is the exhaustive list of the main model entities with their main attributes and dynamics.

2.2.1 MUNICIPALITYSET

The set of municipalities can be of various sizes. It can represent a region of type NUTS 2 or NUTS 3[2], or more Local Administrative Units (LAU) or intermediate sets of municipalities such as "communauté de communes" in France. Talking about the set of municipalities we study by simulation, we called it the "bunch".

Parameter:

- proximity: a threshold distance between two municipalities: beyond this distance the municipalities are considered as far from each other.

2.2.2 MUNICIPALITY

It corresponds in general to LAU2[3], although we also consider smaller settlements if they are relevant for some case studies. The municipality is the main focus of the model, and it includes the following variables, also presented in the Figure 1 :

- A set of households living in the municipality. The household is considered as corresponding to the nuclear family[4]. The households include a list of individuals who have an occupation located inside or outside the municipality).
- The set of jobs existing on the municipality (by type), and how many of them are available for the population of the model (i.e. subtracting the jobs occupied by people living outside the modelling municipality set).
- The distribution of residences, or lodgings, on the municipality (by type corresponding to its size). In a residence there is generally 0 or one household, but there can also be several households. This is the case for instance when a couple splits up and one of the partner remains in the common residence for a while. It is also the case in some European countries where it is customary for several generations to live under the same roof.

A municipality called "Outside": this particular municipality represents the available jobs accessible from municipalities of the considered region, but which are not in the considered set of municipalities. The job offer of Outside is ruled differently depending on the case study:

- For a very small set of municipalities: by a scenario given the job offer and its evolution at various date. This means these values are exogenously defined;

[2] Eurostat defines the NUTS (Nomenclature of Territorial Units for Statistics) classification as a hierarchical system for dividing up the EU territory for the purpose of: the collection, development and harmonisation of EU regional statistics; Socio-economic analyses of the regions. Various levels are identified: NUTS 1for the major socio-economic regions; NUTS 2 for the basic regions for the application of regional policies; NUTS 3 as small regions for specific diagnoses; LAU (Local Administrative Units 1 and 2) has been added more recently to allow local level statistics

[3] consists of municipalities or equivalent units

[4] A nuclear family corresponds to the parents and the children; that is a reductive definition of the family corresponding on the most common way to define the family in Europe nowadays.

– For a large set of municipality (as for the Cantal county in France composed from 260 municipalities): the job offer is infinite and the occupation is defined by a probability of individuals to commute outside the set of municipalities (see 2.7.2 for details).

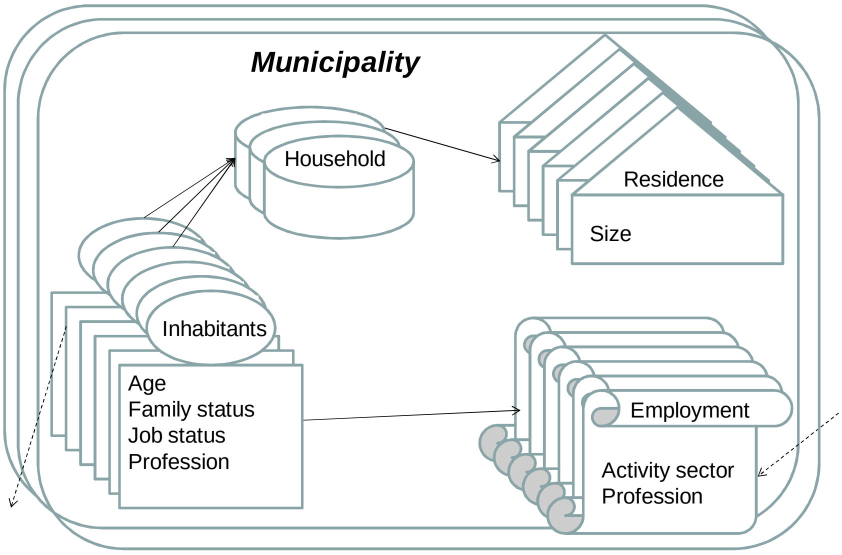

Figure 1. The entity "Municipality"

Parameters:

– An initial population of households composed by individuals with their attribute value and their situation on the labour market
– A residence offer: available number of residences for each type. A type corresponds to a number of rooms
– A job offer: number of jobs offered by the municipality for each type of job ; the exogenously defined part of job offer is distinguished from the endogenously defined part in order to update this last part easily (see 2.7.4 for more details)
– A set of close municipalities, the form depends on the size of the case study:
  ▪ for a small set of municipalities: the initialisation directly gives a list of easily accessible municipalities for each departure municipality;
  ▪ for a large set of municipalities (as for the Cantal county), we define several rings of close municipalities (practically every 3 Euclidian kilometre) with a maximum distance of 51 Euclidian km : the accessibility of each ring varies depending on the process (commuting [see 2.7.2], looking for a residence [see 2.7.3], looking for a partner [see 2.2.6]) following appropriate probability distribution laws. In this case, the parameter proximity (see 2.2.1) is the threshold distinguishing close from far municipalities.

- Spatial coordinates

As said earlier, in case of the special municipality called "Outside", all the variables, except the job offer and the job occupation, are empty.

2.2.3 THE JOB

A job has two attributes which define it: a profession and an activity sector in which this profession can be practised. It is available in a municipality and can be occupied by an individual.

2.2.4 THE RESIDENCE

The residence has a type which is classically its size expressed in number of rooms. A residence is available in a municipality and can be occupied by 0, one or more households.

2.2.5 HOUSEHOLD

Table 1. Attributes defining the household state

Name	Type	Values
Members	List of Individuals	
Couple	Boolean	True, false
Leader	Individual	
Residence	Residence	Object with a list of households and a type given the size of the residence
Residence need	Boolean	True, false
Municipality of residence	Municipality	

At the initialisation, the residences are associated randomly with the households. Then, new households are created when new couples are formed or when in-migrants come into the municipality. Households are suppressed when their members die, or when the couple splits up, or when they simply migrate outside the municipality set. When a behavior of an individual can have an impact at the household level, a leader is picked out at random, or designed depending on the process. This leader will be the one deciding for the household. That is for example the case when an individual finds a job very far: he becomes the leader to make the household moving and finding a residence close to hers new job.

2.2.6 INDIVIDUAL

The individual comes to the world via one of the adults of a household having the "couple" status in the birth method, or directly from the initialisation of the population, or from the in-migration.
The age to die, the age it will enter on the labour market, and its age of retirement are attributed to the individual when it is created. These ages are picked out following a probability law. The activity status defines the situation of the individual regarding employment, especially whether or not she is looking for a job. The individual can quit a job, change jobs, searches for one or not…
The profession is an attribute of the individual indicating at the same time her skills, level of education and the occupation she can pretend to. The job the individual occupies should have the same profession attribute as the individual has.
The main attribute values and the related dynamics highly depend on case study in which culture, regulations and available data differ a lot.

Table 2. Attributes defining the state of an individual

	Type	Values
Activity status	enum	Define if an individual is susceptible to search for a job: Depends on case study. For example, for France: student, inactive, retired, employed, unemployed (only the two last can search a job)
Profession	enum	Depends on case study
Job	Job	Depends on case study
Place of work	Municipality	Nil or a Municipality
Household status	enum	Adult, Child
Age to die	integer	Drawn from a distribution
Age in labour market	integer	Drawn from a distribution
Age of retirement	integer	Drawn from a distribution

2.2.7 LABOUR OFFICE AND REAL ESTATE

These objects rule the propositions for jobs and residence respectively. They also update the available jobs and residences in the municipalities. They are related to the dynamics described in 2.7.2 and in 2.7.3, respectively dedicated to the job search and the residence search processes of the individual and the household.

2.2.8 SCENARIO

A Scenario object contains all the exogenous changes to apply to the objects of the model at a given date. They can be a change in job offer for a municipality or a change of a parameter value defined at the municipalitySet level, such as the average fertility level for example.

2.3 PROCESS OVERVIEW AND SCHEDULING

2.3.1 THE MAIN LOOP

The main loop calls processes ruling demographic evolution, the migrations, the job changes, and their impact on some endogenously created services and/or jobs. First, the scenarios are applied to the municipalities. Then, the available endogenous jobs and services are updated in municipalities. Finally, the demographic changes are applied to the list of households. The following pseudo code sums-up the global dynamics:

```
At each time step:
   For each municipality
      municipality.update external forcings: offer of jobs, residence
      municipality.update endogenous job offer for services to residents
      municipality.compute in-migration
   For each household:
      household.members.job searching decision (a complete loop on every household
         since this process can make free some jobs from people becoming retired
         or inactive)
   For each household:
      household.members.searching for a job
      household.members.household-individuals events (coupling, divorce, birth,
         death)
      household.residential migration
      household.members.individual ages
```

The time is discrete. One time step corresponds to a year. The households are updated in a random order during a time step. We shall calibrate the model on the first 16 years and study its evolution on the next 24 years.

2.3.2 THE MUNICIPALITY: OFFER FOR JOBS, SERVICES AND LODGING

In the municipality objects the jobs, services and dwelling offers are ruled.

The job offer process is twofold: a part which is defined through scenarios which specify the increase or decrease of jobs in different sectors, another part concerns the proximity service jobs, which are derived by a specific statistical model. As the job offer plays a role in the definition of the commuting network, more details are given about it in the section 2.6.2 and 2.7.4.

The changes in the dwelling offer are specified in scenarios. Various sizes are considered in order to match the needs of household.

The households can move from one municipality to another, and this has an influence on the commuting network. More details are given about it in the section 2.7.3.

2.3.3 THE HOUSEHOLD AND INDIVIDUALS: HOLDING OR SEEKING JOBS, GENERATING SERVICES AND OCCUPYING DWELLING

A new individual can be generated in a household having the “couple” status in the birth method, or directly from the initialisation of the population, or from the in-migration method. Her life begins with a student status until she enters the labour market with a first profession. Then, she becomes unemployed or employed with the possibility to look a job. She may also become inactive for a while. When she gets older, she becomes a retired individual. All the changes in this status are linked to the ageing process ruled by an “update age” method incrementing the age and comparing the new age to the age of status change. The different actions she can have on the labour market and the different events changing her household status are described in the following.

Being on the labour market

This process represents a large set of actions of the individuals which are going to define if and how the individual searches for a job. More details are given on these actions in 2.7.1 and 2.7.2: the submodels of research decision and research itself are only quickly overviewed in this section. To sum-up, the individual enter on the labour market at a given age and a given first profession is attributed to him. From this point, it can change her activity status: she can become inactive (temporarily stopping to search for a job), retiree (definitely stopping to search for a job), unemployed or employed (both with a probability searching for a job).

Most of the attribute values for these actions of the individual are computed at its birthday time and applied when the updateAge process lead to the chosen age.

Entering on the labor market

The individual stops being a student at the age to enter on the labour market and becomes unemployed. She searches immediately for a job and can get one during the same year. A first profession she looks for has to be defined at the same time the first age of research is determined.
Parameters: probabilistic laws to decide the age a student enters on the labor market and the first profession she is going to look for.

Become a retiree

At a given age, the individual becomes a retiree. We assume, for sake of simplicity, that a retiree does not search for a job.
Parameter: probabilistic law to decide the age the individual retires.

Individual job searching decision

The decision to search for a job depends on the current activity status of the individual. If she is a student, an inactive or a retiree (in France at least), she is not going to search for a job. If she is unemployed or employee, she has a probability to search for a job and a probability to search for a given profession depending on her current profession. The whole dynamics is described with more details in 2.7.1.

Individual searches for a job

Since she knows which profession she is looking for, two different ways of searching can be used:

- she collects all the matching job offers in the municipalities identified as accessible through the network of proximity of its municipality of residence and picks one at random if the resulted vector is not empty;
- she chooses a distance where searching and collect the matching job offers at this distance before picking one at random if the vector of collected job offers is not empty.

In both cases, more numerous available jobs in the network of proximity will have a larger probability to be chosen. In the second case the probability will also take the distance within this network into account.

If the individual has no job in the end of this process, the decision to search is made again the next year. More details about this dynamics are given in 2.7.2.

Household-Individuals demographic dynamics

This part describes mainly the demographic dynamics. Some processes are designed in a microsimulation approach while others are more designed in an agent-based modelling approach, like for example the search for a partner. The interest of such a hybrid approach is pointed out in the review done in the framework of the European project SustainCity (Morand et al. 2010). This project has developed a demographic module (Turci et al. 2010) coupled to UrbanSim (Waddell et al. 2003) and other modules improving the initial UrbanSim and adapting it for Europe. One of these modules is dedicated to the residential choice.

Three main dynamics apply to the households, depending on their type (single, couple, with or without children and complex[5]): makeCouple; splitCouple and givingBirth. The individual status transition, becomingAnAdult, implies the individual forms her own household and can also have impact on the parental household status if she is the last children of the household. Similarly, the death has an impact on the household status.

MakeCouple

The method works as follows:

- During each time step, each single (with or without children) individual inhabitants has a probability to search for a partner;
- If the individual tries to find a partner, she tries a given number of times in every municipality close to her own (her own included) to find someone who is also a single and whose age is not too different (given from the average difference of ages in couples and its standard deviation); she can search among the inhabitants or the potential in-migrants; the close municipalities are at a maximum distance defined by the parameter "proximity" of the MunicipalitySet (see 2.2.1) ; old people search for a partner only in their own municipality (see 2.7.3 for more explanations);
- When a couple is formed, the new household chooses the larger residence (the in-migrating households always go into residences inside the simulation); this move can lead one couple member to commute very far. This situation can change only when she is becoming the leader in the job search implying the household to try moving closer to her job location.

Parameters: probability to search for a partner; maximum number of trials (the result of the procedure is also linked with the neighbourhood of the municipality for which we use the municipalities where people commute); average and standard deviation of difference of age between couple members.

SplitCouple

All couples, except the potential in-migrants (see 2.6.3), have a probability to split up. When the split takes place, the partner who works further from the common residence leaves the household and creates a new one. When there are children, they are dispatched among the two new households at random.
Parameter: probability to split

Giving birth

To simplify, we made the assumption that only households with a couple can have children, and one of the adults should respect the conditions of age for giving birth. We assumed that couple has a constant probability to have a child over the years. The parameters are the minimum and maximum ages to have a child and the average number of children by couple. From these parameters, we compute the probability for a couple with one randomly chosen individual in age to procreate during a year.
Parameters: minimum and maximum age to give birth, number of children an individual can have during her life on average

BecomingAnAdult

Becoming an adult means an individual creates her own household. This can lead her to more from parental residence because of a low dwelling satisfaction level, but it's not always the case (see 2.7.3 for details). An individual loses her child status and becomes an adult when:

- she finds her first job;
- or she is chosen as a partner by a single adult;
- or she remains the only children in a household after her parents left or died and she is more than parameter firstAgeToBeAnAdult.

Parameter: first age to become an adult.

Death

The death age of the individual is computed at her entering in the simulation (through birth, initialisation or migration). When an individual dies, its household status is updated depending on the number of remaining

[5] A complex household is a household which is not a single, a couple with or without children one.

members and their statuses, parent or children. Households are suppressed when their members die or when the couple splits up, or when they simply migrate outside the municipality set.
Parameter: probability law for death

Household migration (or mobility)

In changing residence process, we include both residential migration and mobility without making a difference, between short and long distance move, as it is often the case (Coulombel 2010) in the literature. The submodel we propose directly manages both types of moving. However, it turned out easier for us to distinguish two categories of migration: the migration of people coming from outside to live inside the bunch; the migration of people who already live inside the bunch. The in-migration in the bunch is an external forcing. It is described in the Input data section (2.6.3). The mobility of people already living inside the set of municipalities is managed by the submodel described in 2.7.3. Such a mobility can lead the household simply to change residence, municipality or to quit the set of studied municipalities.

Overall, a household decides looking for a new residence when:

- a new couple is formed: the couple chooses to live initially in the largest residence among the ones the partners;
- a couple splits: one of the partners, randomly chosen, has to find out another residence even if she remains for a while in the same residence (creating her own household);
- an adult of the household finds a job far from the current place of residence (far is defined by the parameter proximity of the MunicipalitySet);
- a student or a retiree decides to move;
- the residence is too small or too large. That can be due to a birth, a new couple or to someone who left the residence for example.

The choice of a new household (distance, place and size) is described in 2.7.3. A move of a household can lead some of its working members to commute very far, further than the proximity parameter. A far commuter remains so until she becomes the leader through the job search leading the household to look for a residence closer to her job.

Parameters:

- For choosing a new dwelling: in first proposed simple model, we considered that on average the households are satisfied with a dwelling including the same number of rooms as the size of the household, and we defined a parameter called "tolerance" defining the number of rooms higher or lower than this average where the satisfaction was similar. We also needed a probability to accept a proposed residence within this tolerance; in a more elaborate model, we define the satisfaction as a function of the size of the household and of the age of its members (see the dynamics explained 2.7.3 in for more details);
- Laws for migration of students and retirees and acceptable distance of commuting (see 2.6.3 and 2.7.3 for details on these processes)

2.4 DESIGN CONCEPTS

The following important modelling choices need to be stressed:

- There is no explicit representation of the revenue of the households, nor of the price dynamics of various goods. The main reason for this choice is the willingness to keep the model as simple as possible. Hence, the scenarios should be directly expressed into changes in jobs, land use, housing, services, and these changes can reflect some economic changes (especially in the evolution of available jobs). Similarly, the possible use of European funds should be translated into creation of jobs, services or changes in land use.
- An individual only looks for a profession; she is not interested in the activity sector. The activity sector will be defined by the found job among the set of possible job offer for the individual. We bet this is sufficient to obtain proper results regarding the unemployment and the job occupation.
- When the household is moving because its leader works too far, the other members of the household do not look for a job until the new dwelling is found, and then they look for a job in proximity to this new dwelling.

2.4.1 ADAPTATION

Three kinds of adaptation are expected in the model.

- The first one relates to the job offer in the service sector. It endogenously evolves in each municipality depending of the number of its inhabitants and its distance to the closest pole of services (which can be the municipality itself).

- The second adaptation that we expect in the model is due to our difficulty to get the correct information from the census data to design the job scenarios properly. Indeed, the census data provides us with the number of occupied jobs and gives no information about the offer. For future scenarios, we expect the stakeholders to propose such an evolution of the job offer. However to calibrate the model, we only used the census data, and we relied on some capacity of adaptation of the model to distribute the change of job occupation over time. For example, suppose we have data of job occupation in 1990 and 1999: if the job occupation is higher in 1999 than in 1990, we transform the difference in a job offer, made available in 1991. We assume that the model will progressively match the offer of jobs with job seekers and reach the correct job occupation in 1999. If the job occupation is lower in 1999 than in 1990, we let the model manage this evolution, considering that it is mainly due to the aging of the population, in our case study. We proceed similarly with the occupation and offer of dwellings.

- The third one concerns the individuals and households location. The submodels of location and job choices ensure the distance between the residence and work places is small. Then, when an individual works too far from her residence, she is going to change her job or her residence to reducing this distance. We expect being able to maintain the commuting network properties through these mechanisms.

2.4.2 OBJECTIVES

From the adaptation mechanism of the municipality regarding their job offer in the service sector, we expect: a growing municipality will grow more and more due to this mechanism; a decreasing municipality will decrease more and more.
From the submodels of location and job choices of the individuals and households, we expect observing an increase of the population of the municipalities close from a municipality from which the population increases. The objective is to reproduce the spatial diffusion of the dynamism of the municipalities.

2.4.3 LEARNING

The individuals have no memory, hence they cannot learn. They simply evolve depending on their age or on their other attribute value as their profession for example.

2.4.4 PREDICTION

As the model is mainly based on the microsimulation principles, the decision-making of individuals is probabilistic. Thus our individuals make no predictions and have no expectations.
However, in the residence search for active household or in the job search, the individual implicitly assumes, after having chosen a distance at which it is going to look, that there are some available residence and/or jobs at this distance. That is due to the way this process has been empirically built (see 2.7.3 and 2.7.2 for more details).

2.4.5 SENSING

The individual senses through the accessible municipalities the presence of possible partners, the job offer and the residence offer. The accessibility of the other municipalities depends on some functions of distances. The individual picks out a distance from these functions to decide where she is going to search for a partner, a job or a residence.

2.4.6 Interaction

Following the basic principles of a microsimulation model, the interactions between the individuals are mostly indirect, taking place through a competition for resources: jobs and dwellings.
However the individuals have some interactions within the household. For instance, being a member of a couple determines if the individual can have a child. The household also determines the place of living of the individual because the leader of the household (randomly chosen adult) is going to decide where to search for another dwelling when there is a need for changing residence.

2.4.7 Stochasticity

Our individuals decide following probabilistic laws. Thus, there are a lot of sources of stochasticity is the model. That is mainly to be able to reproduce properly the measures done by the National Statistical Offices.

2.4.8 Collectives

Our individuals are embedded into two types of collectives: the household and the municipality. These collectives have an impact on their lives. The household is, by its size and status, make them more or less able to move, but also to get children. The municipality as a collection of individuals is going to decide increasing or decreasing its job offer in the service sector depending of its number of inhabitants.

2.4.9 Observation

We measure aggregate demographic values (number of household types, number of individuals by age ranges,…) and about work (number of jobs occupied of different types and sectors, number of unemployed and inactives), and compare them with the census data for calibration and validation.

2.5 Initialisation

Following (Berger and Schreinemachers 2006), we try to have strong linkages to empirical data in order to provide scientific information to policymakers and stakeholders to better support their planning and decision-making processes.

This means the variables in relation with the objectives of the model have to be properly controlled in the initial population. It determines what should be very robust and statistically consistent with empirical observations at every step of a simulation, including obviously the initial state. At the initialisation, we have to control carefully:

- the number of individuals in every age range living in a municipality: it is an absolute requirement since we want to study the local presence of populations considering different evolutions of the individuals and their households knowing that a lot of processes ruling these evolutions depends on ages;
- the number of households in every size range: that is to get a realistic distribution of households since a large part of the demographic events considers the current status of a household ;
- the probability distribution of the household type (single, single-parent, couple without children, couple with children, other households type) at the municipality level for the same reason as the one of the previous dot;
- the probability distribution of the professions at the municipality level: the strands describing the individual occupation of the individuals has an impact of the probability to move to another municipality and/or another job or activity status changing the relationship strength between the municipalities;
- the probability distribution of the place of work at the municipality level: for the same reason as the one of the previous point.

To compute a population with good enough local statistical properties both for individuals and households, we propose an algorithm (Gargiulo et al. 2010) where individuals of a municipality are described by their age, and are gathered in households respecting a variety of statistical constraints (distribution of household types, sizes, age of household head, difference of age between partners and among parents and children). Since all the individuals and their households are created in their municipalities, a status and a profession are attributed to adults following the distributions of these attribute in the real municipality-level data. If an individual is employed, a place of work is then attributed to him considering the measured data on the commuting network and the measured data on job occupation in every municipality. In case the modeller lack of data regarding the commuting network, an algorithm allowing computing virtual commuting networks starting from aggregated data on the number of people working outside a municipality and the number of people working in a municipality and living in another, has been proposed (Gargiulo et al. 2011) (Lenormand et al. 2011a).

2.6 INPUT DATA

This part relates to all the exogenous dynamics parts of the model. Three different groups can be distinguished:

- temporal changes of the parameters of the dynamics itself: it can be for example the age of retirement;
- exogenously fixed migration of people coming from outside the region or from the large cities ;
- policy action impacts. The policy actions implemented at the municipality level, or at a set of municipality level, or even at the regional level, can have an impact on the municipal offer of jobs, residences and services. It can also have an impact on the proximity between municipalities, as in when new a highway is built for example.

For the three sets, starting from an initial value, we consider that events increasing or decreasing the initial value occurred during a period of time starting a given year and finishing another year. A scenario is composed from one or several such a period. That is the object we use to store the inputs.

Scenarios deal with the exogenous modification of the system state over time. A scenario is hence a set of discrete events that occur during the simulation

Practically, from the past data, we often only have the difference of a parameter value between two dates representing the period. We have to define how the parameter evolved in the other dates of the period, whereas we generally have no data about this.

Another problem is connected with the jobs in proximity services, because we do not have these data explicitly. The scenario of jobs in the services must take into account only the other types of services, which is not easy to extract from the available data.

As explained earlier, we had to overcome some difficulties met in building the job offer scenarios from the census data. This is difficult because only the job occupation data are available. Moreover, we have no information about the evolution between two census dates. When the job occupation increased between two census dates (say 1990 and 1999), we transformed this difference into an offer of jobs, made available just after the first census date (in 1991). The model determines the rhythm of taking these offers by itself. If the job occupation, decreased, then we did not change the job offer scenario, considering that for this case study, the job decrease is mainly due to population ageing and decreasing.

One can see the section 3.2.1 for more details about the practical implementation of this approach in a case study.

We have also to stress out a particular scenario which takes the form of a population. That is the migration scenario. It describes the population of households trying to move inside the region during a given period.

The three main scenarios of the model, dwelling offer, job offer and in-migration, are presented in the following sections.

2.6.1 THE EVOLUTION OF THE DWELLING OFFERS

Dwelling is described by its number of rooms. Each time the data are available, the offer is redefined as described earlier. We consider two types of dwelling: those for households and the retirement homes. This last category is not directly taken into account. We just consider the number of beds of a retirement home can be assimilated to the same number of flat having a size one room. That is necessary to consider retirement homes because the number of beds can be locally very important compared with the size of the population. For example, a municipality of the Cantal in France offers 140 retirement home beds while the municipality counts only 60 other inhabitants. We have not considered the dwelling for students even if a part of them are counted as dormitory, and not as dwelling for households. We decide neglecting them since they are generally located in large cities which are not included in the model.

2.6.2 THE EVOLUTION OF THE JOB OFFERS

Several types of scenarios ruling the job offers must be considered, some of tem concering the "outside" of the simulation municipality set. The outside represents a source of employment for people living in studied municipalities sufficiently close to this source to work in. It also always corresponds to the municipalities close to the border the set of studied municipalities. The scenarios to build are the following.

1. For each identified outside*: the job offers for people living in the neighbouring municipalities of each outside.
2. At the municipality level: the job offers by the municipality; that is necessary to distinguish between the exogenous job offer and the endogenous proximity service jobs.

Since the offer is generally not an available data, we suppose that the quantity of job offers is equal to the quantity of job occupied at the initial date for which we have the data.

The outside job offer scenarios.

Depending on the number of municipalities simulated in the municipality set, we adopt a more or less ad-hoc way to build the outside job offer scenarios.

For a small number of municipalities:

The purpose is to design, for each identified outside, the job offers for people living in their neighbouring municipalities. This job offer can be extracted from data related to commuting, whatever they are, measured by a statistical office, or virtually generated from the algorithm we propose (Lenormand et al. 2011a). That is simply to say the job occupation in the outside from people living in all the municipalities from the set corresponds to the job offer of Outside.

For a large number of municipalities:

When the number of municipalities is large, it becomes difficult to consider only one outside municipality since the geographical size of the studied area is large also. To solve this problem, we define the job offer from outside infinite and model the probability the individual commutes outside the set of municipalities considering where he lives. Thus, an individual has a probability to commute outside depending on the distance of her municipality of residence to the border of the municipality set. The closer she lives, the higher is this probability. The probability is used in the stochastic model (compared to a picked out random number) in order to properly take into account the large observed variation, assumed depending mainly on the number of commuters of the municipality (which can be very small). The probability law linking distance to border with a probability to commute is extracted from the "mobility" database of 1999 collected during the Census for France for example. More details are given on this procedure in 2.6.2.

The municipal exogenous job offers scenarios.

At the municipal level, we can distinguish two different scenarios which can be grouped in only one considering the problem as a problem of scenarios conception. In order to be clear, let's remind the offer is considered equal to the occupation. Two subgroups have to be identified to conceive the municipal job offer scenarios in a correct way:

The jobs occupied by individuals living outside the set of studied municipalities (i.e. outside the region), denoted A.
The rest of the jobs, occupied by or available for individuals living inside the municipality set, denoted B.

The total job offer for individuals living inside the set is then: $T = B – A$. However, T includes both the exogenous (scenario) T_{exo} and endogenous (proximity services) T_{end} job offers. For every activity sector except services, $T_{exo} = T$. For the service sector, we are able to compute, as presented in the next section, an endogenous offer of proximity services which is going to evolve with the municipality population size. We have $T_{exo} = T - T_{end}$.

Then, the scenario is parameterised giving the total offer *T* for every job type, and the model updates each year the exogenous offer by extracting the endogenous offer computed and updated each year from the population of the set. This computation is now described.

The endogenous job offer in proximity services

For a partly endogenous process such as service dynamics, one has to distinguish a dynamics linked to the size of the population from the impact of a punctual policy action. A computation to approximate the dynamics linked to the residential economy has been proposed in (Lenormand et al. 2011c): it determines the number of jobs in proximity services, possibly taken into account the distance of this individual to the closest pole of services. Then, a job offer depending on the number of inhabitants of a municipality can be defined and used in the model.

Parameters: total job offer of a municipality; regression coefficient of the computation function for each category of distances to a pole of services; category of distance to the closest pole of services for every municipality of the set.

2.6.3 MIGRATION FROM THE OUTSIDE TO THE SET OF MUNICIPALITIES

Each year, a number of potential in-migrants from outside the bunch are added to the municipalities of the bunch. These potential in-migrants can really become inhabitants of the bunch if they find a residence by themselves or by being chosen as a partner by someone already living in the bunch in case they are single (with or without children). Thus, looking for a place of residence is the only action they do until they become an inhabitant of the bunch. Until the potential in-migrant becomes a real inhabitant, it cannot search for a job. We do not consider the potential in-migrant looking for a job. Indeed, the job occupied by people living outside the municipality set are already taken into account through the scenario and allowing potential in-migrants to find a job directly would be redundant. The definition of who are potential in-migrants, how numerous they are, when they are introduce in the model is specified in a scenario.

The first step consists in determining the number of potential in-migrants a given year. Then potential in-migrants households are drawn respecting this number and some characteristics of the in-migrants population. The last stage consists in placing this in-migrants household in municipalities where they can look for a residence and/or being chosen as a partner.

Determining the number of in-migrants

To control the past or the future in-migration, we control the yearly migratory rate of the bunch which is a parameter of the application. This migratory rate is a number of inhabitants. Another parameter of the application is the number of out of the bunch migrants during the year before the initialization year. The first number of potential in-migrants is defined as the sum of these two parameters. For the following year, the number of potential in-migrants is determined adding the endogenously defined number of out-migrants from the bunch with the parameter "yearly migratory rate". The way out-migrants are drawn is described later in this paper in the section 2.7.3.

Creating the in-migrants household: their characteristics

The in-migrants are picked out from the existing population following different probabilities giving the characteristics of the in-migrants (size of the households, age of individuals...). In-migrants household are picked out until respecting the total number of potential in-migrants defined in the previous step. Each potential in-migrants household is affected to a municipality.

Placing the potential in-migrants household into the municipality

In order to guide where they are looking for a residence or being chosen as a partner, the in-migrants should be temporarily affected to a municipality from which they can find a residence or being chosen as a partner through the network of the municipality. To place the in-migrants household, a probability to be chosen is computed for each municipality depending on the population size of the municipality and its distance to the frontier of the region. Some specific mechanisms to place the in-migrants can be added if required for a particular case study. That can be for example, a particular attraction of young people for larger municipalities.

Parameters: yearly migratory rate; number of out of the bunch migrants the year $t^0 - 1$; probabilities giving the characteristics of the in-migrants (size of the households, age of individuals...); This probability depends on the population size of the municipality and its distance to the frontier of the region

2.7 SUBMODELS: HYBRID

We consider an individual able to change her job and/or her residence. Several submodels should be designed to these purposes:

- decision of the individual to change her job for another job;
- search strategy for a new job;
- household to moving.

The two last submodels are very sensitive because they rule the spatial distribution of households. They also control the out-migration which is then largely endogenously defined.

Another submodel makes the municipality job offer dynamics partly endogenous. We will see that job offer in the service sector can be defined as dependent from the local population and the distance to a pole of services.

All these submodels have an impact on the commuting network and on the spatial distribution of individuals. To get the model predicting correctly the spatial features is our main challenge.

At this stage, that is necessary to remind that the submodels depend on the purpose of the case study and of the data availability. The submodels presented in the following are designed for the French case study. They are in the principle applicable to the other cases study but require some modifications to take advantage of, for example, the minimum common available data of the Labour Force Survey ((Baqueiro Espinosa et al. 2001). One has also to pay a particular attention to the definition of used concepts: for example, to be a retiree does not mean that someone does not look for a job while it is mainly the case in France (until a very recent period, very rare are French retirees who search for or have a job).

After these remarks, we begin in the next section by explaining how an individual decides to search a particular job.

2.7.1 JOB SEARCHING DECISION

The decision for trying changing job is a two-step process. First, an individual has an activity status indicating if she susceptible to search for a job or not. She can change her status and then her probability to seek a job. When she decides searching, she has also to decide what type of job searching for. The three following subparts give details about this dynamic.

Activity statuses and looking for a job or not

Five different activity statuses define the individual situation regarding the labour market in the model:

1. The **student:** an individual is a student only in the first part of its life. She remains a student until the age she enters on the labour market. We consider the probability of a student to look for a job is 0. Indeed, the possibility to work for the students is not considered since we assume they mainly look for a job in the large cities where they study. These large cities are not included in our population since we are only interested in rural municipalities.
2. The **unemployed**: an individual is unemployed when she is considered as an active (on the labour market) and has no job. For sake of simplicity, we assume an unemployed has a probability 1 to look for a job. However, one can consider only a part of unemployed is actually searching.
3. The **employed**: she is an individual who has a job. She can decide searching for another job, in the same profession or not. Her probability willing to change job classically depends at least on her age.
4. The **inactive**: she can be inactive for a long time or just stopping to work for one year, having a baby for example. During this period, her probability to search for a job is 0.

5. The **retired**: at the age of retirement, an individual becomes a retired. Her probability to look for a job is then 0 (but it can vary in a country different from France, or over the time). The retired situation is considered as final since retired people cannot come back to a status of employed or unemployed (i.e. they don't search for a job), or inactive. The method to define the age to retire is presented in 3.2.1.

The military people are neglected in the model since they are in a particular type of household. Moreover, their localisation, the quantity of job offer for military people is far from being a rural local decision. They represent a small part of the rural population even if it can be wrong very locally.

We have seen the probability to search the job (or the law ruling this probability) depends on the activity status. The next part describes how the individual changes her activity status.

Changing activity status: searching decision and object

Figure 2 describes the way an individual reaches the different activity statuses.

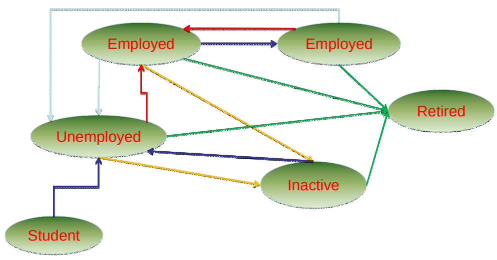

Figure 2 - Transitions of status and their link to the data. Red arrows: change by finding a job; grey arrows: when she is fired; green arrows: at the age of retirement (picked out from a law extracted from data); yellow arrows: due to a probabilistic decision of becoming inactive extracted from the Labor Force Survey data; purple arrows: due to probabilistic decisions extracted from the Labor Force Survey data.

Entering on the labour market, the student becomes unemployed and searches for a job with a probability 1. An unemployed, as an employed, can find a job through processes presented in the following sections and become employed. If an unemployed always searches for a job by assumption, that is not the case for an already employed individual. From the European labour force survey, it is possible to know at least the part of already employed people who has changed job. However, we have to assume, to use these data to parameterise the search decision that there are more searchers than finders. Then it is in this case necessary to add a parameter, to determine if an already employed is going to look for another job. The French Labour Force survey contains a very interesting question also asked to the already employed people: "are you seraching for a job?". Therefore, for the French case we could get directly data about the probability for an already employed individual to search for a job.

Employed and unemployed individuals can also become inactive. Then we assume that they stop searching for a job the time they remain inactive. Every activity states, except student, can be followed by the retirement state in which we assume the individual stops searching for a job.

An inactive, if she doesn't retire, either can come back on the labour market adopting an unemployed status to search for a job or can remain an inactive. The complementary probability corresponds to the probability of becoming an unemployed searching for a job or a retired. However, in the global loop, the individual has already decided not to become a retired at this moment. Thus, she decides to remain an inactive or to be an unemployed. Then, if she doesn't remain an inactive not searching for a job, she becomes an unemployed looking for a job.

Most of the laws ruling the activity statuses changes are extracted from data (mainly from the European Labour Force Survey data). Only the grey-arrows transitions, that is the employed to unemployed transition is due to the decreasing availability of job offer implying a sacking. It can also be due to a resignation of an individual quitting her municipality to follow her partner far from the actual place of residence for example. This availability is partly exogenously defined (see 2.6.2) and partly endogenously defined (see 2.7.4).

Knowing an individual searches for a job, we have to compute which profession she looks for. From the labour force survey again, we can extract some probabilities. However, again as for the searching decision, we got data in the French labour force survey that allow us to derive directly the profession an individual tends to look for (with which probability). In the countries where these data are not available, we derive the probability to look for a given profession from the data about the actual changes of jobs.

One can notice that an individual only looks for a profession; we neglected to take into account the activity sector in her choice. The activity sector will be defined by the found job among the set of possible job offer for the individual. We expect the job offer to be a sufficient constraint on the activity sector to allow the model to exhibit a job occupation statistically correct distribution of occupied jobs by the activity sector.

List of the parameters ruling the job research decision:

- probability to become an inactive
- probability to stop being inactive
- probability laws defining what profession searching for knowing the current activity status, profession and age
- parameters for entering on the labour market and retirement (see 2.3.3)

2.7.2 SEARCHING FOR A JOB

The question for the individual is now to decide where searching for a job. The challenge consists in preserving the properties of the commuting distance distribution. Both the choice of the place of work and the choice of the place of residence impact on this distance. Thus, these processes have to be designed under this constraint. However, the place of work is not only defined by the strategy of search. That is also constrained by the job offer which has to be properly defined.

Figure 3 shows the searching procedure of an individual. Considering a given household, each individual searching for a job is going to search if the household has not already a leader and a need for residence. Indeed, having a leader and a need for residence at the same time means that one member of the household has already found a job far (further than the proximity attribute) from the place of residence. In this case, the household is trying to move close the leader's place of work. In this situation, we consider that the other household members, waiting for a change of residence, do not try to change job since they do not know where they will be living. Until the household finds out a new residence place, nobody is going to change jobs.

If the individual is searching for a job, we consider she begins by choosing where she wants to work. Practically, she picks out a distance in the probability law of the "accepted distance to work place". The way we build the "accepted distance to work place" is described later. Then the individual chooses a job if one is available at this distance.

Then, if the distance is higher than 0, she has to decide to work outside the set of municipalities or not. The decision to work outside is described later. If she decides working outside, she automatically has a job. If she doesn't, she collects the offers of the municipalities situated at the chosen distance d and picks out one at random. If she finally chooses a job at a distance higher than the proximity distance (illustrated by the value 25 in the Figure 3), she becomes the leader of her household. If the distance is less than the proximity, the next household member, it she exists, will be able to search for a job. The search procedure is repeated x times if the individual has not found a job. This number of times is a parameter of the model.

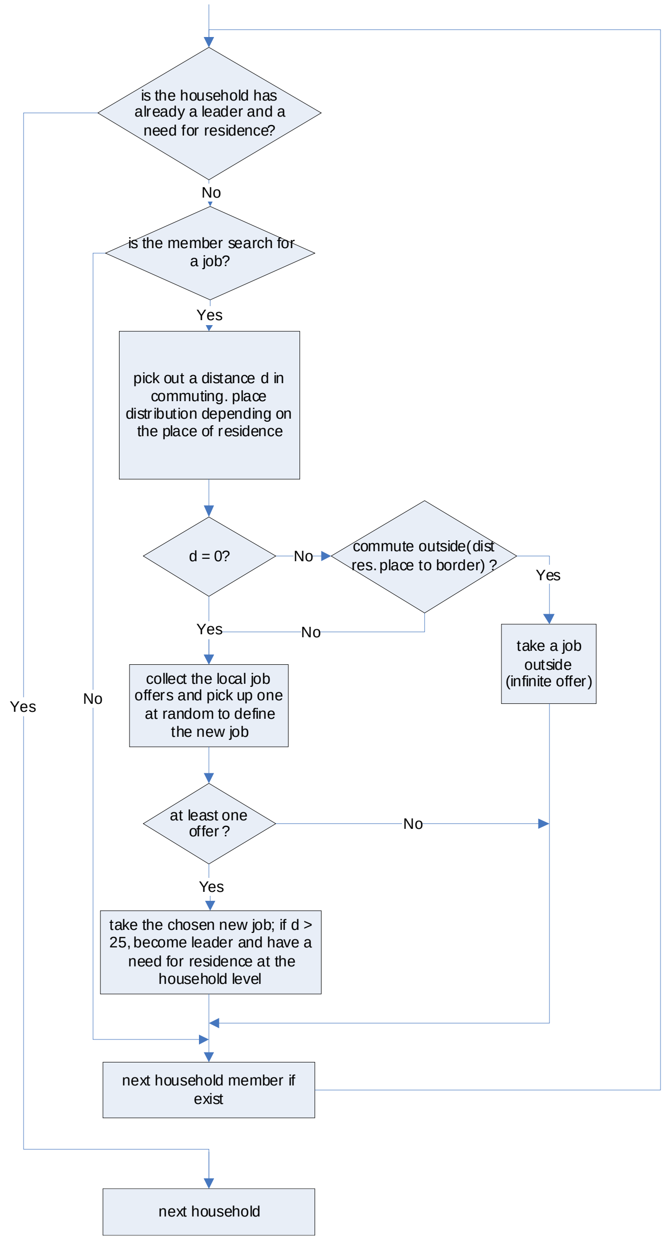

Figure 3. Searching procedure of a household member looking for a job

The "accepted distance to work place"

This distance of search a job is picked out from a probability law giving the probability to accept a distance to work place. This probability law is extracted from data as it is presented in 3.2.1. The principle is very simple: the probability to commute at a given distance *i* [*pc*(*i*)] is assumed to be the product of a probability to accept distance *i* [*pa*(*i*)]by the offer amount at *i* [*Oi*] with a renormalisation coefficient *k*.

$$pc(i) = k\ pa(i) * Oi$$

Then it is possible to extract the probability to accept a given distance (*pa*) to work place which will be used in the model. This procedure, coupled to an appropriate job offer, will allow maintaining the statistical properties of the *pc* distribution over the simulation.

Coming back to our job searcher, she picks out a distance from this distribution of acceptable distance to work place. If this distance is equal to zero, she is going to search for a job in its own municipality. If this distance is higher than zero, the individual has to decide if she is going to outside or inside the bunch.

Going to work outside the bunch

The individual chooses at random to work outside depending on a probability which is a function of the distance of her municipality to the border of the bunch. This function is extracted from data (see 3.2.1).

If the individual goes to work outside, it is counted as an outside commuter and the job offer of the outside for the individuals living inside the bunch is implicitly defined by the number of commuters to the outside. This job occupation of the outside and its spatial distribution can be used to calibrate the model.

For a large set of municipalities, the job offer of the outside is infinite. For a smaller set, that is possible to define it exactly and to include the outside directly in the neighbourhood of the municipality close to it. Indeed, for a small set, the law defining the probability to commute outside is totally inaccurate.

If the individual does not go to work outside, she is going to look at the available jobs at the distance *d* it has picked out in the beginning of it searching.

Find a municipality to work in at the distance d of the place of residence

The labour office collects every job offer corresponding to the profession the individual is looking for at the chosen distance *d*. Then the individual chooses one at random. This procedure allows reproducing the effect of the local offers quantity given a greater probability to be chosen to the municipality which has a larger job offer.

Summation of the parameters involved in the research for a job:

- accepted distance to cross over probability distribution
- probability to commute outside for an inhabitant of every municipality

2.7.3 Residential mobility

Two types of migration have to be distinguished:

- migration of households coming from outside to live inside the bunch: the quantity of in-migrants from outside and their features are an external forcing. However, they are created as potential in-migrants (see 2.6.3) in municipalities. Their “actual” settlement in the municipalities remains to be processed and that is one of the aim of the residential migration submodel;
- migration of individuals who already live inside the bunch: they have to decide if they want to move, and in case they move, where they want to move, in what type of dwelling. This process is going at the same time model the flows of people inside the set of municipalities and the flows leaving the set for the outside. That is also the purpose of the residential migration submodel.

The migration (often assimilated in the literature to the long distance household mobility) and the residential mobility (short distance mobility) (Coulombel 2010) are with death and birth the most important processes in the design of the presence of the population in a municipality. A large flow of people come from the urban area to the rural area, answering to a desire of families to live in the countryside (campagne 2005, 2009; CNASEA 2007a, 2007b; CNASEA and BVA 2008). However, the frontier between rural and urban areas become less and less clear due to an increasing enlargement of the urban area over the countryside (Sencébé and Lépicier 2007). Also the surveys from the CNASEA and BVA regarding the wish of urban people coming to live in the rural areas (campagne 2005, 2009; CNASEA 2007a, 2007b; CNASEA and BVA 2008) (IPSOS 2002) have changed all along their surveys the threshold of population size defining the rural against the urban area in order to include larger and larger municipalities in the rural area. Then it is really difficult to reduce the residential migration question to this urban-rural migration. That is even more the case in our model because the most urban area is excluded from our study. Therefore, the migration coming from very urban zones (and outside the studied set of municipalities) is exogenous while the rest of the mobility is endogenous. Figure 4 shows the different flows of individuals in millions in France from 1990 and 1999 among the different spaces. One can notice that mobility between rural areas is quite large.

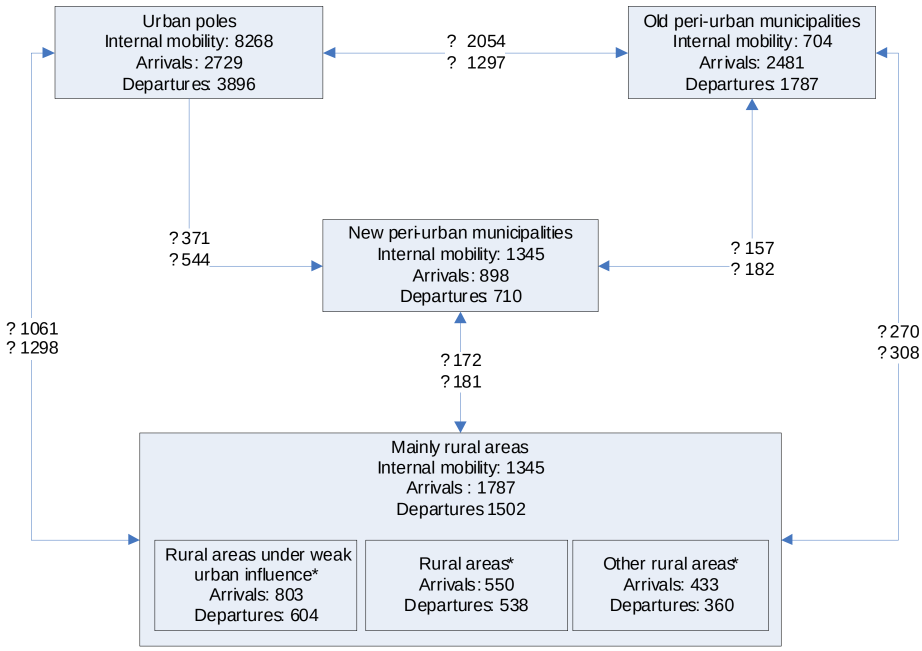

Figure 4. French intra-migration in millions from 1990 to 1999 (source: French Census 1999

From (Gobillon 2001; Minodier 2006), we know that the main reasons to move are firstly related to family events. Following (Debrand and Taffin 2005, 2006) based on the analysis of data coming from various French surveys, creating a couple and splitting up a couple are the factors explaining most of the residential mobility. The second set of reasons is professional. (Debrand and Taffin 2006) notice that moving decreases with age. They point out that the short distance mobility is rather linked to the modification of the family structure while the long distance mobility is more often associated to professional changes. The third type of reasons concerns the change in the tenure (mainly between renters and owners) (Djefal and S. 2004) however this is not considered in the model for now since the decision to buy a house is a source of complexity that we chose to neglect.

From this literature review, we retain some mechanisms for our model which imply a decision to move:

- the formation of a new couple;
- the split of a couple;
- a too large commuting time (higher than the proximity parameter) after a change of job, a new partnership or a move;
- a change in the dwelling satisfaction level due to a family event implying the household is unsatisfied: we decide trying to capture this change through the relevance of the dwelling size to the family size taking into account an impact of the age.

All these events set at true the need for residence change attribute of the household. The next part gives more details on the moving decision.

Deciding mobility

To complete the literature review, we analyse the data related to the residential mobility in France between 1990 and 1999. Figure 5 shows different groups having very different probabilities to change their municipality of residence in the four “départements” of the Auvergne region in France. Very young active people (i.e. 15-29 years old except students 18-29) change a lot of municipalities while old people (at least 60) rarely change. Students being 18 to 29 often move to continue their study except in the Puy-de-Dôme (63) where many live and study in cities where they can study. One third of families with children move each year (even more in Puy-de-Dôme (63)) probably from the large city (Clermont-Ferrand) to the peri-urban or rural areas around.

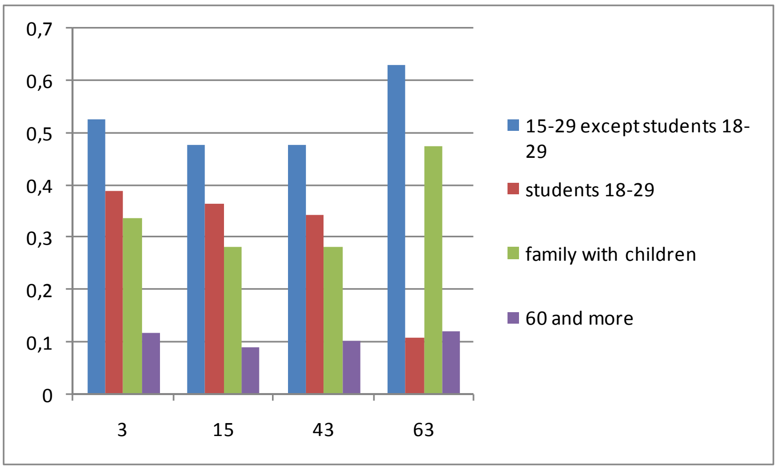

Figure 5. Probability to change municipality of residence knowing the category of the individual (15-29 except students 18-29; 18-29 students; 60 and more; the rest of the population) for the four "départements" of the Auvergne region: Allier (3), Cantal (15), Haute-Loire (43) and Puy-de-Dôme (63)

These groups have also different reasons and constraints to move which force us to consider three subpopulations for our "residential migration model":

- The students can change their municipality of residence in order to find out a proper place for studying. This reason is not captured by the already identified events implying a decision to move. Thus, their decision to move have to be modelled in a specific way;
- The actives, occupied or not, from 15 to less than 60 who move with their children for family (short distance mobility) or professional reasons (long distance mobility); we add inactive individuals to this category since in most cases, an inactive can change her mind and become an active. These households moving decision is going to be taken using the different events previously extracted from the literature;
- The retired people who can migrate to a secondary residence or to live closer to services or children. The group of 60 or more has also reasons to move which are not captured by the dynamics of migration previously identified. For example, they can move to a retirement home. To simulate this last move correctly, we add to the municipalities where it exists a retirement home, an offer of dwelling of size 1 equal to the capacity of the retirement home. We choose to implement a particular mechanism for changing municipalities while we can use the same rules as the one for the others regarding events at the couple level and satisfaction regarding dwelling for a move in the same municipality of residence. Indeed, the study of the French data shows that the tendency to move in the same municipality does not differ for people at least 60 (on the contrary to the move to a different municipality).

Regarding these three different sub-populations and our ability to take into account in the model their reasons to move, we finally consider different ways to decide moving or different ways to decide where looking for a new residence. The Table 1 sums-up the whole procedure.

	Decide to move only in the same municipalities	Decide to move everywhere (comprised outside)
The decision to move is taken at the household level		
When a new couple is formed (one partner comes to live in the other's dwelling)	one partner goes to live to the dwelling of the partner having the larger flat (random choice in case no larger one); more than 60 : they look for a partner only in the same municipality since the decision to move further is probabilistic; idem for potential in-migrants being at least 60	one partner goes to live to the dwelling of the partner having the larger flat (random choice in case no larger one); only for those less than 60 years old and the potential in-migrants
When a couple splits (one partner has to live - this first who find)	only for household composed of adults who are at least 60 - impossible for potential in-migrants	picking out in a list of convenient and available dwellings at a randomly chosen distance from the place of work of the one who commutes far (or the place of residence if nobody has commuted far) if she has not randomly decided to move outside; also for the potential in-migrants except they don't decide going outside
When one active have commuted far from her place of residence		
When the household is not satisfied of the size of the flat regarding to the number of residents and depending on the average age of the adults of the household	only for household composed of adults who are at least 60 - impossible for potential in-migrants	
The decision to move is taken by an individual		
Probabilistically for one being at least 60		picking out in a list of convenient and available dwellings at a randomly chosen distance if she has not randomly decided to move outside; not for the potential in-migrants
Probabilistically for one being 18 to 29 and having a child student status		

Table 1. Decision to move at the household and at the individual levels

Let's also remind the potential in-migrants have automatically a need of residence at true. Thus, they are trying to move in the set if municipalities as the inhabitants do.

We have seen that two ways deciding to move relate to the distance of commuting in the one hand, the satisfaction on the current dwelling on the other hand. An individual decides to move only if her commuting time is too large: that is what makes the difference between the short and the long distance mobility. However, we did not find in the literature how to define a threshold between short and long distance. The next section presents how we define such a threshold.

How to know what is a long or short distance commuting?

We extracted a threshold splitting short from long distance from the data related to the residential and commuting mobility in Auvergne in France from 1990 to 1999. Comparing the residential migration distance distribution to the commuting one, it appears that from 25 km, the residential migration flows is larger than the commuting one, while it is the contrary for every distance less than 25 km (see 3.2.1.). Then, we assume that the residential migration:

- **at a distance below 25 km**, corresponds to a migration unrelated to job. This threshold corresponds to 78% of the migratory flow and 92% of the commuting flow in the data.
- **at distance beyond 25 km**, corresponds more the migration of inactive people or active ones who change for professional reasons. That means, if someone has found a job at a distance higher than 25 km, her household is going to move looking at a new residence in a circle of 25 km around the new place of work of this individual. In other words, we assume most of the 8% of commuters with a larger distance than 25km have a transitory situation and wait for moving.

A second way deciding to move relates to satisfaction about the current dwelling. How to define such a satisfaction is the subject of the next section.

The household satisfaction about dwelling

We propose two models of the satisfaction about dwelling: A first one very simple and a second one more elaborate.

The first considers that the household is satisfied of her current dwelling if its number of rooms more or less a tolerance value includes the size of the household. When proposed dwelling, the household is satisfying only if the number of rooms is exactly equal to household size but a parameter ruling the probability to accept the proposed dwelling makes the household more demanding. This model has been used in the Condat bunch case study. It was changed since the satisfaction level cannot be controlled with enough details. Indeed, practically, data are available only for four dwelling sizes, then a tolerance threshold of more or less 2 makes everyone satisfy except the household of size 1 or the ones of size 4 and more. Moreover, it appears from the data analysis in France that there are very few dwellings of size 1 compared to the number of households of size 1. The average number of individuals by room varies from 0.5 to 0.7 in 1990 and 1999. The number of dwellings of size 1 is 2304 in the Cantal department in 1999 while the number of households comprising only one member is 19142. Identically, the dwellings of size 2 correspond to 9.4 % of all the dwellings while the households comprising two members represent 33.02 % of the households in 1999. The correspondence between the size of the dwelling and the size of the household is thus not a reliable approximation.

The second model has been implemented for the Cantal case study. It considers the household satisfaction about:

- its current dwelling;
- a proposed new dwelling, once the household has decided to move.

We define:

- I_d: ideal size of dwelling for the household size
- I_c: size of the currently occupied dwelling
- I_p: size of a proposed new dwelling
- *nbSizes*: total number of sizes considered in the model
- β: parameter ruling the impact of the age;
- a: average age of the adults in the household

We define a probability to be satisfied *ps* by a current dwelling as:

$$ps = 1 - \left(\frac{|i_d - i_c|}{nbSizes} \exp(-\beta(a - 15)) \right)$$

The household is satisfied if *ps* is higher than, or equal to, a random number. The household need of residence attribute is set to true when the household is not satisfied of its residence.

We also compute the probability to refuse *pr* a new dwelling of size *p*:

$$pr = \left(\frac{|i_d - i_p|}{nbSizes} (1 - \exp(-\beta(a - 15))) \right)$$

The household is susceptible to accept the new proposed dwelling if *pr* is smaller than, or equal to, a random number.

The ideal size of dwelling for a household size is a function based on the ideal number of rooms per individual of a household. The simplest case is to consider one room for one individual but it can be a much more complex function.

The Figure 6 shows the impact of the age for a fixed *β* on the tendency to be satisfied or to accept by/a dwelling having a varying distance to the ideal size. It perfectly illustrates the principle: the older are the adults of a household, the more satisfied they are with the current situation and more demanding they are for a new dwelling.

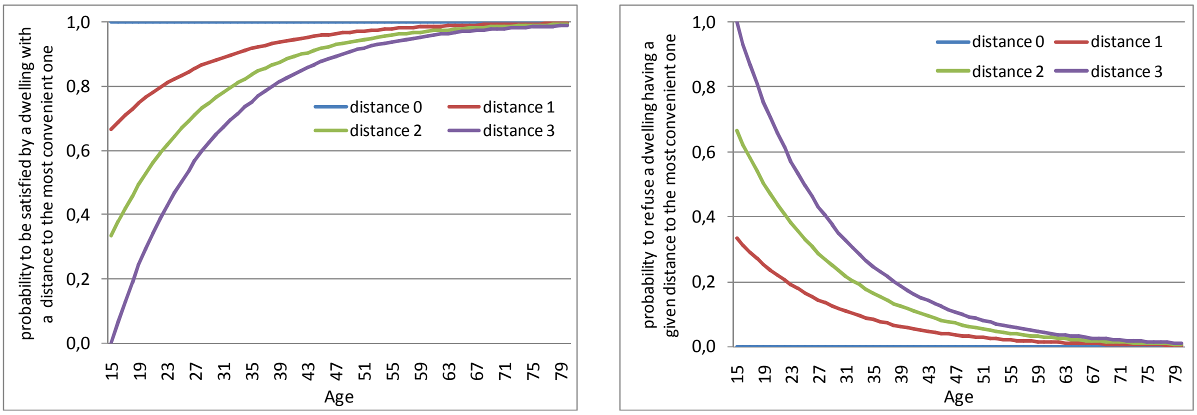

Figure 6. Examples with *β*=0.07 of probabilities to be satisfied by a different dwelling size at a given age (on the left) and to refuse a given dwelling size at a given age (on the right) - the distances 0, 1, 2, 3 correspond to the distance expressed in number of rooms between the ideal size and the current or the proposed size of dwelling.

List of the parameters involved in the migration decision:

- Probability to look for a partner
- Number of join trials
- Probability to split for a couple
- Probability to search for a job for an unemployed and for employed
- Distribution of the probabilities to accept crossing over a distance to get a job starting from the place of residence
- Threshold indicating a far distance
- *β*
- Probability to migrate in another municipality for people at least 60
- Probability to migrate in another municipality for student from 18 to 29

Figure 7 describes the algorithm ruling the residential mobility. The decision process is shortly presented and the decision about where to move is presented with more details. That is the subject of the next section.

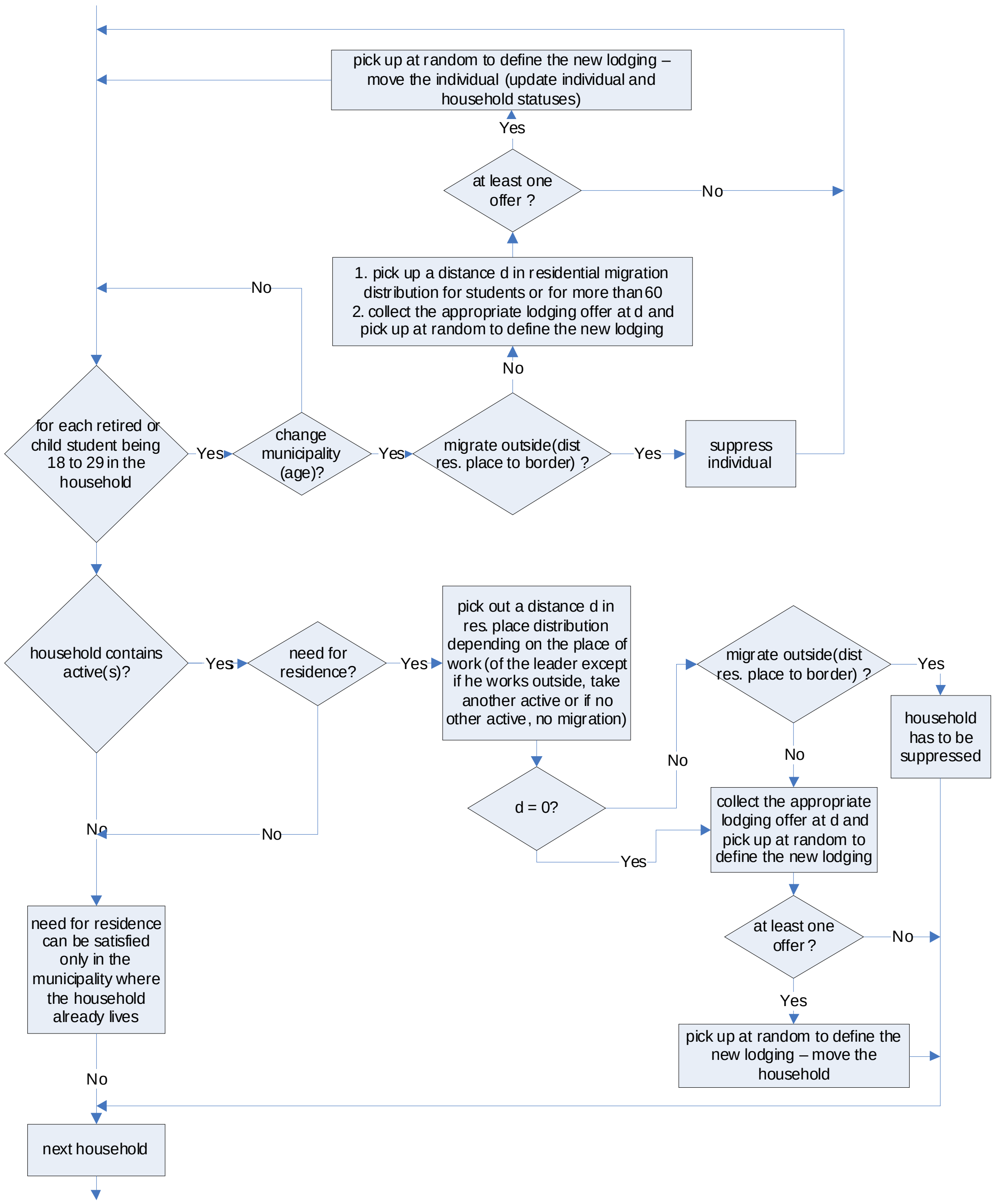

Figure 7. Diagram of the migration decision at the household level

Deciding where and for what

Studying mobility data, it appears relevant to distinguish three types of households: students, old single or couple, and all the others that we call actives, to simplify.

The probability that a household moves outside the considered municipality set depends on its type. This mobility to outside decision is described in the first subpart of this section. The decision to move outside is taken by a household which already knows it wants to change municipality.

When moving inside the set of municipalities, a household picks out the distance where to search the new dwelling into a distance distribution. The distance distribution is based on change data for students and old households, while it is based on commuting data for the rest of the population. Students and old households necessarily change their residence municipality while it is not necessarily the case for the others (i.e. actives). For the "actives", the distance is picked out first, and the question "going outside?" is considered in the case this distance is higher than 0; for students or old people, since we know they change of municipality, the question "going outside?" can be directly asked. If the household does not move outside, it looks for a new dwelling at a given distance. This search is described in details in the second subpart of this section.

Migrate outside the bunch

At first, a household, knowing it wants to change municipality of residence, has to check if it is going to move outside the bunch. Indeed, it has a probability to move outside the bunch depending on the distance of its municipality of residence to the border of the bunch. This probability is extracted from data. Figure 8 presents examples of probability laws to move outside for various French regions. We clearly see that the probability decreases with the distance to the border of the regions. However, the law changes significantly from a region to another.

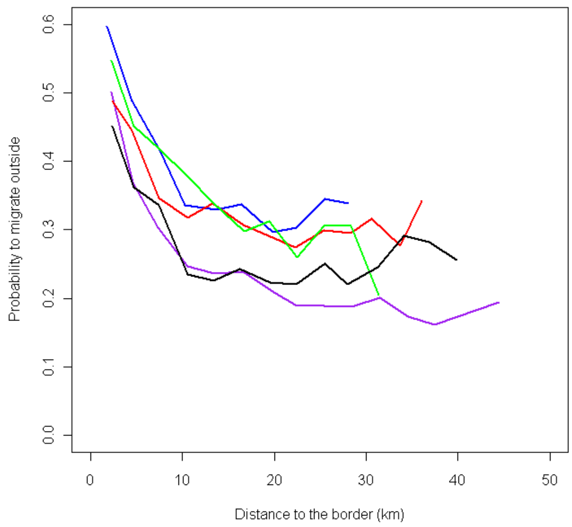

Figure 8. Probability to migrate outside the bunch (ordinate) depending on the distance of the municipality of residence to the frontier of the bunch (abscissa in Euclidian kilometers) for different French region or sub-regions: Blue: Cantal ; Black: Puy-de-Dôme bunch; Green: Haute-Loire; Red: Allier; Purple: Auvergne

As this probability corresponds to the probability knowing the individuals move, it is not sensitive to the type of household (young, old, active). Thus we use the same distribution for the three types.

Migrate inside the bunch

A household which has not decided to move outside is going to collect the acceptable and available dwelling in the municipalities located at the distance range it has picked out from the appropriate distribution. The acceptability is defined by the satisfaction function about dwelling presented earlier (see the “deciding mobility” part. A new dwelling is chosen at random in the list of available and acceptable dwelling if it is not empty. The potential in-migrants move only inside the bunch. As their need for residence is at true, they choose a new dwelling following this same rule.

Two distance distributions are used at least: one for student and retired coming for the residential mobility data and corresponding to the “real” distance distribution of migrants; one for “active” households which corresponds to the distribution of acceptable distances from residence to working place. This last is of the same type as the one used to search a job starting for a place of residence (see 2.7.2) but is extracted from the data considering the place of work as the starting point. The idea is to suppress the effect of the residence offer from the residential mobility distance distribution not to take it into account two times. However, we cannot do the same for people of more than 60 and students. This is a source of errors.

Another possible source of errors is related to the couple formation. We assumed that the search for a partner is made in a area of short distance to the residence place (i.e. at 25 Euclidian km radius at most). As soon as the new couple is formed, the partners live together in the larger dwelling between the two possible ones (or random if the size is the same). Thus, these moves, if they respect the short distance law, do not respect the distribution of acceptable distances. To reduce the impact of this bias and not to be redundant with the probabilistic residential move for people being of more than 60, we suppose that more than 60 individuals search for a partner only in the municipality where they live. In the same spirit, the household composed of more than 60 adults can move only in the municipality where they already live if they are not satisfied of their dwelling.

When the household has chosen a new dwelling and has moved (whatever the reason is: partnership formation, job change or need for another size of dwelling), one active member of the household can have a too high commuting distance (higher than the proximity parameter). If the member, who became a far commuter, is not the leader of the household (i.e. the one that the other household members have to follow since her working place is the place from which a distance should be considered to choose a new residence place), we assume she will quit her work.

List of the parameters involved in the decision regarding the place and the type of dwelling:

- *β:* impact of the age on the demand regarding the size of dwelling (see satisfaction function)
- range of distance to border for each municipality.
- probability to migrate outside the bunch given the range of distance to border in km of a municipality.
- probability to migrate outside the bunch given the range of distance to border in km of a municipality.
- probabilities people being 60 and more cross over a certain distance inside the bunch when they have decided to change municipality of residence
- probabilities child students from 18 to 29 cross over a certain distance inside the bunch when they have decided to change municipality of residence
- distribution of probabilities that an individual accept to cross over a certain distance to get a residence starting for her place of work.

We have seen how modelled two of the three main endogenous important mechanisms involved in the determination of the individual locations: the job search process and the residence search process. The third one is the municipality job offer. That is the one presented now.

2.7.4 EVOLUTION OF THE MUNICIPALITY JOB OFFER

Numerous are the researches pointing out the importance of services for the rural areas dynamism (F. Aubert et al. 2009; Dubuc 2004; Fernandez et al. 2005; Soumagne 2003). Also the residential economy shows the importance of the presence of the population in rural municipalities (Davezies 2009). We assume the job offer in the proximity service sector is directly linked to the size of the population of the municipality. We use the idea of the *minimum requirement* which defines the number of jobs in an activity sector which are necessary to satisfy the local needs.

Practically, we distinguish the proximity services which rely directly on the presence of population from the services which are decided according to other factors (assets of the location, political will at different levels, etc.). We integrated of the dynamics of creation and destruction of proximity services jobs in the micro-simulation model, using a statistical model derived from the data of the region. We studied extensively this data and found out that we cannot define directly the number of jobs in proximity services (Lenormand 2010a, 2010b). However, starting from the classical minimum requirement approach proposed by (Ullman and Dacey 1960), *(Lenormand et al. 2011d)* we propose an improvement which takes into account the distance a municipality to its closest pole of services. This new model has been grounded on detailed data related to jobs and poles of services. Therefore, we use this statistical relation to adjust the number of jobs in proximity services in the municipalities of the model. The other creations and destructions of jobs are ruled by scenarios.

Updating the number of jobs in proximity services

We derive the statistical model from the INSEE data dedicated to the population and the jobs in the service sector (Lenormand et al. 2011c). Based on the minimum requirement principle modified to predict the employment offer and take into account the distance between municipality and its closest pole of service, this function is:

$$E = \beta_0 + \beta_1 \ln P + \varepsilon$$

With E = minimum employment offer in the municipality to satisfy the need for services of residents
P = the population of the municipality
β_0 and β_1 = parameters

Figure 9 shows the form the function can take for different municipality sizes with various distances to the closest pole of service (called MFM). In any case, the job offer is higher in the pole of services and decreases in the surrounding. However, further from the pole of services, the number of jobs increases again until reaching a plateau at a distance higher than 10 minutes. We can also see that the larger is the municipality, the higher is the number of jobs in proximity services.

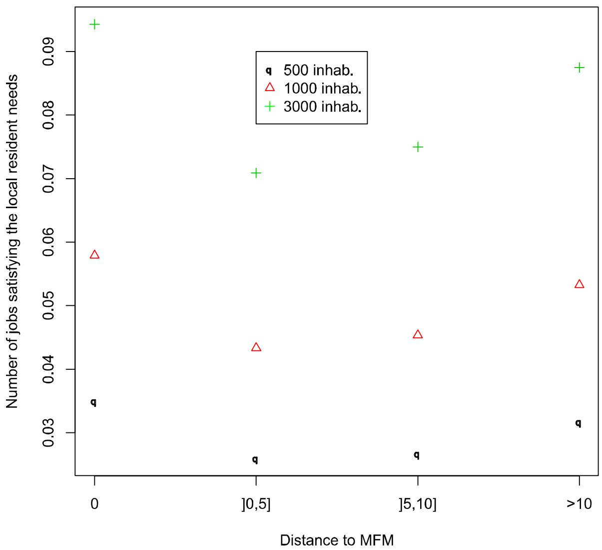

Figure 9. Number of jobs satisfying the local need for services of one inhabitants of municipalities having 500 (in black), 1000 (in red) or 3000 (in green) inhabitants and located in a range of distances of 0,]0,5],]5,10], >10 minutes of its closest pole of services (called the Most Frequented Municipality, MFM).

This function is computed every year in order to update the service sector job offer. However, it would be possible to add a parameter indicating the frequency of updating of this offer since the result can be very sensitive to this frequency.

Parameters: class of distance to the most frequented municipality (MFM) for every municipality; regression coefficient β_0 and β_1

We do not consider in this approach the employment in tourism. It would be possible to include them based on an approximation such as the one proposed by (Baccaïni et al. 2006). It would be very interesting since tourism is a source of dynamism in rural areas and that can be an improvement for future development.

3 THE CASE STUDIES

We present two French case studies. We began the simulation in 1990 and stop it in 2030. The period from 1990 to 2006 is used to calibrate the model.

3.1 THE CONDAT SET OF MUNICIPALITIES

Seven municipalities of the Cantal département in France have been selected to test a first version of the model. They are Condat and the municipalities around shown in Figure 10. This set of municipalities comprises 3065 inhabitants in 1990 and 2302 in 2006. More details can be found in the synthesis of statistics realized by

(Gomes et al. 2011) and the summation of the discussions with the stakeholders of the Condat bunch (Gomes 2011).

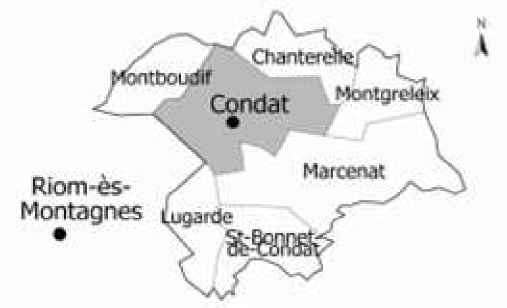

Figure 10. The seven municipalities of the Condat bunch

Some municipalities of the Condat bunch are areas where it remains a lot of small farms, as pointed out by (M. Aubert and Perrier-Cornet 2009). These authors question the capacity of these farms to survive in the future.

3.2 THE CANTAL DÉPARTEMENT

The Cantal is a French « département » comprising 260 municipalities and about 150000 inhabitants. Following the document "Assises des territoires ruraux, rapport de synthèse de consultation du département Cantal. Ministère de l'espace rural et de l'aménagement du territoire. 26 novembre 2009, 28 pages", the Cantal has the features of a very deep rural "département":

- Average density: **26 inhabitants/km2**
- Decreasing population from 1990 to 2006
- 50% of the road network at an altitude **higher** than 800 meters
- An economy based on **agriculture** (constrained by the severe climate)
- **A main town distant** from more than one hour of the closest highway, from more than 4 hours of a TGV railway station

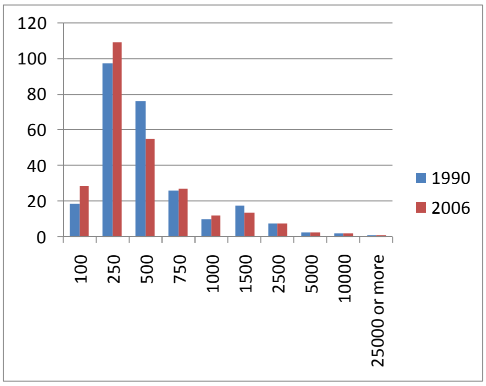

Figure 11. Frequency of sizes of the 260 municipalities of the Cantal in 1990 and 2006 (abscissa: ranges of size, higher bounds; ordinate: number of municipalities of the range)

The Figure 11 shows the distribution of the number of inhabitants of the municipalities in the Cantal in 1990 and 2006. The number of small municipalities is very high and has increased during the period.

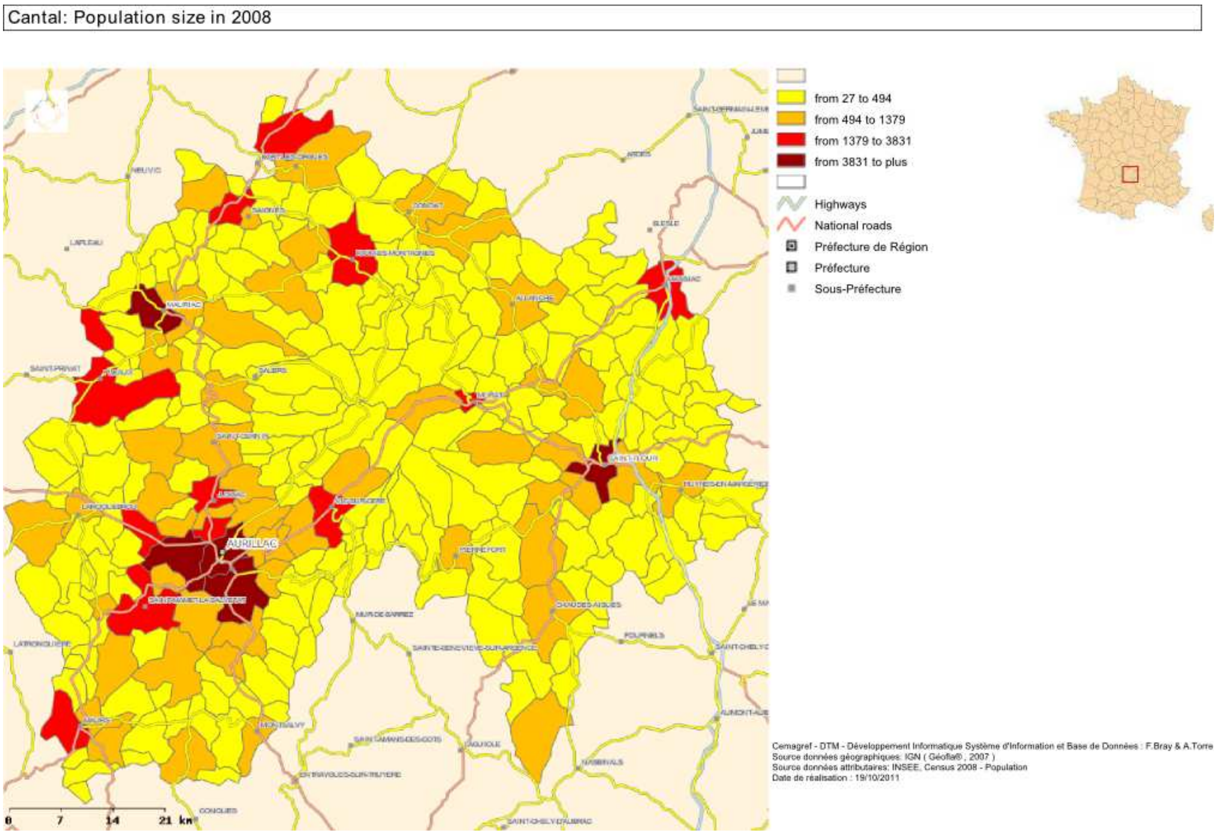

Figure 12. Cantal map of the municipality population in 2008. Source : INSEE. Made available by SIDDT

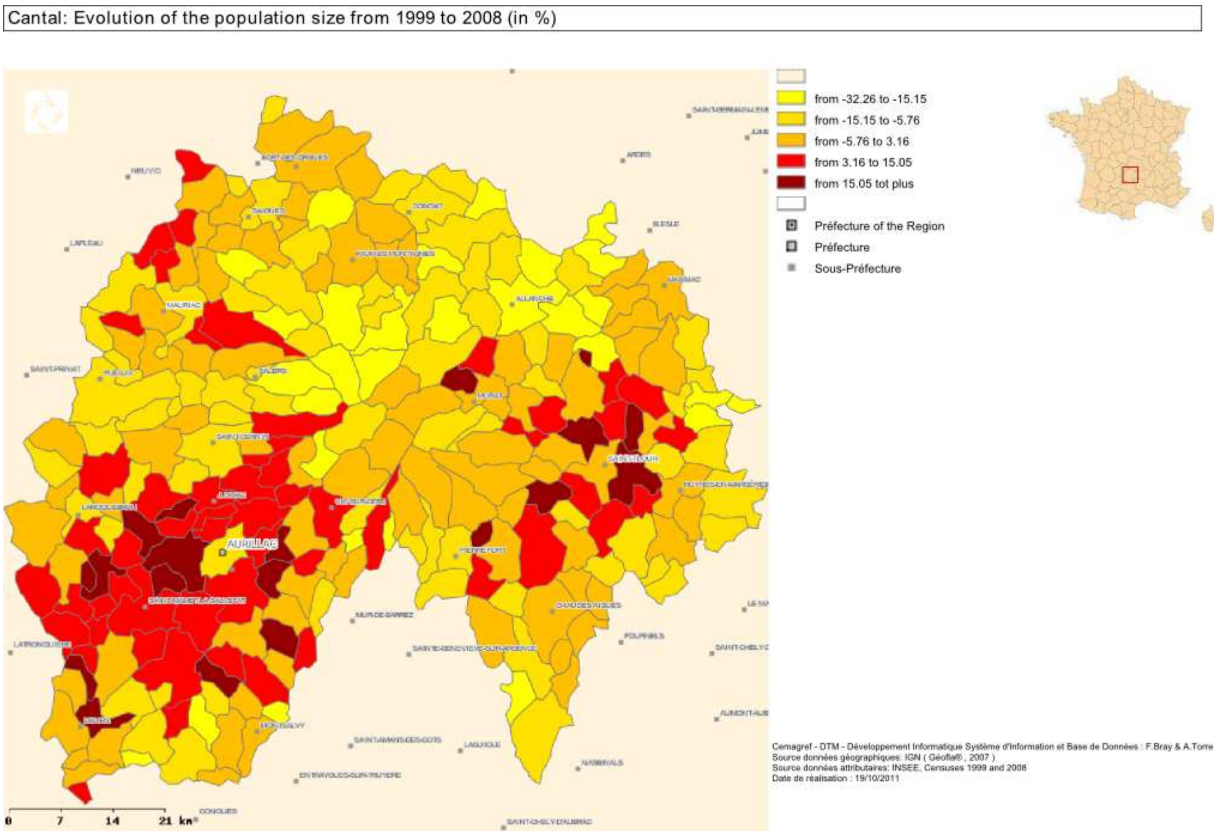

Figure 13. Cantal map of the evolution of the municipality population from 1999 to 2008. Source : INSEE. Made available by SIDDT

Figure 12 and Figure 13 show the population at the municipality level and its evolution from 1999 to 2006. The population size at the population level has not changed at lot during this period. However, we observe very contrasted evolution on the map with some areas having a decreasing population while the population has increased around Aurillac (at the bottom on the left).

Figure 14 and Figure 15 give details about the population change from 1999 to 2006 at the municipality level: one describes the migratory balance; the other shows the natural balance. We observe the migratory balance is much more positive than the natural one. The natural balance is still negative at the department level while the migratory balance tends to be neutral. However, the natural balance is positive in the surroundings of Aurillac (at the bottom on the left). Both are very heterogeneous regarding the spatial distribution.

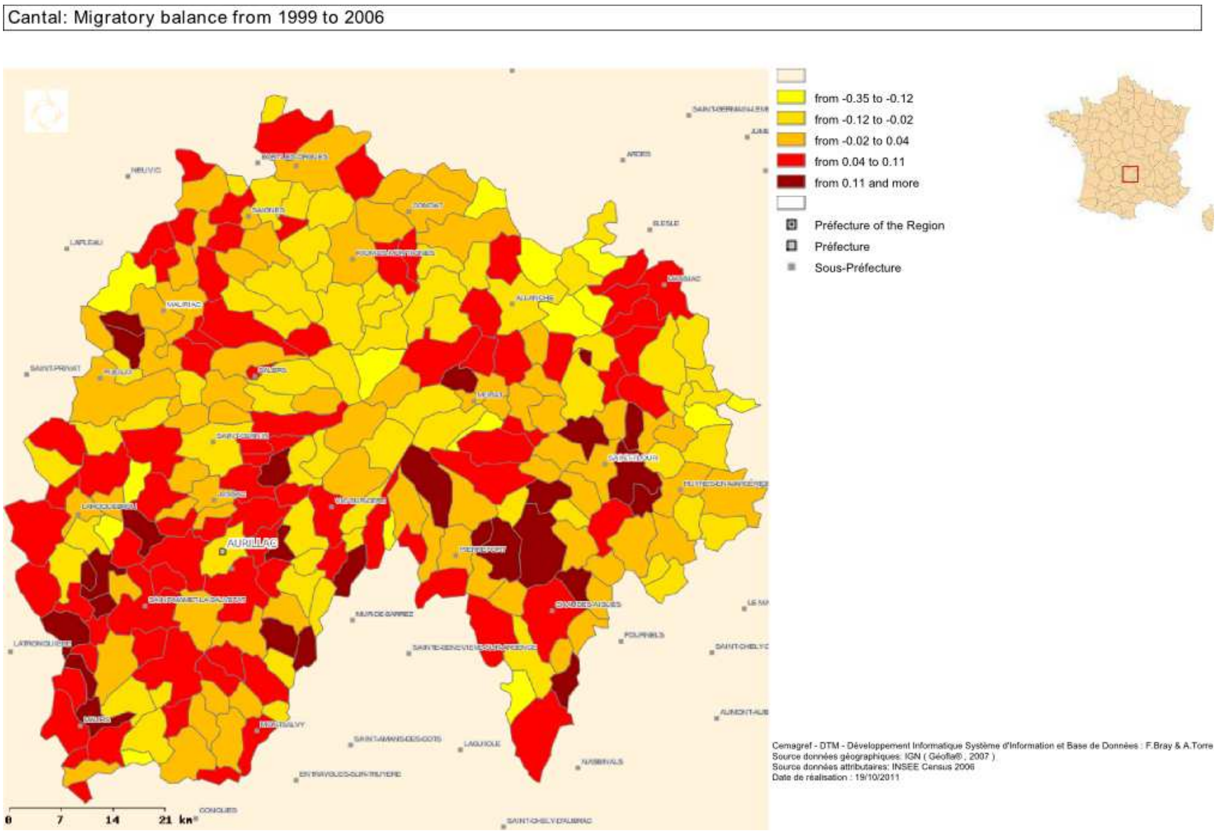

Figure 14. Map of the migratory balance at the municipality level from 1999 to 2008. Source : INSEE. Made available by SIDDT

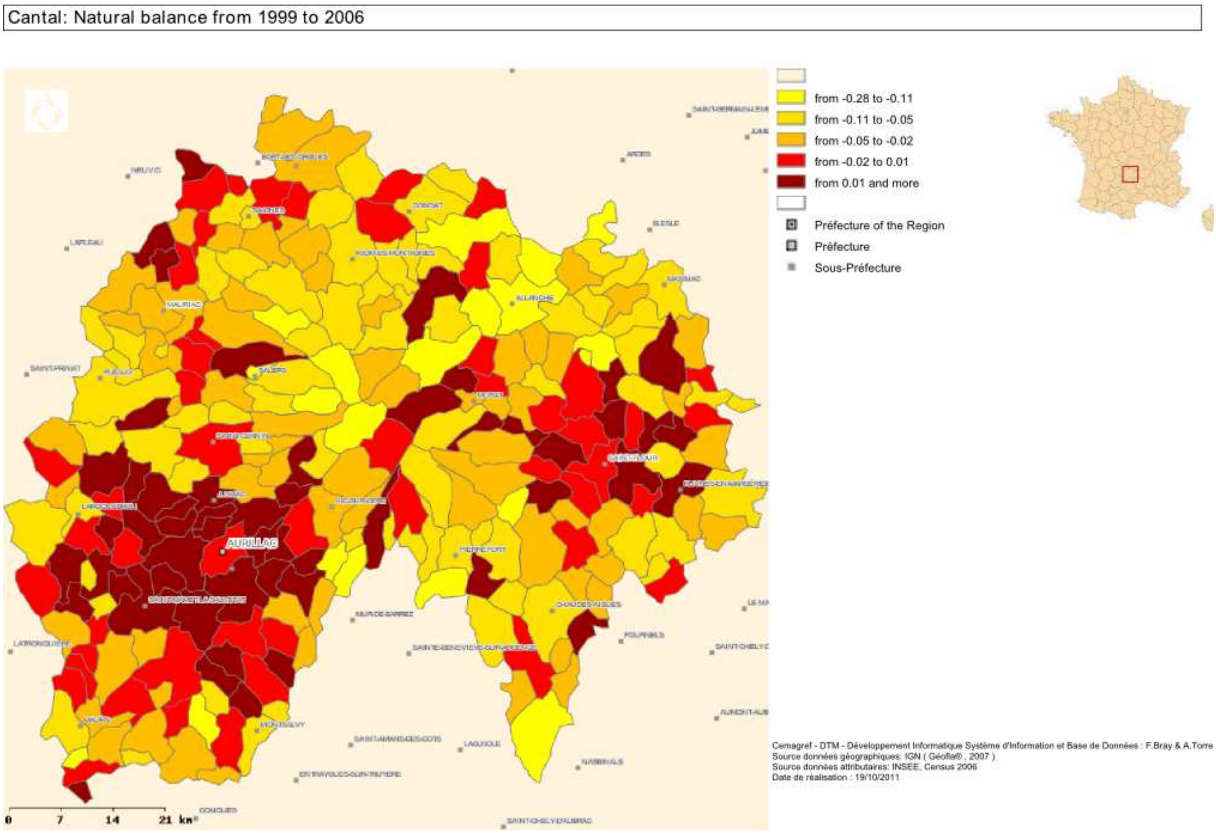

Figure 15. Map of the natural balance at the municipality level from 1999 to 2008. Source : INSEE. Made available by SIDDT

The analysis of the French National Statistical institute (INSEE) regarding the past and the future of the Cantal is summed-up (Delaveau and Vallès 2007) as follows the conclusions of the current situations and its demographical projections: *"In 2005, the Cantal has the same number of inhabitants as in 1999. After 30 years of a continuous decreasing of the population size, this stable state is mainly due to a reinforcing of the attractivity of the "département". The demography is still characterised by a low birth rate and a strong aging of the population implying more death than birth In-migration compensates the natural deficit but is not able to stop the depopulation or change the ageing tendency of the population. From 2005 to 2030, depending on the studied scenarios, the population of the Cantal will decrease from 3% to 13%. Keeping a good attractivity and an increasing of the fecundity are necessary to stop the population decreasing."*

3.2.1 PARAMETERIZATION

We present the parameterization of the model considering three different sections: the initial population and the demographic events; the municipality jobs and services; the individual events on the labor market. Most of the parameters concern a higher geographical level than the Condat bunch or the Cantal department. They have been computed at the French level or at the regional level for Auvergne. The one computed at a lower scale are especially mentioned.

The demographics

Initialisation of the population

To compute a population having good enough local statistical significance at the same time at the individual and the household levels, we propose an algorithm (Gargiulo et al. 2010) where individuals of a municipality are described by their age, and are gathered in households respecting a variety of statistical constraints (distribution of household types, sizes, age of household head, difference of age between partners and among parents and children). Since all the individuals and their households are created in their municipalities, a status and a profession are attributed to adults following the distributions of these attributes in the municipality-level data. If an individual is employed, a place of work is then attributed to him according to the data on the commuting network and on job occupation in every municipality. The details related to the generation of the initial population are described in (Baqueiro et al. 2010). It can occur that an individual is initialized with a job which is not in the list of the corresponding municipality. Indeed, the job in the generation of the initial population is defined by the profession for the individual and by the activity sector in the municipality list for in-commuters. Then, it cannot guarantee a job, a specific profession in an activity sector, is in the list of the municipality. If such a non correspondence occurs at the time 0 in the model, the individual searches for another job the dynamic rules of the model, until she finds one.

To model the commuting network, as in (Patuelli et al. 2007), we start by analysing its properties in Auvergne, comparing it to other French or Europeans networks (the one from the National Statistical Institute) (Gargiulo et al. 2011) and to the ones built with the generation algorithm we propose to compensate the lack of detailed data. Finally, we propose an algorithm computing virtual commuting networks starting from aggregated data on the number of individuals working outside and inside a municipality and living in another (Lenormand et al. 2011a).

The family events

We initialise the population of households from the data of the 1990 Census, using a specific algorithm which ensures the quality of the household description at the same time as the quality of the individual description (Gargiulo et al. 2009). The residences are affected to the households with a fast first optimisation of the type of residence with respect to the size of the households. Then new households are created when new couples are formed (see method *makeCouple*) or for immigration purpose (see Migrations). Following (Debrand and Taffin 2005, 2006) based on the analysis of data coming from various French surveys, creating a couple and splitting up a couple are the first factors explaining the residential mobility (respectively with a coefficient of 0.841 and 0.632 for the estimate of a probit model). Therefore it is particularly important that these methods should be accurate enough and well calibrated.

MakeCouple

The parameters are: probability to search for a partner; maximum number of trials (the result of the procedure is also linked with the neighbourhood of the municipality for which we use the municipalities where people commute); average difference of age between couple members and its standard deviation. The last one is given by the INSEE at the national level based on the data from Census.
For the two first, they have to be calibrated since they do not correspond to existing data.

SplitCouple

A study of the French Statistical National Institute (Vanderschelden 2006) shows that the probability to split up for a couple is quite constant over the couple's life. This probability depends on the year the couple members met, and not on the relashionship duration. It tends to be higher for couple members who met more recently. It is mentioned for example that the total proportion of couple having split after 10 years is 0.05 if their members met in 1950 against 0.2 if they met in 1980.
Applying this rule for the model parameterisation is impossible since we don't have the meeting date for initial couple. However, to limit the number of parameters, we use a constant probability to split that we will calibrate, trying to find out a kind of average probability to split over the different unknown year-meeting couples.
The parameter ruling the splitting of couples has to be calibrated.

Giving birth

The usual ages to procreate consider ranges from 18 to 45. That is the usual base to compute the total fertility rate corresponding to the number of children divided by the number of women in age to procreate during a given year. From this rate, it is possible to compute the average number of children of an imaginary woman who has every year of her reproductive life this rate to give birth. This is about 2 for France. We can start with this value to parameterize the model. But the number of children by couple has to be calibrated since the observed fertility rate of our simulated population can vary from the value of the parameter. Indeed, the birth process is constrained by the existence of couples composed from individual having the good age.

BecomingAnAdult

The parameter firstAgeToBeAnAdult corresponds to the minimum age at which an individual can become an adult and having its own household. It is generally valued as 15 years old by the National Statistical Institutes in Europe.

Death

The individual dies at an age picked out from the total distribution of probability to die by age (made available by INED from the various French Censuses at the national level).

Migration from the outside to the set of municipalities

Each year, a number of potential in-migrants from outside the bunch are added to the municipalities of the bunch. These potential in-migrants can really become inhabitants of the bunch if they find a residence by themselves or by being chosen as a partner by someone already living into the bunch in case they are single with or without children.

The building of the potential in-migrants varies depending on the size of the set of municipalities. For a level as the Condat bunch one, we exogenously fix how many potential in-migrants have to be added to each municipality. Only the creation of their characteristics is done with the same process as the one used for a larger bunch (see in the following).

For a large set of municipalities, as the Cantal département, we use a much more automatic design. That is the one described in the following. It is three-step process: the first consists in determining the number of in-migrants at the set of municipality level; the second one creates the household of potential in-migrants; the last one places these household in the municipalities of the bunch.

The first step consists in determining the number of potential in-migrants a given year. Then potential in-migrants households are drawn respecting this number and some characteristics of the in-migrants population. The last stage consists in placing this in-migrants household in municipalities where they can look for a residence and/or being chosen as a partner.

Determining the number of in-migrants

To compute the number of yearly potential in-migrants at the department level, we add the endogenously defined number of out-migrants from the bunch to the parameter "yearly migratory rate". As the number of out-migrants is not available in the model the first year, it is a parameter of the model. The yearly migratory rate is extracted from the Census data giving the migratory rate between two dates. The number of out-migrants to consider the first year is also approximated via the Census data.

For the Cantal, we have the following values (source : SIDDT, INSEE):

Out-migrants 1989	*4306*[6] *annual number of out-migrants between 1990 and 1999*
Years	Yearly migratory rate (in number of inhabitants)
90-99 comprised	-330
99-06 comprised	352
06-07 comprised	-26
07-08 comprised	22
Future[7]	110, low scenario ; 210, mid scenario ; 510, high scenario

Regarding the time table of “real” insertion in the population of the potential in-migrants, it is not fixed. The dynamics of the model regarding the offer of residence proposals and the making couple mechanism are going to rule the speed of insertion.

Creating the in-migrants household: their characteristics

[6] For memory: the probability have been computed in the file MigrantDistMinFrontiereHorsAuvergne.xlsx

[7] Source: "Population, Projections démographiques : de nouveaux scénarios pour le Cantal". *La Lettre n°46 INSEE Auvergne, novembre 2007*

The in-migrants are picked out from the existing population following different probabilities giving the characteristics of the in-migrants (size of the households, age of individuals...). In-migrants household are picked out until respecting the total number of potential in-migrants defined in the previous step. Each potential in-migrants household is affected to a municipality.

Figure 16 shows the distribution of probabilities of the in-migrants from 1990 to 1999. On the left, there are probabilities an in-migrant household has a given number of members. On the right, the probabilities of age ranges are presented. We can see that most of the households coming to live in Cantal are of size 1 or 2. Regarding the age, the most represented ranges are 0-14 and 30 to 59. That means that most of them compose family with children.

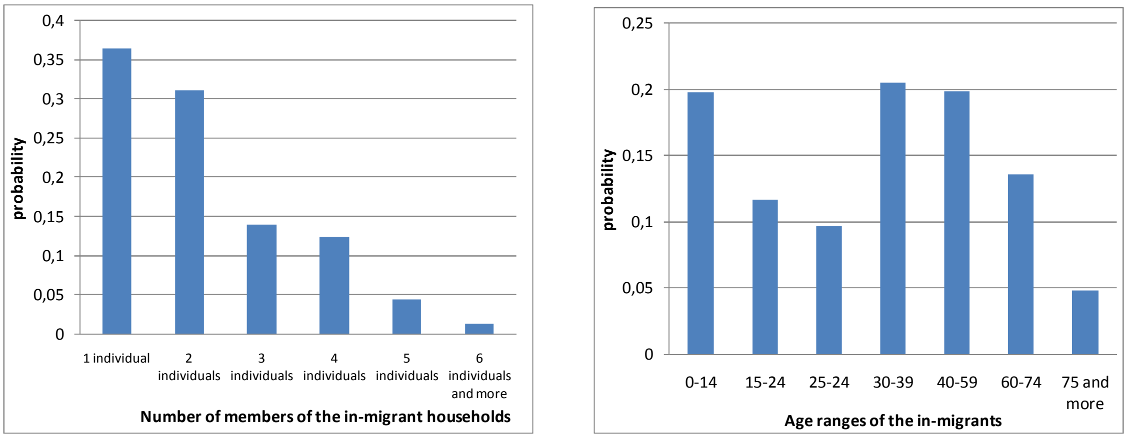

Figure 16. Characteristics of the in-migrants from 1990 to 1999 (source INSEE, residential mobility data 1999)

These distributions are extracted from the residential mobility data collected during the French Census in 1999. Following the same method, we can extract the distribution for in-migrants from 1999 to 2006.

Regarding the future, we assume the characteristics remain the same as the last ones available (2006).

Placing the potential in-migrants household into the municipality: a law depending on the municipality size, its distance to the bunch frontier and the type of household

The in-migrants should be temporarily affected to a municipality. At this stage, they are potential in-migrants and become "real" in-migrants when they find out a residence. To place the in-migrants household, the yearly number of in-migrants of each municipality from a function extracted from INSEE mobility database for 1999 and the municipality population sizes given by the 1990 census. We use the same function all along the duration of the simulation since the mobility data for the next period are not so reliable than those of 1999. The function depends on the size of the municipality and its distance to the frontier of the bunch.

- For the Cantal département: (computed on all the municipalities having less than 2000 inhabitants, representing about 95 % of the total number of municipalities) – adjusted R^2 0.9122

$$m_i = 1.066362\ p_i/P - 0.00003203865\ dF_i\,M$$

- For the Auvergne region: (computed on all the municipalities having less than 5000 inhabitants, representing about 95 % of the total number of municipalities) – adjusted R^2 0.9342

$$m_i = 1.158021\ p_i/P - 0.000005.615703\ dF_i\,M$$

where m_i: number of in-migrant of a municipality i expressed as a real number
M: total number of in-migrants of the bunch
p_i: population of the municipality of which we define the number of in-migrants
P: total population of the bunch
dF: distance of the municipality i to the frontier of the region in Euclidian km (approximated by the distance to the closest outside region municipality)

We will use the law for the Cantal département to parameterise our application on Cantal. Then the potential in-migrant households are placed into the municipalities using the following algorithm. We suppose the potential in-migrant households build previously stored in a list "households to place".

```
While (it remains an household to place of size > 1 in the list)
        Pick out a household size > 1 in this list
                mun = chooseMunicipality(household)
                Place the household into the municipality mun
                Suppress the household from the list
                Update the municipality counters of remaining in-migrants to welcome
End While
While (it remains an household = 1 in the list)
        If the household is composed from an individual being less than 25
                If a random < rateBigTown then affect the household to Aurillac if the counters given the number of
                remaining individuals to place in is higher than zero
                Else while (mun = bigTown)
                        mun =chooseMunicipality(household)
                        Place the household into the municipality
                        Update the municipality counters of remaining in-migrants to welcome
        Else
                mun = chooseMunicipality(household)
                Place the household into the municipality mun
                Suppress the household from the list of municipalities to place
                 Update the municipality counters of remaining in-migrants to welcome
End While
============
chooseMunicipality(household)
if (every municipality counters of remaining in-migrants to welcome are between 0 and 1)
        mun = pick out a municipality in the lot of municipalities having the counters > 0 and < 1
else {
        mun = pick out a municipality in the lot of municipalities having the counters given the number of
        of remaining individuals to place in is higher than the household size
}
return mun
============
```

Where *rateBigTown* is valued *0.45* for the Cantal département and corresponds to the young people who go to study in the city *(bigTown* is Aurillac for Cantal, Clermont-Ferrand for Auvergne). At the two level, département one and regional one, we know from the data that the larger town attract much more the young people for study purpose than the rest of the bunch compared to the rest of the population.

After the parameterisation of the in-migration, we have to deal with the mobility inside the set of municipalities and the out-migration..

Household mobility and out-migration

The «mobility » data from INSEE (Census of 1999) suggest distinguishing again subgroups among migrants living in Cantal. Indeed, these subgroups have been already identified during the construction of the mobility dynamic (see 2.7.3). Figure 17 shows the probability to move to a given distance knowing the subgroups: the individuals aged more than 60; the student being 15 to 29; and the rest of the population. We notice young people go further while old people tend to go more at intermediate distance. Families and the rest of the population mainly move at short distances.

That is possible to make the link between the subgroups identified in the data and subgroups in the virtual population of the model. Table 2 shows how we establish the relation.

Data mobility 1999 – INSEE	**PRIMA population**
Students from 18 to 29	Individual: Child, student from 18 to 29 years' old

15-29 years' old without students 18-29 years' old + 30-59 years' old and children being 0-14 years' old	Household composed of at least one active, employed or unemployed , and inactive individual with possibly their children
More than 60	Individual: more than 60

Table 2. Relation between the groups of migrants in the mobility data of INSEE and the groups of potential in-migrants in the PRIMA population

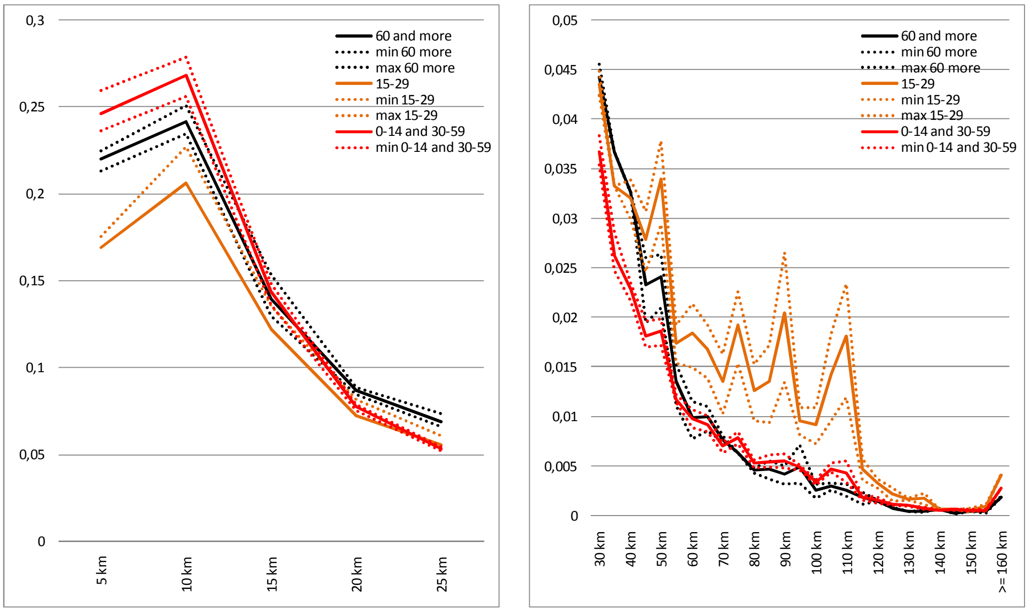

Figure 17. Density distribution (summed to 1) of the probabilities to move at a given distance depending on the age range from 0 to 25 km on the left, further on the right

From there, it is easy to compute the parameter for our subgroups. From We 2.7.3, we know we need two types of parameters:

- Tolerance expressed in number of rooms lacking or supplementary and a probability to accept a proposed residence, or a *β* value ruling the impact of age on the satisfaction level depending on the method used to compute the satisfaction (see 2.7.3 for details): whatever it is, this parameter has to be calibrated since it can hardly be in relation with some available measured variables.
- Probability to move outside
- Probability to move for students and retirees;
- Distance of mobility for students and retirees;
- Acceptable distance to find a residence for household of “actives and inactives”.

Probabilities moving outside

The probability to move outside the bunch depends on the distance of the municipality of residence to the frontier of the bunch. These probabilities are extracted from data. The Figure 8 presents the probability law used for the Cantal department.

Probabilities moving for "16-29 students" and "60 and more"

They can be extracted from data. They are high for 16-29 students and low for “60 and more”.

Distance of mobility "16-29 students" and "60 and more"

A distribution of distance is extracted from the residential mobility INSEE database to parameterise this process. Figure 18 shows these distributions of probabilities.

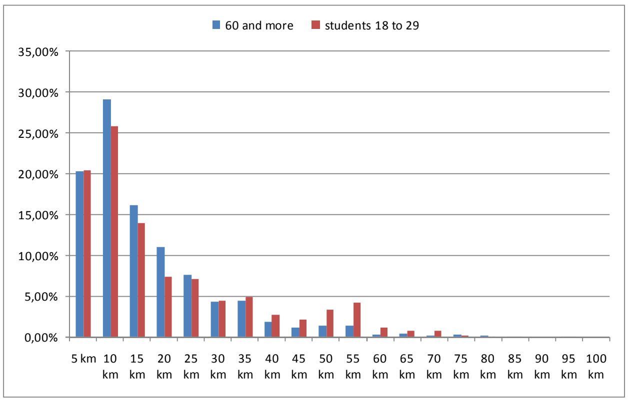

Figure 18. Mobility distance probability distribution for 60 and more and students 18 to 29 (Source INSEE, mobility 1999)

Distance of mobility for the category household containing at least one active

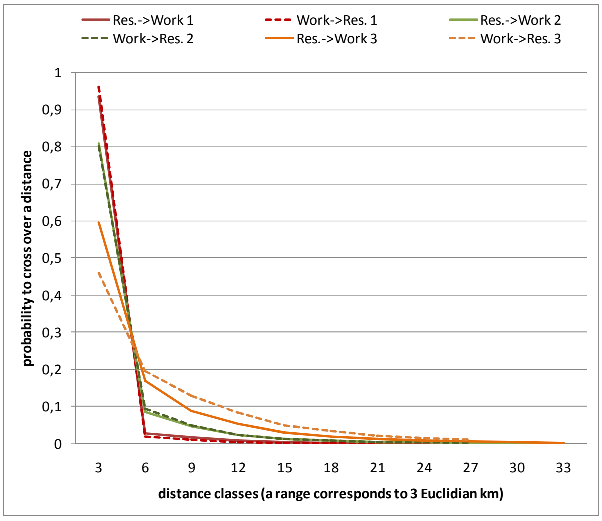

Figure 19. Probability to accept a residence at a given distance from working place (work-> res.) or to accept a job at a given distance from the residence (res.-> work) for three different size of starting point municipalities - The work -> res distributions are used to decide about the accepted distance in the migration process of households containing at least one active. The res -> work distributions are used to decide about the accepted distance to get a job for individuals looking for a job.

Figure 19 presents the three distance distributions extracted from the commuting data in the same way that distributions to know where searching for a job has been extracted (see above in the "searching for a job" section 2.7.2 for details). One can notice that the accepted distance is similar for the residence to job or the job to residence cases. Globally, we notice that the larger is the municipality, the lower is the probability to work in the municipality of residence and the longer is the distance between residence and work. Moreover, in the large municipalities (group 3), individuals tend to find a work in the municipality where they live more easily than to find a residence in the municipality where they work. This result is quite robust since it has been obtained for various French regions. However we don't know how to explain it.

Municipality story strands: offer for jobs, services and lodging

The job offer

How is a job described in French statistical data?

Considering European data, a job is defined as a couple of values: a profession and an activity sector. We now describe which INSEE data these categories correspond.

The most aggregated available data close to the profession definition is the socio-professional category (SCP). We decide to use the six modalities which define at the same time a kind of occupation, an average level of education and an approximate salary. These modalities also reflect some elements about the different subcultures in the French society. There are: farmers; craftsmen, storekeepers, business owners; top executive managers, upper intellectual profession (senior executives); intermediary professions; employees; workers, etc. For the possible activity sector (AS) in which an individual can work, we use: Agriculture, Forestry and Fishing, Industry and Building; Services and Commerce. The data for these four activity sectors are always available in our data sources. Moreover, the Auvergne region is quite heterogeneous regarding the activity sector and these four sectors are large and diverse enough to represent this heterogeneity.
Overall, considering these six SCP and the four AS, we obtain 24 jobs which can be occupied by our virtual individuals. That is a small number of jobs compared to the diversity of the “real” job market, but it is large enough to catch a reasonable diversity and still manageable in our model.

How the compute the job offer

Several types of scenarios ruling the job offer have to be designed. Indeed, we need to keep in mind that the outside represents a source of employment for people living in studied municipalities sufficiently close to in the border. Therefore, the scenarios to build are the following.

1. for each outside*: the job offers for people living in the neighbouring municipalities of each outside.
2. for each municipality: the job offers; distinguishing between proximity services jobs and the others.

Since the offer is generally not available in the data, the main hypothesis we start with is that the quantity of job offers equals to the quantity of job occupied at the date the data were collected. Before describing how to construct these scenarios, we give more details about the sources of data used for the French case study:

- 1990 French Census. Tables at municipality level give the cross distribution of the number of individuals having a socio-professional category and a given activity sector counted on their place of work (i.e. working in the municipality, not necessarily living in it).
- 1999 French Census.
  - At the municipality level, on the one hand, we know how many people work in this municipality in the various activity sectors. On the other hand, we know how many people work in this municipality within the different socio-professional categories.
  - The "mobility" database which gives for each individual the place of living and the place of working.
- 2006 French Census. The most refined spatial level we have is the "canton-ville" grouping the municipalities to have at minimum about 5000 inhabitants. This is a problem we have to solve.

We never have the details about the time evolution of the job offer. One way to overcome the difficulty is to let the model driving the event considering the internal event it is able to produce. Then, the job offer built from a given date of Census is made available in the model to the virtual population just after the given date of Census. We suppose these offers have been taken or suppressed during the two Censuses. As we don't know the rhythm and the events leading to the particular measure of the INSEE of the occupied jobs, we let the model managing this during the simulation period. We assume very few people are fired. Then, jobs are quitted by retirement and taken when requested. We observe, at least for the Condat set of municipalities, that avoiding making time and event assumptions on what leads to the particular offer in a Census is sufficient to obtain a 100% occupation of the job offer (which is in accordance with the available data).

We now describe how to define the job offer of the outside at first, at the municipality level in a second time.

The outside job offer scenarios.

Depending on the number of municipalities simulated in the municipality set, we adopt a more or less ad-hoc ways to build the outside job offer scenarios.

For a small number of municipalities:
The purpose is to design the job offers of outside for people living in their neighbouring municipalities. For the Condat case study, we know the real quantity of people in this situation in 1999 from the "mobility" database.

For 1990, it can be extracted from the generated population of individuals and their activity. However, as the generation algorithm used the data from 1999 to compute probabilities of working in a given place and living in another one and apply them to decide about the working locations in 1990, it can be marginally false. If a given case study region has no detailed data available about the commuter migration, it remains possible to approximate the quantity linked to the real job occupation by people living inside neighbouring municipalities and working in this outside. The algorithm of generation of the commuter network proposed by Gargiulo and al (2010), and more especially for the outside (Lenormand et al. 2011a), is an appropriate tool to compute the required quantities.
For a large number of municipalities: that is the simplest case since the offer is infinite (see the dynamics explained in 2.6.2 for more details).

The municipal job offers scenarios.

At the municipal level, we can distinguish two different scenarios which can be grouped in only one. Keep in mind that the offer is considered equal to the occupation at the dates of census. Two subgroups have to be identified to conceive the municipal job offer scenarios in a correct way:

- The part of jobs occupied by individuals living outside the set of studied municipalities (i.e. outside the region), noted *A*.
- The part of the jobs in the municipality for people living in the set of studied municipalities, noted *B*.

The first parameter we need to build the job offer scenario is *T*, the total job offer at the municipality level. We assume *T* equal to the job occupations which is available in the Censuses in 1990, 1999 and 2006 called "employments counted at the working place".

At the initialisation time

The first step consists in defining *A*, the part of individuals working in the municipality and living outside, which is given by computing the following difference:

$$A = T - B$$

At the initialisation time, in 1990, we have *T* which is a parameter and we can extract *B*, the individuals living and working inside from the virtual population we have generated. Indeed, in our virtual population, *B* corresponds to the jobs occupied by people working in the studied municipality and living in the municipality plus the one working in the studied municipality and living outside the set of municipalities. The method "giveJobsOccupiedByInsideRegionPeople()" from the Municipality class allows to extract *B*. Thus, we deduce the value of *A*.

A last difficulty to solve consists in distinguishing the proximity service jobs. Indeed, *T* includes both the exogenously defined T_{exo} and endogenously defined (proximity services) T_{end} job offers. For every activity sector except the service, $T_{exo} = T$ and $T_{end} = 0$. For the service sector, the endogenous offer has to be computed and the exogenous offer deduced. These computations are explained in the following sections.

The "service" activity sector: computing the proximity service job offer

For the service sector, we are able to compute, as presented in the next section, the proximity service offer which is going to evolve with the population. We have $T_{exo} = T - T_{end}$. Then, the scenario is parameterised giving the total offer *T* for every job, and the model updates each year the exogenous offer by extracting the proximity service offer computed and updated each year from the population (Lenormand et al. 2011c). Based on the minimum requirement principle modified to predict the job offer and take into account the distance to the closest pole of service, this function is:

$$E = \beta_0 + \beta_1 \ln P + \varepsilon$$

With E = minimum employment offer in the municipality to satisfy the need for services of residents
P = the population of the municipality
β_0 and β_1 = parameters

Then the number of jobs in services for the population of a municipality is E by P. More details about this function are given in 2.6.2 and in (Lenormand et al. 2011c). The work has been based on the data coming from the French Censuses of 1990, 1999 and 2006 managed by the French Statistical Institute, INSEE and from the French Municipal Inventory of 1999. The variables of the Census are the Number of inhabitants and the Number of jobs in the French tertiary sector in 1990, 1999 and 2006. The variable of the Municipal Inventory is the Most Frequented Municipality (MFM) for every municipality. The MFM of a given municipality is assumed to be the same in 1990 and 2006 that the one giving by the data of 1999. All these data are kindly made available by the Maurice Halbwachs Center.

For the Cantal, four different functions depending on the distances in minutes to the MFM have been extracted from the Auvergne data. The regression coefficients for each class are given in Table 3. The details regarding the distances to the Most Frequented Municipality of every municipality of the Cantal is not given here. These coefficients appear sufficiently stable over the time not to be changed during the simulation time.

Classes of distance in minutes to the Most Frequented Municipality	β_0	β_1
0	-0.170901146	0.033121263
]0,5]	-0.130158882	0.025111874
]5,10],	-0.141049558	0.026983278
>10	-0.162030187	0.031165605

Table 3. Regression coefficient for the four classes of municipalities of the Cantal

The proportion of proximity service jobs over is assumed to be the same for all service professions (which is probably a strong approximation). This allows us to distribute the proximity service jobs in the different jobs in the service sector.

We did not include this endogenous dynamics of proximity service jobs in the first version of the model for the Condat bunch.

It can occur that the computed number of proximity service jobs exceeds the total service jobs from the data. Indeed, the the proximity service jobs are computed on the first vigintile for each class of municipality size (see (Lenormand et al. 2011c)). In this case, we fix the proximity service jobs at T and the exogenous offer at 0.

The "service" activity sector: computing the exogenous job offer

Since we have T for each job and T_{end}, w have $T_{exo} = T - T_{end}$. However, due to the stochasticity of the model and the difficulty to calibrate it properly, nothing insures that $T \geq T_{end}$.

At the next census dates 1999 and 2006

T is defined by job in the first Census in 1990. For the next steps in 1999 and 2006, we only have the total of employments occupied by activity sector and the total employments occupied by SPC (used as a proxy for profession). The job distribution of offer corresponds to the joint distribution activity sector x SPC. We can build the lacking joint distribution SCP x activity sectors starting from the joint distribution from 1990, and the SCP distribution and the activity sector distribution in 1999. We apply the Iterative Proportional Fitting (IPF) (Deming and Stephan, 1940) method to compute a very probable joint distribution in 1999 and 2006. This procedure allows us to define T in 1999 and in 2006. Figure 20 shows T at the three different dates for each of the 24 jobs we model. The more noticeable is the increase of the job offer in the service sector and the decrease of jobs for farmers.

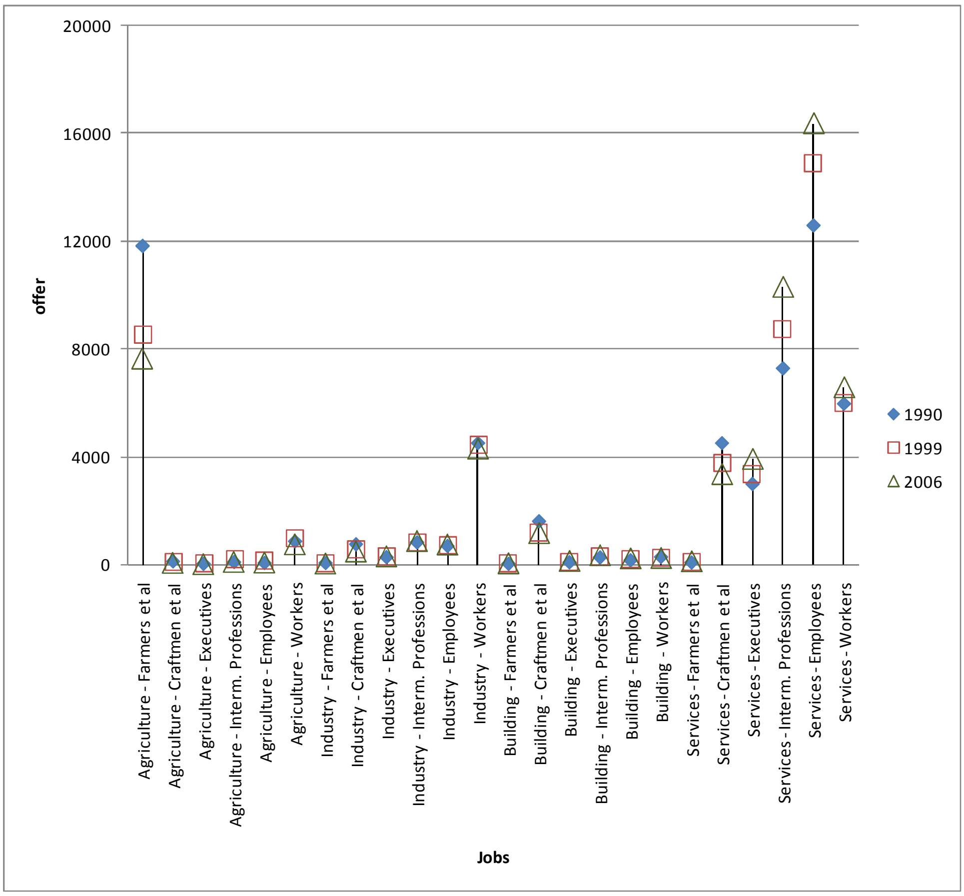

Figure 20. Total job offer (equal to job occupation) in the Cantal in 1990, 1999 and 2006

The parameters for the next steps are now only the exogenous job offer by municipality that is extracted by the user. The method to apply is the one explained previously and computed by the model at the initialisation.

The models update separately the exogenous (using the scenarios) and the endogenous (derived from the population of the municipalities). The difference, both for endogenous and exogenous, is distributed over the jobs occupied by people living outside and jobs offered for people living inside the set of municipalities. The initial respective part of each of them is maintained all along the simulation.

The dwelling offer

Dwelling is described through its size expressed in number of rooms. The offer is exogenously defined by scenario. The French Census gives the number of dwellings having a given size occupied by household at the municipality level at different dates (1990, 1999 and 2006). The data are available for the size 1, 2, 3, 4 or more rooms. They are available for more sizes but only from 1999, thus we define the sizes we consider constrained by the level of data availability in 1990 (i.e. the year from which the least amount of data are available). We add to these data the number of vacant dwellings also given by the French Census. As the detail by size is not available, this total number is distributed over the sizes using the law given by the occupied dwellings. To the size 1, we add the number of beds of the retirement home which were available in the Census in 1990. We update this number by a research of the Retirement Home and their capacities on the web. We have not considered the lodging for students (when they are not registered as a lodging for occupied by households as dormitories) since most of them move to large cities not included in the model.
Some data are available about the secondary residences but they are neglected since the model does not consider a household can have two residences.

What is proximity?

A threshold splitting short from long distance has been extracted from the data related to the residential and commuting mobility in Auvergne in France from 1990 to 1999. Figure 21 shows these data. Comparing the residential migration distance distribution to the commuting one, it appears that from 25 km, the residential migration flows is larger than the commuting one while it is the contrary for every distances less than 25 km (see 3.2.1.). Then, we assume that the residential migration:

- **at a distance until 25 km**, corresponds to a migration unrelated to job. This threshold corresponds to 78% of the migratory flow and 92% of the commuting flow in the data.
- **at distance higher than 25 km**, corresponds more the migration of inactive people or active ones who change for professional reasons. That means, if someone has found a job at a distance higher than 25 km, her household is going to move looking at a new residence in a circle of 25 km around the new place of work of this individual. In other words, we assume most of the 8% of commuters with a larger distance than 25km have a transitory situation and wait for moving.

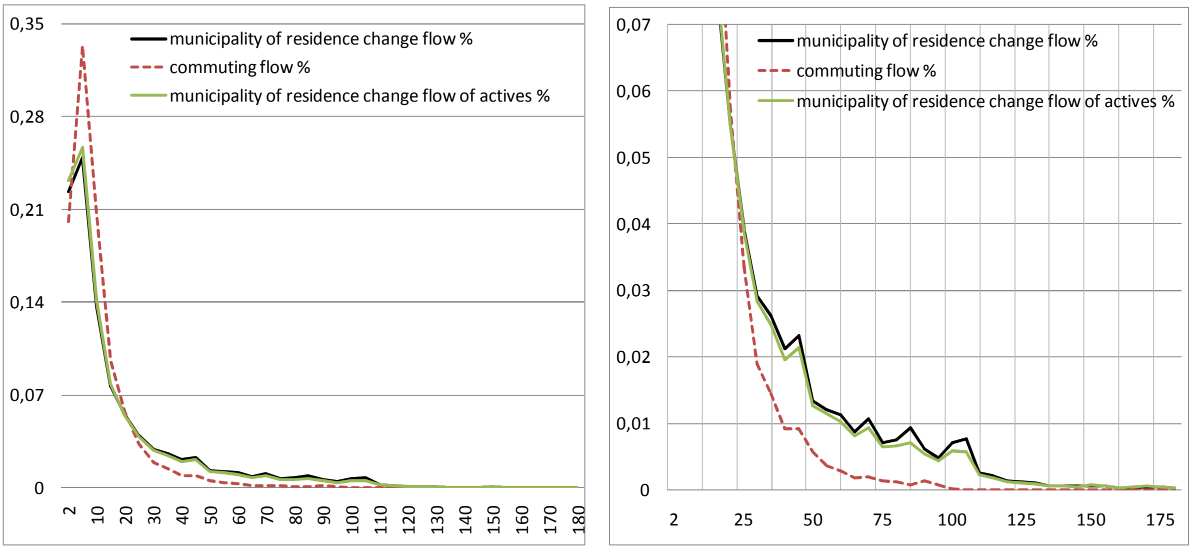

Figure 21. Density distribution of the cross over distance (in abscissa in Euclidian km) to change municipality of residence for the moves from Auvergne region to Auvergne region (INSEE 1999) – On the left: the whole distribution; on the right: zoom onto the lower part of the graph

Household story: demanders and users of jobs, services and lodging

This part is dedicated to the parameterisation of the different event occuring to an individual on the labor market. The data are extracted from the Labour Force Survey called "Enquête Emploi" in France. The data are made available by the Maurice Halbwachs Center of the Quételet Network[8].

Entering the labor market

A process decides the age at which the individual is going to look for a job for the first time. At the same time, a first SPC (proxy used for defining the profession) has to be affected to the individual allowing us to known what she's going to look for. We know that both these variables, the age of entry and the first SPC, are not independent. Moreover, a social determinism rules the choice of the profession by children compared to the profession of their parents. Figure 22 presents such a relation for the Auvergne population. It shows, for example, that almost only farmers' children become farmers or that executives' children mainly become executives and/or adopt an intermediary profession.

Thus, starting from this social determinism, we have some indications to set the SPC of the children. However, we also have to decide the age of entry in the labor market, and we know that this age is not independent from the level of education, which can be related to the SPC. Consequently, we apply a two-time process which, at first, decides the age to enter on the labor market using the father's SPC and then determines the child's SPC depending on the age of entry.

[8] http://www.reseau-quetelet.cnrs.fr/spip/

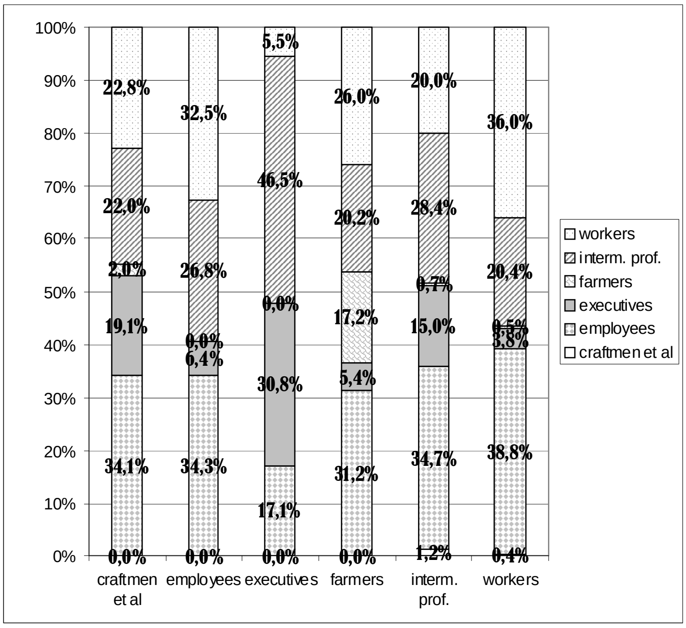

Figure 22. Distribution of SPCs choices by children regarding the father's SPC (in abscissa) for the Auvergne population. Source: French Labour Force Survey, 1990 to 2002 data.

Age of entry depends on father's SPC:

The age of entry on the labour market is determined by the SPC of the father. Since the individual has no gender in our model, the father is randomly chosen between the two parents when there are two.

A criticism can be formulated to this approach since the SPCs of the couple members is not controlled, while we know from the literature that the partner is not chosen at random regarding her SPC (Bozon and Héran 1987). The homogamy can be explained by the constraint associated to the meeting places (Bozon and Héran 1988). It has been identified as a possible next step for modelling.

Figure 23. Distribution of probability to enter the labour market at a given child age for each of the six father's SPC considered – French population. Source: French Labour Force Survey, 1990 to 2002 data.

Figure 23 shows the distributions of probabilities to enter the labour market depending on the various ages of the child for each of the six SPC attributed to the father. We can for example read that if the father is an executive, the most probable age to enter on the labour marker is 25; if he is a farmer, it is 21 as in the other SPCs (except executives). Moreover, one can notice that the probability to enter at 17 is very high if the father is a worker and average if the father is a craftsman or an employee, while it is quite low for the others father's SPC. Since our individual now has an age to enter the labour market, we can determine its first SPC.

First assigned SPC depends on age of entry into the labour market:

Figure 24 shows for each age of entry on the labour market presented in abscissa the distribution of probability over the possible SPC to provide the individual with a first SPC. For example, one can notice how high the likelihood of looking for a worker position for the individual looking at first for a job at 15 is, while at 30, she will mostly look for intermediary or executive positions.
Another way to make the transition to adult is to find a partner to create a couple. If the individual is still a child but more than 15, she can be chosen as a partner by an individual who is already an adult. Note that she cannot directly look for a partner while she is a child. Since she has been chosen as a partner, she becomes an adult in the new couple household. This new couple starts living in the larger residence among those of the two members of the couple. But since the occupied residence is probably not large enough for two, the couple is likely to try to move. The move method is presented in the section describing the dynamics of the household.

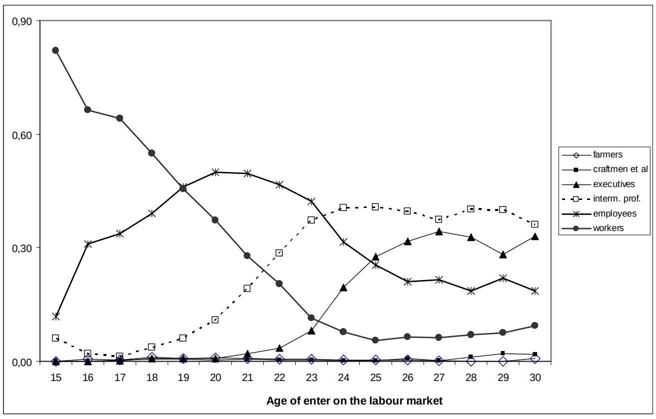

Figure 24. Probability of a "first" SPC depending on the age of entry in the labour market

The individual who enters the labour market can look for a job. But before giving details on how she searches, we describe the final event which is going on retirement.

Going on retirement, and stop searching for a job

We assume that the retiree does not search for a job anymore since it is generally true in our case study.

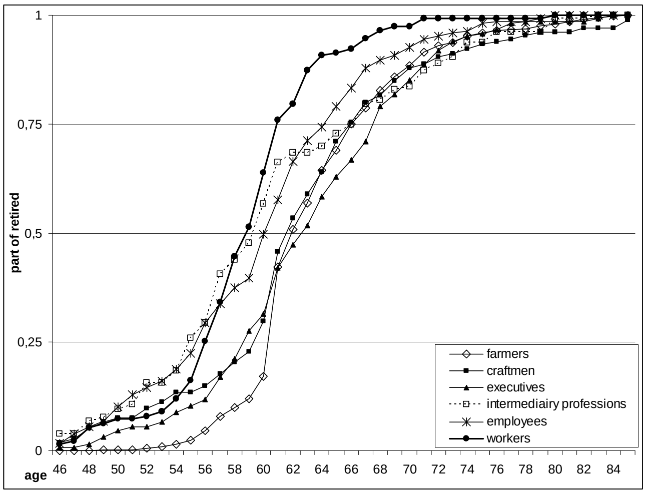

Figure 25. Speed of going into retirement by SCP (source LFS) – France level

Figure 25 shows that the speed of going into retirement varies a lot from one SCP to another: we can read for example that, at 60, 63 % of workers are retired while only 17 % of farmers are retired. Then, instead of considering a unique law for all the individuals to go on retirement, we consider a law by SCP. Indeed, as these laws partly defined the job availability at a given moment, it is very important to be sufficiently precise.

Individual job searching decision

An individual decide stopping to search when:

- She becomes inactive: the law ruling the transition to inactivity from the unemployed and employed statuses is presented in Table 4 considering the profession of the individual.
- She becomes retired: the law has been already presented.

She decides searching when:

- She becomes unemployed after being student, employed or inactive: we have already seen the law by which she enters on the labour market; the laws by which she can be fired or she resigns are endogenous; the laws by which she can become unemployed after being inactive is presented in the Table 4. What she searches for is presented in the next section.
- She is already employed and wants to change job: that is described with more details in the following.

		Arriving situation	Inactives	Unemployed					
Starting situation	**Starting SCP**	**Arriving SCP**		farmers	craftmen et al	executives	interm. profes.	employees	workers
Inactives				0.00005557	0.00055947	0.00031037	0.00172877	0.00644310	0.00604629
Unemployed	farmers		0.05462738						
	craftmen et al		0.06335331						
	executives		0.11808481						
	interm. profes.		0.06202433						
	employees		0.07066007						
	workers		0.06165634						
Employed	farmers		0.00650018						
	craftmen et al		0.01423226						
	executives		0.01729000						
	interm. profes.		0.01192824						
	employees		0.00930251						
	workers		0.01129013						

Table 4. Annual probability of the transitions: "Unemployed → inactive" and "Employed → inactive" and "Inactive → unemployed" knowing the profession of an individual

The next sections describe with more details what an individual searches for when she searches. One has to remind the probability to search for a profession sums to 1 in case of an unemployed individual but it is not the case for an already employed individual. Indeed, the probability to be willing to change job is quite low.

Looking for a job when unemployed

The unemployed people for the model are those who search for a job. Then, in the labour force survey, that does not correspond to the declared unemployed people who sometimes do not search for a job. The probability to begin searching when you did not search previously (not because you're employed) corresponds in the model to the transition from inactive to unemployed. As already said, it is the complementary value for each age range of the value to make the transition from inactive to inactive.

The probability to look for a job for the individual who hasn't got one is quite stable until 54 years of age and dramatically decreases for older individuals. We also analyse how different parameters describing the household (the number of unemployed of the household, the number of children, the type of the household), influence the probability to look for a job, and we did not find any clear dependence.

Since an individual is unemployed, it is necessary to define which SCP she is going to search for. It varies a lot with the current SCP of the individual. As shown in Table 5, even if there is a tendency to look preferentially for her own SCP, an unemployed individual can prefer changing SCP. That is particularly the case of farmers and craftsmen. Then, we parameterise the process from the computation of the probability distribution to choose a SCP knowing the current SCP.

Table 5. Probability for unemployed people to search for a job with various SCPs knowing the current SCP of the individual

SCP / Looks for	Farmers	craftsmen et al	executives	interm. prof.	employees	Workers
farmers	0,000	0,000	0,000	0,177	0,376	0,447
craftsmen et al	0,000	0,079	0,012	0,088	0,443	0,377
executives	0,000	0,037	0,499	0,256	0,171	0,037

interm. prof.	0,000	0,009	0,053	0,591	0,273	0,074
employees	0,003	0,007	0,006	0,063	0,808	0,113
workers	0,006	0,010	0,003	0,056	0,251	0,674

Looking for a job when already employed

We consider the employed people of the survey who answered that they are looking for another job. We have the age of these people, as well as the type of their current job. The analysis shows that the age is a very significant variable for determining if an employed individual looks for another job (see Figure 26). Young people are more susceptible to look for another job and this tendency decreases with age.

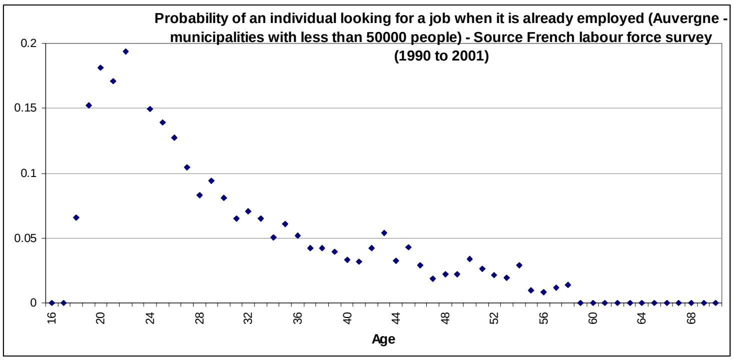

Figure 26 - Probability for an already employed individual to look for another job according to the age.

The SPC is also a significant variable to predict the probability to look for a job (see Figure 27). Some SPC, such as employed farmers or craftsmen et al are not very susceptible to look for another job. On the contrary, others, such as workers, and especially employees, have quite a high probability to look for another activity.

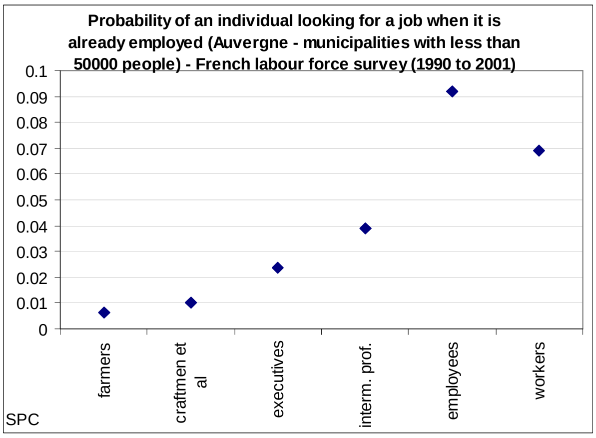

Figure 27 - Probability that an already employed individual looks for another job according to socio-professional category.

Table 6 shows the whole parameter values for the decision searching for a given profession when the individual is already employed.

Age	Looks for/ Is a	farmers	craftmen et al	executives	interm. prof.	employees	workers
15	farmers	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
	craftmen et al	0.0000	0.0000	0.0000	0.0000	0.0011	0.0014
	executives	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000
	interm. prof.	0.0000	0.0000	0.0000	0.0000	0.0143	0.0040
	employees	0.0000	0.0000	0.0000	0.0000	0.1319	0.0168
	workers	0.0000	0.0000	0.0000	0.0000	0.0162	0.0498
20	farmers	0.0054	0.0000	0.0060	0.0009	0.0000	0.0004
	craftmen et al	0.0000	0.0723	0.0000	0.0000	0.0017	0.0031
	executives	0.0000	0.0000	0.1097	0.0092	0.0015	0.0000
	interm. prof.	0.0000	0.0412	0.0445	0.0655	0.0217	0.0091
	employees	0.0114	0.0580	0.0153	0.0243	0.2002	0.0379
	workers	0.0183	0.0165	0.0055	0.0079	0.0246	0.1128
25	farmers	0.0016	0.0000	0.0025	0.0011	0.0000	0.0003
	craftmen et al	0.0000	0.0056	0.0000	0.0000	0.0009	0.0021
	executives	0.0000	0.0000	0.0458	0.0115	0.0008	0.0000
	interm. prof.	0.0000	0.0032	0.0185	0.0819	0.0112	0.0062
	employees	0.0033	0.0045	0.0064	0.0304	0.1029	0.0257
	workers	0.0053	0.0013	0.0023	0.0099	0.0126	0.0766
30	farmers	0.0018	0.0000	0.0012	0.0005	0.0000	0.0002
	craftmen et al	0.0000	0.0041	0.0000	0.0000	0.0007	0.0014
	executives	0.0000	0.0000	0.0215	0.0051	0.0006	0.0000
	interm. prof.	0.0000	0.0023	0.0087	0.0362	0.0083	0.0041
	employees	0.0037	0.0033	0.0030	0.0134	0.0762	0.0171
	workers	0.0060	0.0009	0.0011	0.0044	0.0093	0.0510
35	farmers	0.0021	0.0000	0.0012	0.0003	0.0000	0.0002
	craftmen et al	0.0000	0.0015	0.0000	0.0000	0.0005	0.0013
	executives	0.0000	0.0000	0.0215	0.0027	0.0004	0.0000
	interm. prof.	0.0000	0.0008	0.0087	0.0188	0.0059	0.0038
	employees	0.0043	0.0012	0.0030	0.0070	0.0544	0.0160
	workers	0.0070	0.0003	0.0011	0.0023	0.0067	0.0476
40	farmers	0.0011	0.0000	0.0007	0.0002	0.0000	0.0001
	craftmen et al	0.0000	0.0045	0.0000	0.0000	0.0005	0.0009
	executives	0.0000	0.0000	0.0124	0.0017	0.0004	0.0000
	interm. prof.	0.0000	0.0026	0.0050	0.0123	0.0067	0.0025
	employees	0.0023	0.0036	0.0017	0.0046	0.0613	0.0106
	workers	0.0037	0.0010	0.0006	0.0015	0.0075	0.0314
45	farmers	0.0000	0.0000	0.0005	0.0001	0.0000	0.0001
	craftmen et al	0.0000	0.0036	0.0000	0.0000	0.0004	0.0007
	executives	0.0000	0.0000	0.0089	0.0011	0.0003	0.0000
	interm. prof.	0.0000	0.0020	0.0036	0.0076	0.0050	0.0019
	employees	0.0000	0.0029	0.0012	0.0028	0.0463	0.0080
	workers	0.0000	0.0008	0.0004	0.0009	0.0057	0.0237
50	farmers	0.0005	0.0000	0.0004	0.0000	0.0000	0.0001
	craftmen et al	0.0000	0.0022	0.0000	0.0000	0.0005	0.0007
	executives	0.0000	0.0000	0.0069	0.0003	0.0004	0.0000
	interm. prof.	0.0000	0.0013	0.0028	0.0023	0.0060	0.0019
	employees	0.0011	0.0018	0.0010	0.0008	0.0553	0.0079
	workers	0.0017	0.0005	0.0003	0.0003	0.0068	0.0236
55	farmers	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	craftmen et al	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002
	executives	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000
	interm. prof.	0.0000	0.0000	0.0000	0.0000	0.0030	0.0005
	employees	0.0000	0.0000	0.0000	0.0000	0.0274	0.0021
	workers	0.0000	0.0000	0.0000	0.0000	0.0034	0.0062

Table 6. Probabilities for employed people with a given SPC and a given five-year old age to look for a job within a given SCP.

Individual searches for a job

Since the individual knows which profession she wants to search for, she has to find a place where looking for a job. If the set of municipalities is small, the individual is looking for an available job in her municipality and in the municipality exogenously fixed as neighbor of her municipality of residence. If the set of municipalities is large as for Cantal, the individual should picked out a distance where searching in the accepted distance to cross over to work probability distribution. The maximum number of times an individual search for a job during one year has been fixed to 10.

The "accepted distance to cross over to work" law

This distance of search is picked out from a probability law giving the probability to accept to cross over a distance to get a job. This probability law is extracted from the mobility data of 1999 Census regarding the commuting network and the number of occupied jobs – both for each municipality. The number of occupied jobs is used as a relevant proxy for the job offer of a municipality. An exhaustive description of the work allowing to build this probability law is given in (Felemou 2011). A short cut can be as follows. For every municipality of the Auvergne region, we have:

- Data on commuting (*pc*)
- Data on job occupations assumed equivalent to job offers (*O*)

Figure 28 on the left shows an example of commuting data probability distribution (DDC) and of job offer probability distribution (DOE) for one municipality.

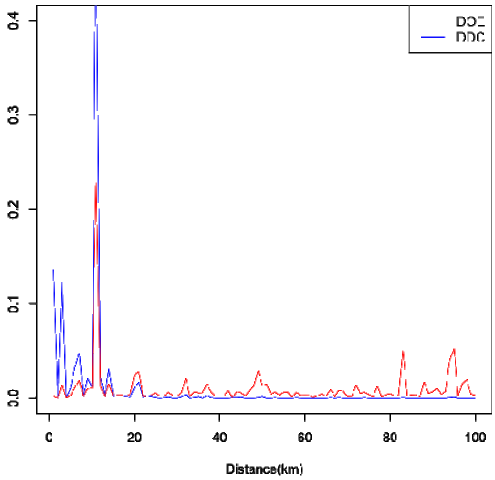

Figure 28 - Example for one municipality of the density distribution of job offers (DOE) and the one of commuters (DDC)

The probability to commute at a given distance *i* is assumed to be the product of a probability to accept crossing over *i* by the offer amount at *i* with a renormalisation coefficient *k*.

$$pc(i) = k\ pa(i) * Oi$$

Then it is possible to extract the probability to accept a given commuting distance (*pa*) to get a job which will be used as a decision base in the model. This procedure, coupled to an appropriate job offer, will allow maintaining the statistical properties of the *pc* distribution over the simulation time.

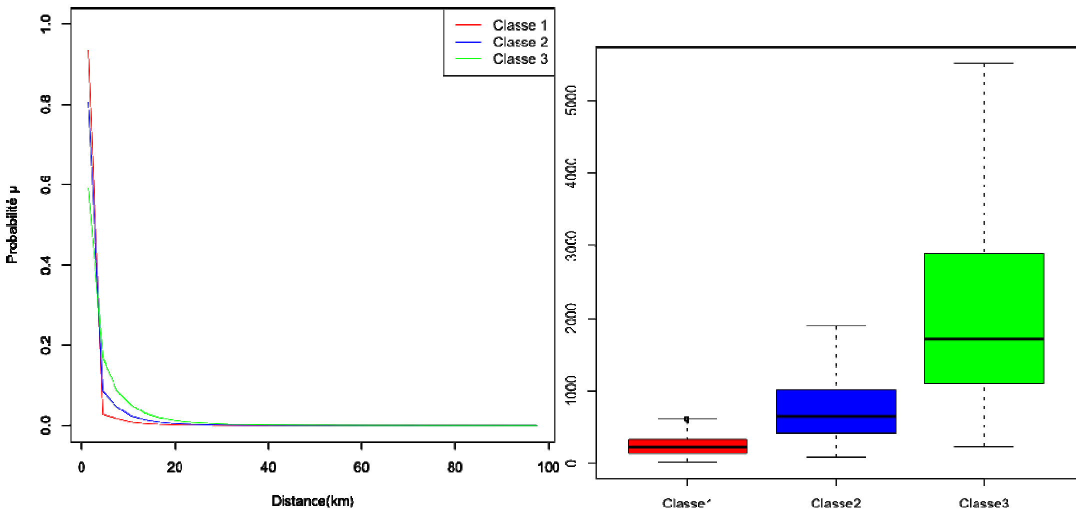

Figure 29 - Probability laws that an individual accept to a certain commuting distance knowing that a job is available for it.(on the left) - Different population sizes for the municipalities of each sub-group (on the right)

A classification over the accepted distance distributions shows they can be classified in three different groups, apparently depending on the size of the municipality of residence. Thus the parameter takes at the end the form of three probability distributions shown on the left of Figure 29 for three different classes of municipality described regarding their sizes on the right of Figure 29. The laws have been already presented in Figure 19. Globally, we notice that the larger is the municipality, the lower is the probability to work in the place of residence and the longer is the commuting distance.

Going to work outside the bunch

For a large set of municipalities, the job offer of the outside is infinite. For a smaller set, that is possible to define it exactly and to include the outside municipalities close to the border. Indeed, for a small set, the law defining the probability to commute outside is inaccurate. Then, in a small set of municipalities, the individual chooses at random a place of work where a job is available among the possible ones in the network of her residence place. The outside can be one of the neighbouring municipalities of her place of residence.

For a large set of municipalities, when the individual is sure commuting – meaning she has picked out a distance of research higher than 0, she has to check if she has a chance to commute outside considering her place of residence. Indeed, an individual living close to the border of the bunch has a higher probability to commute outside the bunch. Then, the individual chooses at random to work outside depending on the probability associated to her municipality of residence. Each municipality has such a probability which is a function of its distance to the border of the bunch. This function is extracted from the mobility data from 1999 (Source: INSEE). Figure 30 shows this function for the Cantal department and the whole Auvergne region from which Cantal is a part. Both laws are quite close and it appears relevant to use as a parameter the law extracted for the whole region since it is probably less noisy.

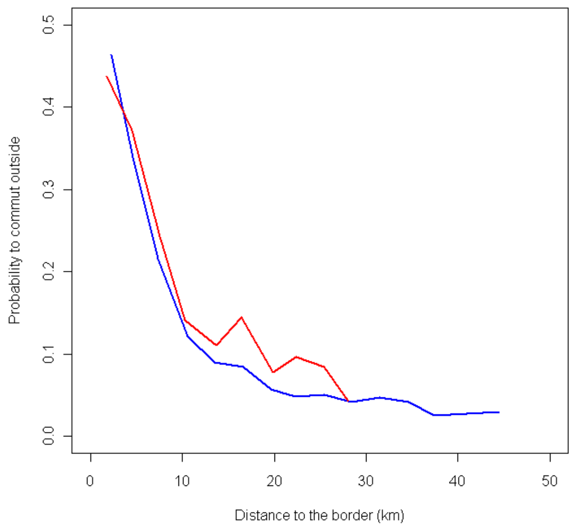

Figure 30 - Probability to commute outside the bunch (ordinate) depending on the distance of the municipality of residence to the frontier of the bunch (abscissa in Euclidian kilometers) - Red: Cantal; Blue: Auvergne

3.2.2 Calibration

The last step to ensure the quality of the simulation, after controlling the initial state, choosing parameterisation laws depending on controlled variables, is to calibrate the model in order to define the values of the parameters which cannot be set from the literature or derived from the data and which are important for the dynamics. Those have been already presented in 3.2.1 and summed-up in the following list:

- probability to search for a partner if single;
- maximum number of trials to meet someone matching the conditions (single, difference of age, …);
- split couple probability;

- tolerance for being satisfied of the lodging (in the small set of municipalities case) ; impact of the age in the decision to move and in the acceptation of a given size for the new lodging (in the large set of municipalities case).
- number of children;

Following (Debrand and Taffin 2005, 2006) based on the analysis of data coming from various French surveys, creating a couple and splitting up a couple are the factors explaining most of the residential mobility. Then it is particularly important that these methods should be well calibrated.

We are going to choose their value by looking for the values minimising the distance between the simulation results for a list of indicators and the corresponding data given by the French Censuses in 1999 and 2006. These indicators describe the whole municipality set because optimising on all the municipalities would lead to an untractable complexity. They are:

- number of out-migrants moving outside the set of municipalities (the migratory balance is a parameter): expected sufficient to reproduce correctly the local evolution;
- number of out-migrants going in the set of municipalities
- the job occupation of outside (number of individuals living inside and working outside the set of municipalities): a good value implies the actives residence locations are correctly distributed (since the job offer of outside is infinite).

Moreover, we have the indicators set at the initialisation:

- the number of individuals in every age range living in a municipality: it is an absolute requirement to initialise these values accurately because a lot of processes ruling the considered evolutions depend on ages;
- the number of household in every size range: that is to get a realistic distribution of households since a large part of the demographic events considers the current status of a household ;
- the probability distribution of the household type (single, single-parent, couple without children, couple with children, other households type) at the municipality level for the same reason as the one of the previous dot;
- the probability distribution of the professions at the municipality level: the strands describing the individual occupation of the individuals has an impact of the probability to move to another municipality and/or another job or activity status changing the relationship strength between the municipalities;
- the probability distribution of the place of work at the municipality level: for the same reason as the one of the previous dot.

We developed a new algorithm optimising Approximate Bayesian Computing approaches to calibrate complex models (Lenormand et al. 2011b). This algorithm controls the number of simulations and the stopping criterion with more efficiency than the existing versions.

3.3 Comparing the simulation results with the reference data

3.3.1 Condat case study

The following figures show on the past period the comparison for various indicators between the reference data (those measured by INSEE, the French Statistical Office) and the simulated data. We calibrated the model with a first simplified version of the calibration algorithm. It has been improved since when.

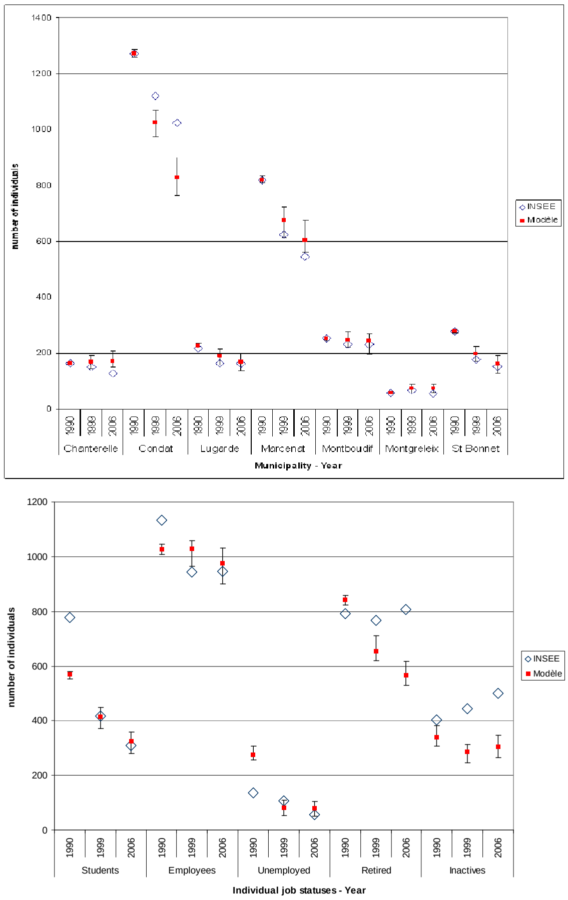

Figure 31. Values of reference (from INSEE in red) against simulated value averaging over 30 replicates (in black) at three different dates (1990, 1999 and 2006) for the number of inhabitants of the seven villages (on the left) and the activity statuses (on the right) – The error bars represents the minimum and the maximum value obtained over 30 replicates

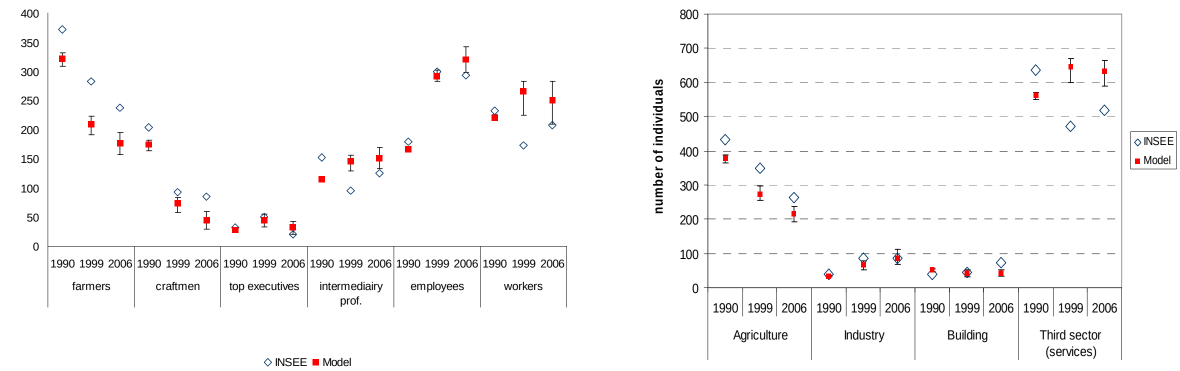

Figure 32. Values of reference (from INSEE in red) against simulated value averaging over 30 replicates (in black) at three different dates (1990, 1999 and 2006) for the distribution over the SPC (on the left) and the distribution over the activity sector (on the right) – The error bars represents the minimum and the maximum value obtained over 30 replicates

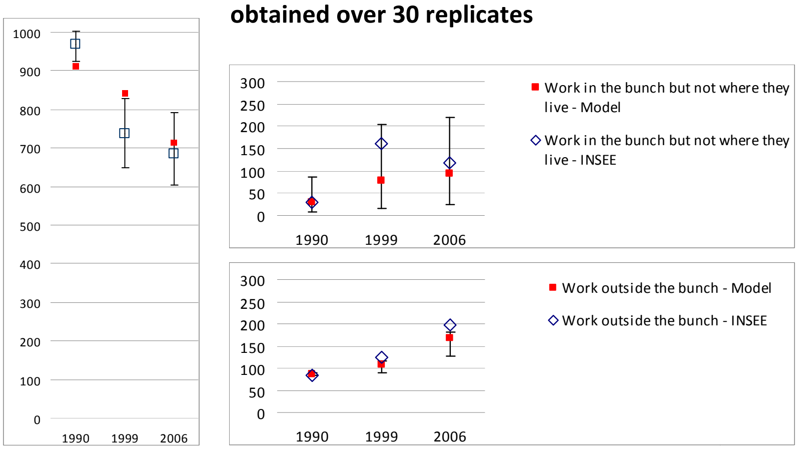

Figure 33. Values of reference (from INSEE in red) against simulated value averaging over 30 replicates (in black) at three different dates (1990, 1999 and 2006) for number of individuals working where they live (on the left); number of individuals working in the bunch in a municipality different from their residence one (on the right at the top); number of individuals working outside the bunch (on the right at the bottom) – The error bars represents the minimum and the maximum value obtained over 30 replicates

The results obtained with the first version of the model designed for a small set of municipalities are satisfactory but we notice that:

- The initialization has to be improved in order to be closer to the reference values;
- The relation between the place of residence and the place of work has to be improved; this random choice within a fixed neighborhood cannot be relevant for a large set of municipalities.

Both these remarks have been taken into account in the second version of the model dedicated to the larger set of municipalities of Cantal département.

3.3.1 Cantal case study

We did not manage to finalise our work on the Cantal department during the time frame of the project. In particular, we did not have time to calibrate the model. However, we present some results here for a selected set of parameter value, after several explorations of the model made manually. We limit the simulation time to the past period in order to compare the reference data from INSEE with the simulated data. These results illustrate the ability of the model to reproduce the local heterogeneity. We shall investigate carefully the predictive ability of the model in the months to come, when it is calibrated.

Figure 34, Figure 35 and Figure 36 show the population of the municipalities of the Cantal respectively in 1990, 1999 and 2008, with the reference map from INSEE (on the left) and the simulation results on the right. The scale is the same for the simulation and reference data. It corresponds to the quintiles defined on the data from INSEE. Figure 37 and Figure 38 show the natural balances at the municipality level, respectively from 1990 to 1999 and from 2000 to 2008, similarly with reference data on the right and simulation results on the left. All these figures show a relatively good fitting of the simulated data to the reference, despite the lack of calibration.

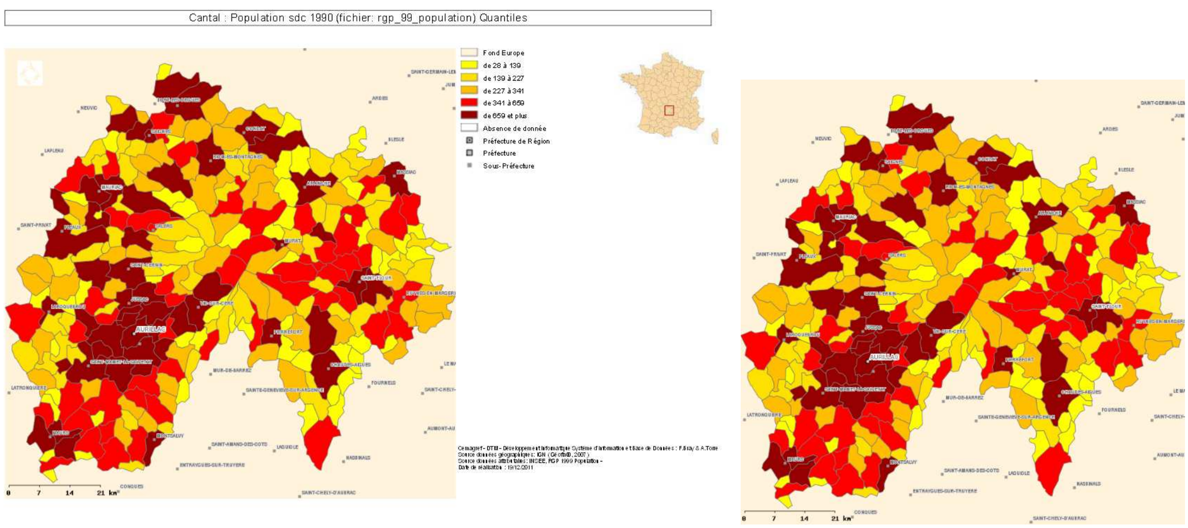

Figure 34. Population of the municipalities of the Cantal in 1990 - on the left: reference map from INSEE, on the right: simulated data; the scale are the same, it corresponds to the quintiles defined on the INSEE data.

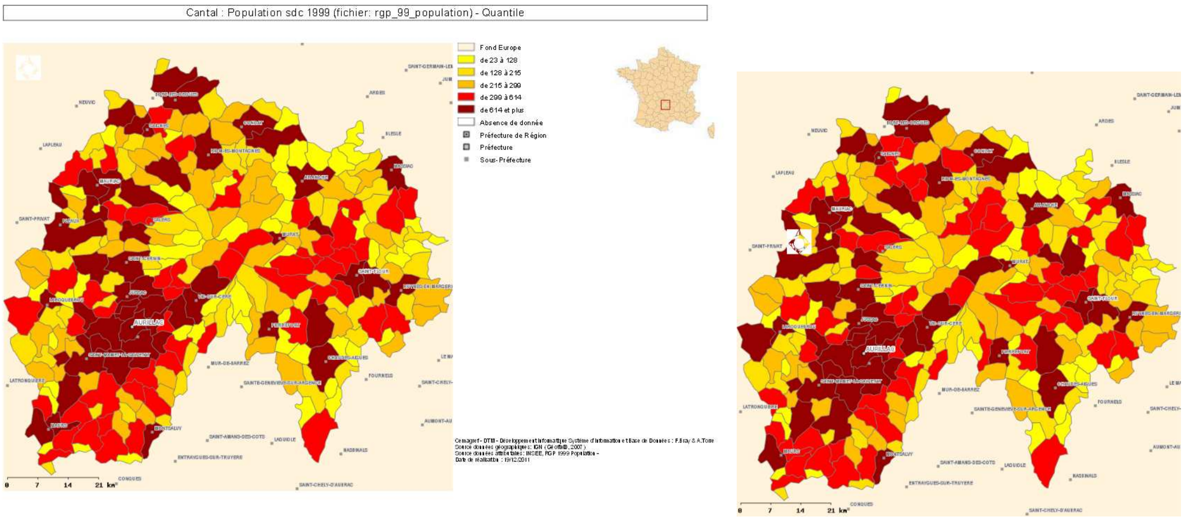

Figure 35. Population of the municipalities of the Cantal in 1999 - on the left: reference map from INSEE, on the right: simulated data; the scale are the same, it corresponds to the quintiles defined on the INSEE data.

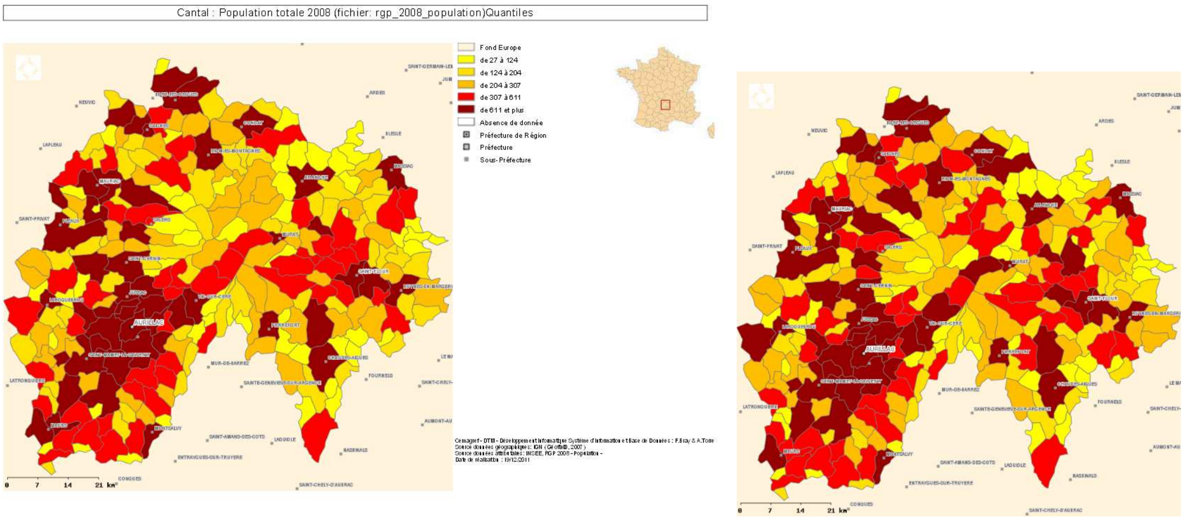

Figure 36. Population of the municipalities of the Cantal in 2008 - on the left: reference map from INSEE, on the right: simulated data; the scale are the same, it corresponds to the quintiles defined on the INSEE data.

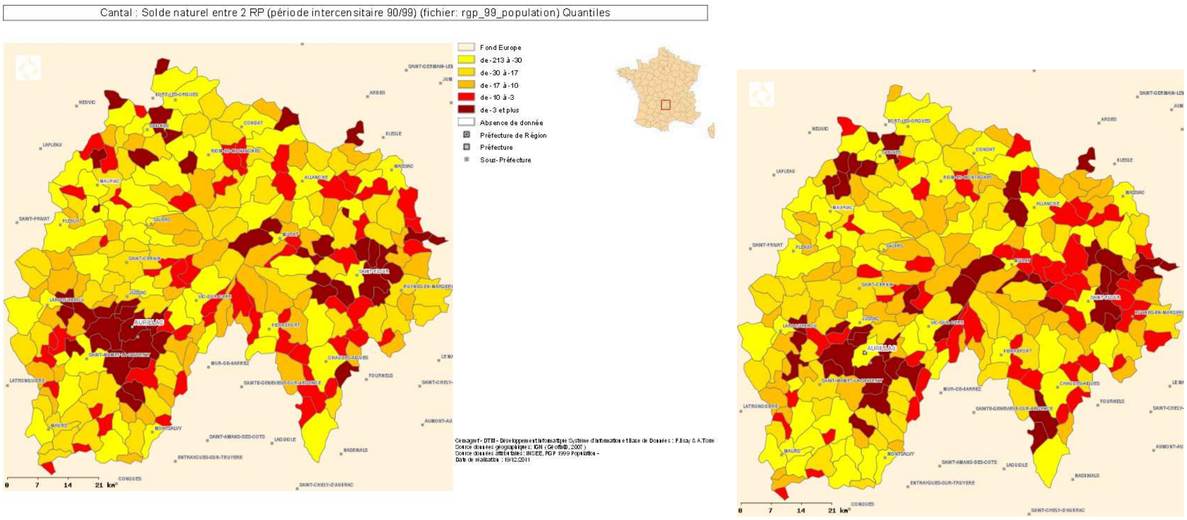

Figure 37. Natural balance from 1990 to 1999 of the municipalities of Cantal - on the left: reference map from INSEE, on the right: simulated data; the scale are the same, it corresponds to the quintiles of the INSEE data.

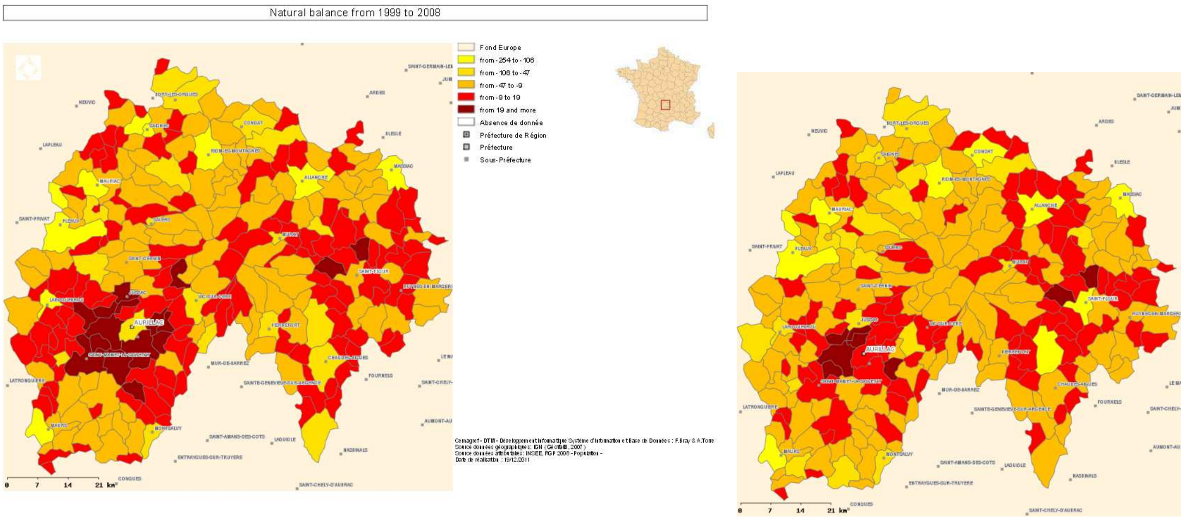

Figure 38. Natural balance from 2000 to 2008 of the municipalities of Cantal - on the left: reference map from INSEE, on the right: simulated data; the scale are the same, it corresponds to the quintiles of the INSEE data.

Figure 39 shows the probability distributions of distance of commuting of the reference data from INSEE in 1999 and simulated data measured in 2008. We notice that the distributions are similar even despite the lack of calibration. This is rather surprising because of lot of processes are involved in the design of this distribution, and because the distributions used for the choice of job or residence places have been drawn from regional data (i.e. at the Auvergne level). We can expect a better fit of these data with a calibrated model.

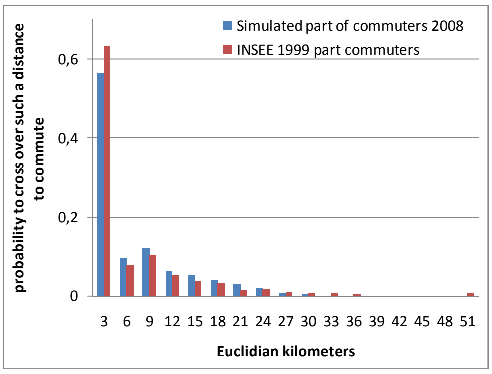

Figure 39. Cantal residents commuting distance probability distribution. Simulated distribution and reference distribution from INSEE

A lot of indicators can be extracted from the model. Some examples are presented on Figure 40. They relate to the demography but it is also possible to obtain indicators about statuses regarding the labour market, job occupations, residence occupations as some are presented for the Condat case study.

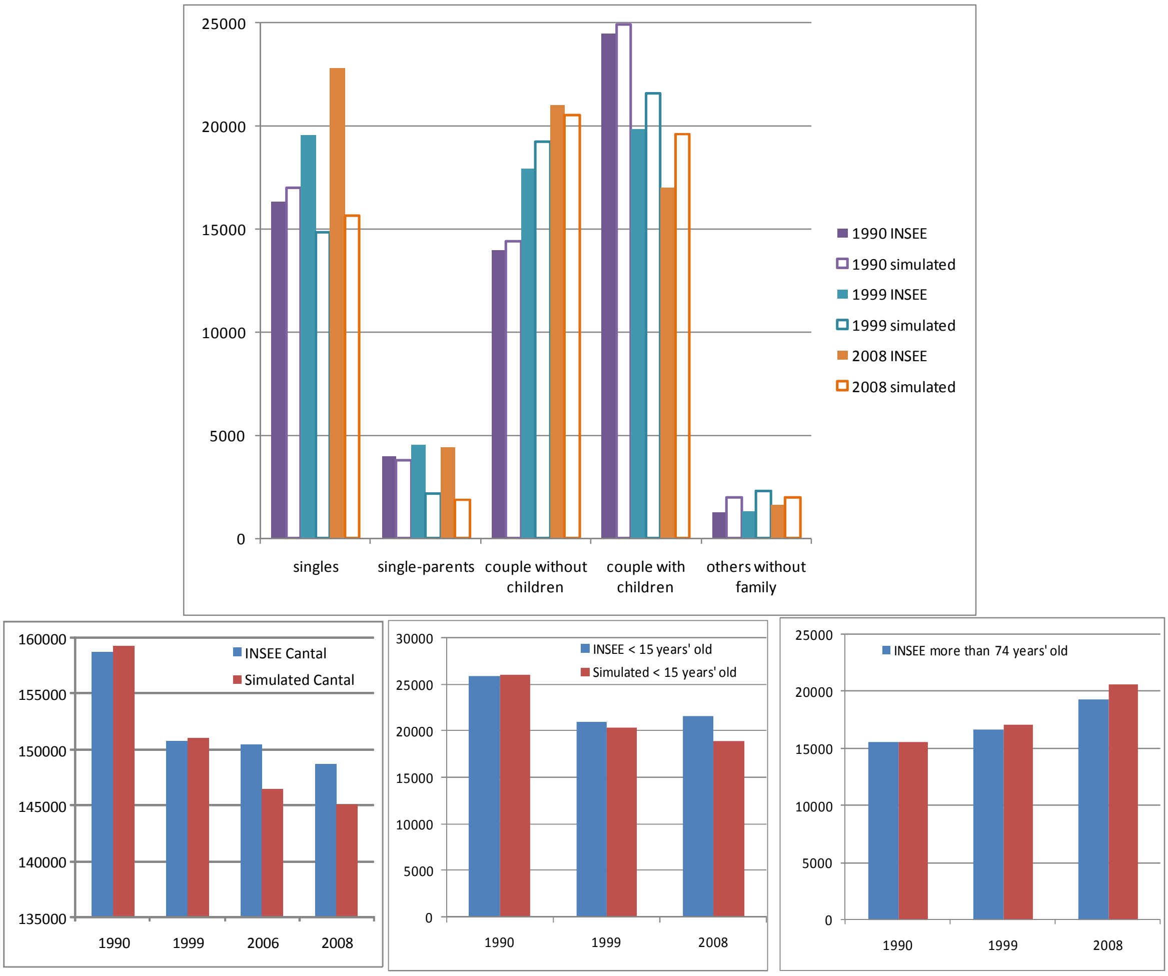

Figure 40. From top to the bottom right: comparison between simulated and reference values of the number of each type of household; the number of inhabitants in Cantal, the number of individuals being less than 15, the number of individuals being more than 74

4 CONCLUSION - DISCUSSION

We proposed a global framework proposed to model the dynamics of the rural municipality networks. We implemented the model and it is currently under study. We also developed tools to studying and calibrating the model (Baqueiro Espinosa 2011; Lenormand et al. 2011b) (including the execution of sets of simulations on a computer grid). However, we could not finish the calibration and study of the calibrated model. We intend also to evaluate the predictive power of the model on the past data. In particular, the comparison between the simulated migratory rates of the municipality and the reference ones from INSEE should be very interesting.

We also developed a user interfaces for defining the parameter values and visualising the evolution of chosen indicators (see annex 5.4 for a presentation). The user can choose these indicators through an XML interface, only giving the name of the indicator he wants to observe. It is possible to ask for a large number of indicators at the same time.

The teams of the project implemented other case studies (Baqueiro Espinosa et al. 2001). They are not based on the last version of the model for a large number of municipalities currently tested on the Cantal département of France. However, our first results are promising.

Moroever, we introduce a lot of innovations in the modelling approach. The rare and recent microsimulation models interesting in rural areas (Ballas et al. 2005) (Leeuwen 2010) are mainly static and dedicated to assess the diversity of geographical impact without considering individual ageing process. In a very recent review of spatial microsimulations models, (Birkin and Clarke 2011) underlines the interest of adding dynamic microsimulation with demographic transitions, coupling agent-based and microsimulation approaches and using stochastic behavioural models. We matched all these challenges in our work.

5 ANNEXES - Available data sources

For the French case study, we benefit from a lot of easily accessible data. However, they are not so easy to use because the surveys in the framework of which they have been gathered have their own purposes. Thus, the data has been designed through an implicit model which aims at answering other questions than ours. This is especially perceptible in the definition of the data which can be more or less different from the definition of our object. Therefore, the data should be used with caution, and the assumptions made to use it have to be identified. Finally, we use more particularly two main sources chosen for their high level of representativeness of the French population: the Censuses and the labour force surveys. We completed those sources using the literature analysing other surveys.

5.1 THE CENSUS

The last French Censuses were done in 1982, 1990, 1999 and 2006. The Census, through its exhaustive analyses, completed by numerous analyses done on a randomly chosen quarter of the local population, provides a very complete description of the French population, generally given at the municipality level. However, the definition of the variables and the level of availability of electronic data have changed a lot since 1982. The level of details in the data tends to increase for more recent censuses. Then, as a compromise between a past period long enough to calibrate the model and a sufficient level of detail to represent our object, we decide to start the simulation in 1990. It allows us to use the data from 1999 and 2006 as calibration values even if we cannot use all their details.

5.2 THE LABOUR FORCE SURVEY

This survey[9] follows the situation of the French population with regards to the labour market. For example, this survey gives the number of unemployed people in France every three months. It has been launched in 1950 and redesigned many times. From 1982, it became annual. The last redesign in 2003 makes the survey continuous, providing quarterly results. It covers private households in metropolitan France. Taking into account the redesign of the survey, we have to distinguish the data of a first period, from 1990 to 2002 when a same individual is interviewed 3 times over 3 years, from the data of a second period, from 2003 since when a same individual is interviewed six times over 18 months (Goux 2003) (Givord 2003). Moreover, the data to select from these two periods varies a bit due to the structural and practical changes in the survey. The survey includes the individuals older than 14. The sample is representative of the French population each year. It is made with geographically delimited areas making the survey representative at the regional level and for the municipalities of less than 50,000 inhabitants (like most of the rural municipalities in Auvergne). The sample size of the survey over the first period varies from 168883 to 187326 individuals. Each interviewee is asked a very complete series of questions relating to its working status. In particular, we can follow her situation year by year, her wish to change jobs and the type of job she is looking for.

5.3 THE LITTERATURE

The consulted literature comes mainly from the French National Institute for Statistics (INSEE) and the French National Institute for the Demography Study (INED). Their studies are mainly data-driven and their results come from the analysis of the data sources we also partly use.

[9] The data of the French Labour Survey from 1990 to 2007 was kindly made available by the Centre Maurice Halbwachs.

5.4 THE USER INTERFACES

Some user interfaces have been developed. They allow parameterising the model and designing a visualisation of the dynamics by choosing the indicators the user is interested to follow. Two XML files are involved in this designing (ficEnt.xml ruling much more the parameters of the application and scenarios.xml dedicated to the scenario definition). An extract of a ficEnt.xml file is presented below.

```xml
<Parameters>
  <seedIndex>0</seedIndex>
  <startStep>1990</startStep>
  <nbStep>18</nbStep>
…
  <ageMinHavingChild>18</ageMinHavingChild>
  <ageMaxHavingChild>49</ageMaxHavingChild>
  <nbChild>1.58</nbChild>
  <avDifAgeCouple>4.7</avDifAgeCouple>
  <stDifAgeCouple>1.4</stDifAgeCouple>
  <probabilityToMakeCouple>1.0</probabilityToMakeCouple>
…
  <regionObservers>
    <fr.cemagref.observation.observers.CSVObserver>
      <sysout>false</sysout>
      <outputFile>dataOut/cantalOut.csv</outputFile>
      <separator>;</separator>
      <observables>
        <string>getPopulationSize</string>
        <string>getServicesJobOffer</string>
      </observables>
    </fr.cemagref.observation.observers.CSVObserver>
    <fr.cemagref.prima.regionalmodel.gui.ChartsPanel>
      <observables>
        <string>getPopulationSize</string>
        <string>getPopulationSize15114</string>
        <string>getPopulationSize15132</string>
        <string>getNbBirth</string>
        <string>getNbDeath</string>
        <string>getNbChildrenLower15</string>
        <string>getNbOldHigher74</string>
        <string>getNbCouplesWithChildren</string>
        <string>getNbCouplesWithoutChildren</string>
        <string>getNbOutMigrants</string>
        <string>getNbImmigrants</string>
        <string>getOccupiedJobsByOutside</string>
        <string>getOccupiedJobsByOutsideFarmer</string>
        <string>getOccupiedJobsByOutsideCraftmen</string-->
      </observables>
    </fr.cemagref.prima.regionalmodel.gui.ChartsPanel>
  </regionObservers>
…
</Parameters>
```

Two parts can be distinguished in this xml file: one in black dedicated to parameterisation; one in red allowing the user to design the result visualisation interface for one run of the model. The parameterisation can be also done via a graphic interface presented in Figure 41.

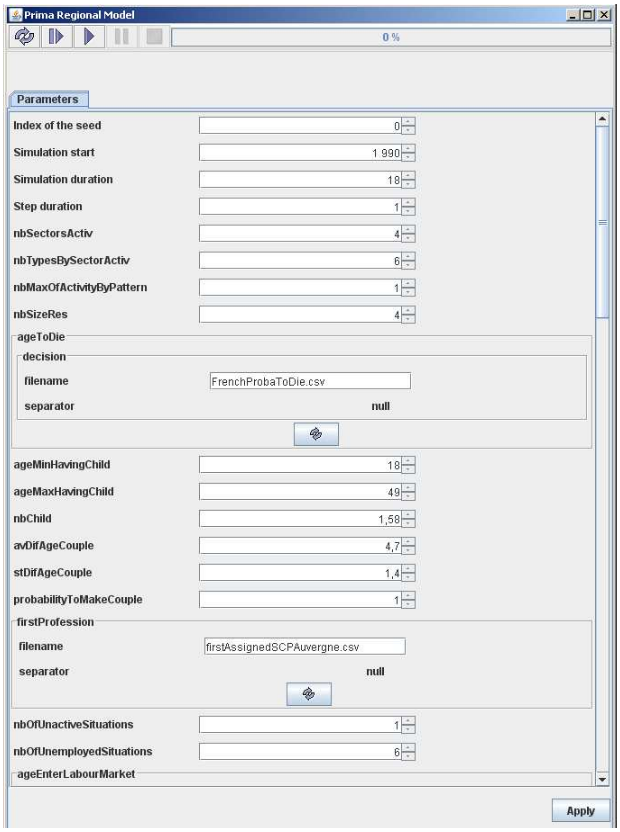

Figure 41. Graphic user interface to parameterize the model

The red part gives an example of the indicators the user can ask for. Indeed, the visualised graphs are not fixed in advance. They can be chosen by the user through an XML interface, only giving the name of the indicator he wants to observe. Almost every indicator is accessible and it is possible to ask for a large number of indicators at the same time. Figure 42 gives an example of what can be seen by the user if he asks for six indicators related to various population sizes.

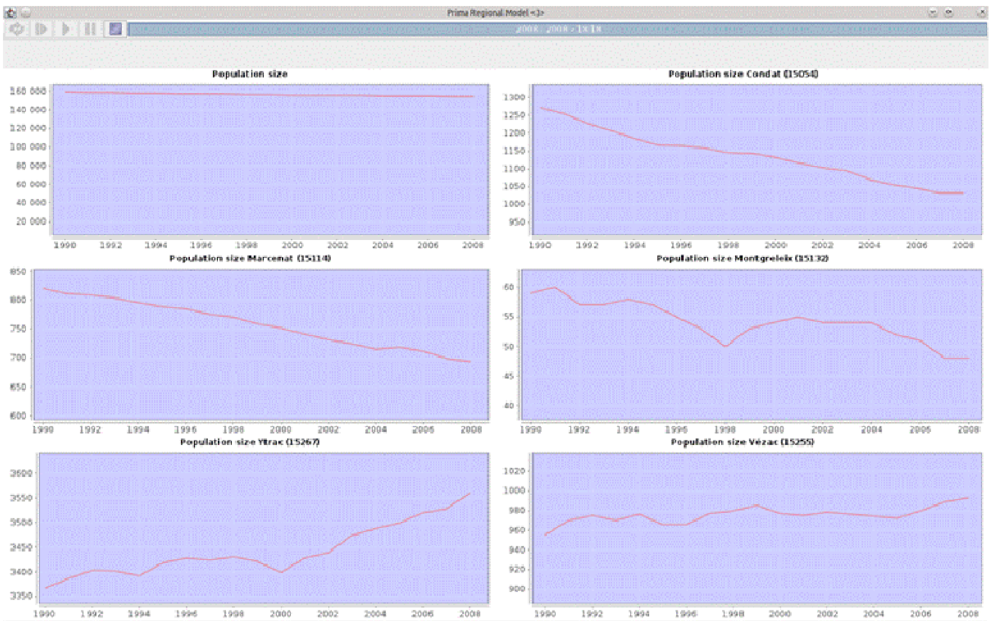

Figure 42. Visualisation of the dynamics on six chosen indicators (the global population size and the number of inhabitants of 5 chosen municipalities of the Cantal).

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