Parameterisation of individual working dynamics

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Chapter 8
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How do European rural areas evolve? While for decades the countryside in many regions of Europe was synonymous with inevitable decline, nowadays, some areas experience a "rebirth, even in areas where until recently development was not considered possible" (Champetier 2000). A recent EPSON (European Observation Network for Territorial Development and Cohesion) project report (Johansson and Rauhut 2007), concludes that "since the 1970s a global process of counter-urbanization has become increasingly manifest". However, this general rebirth of the countryside hides deep heterogeneities. That can be observed in the Cantal "département" in France where the population remains stable after having been depopulated with some subgroups of its municipalities have an increasing population while others have a decreasing one. Our modelling effort aims at better understanding these heterogeneities.

Micro modelling (Gilbert and Troitzch 2005) is a very relevant paradigm to study the evolution of areas composed from various objects appearing as very heterogeneous. It includes three different approaches: cellular automata change (Ballas 2007, p. 17, 2005, p. 3, 2006 p. 4; Brown et al. 2006, p. 18; Coulombel 2010, p. 66; Moeckel 2003, p. 54; Rindfuss 2004, p. 20; Verburg 2004, p. 11, 2006, p. 8, 2002, p. 12), microsimulation (Orcutt 1957, p. 287; INSEE 1999, p. 2; Holme 2004, p. 53; Turci 2010, p. 70; Morand 2010, p. 71) and agent-based models (Deffuant 2008, p. 283, 2005, p. 9, 2002, p. 7, 2001, p. 36; Bousquet 2004, p. 202; Brown and Robinson 2006, p. 63; Fontaine and Rounsevell 2009, p. 65;

Parker Dawn 2003, p. 9) which have been already used to study problem close to ours. However, recent reviews recommend a hybrid approach (Birkin and Clark 2011, p. 81; Birkin and Wu 2012, p. 90), particularly coupling microsimulation and agent-based modelling. Thus, trying to develop an approach which is as close to the data as we can, we decide to use microsimulation and agent approaches allowing us to address some complex individual dynamics, largely unknown and for which no data are available, such as the residential location decision (Coulombel 2010, p. 66).

The problem of such modelling approach is the link to data. If it is obvious in the basic microsimulation, that is not so easily manageable in dynamic microsimulation with a "real" evolution time after time of the individual. Indeed the dynamic microsimulation remains rare (Birkin 2012, p. 90): the most common way to introduce change of the demographic structure is to apply static ageing techniques consisting in reweighting the age class according to external information. That is to avoid considering functions of evolution of the behaviour of the individual and their parameterisation. Regarding the multiagent modelling, (Berger and Schreinemachers 2006) argue it "holds the promise of providing an enhanced collaborative framework in which planners, modellers, and stakeholders may learn and interact. The fulfilment of this promise, however, depends on the empirical parameterization of multiagent models. Although multiagent models have been widely applied in experimental and hypothetical settings, only few studies have strong linkages to empirical data and the literature on methods of empirical parameterization is still limited." An example can be read in (Fernandez 2005, p. 64) which initialise individual preference from analyses of the data coming from an ad hoc survey but don't consider a possible change in the preference of an individual.

In our model,[1] we tried to have a strong linkage to data both in the definition of the initial population and the one of the individual behaviour. This 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. 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, two sets of cruxes can be identified in the model: The individual dynamics which determine the needs for residence and jobs; the dwelling and the job offers exogenous and endogenous dynamics at the local (i.e. municipality) level.

The present paper focuses on how to make such a model close enough to the data to guarantee a good understanding of the dynamics of population/depopulation based on "real" situations, and a real utility for policy makers. As the developed model is very large, taking into account many dynamics, we are going to

[1] This work has been funded under the PRIMA (Prototypical policy impacts on multifunctional activities in rural municipalities) collaborative project, EU 7th Framework Programme (ENV 2007-1), contract no. 212345.

focus on the design and the parameterisation of the individual dynamics regarding the labour market.

After a summary of the whole model, presented in details in (Huet et al. 2011, p. 189), we present how we have conceived and parameterised the submodel of the individual activity dynamics. The final section tries to explain what we have learnt from such an exercise. In particular, we want to stress out the necessity not to only consider the objectives of the model during the design phases, but also since the very beginning censing the existing data sources and studying the implicit model beside the databases.

8.1 Model Description

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, p. 282).

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). Indeed, in the literature, the most cited explanation for the evolution of the rural municipalities is what is called the residential economy (Davezies 2009, p. 73; Blanc and Schmitt 2007, p. 32). It argues that rural areas dynamics is linked to the money transfers between production areas and residence locations. These money transfers are for 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, p. 24). The residential economics 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, p. 26). To summarise, existing literature stresses the importance of the different types of mobility between municipalities, commuting, residential mobility (short range distance), migration (long range distance) (Coulombel 2010, p. 66) and 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.

8.1.1 Main 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.

8.1.1.1 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 LAU or intermediate sets of municipalities such as "communauté de communes" in France. In the present paper, the set corresponds to the Cantal "département" in France composed of 260 municipalities.

Parameter a threshold distance called "proximity" between two municipalities; beyond this distance the municipalities are considered too far from each other, to allow commuting between them without considering to move for instance (parameterised at 25 km).

8.1.1.2 Municipality

It corresponds to LAU2.[3] The municipality is the main focus of the model. It includes:

- A set of households living in the municipality. The household corresponds to the nuclear family.[4] It includes a list of individuals who have an occupation located inside or outside the municipality).
- The set of jobs existing on the municipality and 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.

There is a particular municipality, called "Outside": it represents available jobs accessible from municipalities of the considered set, but which are not in the considered set. The job offer of Outside is infinite and the occupation is defined by a probability of individuals to commute outside the set (see Sect. 8.2.9 for details).

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[2] Eurostat defines the NUTS (Nomenclature of Territorial Units for Statistics) classification as a hierarchical system for dividing up the EU territory: NUTS 1 for 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.

Table 8.1 Attributes defining the household state

Name	Type	Values
Members	List of individuals	
Couple	Boolean	True, false
Leader	Individual	
Residence	Residence	
Residence need	Boolean	True, false
Municipality of residence	Municipality	

Parameters:

- An initial population of households composed of 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 the number of rooms
- A job offer: number of jobs offered by the municipality for each type of job; the exogenously defined part of job offers is distinguished from the endogenously defined part in order to update this last part easily
- The laws ruling the proximity of municipalities: each municipality has rings of 'nearby' municipalities (practically every 3 Euclidian kilometres) with a maximum distance of 51 Euclidian km. The accessibility of each ring varies depending on the process (commuting, looking for a residence, looking for a partner) following appropriate probability distribution laws.
- Spatial coordinates

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

8.1.1.3 The Job and the Residence

A job has two attributes, a profession and an activity sector in which this profession can be practiced. It is available in a municipality and can be occupied by an individual. The profession is an attribute of the individual and can take six various values (see Sect. 8.1.1.5 for details) at the same time it defines a job. There are four activity sectors: Agriculture, Forestry and Fishing; Industry; Building; Services and Commerce. Overall, considering the six professions for four activity sectors, we obtain 24 jobs to describe the whole diversity of jobs in the region we study (i.e. the Cantal "département", called only Cantal later in this chapter).

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. Indeed several households can live in one residence 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 (Table 8.1).

Table 8.2 Attributes defining the state of an individual

	Type	Values
Activity status	Enum	Student, inactive, retired, employed, unemployed (only the two last can search a job)
Profession	Enum	Farmers; craftsmen, storekeepers, business owners; top executive managers, upper intellectual profession (senior executives); intermediary professions; employees; workers
Job	Couple of values	24 couples (profession, activity sector) (see Sect. 8.1.1.3 for details)
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

8.1.1.4 Household

For the initialisation, residences are associated randomly with households. Then, new households are created when new couples are formed or when people from outside the set of municipalities migrate into the municipality. Households are eliminated 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 has an impact on the household, a leader is assigned randomly, 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: she becomes the leader to make the household moving and finding a residence close to her new job.

8.1.1.5 Individual

The individual is instantiated 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 by immigration.

The age to die, the age the person will enter the labour market, and the age of retirement are attributed to the individual when it is created. These ages are assigned by a probability method. 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, search for and change jobs ….

The profession is an attribute of the individual indicating at the same time her skills, level of education and the occupation she can aspire to. Professions take the value of the French socio-professional categories categorised in six modalities that define at the same time a kind of occupation, an average level of education and an approximate salary (Table 8.2)

8.1.2 *Process Overview and Scheduling*

8.1.2.1 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, endogenously available jobs and services are updated in municipalities. Finally, 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 ser-
      vices to residents
    municipality.compute in-migration
  For each household:
    household.members.job searching decision (this pro-
      cess can make free some jobs from people becoming
      retired or inactive)
  For each household:
    household.members.searching for a job
    household.members events (coupling, divorce, birth,
      death)
    household.residential migration
    household.members.individual ages
```

Time is discrete with time steps corresponding to years. 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.

8.1.2.2 Dynamics of Offer for Jobs, Services and Lodging

In the municipality objects, jobs, services and dwelling offers are ruled. Changes in dwelling offers are specified in scenarios. Various sizes are considered in order to match the needs of households.

The job offer process is twofold: one part defined through scenarios which specify the increase or decrease of jobs in different sectors, and a second part concerning the proximity of service jobs, which are derived by a specific statistical model.

Indeed, numerous are the researches pointing out the importance of services for the rural areas dynamism (Aubert 2009, p. 22; Dubuc 2004, p. 26; Fernandez 2005, p. 64; Soumagne 2003, p. 30). Also the residential economics shows the im-

Table 8.3 Regression coefficient for the four classes of municipalities of the Cantal

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

portance of the presence of the population in rural municipalities (Davezies 2009, p. 73). 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 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. Starting from the classical minimum requirement approach proposed by (Ullman and Dacey 1960, p. 259; Lenormand et al. 2012a, p. 258) we propose a model which takes into account the distance between a municipality and its closest centre of services (i.e. most frequented municipality, called MFM). This new model has been grounded on detailed data related to jobs and poles of services (Lenormand et al. 2012a, p. 61). Therefore, we use the extracted statistical relation to adjust the number of jobs in proximity services in the municipalities of the model.

It is $E=\beta_0+\beta_1 \ln P+\varepsilon$ with E= minimum employment offer in the municipality to satisfy the need for services of one resident; P= the population of the municipality; β_0 and β_1= parameters

For each municipality, this function is computed every year in order to update the service sector job offer depending on the distance of the municipality to the closest pole of service (called MFM). The form of the function for different municipality sizes with various distances to the MFM indicates that:

- 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 min;
- the larger is the municipality, the higher is the number of jobs in proximity services.

The other creations and destructions of jobs are ruled by scenarios.

Parameters Distances to the Most Frequented Municipality of every municipality of the Cantal (given by the French Municipal Inventory of 1999); class of distance to the most frequented municipality (MFM) for every municipality and regression coefficients β_0 and β_1 extracted of the analysis of the French Census of 1990, 1999 and 2006 (see (Lenormand et al. 2012a, p. 61) for more explanations; Table 8.3).

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

8.1.2.3 Dynamics of Labour Status and Job Changes

A new individual can be generated in a household having the "couple" status with the birth method, or directly from the initialisation of the population, or from the immigration method. A newly born individual is initialised with a student status that she keeps until she enters the labour market with a first profession. Then, she becomes unemployed or employed with the possibility to look for a job. She may also become inactive for a while. When she gets older, she becomes a retiree. We here describe rapidly these dynamics to situate them in the global picture of them model. We describe them in more details, especially the choice of parameters and link to data, in Sect. 8.3.

8.1.3 Entering on the Labour 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.

8.1.4 Job Searching Decision

The decision for searching a job is a two-step process. First, an individual has an activity status indicating if she is 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 to search for. Five different activity statuses define the individual situation regarding the labour market in the model:

- The **student**: an individual is a student in the first part of its life, until the age she enters on the labour market. We consider the probability of a student to look for a job is 0 since we are only interested in rural municipalities. Students in age working mainly look for a job in the large cities where they study.
- The **unemployed**: an individual is unemployed when she is considered 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.
- 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.

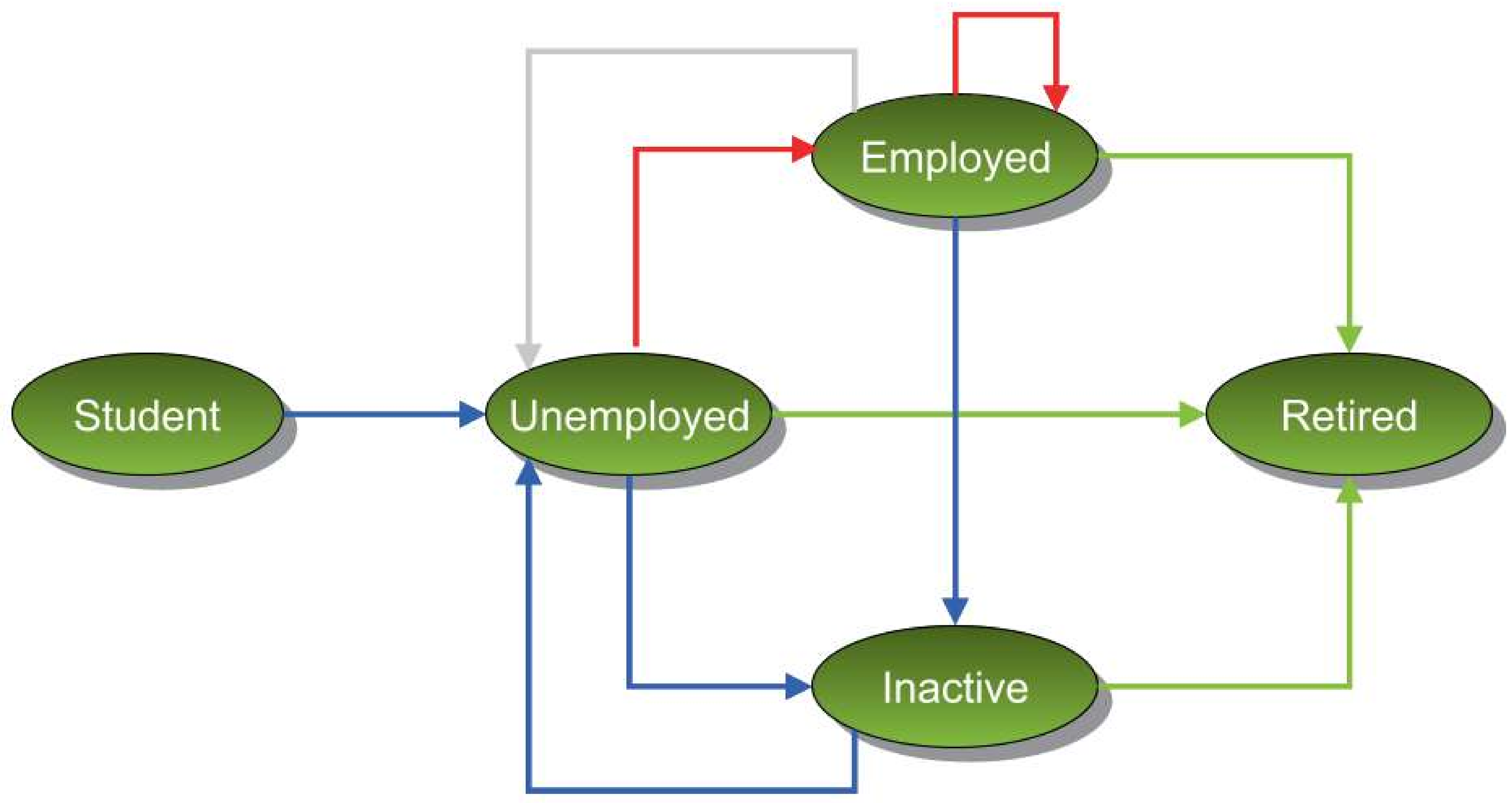


Figure 8.1 Transitions of status and their link to the data. *Red arrows*: change by finding a job; *grey arrows*: when she is fired; *green arrows*: at the age of retirement (picked out from a law extracted from data); *yellow arrows*: due to a probabilistic decision of becoming inactive extracted from the Labor Force Survey data; *purple arrows*: due to probabilistic decisions extracted from the Labor Force Survey data

- The **inactive**: she can be inactive for a long time or just stopping to work for 1 year, having a baby for example. During this period, her probability to search for a job is 0.
- The **retired**: at the age of retirement, an individual retires. Her probability to look for a job is then assumed to be 0.

We have seen the probability to search for a job (or the law ruling this probability) depends on the activity status. Figure 8.1 describes the way an individual changes activity status and thereby the probability to search.

Entering 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 (her probability to search has to be extracted from data). 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 inactive.

Most of the laws ruling the activity status changes have to be parameterised. The grey-arrows transitions are much more endogenously defined. That is the employed to unemployed transition which is due to the decreasing availability of job offer implying a sacking. It can also be, for instance a resignation of an individual leaving her municipality to follow her partner to another place of residence.

Knowing an individual searches for a job, we have to compute which profession she looks for. 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 offers for the individual.

We expect the job offer to be a sufficient constraint on the activity sector to allow the model exhibiting a statistically correct distribution of occupied jobs by activity sector.

Parameters Ruling the Job Research Decision Probability becoming inactive; probability to stop being inactive; probability laws defining what profession to search for; parameters for entering the labour market and to retire.

8.1.5 Searching for a Job

The question for the individual is now to decide where to search for a job. The challenge consists in preserving the properties of the commuting distance distribution that we assume constant. 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 but also constrained by the job offer, which has to be properly defined.

If the leader of the household has already found a job far (further than the proximity attribute) from the place of residence and the household is trying to move close the leader's place of work, then 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.

In the other cases, 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".

Then, if the distance is higher than 0, she has to decide whether to work outside the set of municipalities. The decision to work outside is described in detail in Sect. 8.2.9. If the individual goes to work outside, she automatically has a job. She is counted as an outside commuter. The job occupation of the outside and its spatial distribution can be used to calibrate the model.

If she doesn't work outside, she goes to see the labour office. The labour office collects every job offer corresponding to the profession she is looking for at the chosen distance. Then the individual chooses one at random. This procedure allows reproducing the effect of the quantity of local offers. It gives to the municipality with a larger job offer a greater probability to be chosen.

If she chooses a job at a distance higher than the proximity distance, she becomes the leader of her household. If the distance is less than the proximity, the next household member, if 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. The number of times this procedure is repeated is specified in a parameter.

Parameters Probability distribution of accepted distances to cross over to work place; probability to commute outside for an inhabitant of every municipality.

8.1.6 *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 Probability to decide the individual's retirement age.

8.1.6.1 Demographic Dynamics

A new household can be created when an individual becomes an adult or when a new household comes to live in the set of municipality (i.e. in-migration). The main reasons for household elimination are out-migration and death. Three main dynamics change the household type (single, couple, with or without children and complex[5]): makeCouple; splitCouple and givingBirth. These processes are now described with more details in the same order they have been presented in this introduction.

8.1.7 *BecomingAnAdult*

Becoming an adult means an individual creates her own household. This can lead her to move from parental residence because of a low dwelling satisfaction level, but it's not always the case. An individual loses her child status and becomes an adult when: she finds her first job; or she is chosen by a single adult as a partner; or she remains the only children in a household after her parents leave or die while her age is higher than parameter firstAgeToBeAnAdult.

Parameter First age to become an adult—15 is the age considered by the French or other European National Statistical Offices.

8.1.8 *Household Migration and 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, p. 66) 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 set; the migration of people who already live inside the set.

The immigration into the set is an external forcing. Each year, a number of potential immigrants from outside the set are added to the municipalities of the set.

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

These potential immigrants can really become inhabitants of the set if they find a residence by themselves or by being chosen as a partner by someone already living in the set in case they are single (with or without children). Thus, looking for a place of residence is the only action they execute until they become an inhabitant of the set. Until the potential immigrant becomes a real inhabitant, she cannot search 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 immigrants to find a job directly would be redundant. The definition of who are potential immigrants, how numerous they are, and when they are introduced is specified exogenously. Since they are created, the potential immigrants are temporarily places into a municipality from which they can find a residence or being chosen as a partner. They are placed in a municipality following a probability to be chosen, which is computed for each municipality depending on the population size of the municipality and its distance to the frontier of the set. A particular attraction of young people for larger municipalities is also taken into account.

The mobility of people already living inside the set of municipalities is mainly endogenous. Such a mobility can lead the household simply to change residence, municipality or to quit the set of studied municipalities. Overall, a household decides to look for a new residence when:

- a new couple is formed: the couple chooses to live initially in the largest residence among the ones of 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 away from the current place of residence (beyond the proximity parameter of the MunicipalitySet);
- a student or a retiree decides to move;
- the residence is too small or too large. This can be due to a birth, a new couple or to someone who left the residence for example. The too small or too large characteristic is assessed through a satisfaction function depending on the difference of size between the occupied size and an ideal size for this household, and the average age of the household members. In principle, people tend to move easily when they are younger and/or when the difference of size is high.

The choice of a new household is twofold: first, the household chooses a distance to move; secondly she chooses at random a new residence proposition to examine. The proposition is accepted depending on the level of satisfaction it can give. This satisfaction depends on the difference between the proposed and the ideal size, and the average age of the household members. In principle, with increasing age we assume a decrease in flexibility to accept residences different from their ideal.

A move of a household can result in increased commuting distances for some of its working members, even exceeding the proximity threshold. Such a commuter continues until she becomes the household leader through the job search mechanism and triggers the household to look for a residence closer to her job.

Parameters for Immigration Yearly migration rate; number of out of the set migrants in year $t^0 - 1$; probabilities for characteristics of the immigrants (size of the households, age of individuals…); distance to the frontier of the region of each municipality.

Parameters Within the Set of Municipalities and Out-Migration:

- The level of satisfaction of the size of the current dwelling or the one of a proposed dwelling is a function of the size of the household and of the its age composition; this function requires one parameter called β which has to be calibrated
- distribution of probabilities for an individual to accept moving over a certain distance to get a residence starting for her place of work (see (Huet 2011 p. 89) for more details)
- Laws for migration of students and retirees and acceptable distance of commuting (see for details on these processes).

Except for β, all these parameters can be extracted from the Mobility data collected in the French Census, directly or after applying some statistical tools.

8.1.9 Death

The death age of the individual is determined when she enters the simulation (through birth, initialisation or immigration). When an individual dies, its household status is updated depending on the number of remaining members and their statuses, parent or children. Households are eliminated when all their members die, when the couple splits up, or when they simply out-migrate.

Parameter Probability to die by a certain age – made available by INED from the various French Census at the national level.

8.1.10 MakeCouple

The method works as follows:

- During each time step, each single individual (with or without children) 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 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 immigrants; the close municipalities are at a maximum distance defined by the threshold parameter "proximity" except for old people who search for a partner only in their own municipality;
- When a couple is formed, the new household chooses the larger residence (the immigrating households always go into residences of their new partners; this

move can force one member to commute very far. This situation can change only when she is becoming the leader triggered by the job search method and implying that the household will aim to move closer to her job location.

Parameters Probability to search for a partner; maximum number of trials; average difference of age of couples 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.

8.1.11 SplitCouple

All couples, except the potential immigrants have a probability to split up. When the split takes place, the partner who works further from the residence leaves the household and creates a new household, which implies that she searches for a new residence. When there are children, they are dispatched among the two new households at random.

Parameter Probability to split (no possible data source, has to be calibrated).

8.1.12 Giving birth

To simplify, we made the assumption that only households with a couple can have children, and one of the adults should be in age to procreate. 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 for each couple the probability to have a child during that particular year if one randomly chosen individual's age allows reproduction.

Parameters Minimum and maximum age to give birth, number of children an individual can have during her life on average. Usually ages for reproduction 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 give birth during any given year. From this rate, it is possible to compute the average number of children of any simulated woman, which is about 2 for France. We can start with this value to parameterize the model. But the number of children per 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 can only occur in couples with members having a relevant age. Consequently, the parameter number of children giving the probability of birth does not correspond with the fertility rate (which is a measure in the population, implicitly resulting from different processes leading to a birth).

8.2 Designing and Parameterising the Individual Activity

This part focuses on the design and the parameterisation of the individual activity. The purpose is to illustrate how to model in a micro simulation approach individuals' behaviour on a labour market utilising existing data. The European project that funded this work did not fund specific interviews or surveys for this purpose. But, even if such funding had been available, it would have been difficult to have a sufficiently large sample to ensure the statistical significance of the obtained attributes and behaviours. Therefore, it seemed better to use existing large database dedicating especially to the labour force, such as the labour force survey, which gives information on the labour force based on a very large sample and the weights for projection at various levels. Moreover these databases, developed by the National Statistical Office, have been built on a data collection model designed by experts. They represent common knowledge, largely shared by every stakeholder since they are used as references in decisions and predictions.

We start from existing databases and the objectives of the modelling to characterise our agents and their attributes and behaviours. That is what we discuss in the following first subsection. The two following subsections give details on the initialisation of the attributes and on the parameterisation of the behaviours. The link between attributes and behaviours is guaranteed as this data is implemented to ensure its compatibility with the agent attribute modalities. Similarly, the projection of attributes and behaviour for the whole virtual population is easy: an innovative generation population algorithm builds directly a robust and significant population of individuals while the link between modalities of attributes and their evolving rules allows an automatic projection at the population level.

8.2.1 Data Sources and Main Modelling Choices

This is to identify the agent classes and the structure of agent behaviour in each class. The first steps have been:

- to collect all relevant data source regarding the region we want to simulate considering the exact problem (aim of the project) we need to address;
- to make a state-of-the art;

From the literature and the expertise coming mainly from economists, we identify two complementary groups of dynamics to take into account to model the evolution of a local labour market:

- Job offers and corresponding dynamics;
- Job demand and occupation, and corresponding dynamics.

We identify two possible databases to help us conceptualising and parameterizing the model:

- The Census: it gives indication about the situation of individual when being student, retired, or active and also who is occupied and who is not occupied, what occupations individual have aggregated in socio-professional categories and activity sectors; Census data are available at the municipality level for three different dates 1990, 1999 and 2006. We can also benefit from the mobility tables of the Census giving, at least in 1999, an exhaustive description of the commuting flows between municipalities; French Census data are also available for 1982 but not electronically;
- Labour force survey (from 1990) and census data;

From literature and data, we have to define agents:

- corresponding to the local level of offer: the **municipality**
- corresponding to the job demand and occupation: the **individual** is the one who is going to search for a job, deciding if and where she searches taking into account the **household** of which she is a member and her *municipality* of residence.

Then we have a municipality offering jobs, composed from households, themselves composed of individuals who decide, considering their household, if and where they are going to search for a job. A job can be found in a municipality and individuals accept found jobs based on the distance.

Other available data sources include SIRENE and UNEDIC. The SIRENE database includes information on the number of societies by activity sector. The UNEDIC database includes the number of paid employees by activity sector. But both these data sources describe only a part of our problem and start only in 2000 while the simulation requires longer periods to allow for a proper calibration of the model.

The incompatible coverage also constrains the choice of agents and their attributes. However, given the available datasets we decide to start simulations in 1990. On the one hand, it means some the parameterisation of some attributes is less robust than with shorter calibration periods. A later start would allow us to use the supplementary information given in more recent surveys and not available in older surveys. For example, we use only four modalities of size to describe the size of dwellings because only four are available in 1990 while five and more are recorded in later surveys. On the other hand, the 1990 census data give us the cross distribution socio-professional categories x sector of activities we use to define the jobs while this cross distribution is not available later. Then, we can and have to use IPF to define the job offer after 1990 starting from the 1990 cross distribution.

The definition of a job is directly driven by the available data. Both Censuses and Labour Force Survey (or Employment survey) describe jobs with profession (socio-professional category) and activity sector. Both also contain data on age and situation (student, retired, actives, occupied or not, inactive) allowing us to make a connection between both sources of data. Moreover, when the data sources are "official", it often corresponds to the common knowledge of stakeholders and other decision makers.

Moreover, as a general modelling good practice, it is particularly important to minimise the number of unknown parameters. Indeed, every parameter which is not derived from the data has to be calibrated. The calibration computational cost increases with the number of parameters. Moreover, the more numerous are the parameters to calibrate, the less relevant also is likely to be the model which, given its large number of freedom degrees, can produce almost any trajectory.

8.2.2 Defining the Initial Individual Labour Attributes

The main source of information to define attributes and their values is Census data. The French Census is available for 1990, 1999 and 2006. The 2006 Census has to be used with caution since it is different from 1990 and 1999. It is now a continuous survey which interviews a part of the population every year. Municipalities having less than 10,000 inhabitants are exhaustively surveyed by 1/5 every year. Larger municipalities are sample surveyed every year. In both cases, INSEE, responsible for the Census, give the information allowing the projection at the population level every year. A very good point is that the access to data is easy and free.[6]

To compute a population with sufficiently realistic local statistical properties for individuals and households, we propose an algorithm described in (Gargiulo et al. 2010, p. 7) presenting the generation of households in the Auvergne Region. An improved version has been developed for generating the Cantal population. To summarize our algorithm, we build for each municipality a list of agents with the exact number of individuals being each age and a list of households with the exact number of household members. Then, we try to fill one by one each household with individuals taking into account the probability of households having some particular properties, such as being a couple or having a given number of children. Each time a household is completed, another one is selected to be filled. At the end, we have a virtual population of households following the exact distribution of sizes, having good statistical household properties and composed from individuals following the exact distribution of ages. To built the initial population of Cantal, our algorithm uses for each municipality:

- The distribution of the size of households—available at the municipality level in 1990.
- The distribution of ages of individuals—available at the municipality level in 1990.
- The distribution of ages of the reference person of households—available at the municipality level in 1990.
- The distribution of household types (single, couple, couple with children, single-parent, other)—available at the municipality level in 1990.

[6] made available by the Maurice Halbwachs Center of the Quételet Network (http://www.reseau-quetelet.cnrs.fr/spip) for 1990. For 1999 and 2006, they are directly accessible through internet via the website of INSEE http://www.recensement-1999.insee.fr/ and http://www.insee.fr/fr/publics/default.asp?page=communication/recensement/particuliers/diffusion_resultats.htm).

- The distribution of age differences for couples—only available at the national level in 1990.
- The distribution of the probability to be a child (i.e. living at parental home) by age and for each household type—available at the municipality level in 1990.

This generation method is different from the nowadays used IPF (Iterative Proportional Fitting) which reweight a measured population under some constraints to obtain a virtual population representing the one the modeller is interested in. However this method cannot control the attributes at both levels, the person and the household. Some recent work proposed a hierarchical IPF (Müller and Axhausen 2011, p. 91) to control the two levels but they still required an initial sample, which can be reweighted to fit the scale the model is interesting in.

After the virtual population has been built, individuals require a labour market status. That means the following four individual attributes have to be parameterised during the initialisation: Activity status; Profession, approximated by the socio-professional category; Sector of activity to define, with the profession, the occupied job; Place of work.

To characterize the status we distinguish between active and inactive individuals. Active people can be employed or unemployed. For non-active people we distinguish three categories: students, retired and other. No further characterization is required for non-active person. On the contrary, active people, both employed and unemployed require a socio-professional category (SPC) defining their profession. Moreover, employed individuals require a sector of activity defining the occupation (see Sects. 81.1.3 and 8.1.1.5 for details). Once the municipality of employment is determined, the employed individual is successfully parameterized.

Figure 8.2 shows the generation algorithm. The initialization of the activities starts from the population of households previously generated for each village: each person is assigned an activity, according to the characterization presented above. All the individuals younger than 15 are automatically considered students. For all the others the first step is the decision about being active or not. This decision depends on the age of the person. If the person is not active then her age determines whether she is retired or a student. If she is neither student nor retired, she will be identified with the status “inactive”. If the person is active, the first step is the selection of the socio-professional category (SPC). This choice depends on the age. Secondly it is decided whether the person is employed or unemployed, according to the age. If she is unemployed, no further choices are needed. If she is employed, the municipality of employment is determined. The municipality of employment depends on two questions: first, does she work inside her municipality of residence? If no, find at random a place of work among the possible places of work starting with her own municipality of residence if employment is available according to the SPC. The possible places of work are defined through a generated virtual network built from the mobility data of the French Census of 1999 (see the generation model proposed in (Gargiulo et al. 2011, p. 69) and improved in (Lenormand et al. 2012b, p. 68)). Finding a possible place means the individual can find a free job partly defined by the same SPC as hers. A vector for available jobs is maintained (corresponding to the total number of commuters-in at the beginning of the initialisation) for each municipality

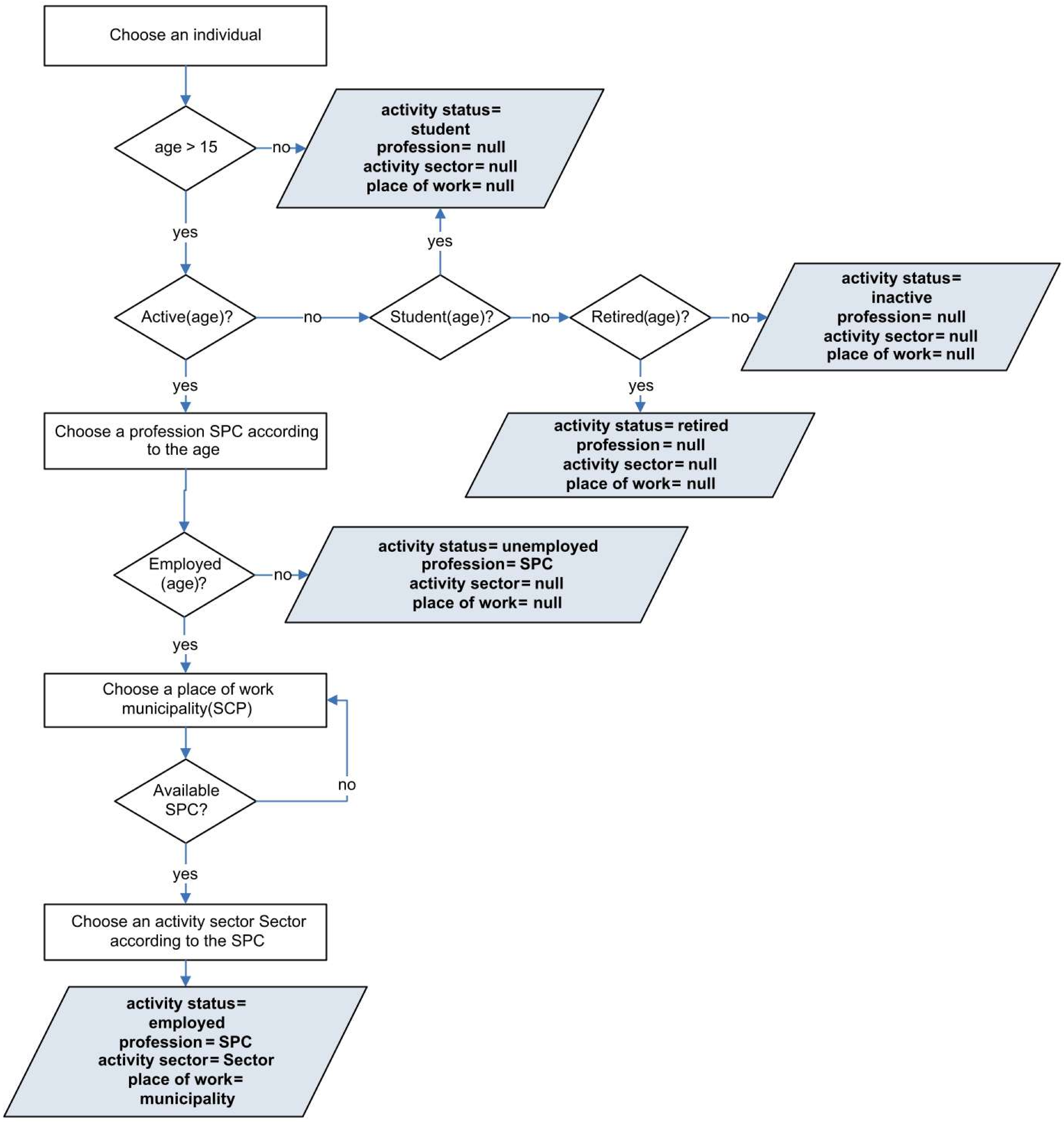


Figure 8.2 Algorithm for the initialization of the activities for Auvergne case study

and decreases with individuals filling vacancies. If no vacancies remain among the possible places of work while an individual is still looking for employment, the attribution of a place of work among the possible ones is forced. Indeed, this can occur due to the fact the generated virtual network is built under the only constraints related to the job demands and the job offers of each municipality. The virtual network doesn't consider the SPC then it can't ensure a demand with a particular SPC can be satisfied by an offer with this SPC in the set of municipalities it has fixed as possible places of work. Finally, an activity sector is attributed to the employed individual based on the cross distribution SPC. We have to acknowledge that the French Statistical Office, as many Statistical Offices, use two ways to count the jobs: counted on the place of residence—that means corresponding to the job occupation by people living in a municipality wherever they work; and counted on the place of work—that means counted on the municipality where people work wherever they live. The algorithm uses the following data for each municipality of the set:

- Age x activity status counted on the place of residence
- Age x SPC for actives counted on the place of residence
- Distribution of probabilities working inside her place of residence by SPC
- A generated commuting network through (Gargiulo et al. 2011 p. 69) (Lenormand et al. 2012b, p. 68) given for each municipality the distribution of commuters out to each of the other municipality
- SPC for actives x activity sector counted on the place of work

8.2.3 Defining the Individual Behavioral Rules Regarding Activity

This part is dedicated to the parameterisation of events on the labour market. Characterization and parameterization is required for those rules that change the value of the individual's attributes related to its labour activity: Activity status; Profession, approximated by the socio-professional category; Sector of activity to define, with the profession, the occupied job; Place of work.

The main data source to do so is the European Labour Force Survey, and particularly its French declination called in French "Enquête Emploi", meaning "Employment survey". The data are kindly made available for free by the Maurice Halbwachs Center of the Quételet Network.[7] This Employment survey was launched in 1950. It was redesigned in 1968, 1975, 1982, 1990 and 2003. From 1982, the survey became an annual survey. Since the last redesign the survey is implemented continuously to provide quarterly results. The resident population comprises persons living on French metropolitan territory. The household concept used is that of the 'dwelling household': a household means all persons living in the same dwelling. It may consist of a single person, or of two families living in the same dwelling.

As our approach starts the simulation in 1990 the first period is based on annual data while from 2003 on values can be considered in quarterly time steps (Goux 2003 p. 56; Givord 2003; the data to select from these two periods vary a bit due to the structural and practical changes in the survey).

Coming back to the description of the whole data, the sample sizes of the data varies from 168,883 to 187,326 from 1990 to 2002 each year and from 92,300 to 95,647 each quarter a year for the new Employment survey. The individuals are asked a very comprehensive series of questions from 1990 to 2006, related to their work. In particular, we can follow their situation year by year, and also their wishes to change job and the type of job they are looking for. Table 8.4 shows the variables we extract from the databases to compute the probabilities we need. However, for the sake of simplicity, we use only data from 1990 to 2002 to explain how to extract the information we need from the data.

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

Table 8.4 Data to extract from the various databases of the French labour force survey to compute the probabilities related to working status of the individual

1990–2002	2003	2004	2005	2006	2007	Meaning of the variable
ag	Ag	Ag	ag	Ag	Ag	Age
annee	annee	Annee	annee	annee	annee	Year of interview
dcse	csepr	Csepr	csepr	csepr	csepr	Socio-professional category
cspp	cspp	Cspp	cspp	cspp	cspp	Socio-professional category of the father
dcsep	cser	Cser	cser	cser	Cser	Socio-professional category one year before
dcsea	cslong	Cslong	cslongr	cslongr	cslong	Socio-professional category which has been occupied for most of the time (for inactive and unemployed people)
tu99	tu99	tu99	tu99	tu99	tu99	Urban area type
fip	eoccua	Eoccua	eoccua	eoccua	eoccua	Occupation one year before
extri	extriA, extriA04	extri99 extri04, extri05,	extri05, extri06,	extri06	extri06	Weights making the interviewed individuals representative (depending on the census done 1999 or of the first result from the last French census (in 2004, 2005, 2006)
rg	reg	Reg	reg	reg	Reg	Region of residence
fi	sp00	sp00	sp00	sp00	sp00	Occupation during the month of interview
–	trim	Trim	trim	trim	trim	For the second period of the survey, the only keep the first quarter of the year
csrech	csrech					Searched socio-professional category
dre1						Situation in regards to employment (mainly to use dre1 = 5 meaning people looks for a job (or another job))
	soua; mrec					Wish another job; Is the individual has searched for a job during the last four weeks?

From the databases, we considered only the population being more than 14 that is not military people of students (FI = 3 and 4)

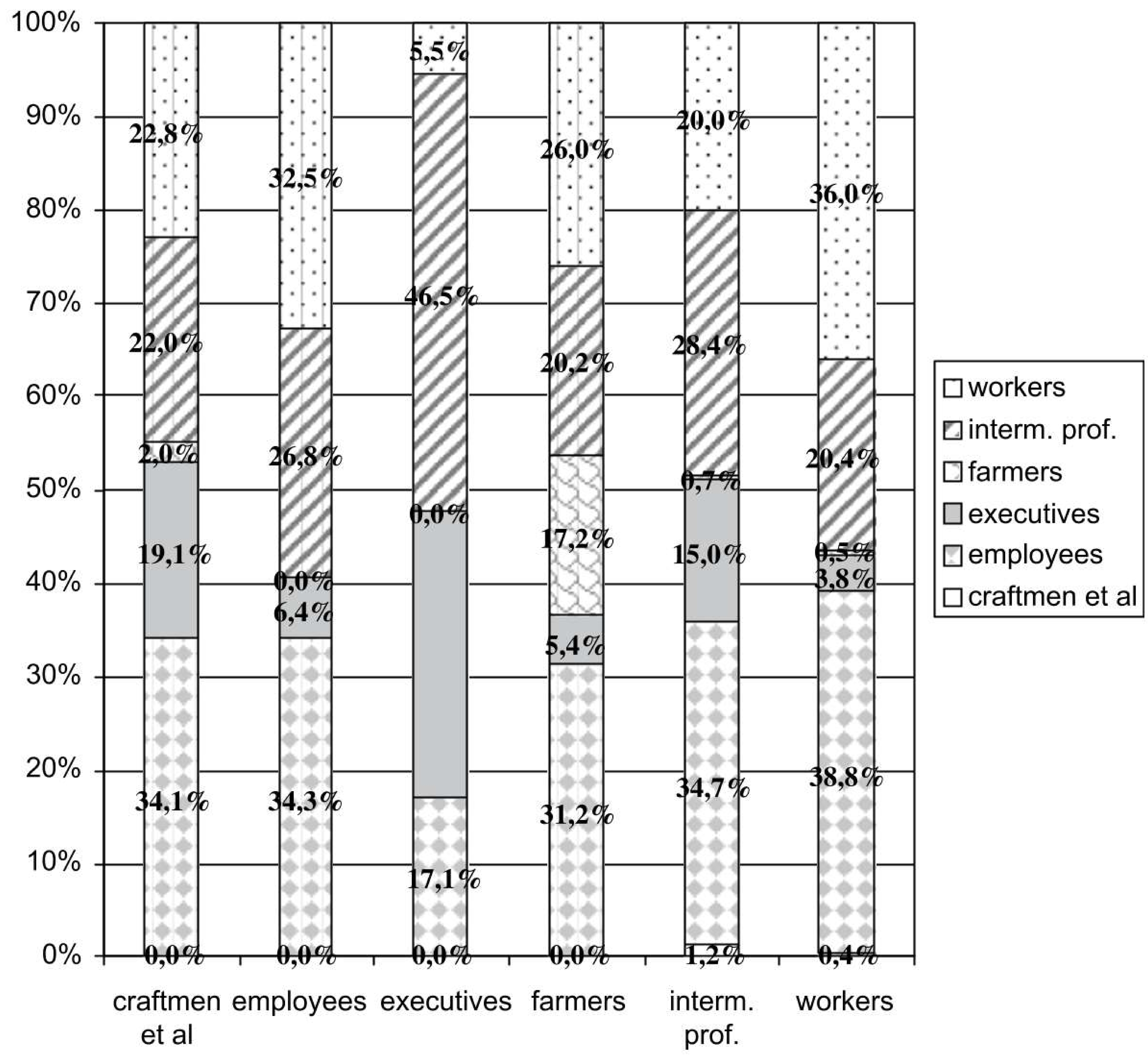


Figure 8.3 Distribution of SPCs choices by children regarding the father's SPC (in abscissa) for the Auvergne population. (Source: French Labour Force Survey 1990–2002 data)

8.2.3.1 Entering the Labour Market

A first step consists of extracting the age from which on the individual is going to look for a job. This will determine the age at which a student status changes to a "on labour market" status. We consider in the period 1990 to 2002 the value FIP = 3, which means that the individual was student the year before and the value FI = all the possible values except 3 means that the individual is not a student anymore. Then, for each five-year step we compute the probability to be a given age and having entered on the labour market for every year.

We used the weights to obtain a projection of the data at the Auvergne level. Auvergne is the region containing the Cantal "département" and three others. That is the closer significant and representative level of the Cantal. Then, we assume the probabilities are the same at the regional and the "département" level.

The second step is to allocate a first SPC (proxy used for defining the profession) to the individual allowing us to approximate what she is 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 8.3 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.

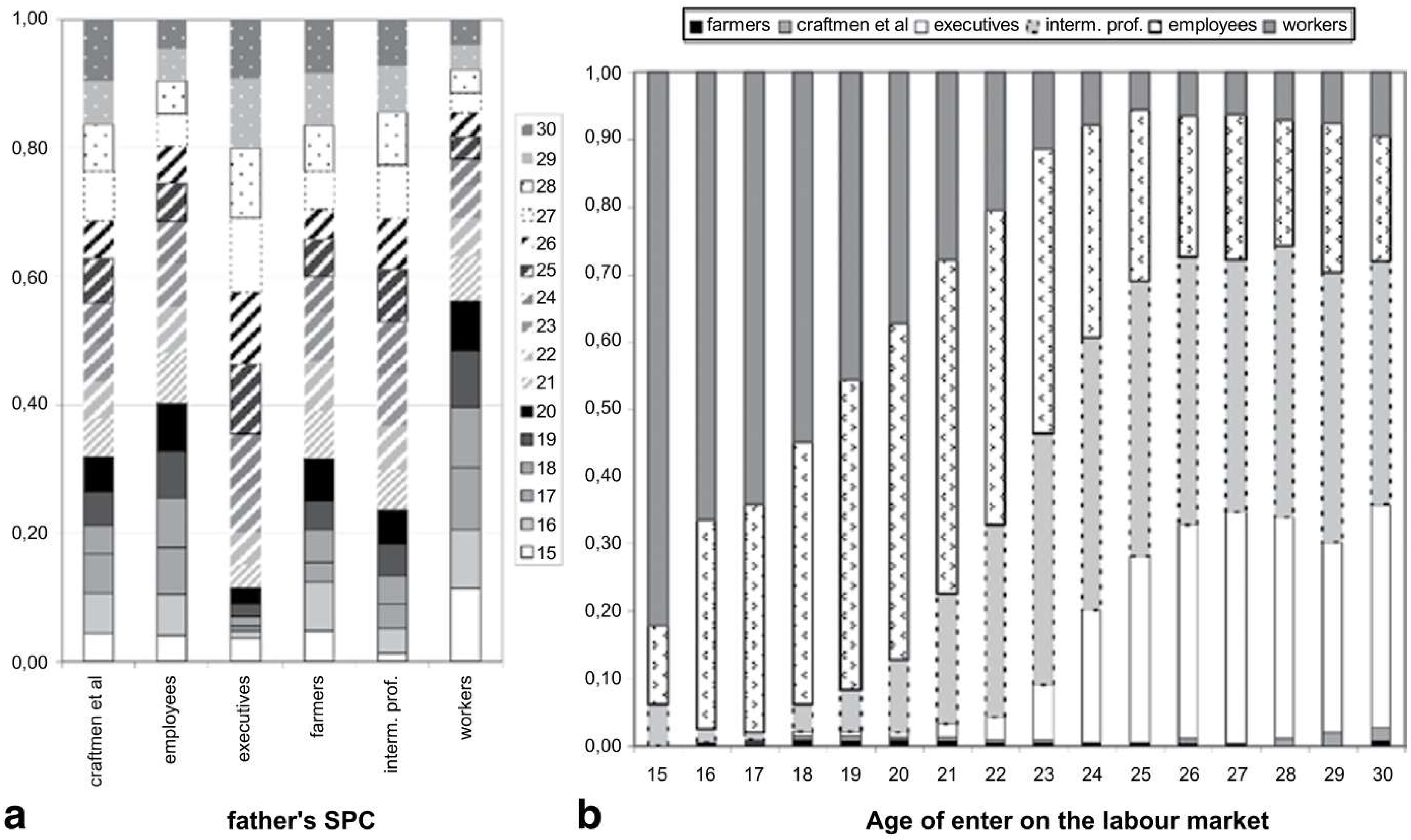


Figure 8.4 (**a** on the *left*) Probability of a "first" SPC depending on the age of entry in the labour market; (**b** on the *right*) Distribution of probability to enter the labour market at a given child age for each of the six father's SPC considered—French population. (Source: French Labour Force Survey, 1990–2002 data)

Thus, starting from this social determinism, we have some indications to set the SPC of 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 at which to enter the labor market using the father's SPC and then determines the child's SPC depending on the age of entry.

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, p. 50). The homogamy can be explained by the constraint associated to the meeting places (Bozon and Héran 1988, p. 51). It has been identified as a possible next step for modelling.

Figure 8.4a shows the distributions of probabilities to enter the labour market depending on the various ages of a child for each of the six SPC attributed to the father. We can for example read that if the father is an executive, the probability to enter on the labour market before 20 is only 0.1 while it is more than 0.5 if the father is a worker. Once our individual has an age to enter the labour market, we can determine her first SPC. Figure 8.4b shows for each age of entry on the labour market (abscissa) the distribution of probabilities 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. The individual who enters the labour market can decide looking for a job.

8.2.3.2 Individual Job Searching Decision

We assume that the probabilities are stable in time for the Auvergne region. Thus, we mix the data from the years 1990 to 2007 in a single sample. Starting from the variables presented in the Table 8.4, we count the frequencies of transitions between inactive, unemployed, employed, from 1 year to the following. For each counted transition, we take into account the weight of the related individual in order to have a probability quantified for the Auvergne level.

Finally, we calculate the probability to reach a given situation by dividing the total obtained for a transition starting from the situation x by the sum of all the totals related to the transitions starting from this same situation x.

We focus on the municipalities of the Auvergne region having less than 50,000 inhabitants using the area type "tu99".

8.2.4 From and to the Inactive Status

The following variables are used to extract the transitions from a starting situation to an arriving situation. They are used for the transitions from and to the inactive status.

- fip = 7 plus 8 or EOCCUA = 6 plus 7 to define the inactive status as starting situation; fi = 7 or SP = 8 to define the inactive status as arriving situation;
- fip = 2 or EOCCUA = 2 to define the unemployed status as starting situation; fi = 2 or sp00 = 4 to define unemployed status as an arriving situation;
- fi = 1 or EOCCUA = 1 to define employed status as starting situation;
- DCSP or DCSA are used to define to starting SCP for unemployed and employed while DCSE is used to define the arrival SCP (for unemployed).

The Table 8.5 shows the extracted probabilities for the Auvergne region.

8.2.5 Probability to Look for a Job with a Given Profession

The probabilities are computed using the same method we used to compute the probabilities of transitions of activity status. The difference is that we use the answers to the questions about the fact that the interviewee looks for another job. For the first period, we select the employed individuals (fi = 1) looking for a job (dre1 = 5). For the second period of the survey, from 2003 to 2007, we assume people look for a job if they have answered SOUA = 1 (want to have another job) and MREC = 1 (have searched for recently) or SOUA = 1 and MREC = 2 and NTCH = 1 or 2 (have not recently search for because they wait for answer to recent applications or they have been ill for a while).

Table 8.5 Probabilities of the transitions "inactive → unemployed", "unemployed → inactive depending on SPC", "employed → inactive depending on SPC"

		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 8.6 Probability for unemployed people to search for a job with various SPCs knowing the current SPC of the individual

SPC/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

8.2.6 Deciding Looking for a Job When Unemployed

Unemployed people are assumed to be those who search for a job. Even if, in the labour force survey, only 80% of unemployed people declare searching a job, we assume the probability to search for a job of unemployed people is one. Indeed, if we consider the whole model, it globally underestimates the job offer and the probability to find a job. This is difficult to correct as, for instance, we cannot consider that in most cases a job offer is proposed before it has been quit while the model time step is not less than 1 year. Also we assume the job offer equal to the job occupation. Then, the probability to search for a job of unemployed people is one in order to compensate a bit this underestimation and be able to occupy every job offer (which is the state the model has to reach). The data indicates the probability to look for a job for unemployed individuals is quite stable until 54 years of age and dramatically decreases for older individuals. A second step of the modelling work would be to see if this dramatic decrease needs to be considered. We also analyse how different parameters describing the household (the number of unemployed in the household, the number of children, or the type of household) influence the probability to look for a job, and we did not find any clear dependency.

The probability to begin searching (i.e. becoming unemployed) if an individual did not search previously (not because she is employed) corresponds in the model to the transition from inactive to unemployed. As already mentioned, it is the complementary value for each age range of the value to make the transition from inactive to inactive.

Since an individual is unemployed, it is necessary to define which SPC she is going to search for. It varies a lot with the current SPC of the individual. As shown in Table 8.6 even if there is a tendency to look preferentially for her own SPC, an unemployed individual can prefer changing SPC. That is particularly the case of farmers and craftsmen. Then, we parameterise the process from the computation of the probability distribution to choose a SPC knowing the current SPC.

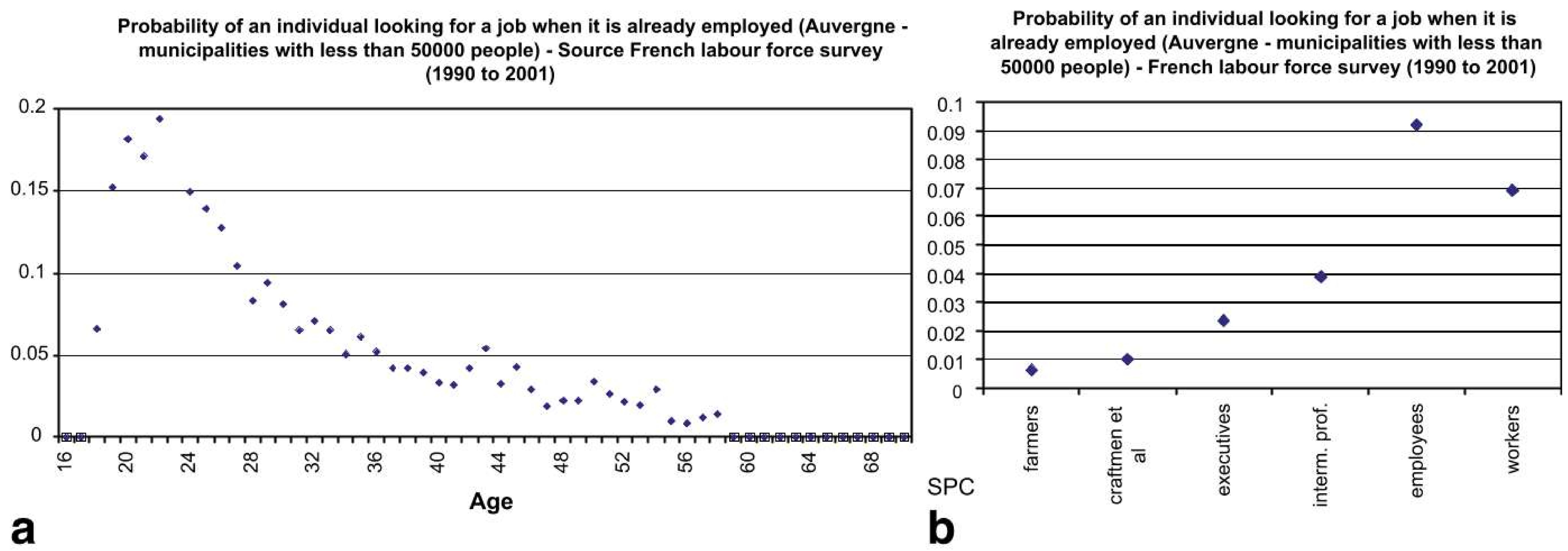


Figure 8.5 **a** Probability for an already employed individual to look for another job according to the age (on the *left*); **b** Probability that an already employed individual looks for another job according to socio-professional category (on the *right*)

8.2.7 Deciding Looking for a Job When Already Employed

We consider those respondents being employed 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 Fig. 8.5a). Young people are more susceptible to look for another job and this tendency decreases with age.

The SPC is also a significant variable to predict the probability to look for a job (see Fig. 8.5b). Some SPC, such as employed farmers or craftsmen 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.

Table 8.7 shows the parameter values for the decision searching for a given profession when the individual is already employed for some age ranges. For employed people, we built a probability containing the both information have decide to search for a job and what she searches for. It is important to point out that the probabilities presented in Table 8.7 do not add up to one but to the overall probability to search, which is quite low for already employed people.

8.2.7.1 Individual Searches for a Job

Since the individual knows which profession she wants to search for, she has to find a place where to look for a job. Firstly, the individual selects an accepted distance she would want to commute. The next section presents how to the related probabilities. If the chosen distance is higher than zero, the individual has to decide if she is going to work outside her set of municipalities. The law allowing this decision and the way to extract it from data is the subject of what follows in the next section. In case the individual has not found a job, she revises the maximum distance. She revises the distance up to 10 times.

Table 8.7 Extract of probabilities for employed people with a given SPC and a given 5-year old age to look for a job within a given SPC

Age range	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
...	Farmers	...	...	...	...	...	...
	Craftmen et al.	...	...	...	...	...	...
	Executives	...	...	...	...	...	...
	Interm. prof.	...	...	...	...	...	...
	Employees	...	...	...	...	...	...
	Workers	...	...	...	...	...	...
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

8.2.8 The Probability to Accept a Distance to Cross Over to Work

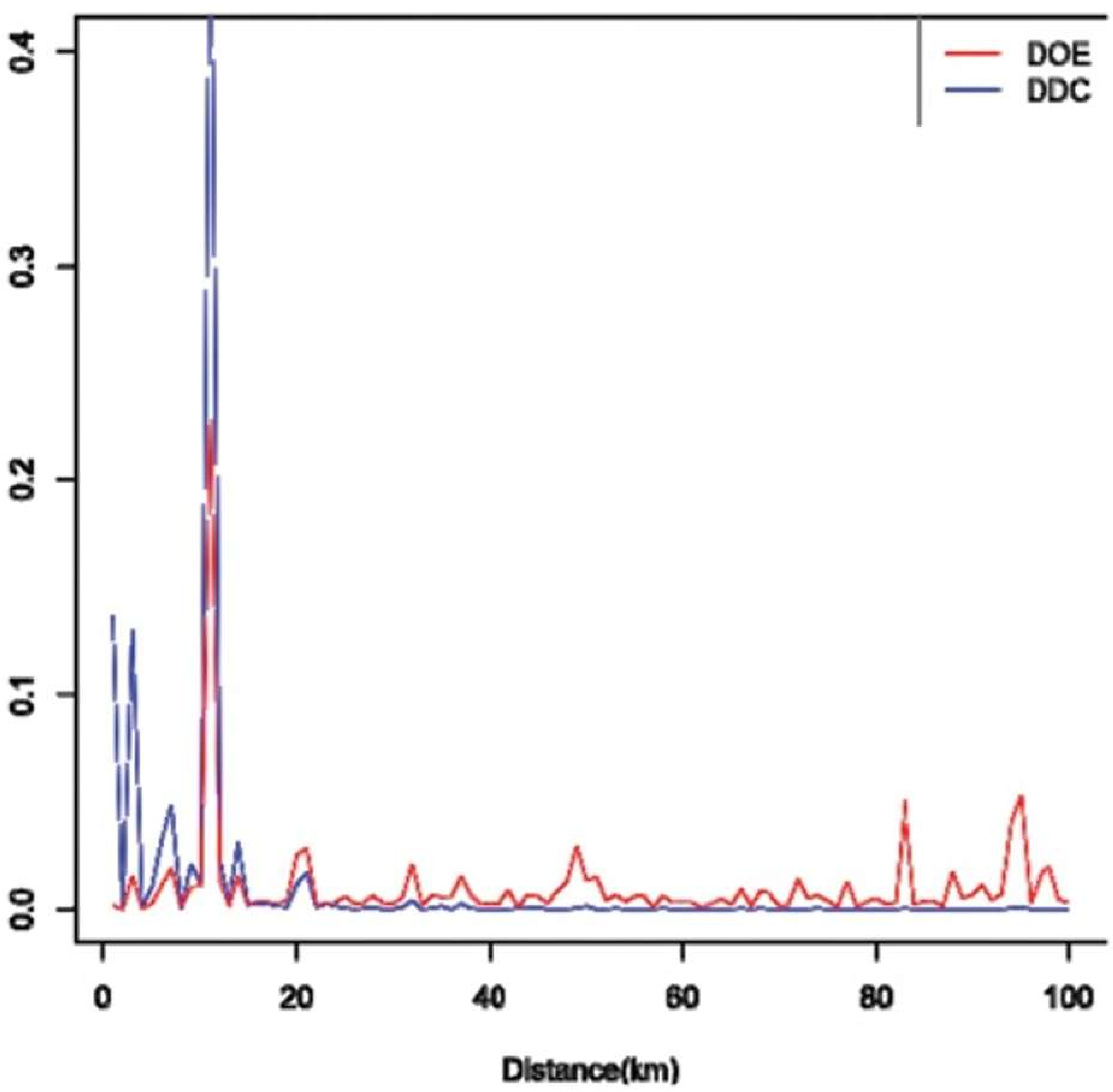
The distance of search for a job is selected from a probability law giving the probability to accept a certain distance between the residence and the work place. The principle is very simple: the probability to commute at a given distance i [$pc(i)$] is assumed to be the product of a probability to accept a certain distance i [$pa(i)$] by the pay offered 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 time of the simulation.

We extract from the mobility data of the 1999 Census for every municipality of the Auvergne region data on commuting (pc) and data on job occupations, which we assume to be equivalent to job offers (O). Evidently, 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, p. 76; Fig 8.6).

Figure 8.6 shows an example of commuting data probability distribution (DDC = *pc)* and of job offer probability distribution (DOE = O) for one randomly chosen municipality

Figure 8.6 Example for one municipality of the density distribution of job offers (DOE = O) and the one of commuters (DDC = pc)



A classification of acceptable distance distributions shows municipalities can be classified in three different groups, apparently depending on the size of the municipality of residence (see Fig. 8.7 on the right). Thus, we assume for this parameter three probability distributions shown on the left of Fig. 8.7 for three different size-dependent classes of municipalities (to the right of Fig. 8.7). The data suggests that the larger the municipality, the lower the probability to work in the place of residence and the longer the commuting distance.

It is important to emphasise that only if the selected distance is higher than zero, the individual has to decide if she is going to outside or inside the set.

8.2.9 Going to Work Outside the Set

When the individual is 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 set has a higher probability to commute outside the set. Then, the individual chooses at random to work outside depending on the probability associated with her municipality of residence. Each municipality has such a probability which is a function of its distance to the border of the set. This function is extracted from the mobility data from 1999 (Source: INSEE 1999). Figure 8.8 shows this function for the Cantal department and the whole Auvergne region of 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.

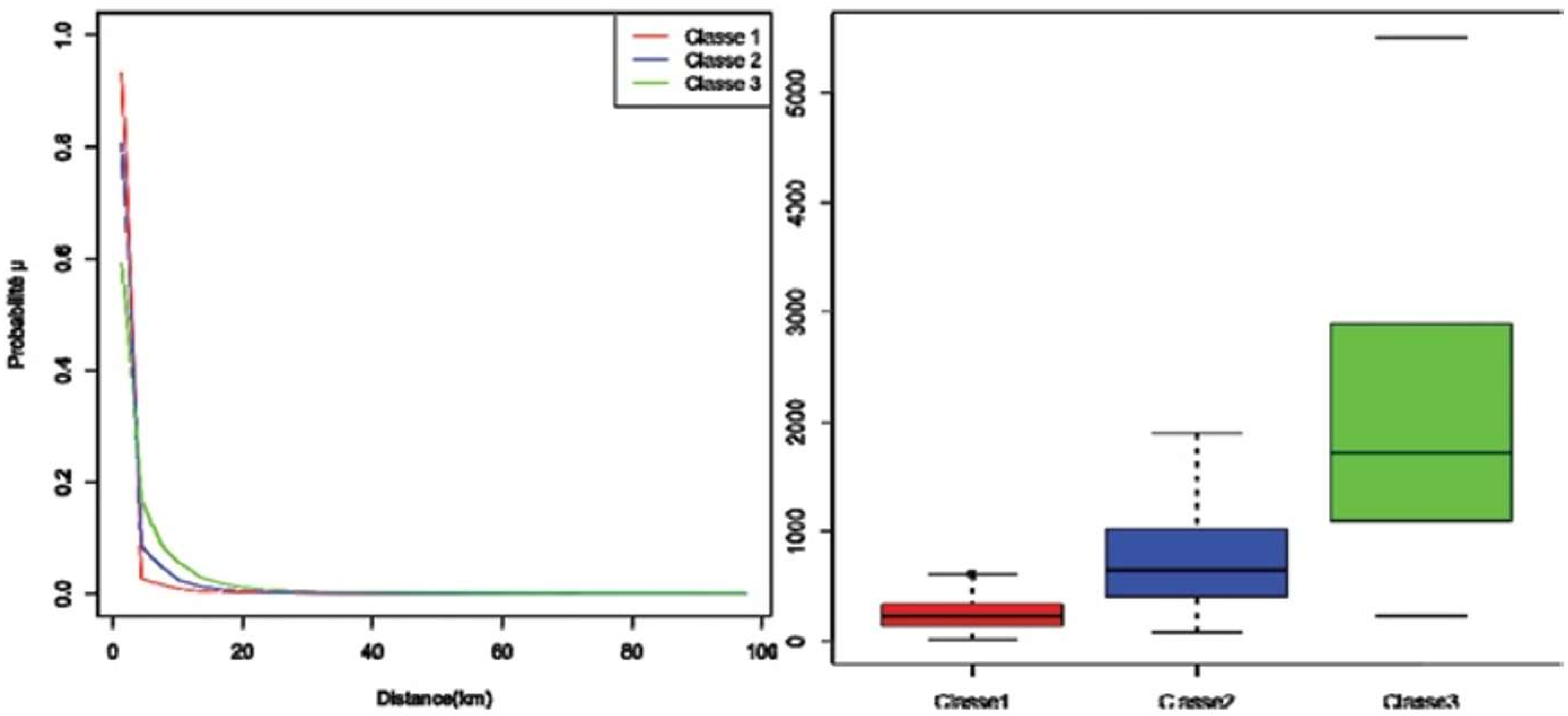
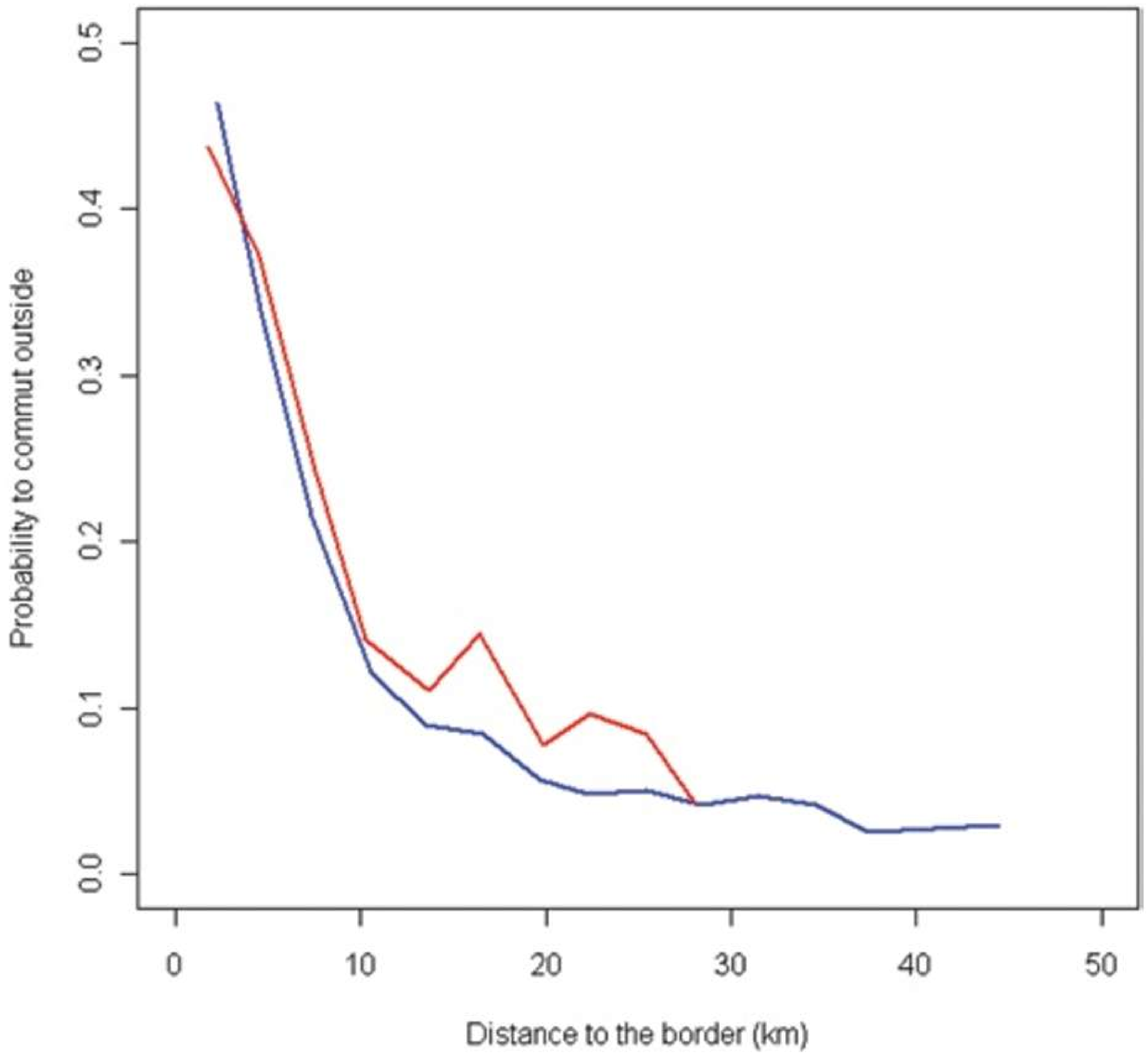


Figure 8.7 Probability laws that an individual accept to a certain commuting distance knowing that a job is available for it.(on the *left*)—different population sizes for the municipalities of each sub-group (on the *right*)

Figure 8.8 Probability to commute outside the set (ordinate) depending on the distance of the municipality of residence to the frontier of the set (abscissa in Euclidian kilometers)—*Red* Cantal, *Blue* Auvergne



We are now describing how to extract the probability law for the final event which is going on retirement.

8.2.9.1 Going on Retirement, and Stop Searching for a Job

To extract the transition to the retirement, we consider, in the period 1990–2002, the value FIP = all except 5 or 6, which means that the individual has not yet retired and

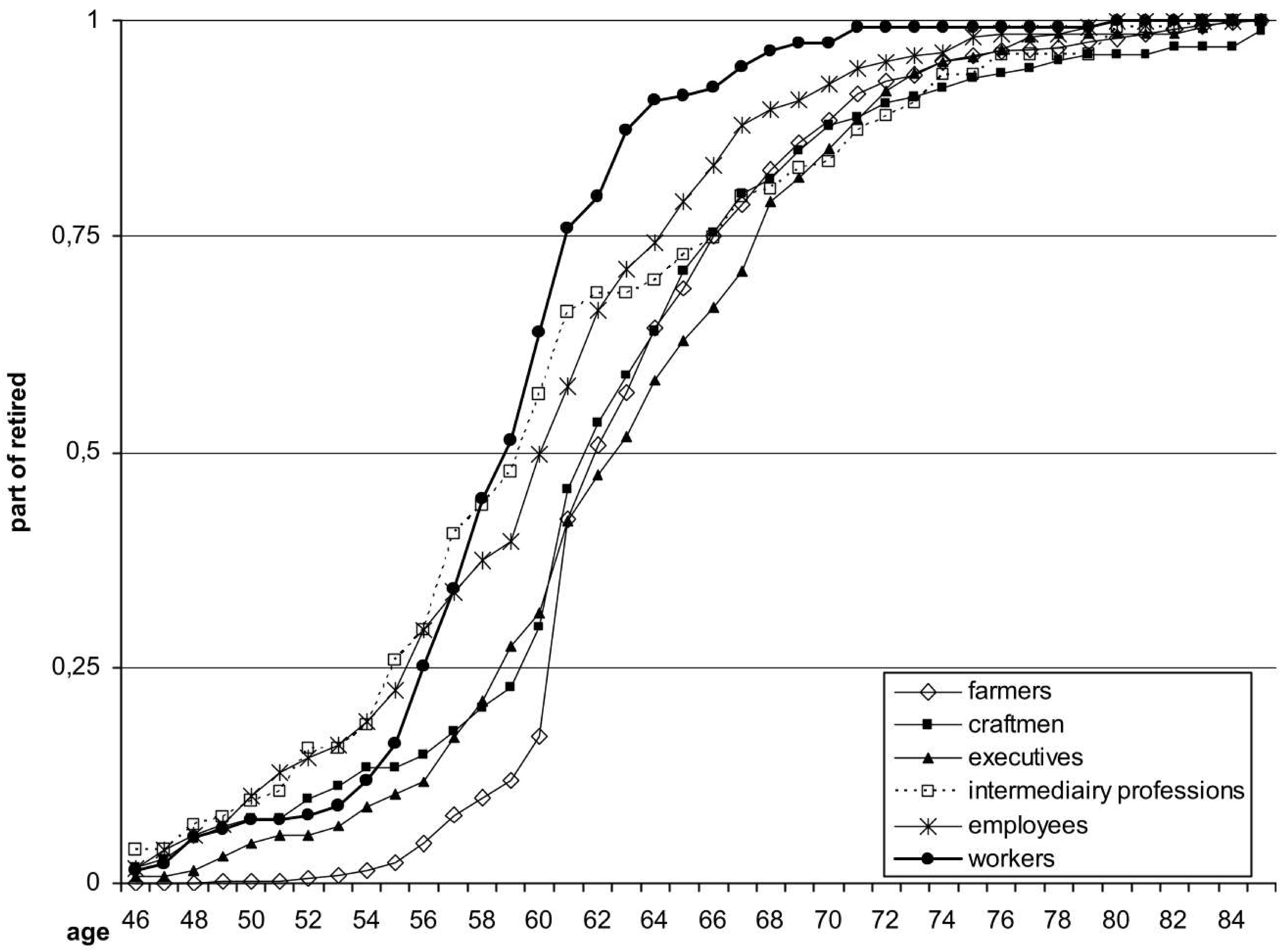


Figure 8.9 Speed of going into retirement by SPC (source LFS)—France level

the value FI = 5 or 6, which means that the individual is now retired. We assume that the retiree does not search for a job anymore since this is generally the case true in France. Figure 8.9 shows that the speed of transitioning into retirement varies a lot from one SPC 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 generic retirement law for all the individuals we consider a law for each SPC. Indeed, as these laws influence the job availability at a given moment it is very important to be sufficiently precise.

8.3 Lessons/Experience

First, we want to stress the necessity to not only consider the objectives of the model during the design, but from the very beginning exploring existing data sources and studying the implicit model beside the existing databases. The availability of data and the more or less implicit model guiding the collection of data constrain the definition of agents, their attributes and behaviours.

Using large existing databases can appear more relevant, especially the "official" ones from the National Statistical office, than collecting a small sample and reweighting it to obtain a statistically significant artificial population.

For these large databases, the models guiding the collection of data represent the expertise knowledge and generally assume some dynamics, particularly if time series are collecting during the survey. Moreover, if the data sources are collected by the National Statistical Office, they probably represent the commonly used information and knowledge by the stakeholders and policy makers. A model which aims to inform decision making is more useful if it can be easily understood and discussed by the relevant decision makers. This is easier if the model starts with common knowledge.

More generally, the modeller has to identify the rationale behind the considered data sources and use it to build the dynamic model. Indeed, this rationale often makes some implicit assumptions on the dynamics. Let's take the definition of a household as an example. "*In surveys prior to 2005, people were required to share the same main residence to be considered as households. It was not necessary for them to share a common budget. De facto, a household corresponded to a dwelling (main residence)*". Thus, until 2005, the French National Statistical Office (INSEE) assumes the household/family is defined by the place where it lives, which is unique. Indeed, following the INSEE definition, each person in a household may belong to only one family. In this framework, residential mobility is a household/family decision and the number of occupied dwellings in a place corresponds to the number of resident households. That is also what we assume in the model. "*Since 2005, a dwelling can include several households, referred to as* "*living units*"*. Every household is composed of the people who share the same budget, that is who contribute resources towards the expenses made for the life of the household; and/or who merely benefit from those expenses*." The new definition is based on the fact that related or unrelated individuals can share the same budget and have a habitual residence (the dwelling in which they usually live). This new definition takes into account some cultural evolutions and allows a European homogenization of the way households are defined. However, it modifies the way the dynamic of move can be considered since each individual of the household can have more than one dwelling. This is to point out that the choice between one data source and another corresponds to a representation of the world to which some particular dynamics can be linked. If the first definition of household is more related to the idea that relationships between people can be identified by the concept of family and/or the identical of place of living, the second definition puts the economical constraints (i.e. the sharing budget) much more at the heart of the dynamics of closeness. A modeler, having the choice between a data source containing data built on the first definition and another one based on the second definition, should be aware of the choice to make and communicate about it. Thus, choosing to only use data on the SCP and the activity sector to describe a job while it is possible to use the salary, which is available in some databases, makes having an occupation much more important than the level of salary. It also implies, for example, that an individual can change jobs just to change their working environment. Differently, the classical economic models considering job change start from the salary and assume an individual changes to increase their salary. We simply assume our individual wants to change jobs, without necessarily changing SCP at the same time. However, one can notice our assumption is relevant due to the existence of a minimum salary in France which ensures a minimum amount of money to live with.

The choice of existing databases for facilitating model design and parameterisation needs to consider:

- a longer as possible period of calibration: indeed it is not sufficient to strongly link the model to data if the model is not calibrated or calibrated with poor data compromising the robustness of the trajectory of underlying model dynamics;
- a sufficient number of modalities for each attribute in order to be able to reproduce the diversity of relevant agent types and behaviours. For example, we chose to aggregate in our work jobs in 24 types; at the end this depends on data availability;
- a minimum number of variables to calibrate: too many unknown parameters implies we don't know much about the dynamics and every explanation for observed trajectories can be valuable;
- the possibility to use them simultaneously for initialising agent attributes and defining agent behaviours: that means in particular that they have to have common variables allowing for a link between them. The challenge is to make an easy fit between attributes and behaviours.

Finally, starting from large national databases makes it likely that the model can be easily implemented and parameterized in another country. For instance, the example on the individual dynamics of activities indicated the possibility to apply the model in another European country even if some small adaptations are required. Indeed, Europe tends to harmonise the data bases in order to have common indicators at the European level. Then, large national databases have been designed or redesigned for answering the European demand. For example, the French "Employment survey" is the data source for the French contribution to the European Labour Force Survey. That is why (Baqueiro Espinosa et al. 2011, p. 83) proposes a way to parameterise our model directly starting from the data of this European survey. For the same reason, national census data in Europe tend to consider more and more comparable or identical variables. That makes it possible to use them to parameterise our model even if a particular attention to the definition of used concepts remains: while to be a retiree in France (at least until a very recent period) means not looking for a job, it is not the case in UK for example.

Taking into account data at an early stage is not an easy task. It is at the same time laborious and confusing since the modeller is confronted with a very large set of information and more or less implicit knowledge. Finding a way to use the data and to choose the object, their attribute and the dynamics in order to remain simple as possible is much more demanding than developing a theoretical model. However, for such complex systems and models as ours that focus on the dynamics of interacting municipalities, the approach allows to properly define and control some sub-dynamics, even if they are not independent from other dynamics in order to test hypothesised system properties. For our concerns, we expect the expertise we developed for the labour market in conjunction with the robust parameterisation of the individual activity dynamics and job offer dynamics, will allow us to better understand how the demography impacts on the population/depopulation phenomena and how these phenomena impact on demography in return.

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