Modeling both sides of the French labor market with adaptive agents under bounded rationality *

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1 Introduction

The model WorkSim is a novel tool of analysis for the recent French labor market. The version presented here aims to simulate the labor market just before the financial crisis, i.e. in 2007, assuming that the exogenous conditions would stay fixed, and the model reach an approximately permanent state that we study. The first objective of the model is to reproduce the gross flows between the important states, employment (distinguishing fixed term contracts and open ended contracts), unemployment and inactivity, and the ratios of individuals in these states. The novelty of the model is that it simulates the flows on the basis of the rational decisions of individual heterogenous agents. Once the model is calibrated, the second objective is to characterize the nature of the labor market under study. This is done, first by examining the patterns of flows and stocks at the aggregate level and at the levels of different categories of labor, second by sensitivity experiments, modifying some exogenous parameters and variables such as the demand for the good. A third outcome will be the follow up of cohorts of workers over the life cycle and their analysis, but is left for future study. Finally the model once calibrated is a tool for experimenting labor market policies, including changes in the labor law.

The multi-agent methodology is the perfect tool for such a research program, since it can model institutions precisely, and account for heterogeneity and individual interactions. Simulation results enable us to compute aggregate variables such as the flows and the stocks, and finally the individual careers and the main types of trajectories. However the labor market is complex, and this means that the modeling progresses only by steps. The present version is consistent as a stock-flow model, and more detailed than other existing stock-flow models of the labor market, analytic, econometric, or multi-agent, but leaves aside important variables such as formal continuous training or the role of households in decisions.

The model builds on the experience of model ARTEMIS proposed by Ballot ([4, 5, 6]) and a preliminary version of WorkSim by Kant and al. [35]. ARTEMIS is the first multi-agent model to have modeled the gross flows between the three main states of the individuals, with the addition of on-the-job search as a state. This was also done within an institutional framework, notably with a temporary help firm, and firing costs. The accounting framework of stocks and flows allowed for a rigorous analysis of the competition between the different categories of labor and threw some light of the effects of aggregate shocks or institutional change on the displacement or integration in open ended contracts of such categories as the young workers, female workers, low educated workers. The underlying hypothesis, that results confirm, is that these effects on the gross flows and stocks are highly non linear, or even non monotonic, and difficult to obtain through available econometric methods. For instance, a negative demand shock could possibly lower the unemployment rate of young non educated workers who would abandon participation.Recent empirical studies reveal an enormous rise in the proportion of young workers who do not search for a job[1]. WorkSim puts emphasis on the most important and acknowledged feature of the French labor market which is the major role of the fixed term contracts, about 70% of the hires in 2007 (see Table 2). The present version is mainly devoted to

*EAEPE 2013 Conference, November 7-9 2013
[1]The NEETS (Not in Education, Employment, Training) phenomenon is increasing

the reproduction of the flows on the basis of our modeling of rational decisions. It then provides a first characterization of the patterns of flows of the different categories of workers, which is key for understanding the nature of a labor market, letting policy design for future work. For lack of space we mainly restrict our economic analysis to the observation of a segmentation, and then throw a first light on the fundamental question: is the segmentation of a temporary or permanent nature for a generation of individuals?

Section 2 will present the theoretical framework, section 3 will develop the model. Section 4 will deal with the calibration procedure, and section 5 the first characterization of the French labor market on the basis of the results. Section 6 concludes.

2 Theoretical framework

WorkSim like ARTEMIS is grounded in the concept of search [19]. It gives its intellectual coherence to the model, and the foundations for many of the decision rules. The search concept is necessary to distinguish the two states of "unemployed" and "inactive" on the basis of rational decisions of agents. The unemployed search for a job, but they sometimes give up search, and net value in terms of utility (time foregone or some psychological cost to search versus the expected gains) has to become negative at some point to explain this flow from unemployment to inactivity. This is distinct from the fact that part of the inactive persons do not want to work because they have some other resources and value non-working time (caring for children). When the cost of search is introduced, the concept of search then also explains - and it was the seminal idea of Stigler [42] - that workers will sometimes prefer not to apply for a job to spend some more time unemployed to try to obtain a better job. An stopping rule follows. The definition of unemployment as an state in which workers act actively to find a job is the one adopted by the ILO, and the French National Statistical Institute (INSEE) in the Enquête Emploi, which measures some of the variables the model wants to reproduce.

The basic concept of search is extended in three directions, in order to build a general theory of mobility :

1. Search is done also by firms that symmetrically look for workers that are high in the productivity distribution. They prefer to keep a job vacant than hire a worker with a poor productivity. An optimal stopping rule taking the form of a minimum productivity requirement or hiring standard follows. A further possibility is that the addition of the costs of search and other costs (wages...) makes the job unprofitable and it is suppressed.

2. The search calculus is extended to all voluntary decisions by workers such as quits to search and on-the-job search. The firms take into account the search costs of replacement when they consider firing a worker, for lack of productivity. Other economic computations of benefits and costs complete the list of separation flows that are based on firms decisions. Finally the hiring decision is the result of the sequential decisions of the worker who applies and the firm which selects and hires. Moreover, we do not use any matching function – like in the canonical model of Mortensen and Pissarides [37] – as it is an aggregate artifact, likely not to be robust to large changes in the labor market, and with weaker microeconomic foundations than our double search decisions. The model definitely belongs to the pure search models, taking into account fully the heterogeneity of jobs and workers,and not to the matching models[2]. It should be noted that the model then simulates not only the stock-flow accounts for individuals, but also for jobs, and the dynamics of the latter is likely to be the engine for the dynamics of the former.

3. Our model integrates wage rigidities and, with the realistic assumption that firms have often several jobs, it allows for the differentiation between demand shocks and productivity shocks, while existing search models do not often deal with this topic[3]. The model then contains some Keynesian features. Demand shocks explain part-time, layoffs, and job creations in the model, while productivity changes explain discharges, promotions and some hires. This distinction has also some importance since the model deals only with the labor market, with no feedback on the goods market. The demand for the goods is exogenous. To make things simple and coherent, we assume that each firm produces a

[2]For evidence of the bias introduced by a matching function as a result of an employment policy, see [38].
[3]See however the survey of Rogerson and Shimer (2011) for the recent advances of search on this subject

> variety of a unique good with horizontal differentiation, and hence a unique exogenous price, considering oligopolistic competition. Each firm faces stochastic shocks ...

However a major difference between WorkSim and the analytical search models relies on our utilization of the concept of Simon's bounded rationality to model the decisions [41]. Three major arguments can be given. First dynamic programming algorithms used to solve the decision problem in analytical search theory cannot be used in a model in which agents move sequentially into many states over time. Second real agents do not make so complex computations but they follow some simple rules. The very important behavioral addition is that they revise their decisions or even their rules by learning through experience and collecting information. This continuous learning is in fact very coherent with search theory. However analytical models, in order to compute equilibrium, assume that individuals have a lot of information such as the true distribution of wages, and firms the true distribution of productivities. We model the simple rules and the learning processes. Third analytical solutions of search models developed in more simple environnements take the form of simple "satisfycing" stopping rules, such as a reservation wage or productivity. The bounded rationality methodology leads to the same types of stopping rules the determinants of which are the same economic variables as in analytical models (leisure foregone for a searching worker, costs of search for a firm with a vacant job...). The parameters of such rules and the learning processes are determined by calibration and/or microeconometric evidence taken form existing studies. The multi-agent tool is the adequate tool to program on a large scale the diverse rules and the learning processes, and has flexibility for adjustment when more evidence is available.

To summarize the new contributions of WorkSim to the present state of the art in the search approach to the labor markets, these are the integration of more decisions than in the existing models, a more complete integration of the institutions that rule the game, continuous learning by agents, and the ability to make individuals agents decisions depend on their history. The contributions to the multi-agent literature on labor markets must also be assessed. This literature is thin but has a long history. Bergmann [12] has developed a simple search model by both sides of the market and obtained simultaneously vacant jobs and unemployment. Eliasson [18] builds a Keynesian and Schumpeterian micro-to-macro model which treats only firms as individual agents but the number of workers in a firm can vary and unemployment is computed. He stresses poaching of labor by firms that grow and the wage competition that eliminates the firms that are not profitable. An extension by Ballot and Taymaz [21] adds human capital and the growing firms poach the more educated workers, enhancing a virtuous cycle of innovation and profit. ARTEMIS, the ancestor of WorkSim, stresses the different personal management types, to study segmentation. Some firms offer internal labor markets with a high selection at entry, but also training and promotion, and others offer lower wages, less selection, no promotion ("secondary management"). Moreover firms can recur to temporary help work, with very short contracts, but less selection than for internal labor markets. The model generates a temporary segmentation of the young workers. Then a demand shock affects very differently the categories of labor, precluding the progressive integration of young workers in the internal labor markets, which leads to a permanent segmentation with serious life cycle consequences.

The years 2000 has mainly seen multi-agents aiming at theoretical research, such as introducing networks, a logical way to consider search in some contexts[20], and the study of the robustness of aggregate relations such as the Beveridge curve when trying to obtain them from bottom up [40]. However Barlet et al. [9] simulate the French labor market for year 2006. They distinguish individuals and jobs but not firms as such although there is labor demand side, with creations and destructions of jobs based on a desired margin and demand. Fixed term and open ended contracts are also distinguished. The flows are obtained from transition rates, often exogenous, but the layoffs are determined by the destruction of jobs. The model is carefully calibrated using an indirect inference method. The model is then used to study the effects of the rise of the minimum wage and a lowering of the social charges on the firms.

The version of WorkSim (in the line of ARTEMIS) presented here then goes beyond the existing multi-agent literature on the labor markets in three directions, as the following sections will show. First it is the only model to be grounded in a double stock-flow accounting, one for the individuals, one for the jobs, and most of the important flows are considered. This accounting is the equivalent of the financial stock-flow accounting for ACE macroeoconomic models, a guarantee of coherence. It also allows for a easy description of the labor market dynamics at the aggregate and any disaggregation level of interest, and the highlighting of the competition between categories of labor (young, adults, seniors,...). Second, it models the institutions and the law at their level of influence, the microeconomic level, since they are rules of the game that agents play. The diverse forms of labor contracts, with very extreme differences, are probably the major feature of the French labor market, and they are at the heart of the model, since they influence the flows[4]. Third, most of the gross flows are generated by rational decisions based on an enlarged search theory, and the effects of shocks we will study then integrate the agents responses and interactions within the rules of the game and the accounting constraints. Our multi-agent model then provides a tool to explore rigorously the complex system constituted by the labor market.

3 Model description

3.1 Labor Market Structure in WorkSim

3.1.1 Agents and artifacts

There are three types of *agents* in WorkSim : Individuals, Firms and a Public Sector that recruits employees, collects payroll taxes on businesses, and sets (exogenously) public policies for the Labor Market (***LM***).

In addition, the model uses three *artifacts*[5] that support process does not correspond to the decisions of agents, but essential :

- *JobAds*, which receives job offers from the firms and job applications from the job seekers. Dissemination of information, however, is based on the job search process described in more detail below, according to the principles of the theory of search.
- a *demographic* module, which manages the demographic processes in the model (retirement, death ...).
- a "*statistical institute*" that calculates all the statistics from a simulation model, and disseminates information to a limited number of agents, as the tension on the labor market. The information is imperfect for agents, and we could specify what information is being broadcasted.

3.1.2 Institutional Framework

One distinctive feature of the WorkSim model is to integrate a fairly complete and flexible institutional framework that includes (1) the necessary elements of the French labor Law (including two types of contract : *fixed duration contracts* (***FDC***) and *open ended contracts* (***OEC***), permanent layoffs and discharges, redundancy payments, ...), and (2) government decisions (minimal wages, welfares, ...).

We will describe now the **simulation cycle**. Each period (tick) includes **four main steps** :

1. Firm decisions (1) : manage contracts & vacancies, evaluations, job creation / destruction
2. Individual decisions : entering/leaving LM, job search
3. Firm decisions (2): manage applications and promotions
4. Demography : births, deaths, retirements, aging

The length of **one period (i.e. one tick) in the cycle** corresponds to ***one week*** in the real world, in order to take into account very short term contracts (one week duration) that are found in the French LM.

Additional Remark When statistics are needed, we took 2007 as a reference year, since many statistical data and sources are available for this period (including an employment survey from the French National Statistical Institute INSEE). In addition, it happens just before the financial crisis, thus allowing to study the labor market outside the effects of the crisis.

[4]The diversity of contracts exists in many other countries, and the model could be adapted to simulate other labor markets

[5]Artifacts in multi-agent systems are the *reactive* entities providing the services and functions that make individual agents work together [39], and must be differed from proactive autonomous entities like the individuals or the firms.

3.2 Firm decisions

At start, each firm has at least one (ofter more) position to offer. Then, at every tick, each firm manages its positions by deciding to create new ones or destroy existing ones, depending on a (exogenous) demand. Then, it manages its employees through evaluation, eventual firings, and manages the fixed duration contracts.

Before showing how a firm will decide on job creation/destruction, we must describe how it will computes several key elements like productivity, salary, etc.

3.2.1 Key Economical Computations

Individual productivity factors In the current version of WorkSim, each employee produces a certain amount of *one unique good*. The only production factor is the labor, like in many agent-based model of LM. This could be justified by the fact that we do not model a market of goods here.

Therefore, the firm production is linear additive in terms of hours of work, and some employees only work part-time. However, positions and employees are not identical in terms of productivity. There is a base productivity attached to each position, and the employee will modulate its value. Moreover, the employer has only a imperfect and evolving information on individual productivities [6].

Basic production per qualification level In the firm an employee occupies an individualized position p, notably characterized by a qualification level q (1 = worker or employee, 2 = middle level position, 3 = executive), but also by the nature of the job contract, the expected duration of this contract, the work time per period (full-time or part-time job).

The weekly basic production at time $t = 0$ for a position p at qualification level q in firm j is randomly drawn from a standard normal distribution with a mean μ_q, which depends on the qualification level of the position, and a standard deviation σ_q :

$$Q^{base}_{j,q(p),t=0} = (\mu_q + \mathcal{N}(0, \sigma_Q)) \times NbHoursPerWeekRatio(contract_p) \quad (1)$$

where $\mathcal{N}$ is the normal distribution function and $NbHoursPerWeekRatio(contract_p)$ a coefficient equals to 1 if the contract of the position is a full-time job (35 hours per week) and equals to $\frac{1}{2}$ if the contract is a part-time job.

Effective productivity The overall equation that gives the effective productivity of an individual i at position p in firm j is given by :

$$Q^{eff}_{i,j,q(p),t} = Q^{base}_{j,q(p),t} \times \mathrm{ProdFactor}^{general}_{i,t} \times ProdFactor^{spec}_{i,j,q(p),t} \quad (2)$$

Hence, it is based on 3 complementary factors : (1) the basic production, (2) general productive characteristics of the employee (core productivity and general human capital), (3) the specific human capital in the position he holds[7].

[6] In this productivity differentiation we found an essential difference with the ARTEMIS model, where individuals were distinguished only by a cost of personal training financed by the firm to reach the same productivity after hiring and training. Compared to the previous version, this version of WorkSim introduced experience factors and imperfect information.

[7] These complementarities are justified by various economic studies. The complementarity in terms of performance between a technological level of a position (related to implicit physical capital associated) and a level of human capital used is a common accepted fact [34], even if it should be finely-shaded. The complementarity between general human capital and specific human capital has the following theoretical basis : the general human capital of an individual allows him to better utilize his specific knowledge [8],[1].

The general productivity factor of an employee is given by :

$$ProdFactor^{general}_{i,t} = nProd_i \times F_{\beta_q}(CH^{general}_{i,t}) \tag{3}$$

with $nProd_i$, the core productivity of the individual i, $nProd_i \sim \mathcal{N}(1, \sigma_{Prod})$ to represent the "innate" skills of the individual. σ_{Prod} is the standard deviation of this core productivity.

$CH^{general}_{i,t}$ is the stock of general human capital acquired by individual i at time t.

Here and throughout this document, F_Y will be the linear function defined by $F_Y(x) = 1 + Yx$.

At first we assume, on the basis of advanced microeconometric analysis[8], that the *general human capital* for individual i is done by :

$$CH^{general}_{i,t} = Experience_{i,t} + Experience_{i,q,t} \tag{4}$$

It depends on :

- general work experience $Experience_{i,t}$ of the individual, which increases by 1 tick each time spent in employment, but are reduced by a percentage $PrLossXP$ at each period spent out of employment, starting the decrease only after 6 months after leaving the qualificationThis is to model the impact of forgotten skills due to a too long period of unemployment or inactivity[9];

- experience in individual qualification at the level q, $Experience_{i,q,t}$, which increases by 1 tick each time spent in employment at the qualification q, but are reduced by a percentage $PrLossXP_q$ at each period spent out of employment at this qualification level, starting the decrease only 6 months after leaving the qualification[10].

  These increases of productivity are mainly related to *learning by doing* phenomena, as highlighted by Arrow [2], and correspond to an increase of free productivity through practice, as well as on job training. The key point is that they are costless, especially without training cost for companies and employees[11].

The *specific human capital* in the original definition of Becker [10] represents the skills acquired by an individual in a firm and only useful in this firm. However, the seniority factor appears to have a little impact (at least on wages) in France since the 90s [11]. In our model, we distinguish positions by qualification and each level in hierarchy allows to acquire specific skills (technological and social) in this qualification :

$$ProdFactor^{spec}_{i,j,q(p),t} = F_{\lambda_q}(CH^{spec}_{i,j,q(p),t}) \tag{5}$$

with $CH^{spec}_{i,j,q(p),t}$, the specific human capital of an individual i in the qualification q at the position p in the firm j is given by:

$$CH^{spec}_{i,j,q(p),t} = Ancien^{spec}_{i,j,q(p),t} \tag{6}$$

where $Ancien^{spec}_{i,j,q(p),t}$ is the seniority in number of periods of individual i in qualification q at position p in firm j. Notice that if the individual receives a promotion and changes his qualification level in the company, the seniority will be reset to 0.

[8]For France see [11] whose results would be a differentiation of the parameters values according to the qualification. The "salary" behaviors have however changed a lot since the 90s.

[9]This is to model the impact of forgotten skills due to a too long period of unemployment or inactivity.

[10]Thus, an individual loose for example his experience as executive, if he is downgraded more than 6 month at a position with a lower level.

[11]Subsequently training expenses will be introduced and will be added to the effects of experience in a following version of WorkSim.

Employee productivity estimation One key theoretical options of WorkSim model is that an employer never knows perfectly the productivity of an employee. This hypothesis is in the line of Jovanovic [32], and was the basis of important developments in labor economics. This hypothesis has multiple potential effects on the functioning of the labor market.

We assume that the company does not have any *a priori* knowledge of the precise levels of real productivity of each of its employees. It is only able to assess a level of *estimated* productivity:

$$Q^{estimated}_{i,j,q(p),t} \sim \mathcal{N}(Q^{eff}_{i,j,q(p),t}, \sigma_{i,j,q(p),t}) \tag{7}$$

This amount $Q^{estimated}_{i,j,q(p),t}$ is drawn from this distribution when the employee is hired, and also at each employee evaluation (see section 3.2.4).

$\sigma_{i,j,q(p),t}$ represents the degree of uncertainty of the company to evaluate its employees. It depends on the seniority of the employee in firm at his level of qualification and on the number of times he has been evaluated by the firm. It is given by the equation:

$$\sigma_{i,j,q(p),t} = \sigma_0 \times (1 - \delta_\sigma \times Ancien^{spec}_{i,j,q(p),t} - \eta_\sigma \times \#Eval_{i,j,q(p),t}) \tag{8}$$

with σ_0, δ_σ et η_σ, three exogenous parameters.

3.2.2 Wage settings

Base salary The weekly base salary at $t = 0$ for a position p at qualification level q in firm j is written $S^{base}_{j,q(p),t=0}$. It is determined from the base production of the firm :

$$S^{base}_{j,q(p),t=0} = Q^{base}_{j,q(p),t=0} \times P \times (1 - \zeta_j) \tag{9}$$

with P is the *exogenous price* of the (unique) good and $\zeta_j = \zeta = constant$ an exogenous parameter that represents the *margin taken by the firm on base productivity*, in order to pay expenses, taxes, interests, dividends, etc.

Weekly starting salary

The starting salary $S^{eff}_{i,j,q(p),t=hiring}$ of an employee i in firm j at level of qualification q at time $t = hiring$ is given by :

$$S^{eff}_{i,j,q(p),t=hiring} = Max(SMIC, S^{base}_{j,q(p),t=hiring} \times F_{\beta_q}(CH^{general}_{i,t=hiring}) \times G(ITENS_{t=creation})) \tag{10}$$

SMIC[12] is the minimum wage in France.

The starting salary is the base salary of the position modulated by the general human capital of the employee (degree, experience). However it does not depend on the same core estimated productivity of equation 7. The reason does not come from an imperfect information since the employer has an (temporary) estimation of this core productivity, but is due to important considerations of equity in terms of human resource management

[13]. Hence, the employer cannot discriminate employes with the same experience.

Here, we refine the salary offer by replacing it by a salary scale depending on experience[14]. This seems quite common in reality.

A final factor affecting wages is the tension on the labor market ITENS. This modulation is taken into account in the posted salary. We take $G(x) = x^\omega$, where ω is an exogenous parameter we have to calibrate. We consider that the relation G is isoelastic, according to the literature on wage curve [13].

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[12] as for “Salaire minimum interprofessionnel de croissance”. In 2007, the hourly SMIC was 8,44 .

[13] See Adams[33] for example. A feeling of unfairness could generate decreases in effort and productivity for the employees who feel unequally treated.

[14] In terms of theoretical consistency, it is necessary to choose a posted salary and not of a negotiated salary based on the expected quality of the matching. The matching theory usually chooses the latter, but the search theory involves the assumption of a distribution of salaries offered by companies, which leads job seekers to identify interesting jobs and apply for it (or not).

Annual increase of the weekly wage The weekly salary of employee i in firm j is reviewed annually at his birthday date of his arrival in the company according to the equation:

$$S^{eff}_{i,j,q(p),t} = Max(SMIC, S^{base}_{j,q(p),t} \times F_{\beta_q}(CH^{general}_{i,t}) \times F_{\lambda^*_q}(CH^{spec}_{i,j,q(p),t}) \times G(ITENS_{t=creation})) \tag{11}$$

with $F_{\lambda^*_q}(CH^{spec}_{i,j,q(p),t})$, the productivity gains factor related to his experience in the qualification in firm which affects his salary. It is assumed here that the company reports only a part of the productivity gains related to specific human capital on wages, thus $\lambda^*_q < \lambda_q$ (from equation 5). However, according to the insiders-outsiders theory , the employee's salary is not affected by changes in the state of the labor market after hiring[15].

3.2.3 Position management

Position creations First, we must determine the demand for each firm. At the initialization of the model, some employees are assigned to each company, in order to get some initial production $Q_{j,t=0}$. At this starting point, we assume the *demand* D_j *for firm* j to be this initial production added with an initial supplementary part that will allow the firm to create some vacancies:

$$\forall j \quad D_{j,t=0} = Q_{j,t=0} \times (1 + InitDemandPart) \tag{12}$$

At time $t > 0$, the demand D_j will evolve stochastically with some small shocks (random walks) applied to its market share at each tick.

Job characteristics The first choice is between creating a FDC (Fixed Duration Contract) or a OEC (Open Ended Contract). This decision is based on exogenous probabilities that differ with the qualification level but are identical for all firms[16]. *Three qualification levels* are currently considered in WorkSim : *employee or worker, middle level, executive.* If a FDC is drawn, its duration will be set by another drawing depending on the qualification. The durations considered for the FDC are : 1 week, 1, 2, 6, 12 or 24 months [17].

However, before definitely creating position p of qualification *q(p)*, ăthe company estimates its *expected income* per period with the following variables : the salary $S^{base}_{j,q(p),t}$ăă, the productivity estimated through prospecting Q^{estim}_{Moy}, and the expected income from this productivity $G_{j,t}$:

$$R^{expected}_{q(p),j,t} = P \times min\left(G_{j,t}, Q^{estim}_{Moy}\right) \tag{13}$$

$G_{j,t}$ is computed from the remaining part of the demand not yet produced (potential new demand part for the firm). Hence, we have :

$$G_{j,t} = D_{j,t} - (Q^{eff}_{j,t} + Q^*_{j,t}) \tag{14}$$

where $Q^*_{j,t}$ is the expected production of all the vacant positions in the firm. Q^{estim}_{Moy} is the average of all the productivity estimates for the individuals that will be evaluated during the prospecting phase.

The *cost* per period is a function of the salary but also includes a potential cost of a contract breach. This cost will differ with the nature of the contract (FDC or OEC) :

$$C^{expected}_{q(p),j,t} = S^{estimated}_{Moy} \times (1 + PayTaxes) + CPosVac^{expected}_{q(p),t} + CEnd^{expected}_{q(p),t} \tag{15}$$

where PayTaxes represents the payroll taxes the firm has to pay for each employee and $CPosVac^{expected}_{q(p)}$ the expected total cost of a vacancy amortized over every expected duration of the contract (cost of publication of the post, time devoted to interviews by recruiters...). This cost is estimated by learning.

[15] See e.g. [36]. Note that very strong recessions like the current crisis might justify to qualify this hypothesis

[16] These probabilities will be drawn from statistics given by the French National Statistical Institute INSEE.

[17] The current formalization is a first step in our modeling of a fully endogenous choice between FDC and OEC, which is a very complex issue, involving economic and legal factors, knowing also that the law is often circumvented.

Now, the firm can estimate its current *expected profit of the position p.*
If $\Phi^{expected}_{q(p),j,t} = R^{expectedu}_{q(p),j,t} - C^{expected}_{q(p),j,t} > 0$, the company publishes a job offer at the salary $S^{base}_{j,q(p),t}$.

Hiring norm Once the decision to create the position has been taken, the company informs *JobAds* of this position and its characteristics, and receives a number of free informations on the characteristics of a sample of job seekers.

The firm calculates the expected profits, and for the positive ones, the company stores the average Φ_{Moy}, the maximum of these profits, Φ_{Max}, and the minimum Φ_{Min}.

As a form of *bounded rationality*, this rule represents some information on the mean and the range of the profit distribution that a company can get.

The search theory leads to derive from these data a profitability threshold below which the company prefers to refuse a candidate. This threshold will be the *hiring norm* of the firm and is given by :

$$\text{HiringNorm}_{j,q(p),t=\text{crea}} = \text{N}_1\Phi_{Moy}(1 + \text{N}_2\frac{\Phi_{Max}}{\Phi_{Min}})\frac{N(d_p)}{G(ITENS_{t=\text{crea}})} \tag{16}$$

With

- N_1, N_2 two exogenous parameters
- $N(d_p)$, an increasing function of the duration of the contract d_p proposed for the job : it has a minimum of N_3 for a very short FDC (duration below one week) and a maximum at 100% for an OEC contract.
- $ITENS_t$, the tension on the labor market. Higher is this tension, more the firms have to lower their requirements if they hope to find a candidate.

This hiring norm is then decreased by a factor N_4ăă at each tick until the position is filled, but never drops below 0
[18]:

$$HiringNorm_{j,q(p),t+1} = max(HiringNorm_{j,q(p),t} - N_4, 0) \tag{17}$$

Position Destruction In the case where $G_{j,t} < -DemandThreshold$, there is deemed significant reduction in demand and the company plans to remove one or several vacancies.

The company randomly draws one of its vacancies and evaluating the interest to keep it or not. To do this, the company recalculates the demand margin $G^{'}_{j,t}$ it would have without this vacancy, and reassesses as above the interest it would have to create the position now. If this time $\Phi^{expected}_{q(p),j,t} < 0$, the company removes the vacancy and $G_{j,t}$ is increased by $Q^{expected}_{j,q(p),t}$. Similarly, the company continues to randomly draws and deletes other positions among its vacancies as soon as $G_{j,t} < -DemandThreshold$. Moreover, the

vacancies that remain unfilled and have a vacancy duration greater than $MaxVacDurationFDC$ for a FDC and $MaxVacDurationOEC$ for a CDI are destroyed.

3.2.4 Employee evaluation

This evaluations takes place :

- At the end of the trial period for FDC and OEC ;
- At the end of FDC contract to decide if it should be renewed ;
- At the end of FDC contract, if the transformation of FDC to OEC is to be considered ;
- Every year, at the contract's anniversary date, for each FDC employee.

In order to decide whether the employee should be kept, the firm calculates a profit for each scenario.

[18] In search theory, the optimal norm does not decrease if the company knows perfectly the profitabilities distribution. This is not the case here because the firm only got a sample of profitabilities. The firm may think after a certain time to have overvalued the distribution.

First scenario : the firm keeps the employee : The company recalculates the demand margin $G^{'}_{j,t}$ it gets without this employee, and reevaluates as in section 3.2.3 the interest it would now have to create this post. This time, the firm has a more reliable estimation of the actual employee's productivity. The weekly estimated profit is given by :

$$\Phi^{estimated}_{i,j,q(p),t} = R^{estimated}_{i,j,q(p),t} - C^{estimated}_{i,j,q(p),t} \tag{18}$$

where $R^{estimated}_{i,j,q(p),t} = P \times min\left(G'_{j,t}, Q^{estimated}_{i,j,q(p),t}\right)$. $Q^{estimated}_{i,j,q(p),t}$ is the employee productivity estimated by the firm at the time of evaluation and $C^{estimated}_{i,j,q(p),t} = CSalary^{estimated}_{i,j,q(p),t} + CEnd^{estimated}_{i,j,q(p),t}$. $CEnd^{estime}_{i,j,q(p),t}$ is the eventual cost to end the contract and calculated according to the type of contract :

	Very short FDC (<=1 week)	Standard FDC	OEC
$CEnd^{estimated}_{i,j,q(p),t}$	0	severance pay $\times CSalary^{estimated}_{i,j,q(p),t}$	Average Firing Cost

Second scenario : the firm does not keep the employee (layoff on personal ground)

1. If the employee is in OEC, the firm evaluates the firing costs on personal ground. It has to pay severance. By relating this firing cost per period until the end of the OEC, we have : $CEnd_{i,j,q(p),t} = \frac{Cfiring_{i,j,q(p),t}}{min(retirementsAge - individualAge_i, averageDurationOEC)}$, with $averageDurationOEC$, the average duration of an OEC, learned by the firm (with a similar learning process as for the vacancy costs). If the employee is at the end of his trial period or at the end of his contract, the firing cost is null.

2. The company computes the potential profit given by a new employee. If the employee is fired, the company performs a calculation of profit considering that it can recruit a new employee to replace the fired employee with the same contract and the same level of qualification. Weekly income and expected costs, $R^{*\ expected}_{j,q(p),t}$ et $C^{*\ expected}_{j,q(p),t}$, related to the hiring of a new employee are defined in the same way as for a new job creation. The weekly benefit related to the creation of the position is then $\Phi^{*\ expected}_{j,q(p),t} = R^{*\ expected}_{j,q(p),t} - C^{*\ expected}_{j,q(p),t}$:

Comparing the two scenarios The firm compares the total profits associated with each scenario. If $\Phi^{estimated}_{i,j,q(p),t} > Max(0, \Phi^{*\ expected}_{j,q(p),t}) - CEnd_{i,j,q(p),t}$, the firm keeps the employee, otherwise, it does not (end of trail period, end of FDC contract, OEC firing on personal ground) and publishes a new job ad to recruit a new employee at the same level of qualification.

Firing for professional misconduct Moreover, at each period, each employee has the probability $PrProfMisconduct$ ăăto be automatically fired for a professional misconduct "observed" by the employer.

The fired individual does not receive any severance pay but he is eligible for unemployment benefits, according to article L. 1243-10 of the labor Law.

Economic firings An evaluation of the financial viability of the company is done every year (52 periods in the simulation). The first date of the balance sheet is drawn randomly, then balances take place every year from this date. The company calculates annual profit made and annual costs: $\Phi^{annual}_{j,t} = \sum_{\tau=t-T}^{t} \Phi^{eff}_{j,\tau}$ et $C^{annual}_{j,t} = \sum_{\tau=t-T}^{t} C^{eff}_{j,\tau}$. Profits and costs, $\Phi^{eff}_{j,\tau}$ and $C^{eff}_{j,\tau}$, are those registered each period by the firm.

We denote $Return_{j,t} = \frac{\Phi^{annual}_{j,t}}{C^{annual}_{j,t}}$. If $Return_{j,t} < ProfitThreshold$, the company has a loss and starts an economic firing process :

- All vacancies are removed.
- We assume that the company fires "randomly" a number of employees on economic ground. This number is chosen as the minimum number of persons to fire in order to return above the profit threshold.

Firm bankruptcy If a company has no employee anymore, it is considered in bankrupt and disappears from the simulation. The manager becomes unemployed.

Firm renewal. However, we decide in our simulations to keep the number of firms constant. Hence, when a bankruptcy has occurred, we randomly select an active individual in the simulation who creates a new firm and sets in as a manager (in OEC) and a producer.

3.3 Individual decisions

The individuals take decisions at each period of the simulation. This decision process is modeled with a *state machine*, where one individual will be in one particular ***state*** : **inactive**, **unemployed**, **employed** (denoted **PAE**), **employed and seeking a new job** (denoted **PARAE**), **student** or **retired**. The transitions between these states can be caused by individual choices (for example : to start studying, to quit a job...), by external events (firing, death...), or eventually by a sequence of two decisions (applying for a job, and the firm hires the candidate).

3.3.1 Overview of the decision-making process

The decision-making process of individuals is sequential. The transition from one state to another is done by comparing the utility level of the current state with the expected utility level in a new state.

The individual decision-making is a sequential process. Each reachable state will be evaluated using a particular utility function, so the agent could decide whether he is better to stay in his current state or to move to a another one. The individual chooses to change state if he finds a new reachable state characterized by a utility greater than the one of his current state. In this case, the individual stops his decision process and changes state, according to the *satisfycing* heuristics of Simon's bounded rationality theory [41].

Utility functions The utility functions have the generic form of a Cobb-Douglas function :

$$U = (Income + Amenity + Stability)^{1-\alpha}(Free\ Time)^{\alpha} \tag{19}$$

This utility function is a weighted aggregation of four factors :

1. *Income* : weekly income in euros
2. *Amenity* : non-monetary features perceived by the individual (social recognition, working environment, job hardness...), converted into a percentage of salary, and expressed in euros
3. *Stability*: criteria reflecting the preference of the individual for stability, i.e. for a job with the longest possible remaining contract duration. The maximum value is given for a permanent position (OEC) because its duration is – theoretically – indefinite. This stability is converted here into a percentage of salary and is expressed in euros.
4. *Free time* : free time per week available for the individual outside his working hours.

The amenity is a proxy for all the factors that makes the work pleasant or painful. We consider the work time per period when we calculate this amenity to avoid a bias, and above all, the amenity is fully revealed to the employee only after hiring. This amenity discovery could cause some early quitting, as it is also happening in reality. Thus, in terms of imperfect information, there is a kind of symmetrical process between amenity discovery for the employee and employee's productivity discovery for the employer. The main difference is that we assume the employee to be promptly informed of the amenity, while the productivity is measured only very gradually (the trial period is too short to reveal the real productivity).

The parameter $\alpha \in [0, 1]$ encodes the preference of the individual for leisure or work. As in the ARTEMIS model [6], α evolves differently for men and women, because gender roles in the household has the consequence that housework and especially the education of children is rather done by women. Indeed in 2007, according to INSEE, the full-time employment rate of women living in a couple with three children or more was 17.3% and 87.7% for men in the same situation [23].

Deciding to start a job search Moreover, before starting a job search that could be time consuming (and psychologically burdensome), the inactives and the PAE (1) perform a self-evaluation of their employability, and (2) process information they already have on the labor market (coming from their personal network : family, friends,...). This constitutes a search that we qualify as "free" (i.e. at no cost). This "free" search is a counterpart to the free information obtained by the firm as mentioned above.

Employability assessment. The employability is computed as the expected productivity in another company modulated by $ITENS_t$, the tension on the labor market : $EMPLOY_{i,t} = ITENS_t \times Q^{eff}_{i,q,t}$, with, as in equation 2, $Q^{eff}_{i,q,t} = Q^{base}_{q,t} \times FactorProd^{general}_{i,t}$. $FactorProd^{spec}$ does not occur here, because specific human capital is zero at the time of hiring.

The individual compares this value with the employability threshold *employabilityThreshold* defined as exogenous parameter and decides to start a search if $EMPLOY_i >= employabilityThreshold$.

Evaluating the current position Every month, the individual receives information about $NPros$ new jobs p prospected. This list of known jobs is obtained by randomly drawing a list of jobs among all job vacancies of *JobAds* which match the current qualification of the individual. On the basis of these informations he receives on these jobs, he assesses the interest to start looking for another job .

We denote $UTIEMP_{i,p}$ the utility of the position p of the firm j prospected by the individual i :

$$UTIEMP_{i,p} = (S^{expected}_{j,q(p),t} + Amen_p + Stab_{i,p})^{1-\alpha_i}(L-T)^{\alpha_i} \tag{20}$$

$Amen_p = PrAmen \times S^{base}_{j,q(p),t=crea}$ is the expected amenity of the contract, and $S^{expected}_p$ is the expected job salary if the individual is hired. This expected wage is calculated from the proposed salary associated with the job, $S^{base}_{j,q(p),t=crea}$ (cf. equation. 9). The effective salary paid to the employee at the moment of his recruitment will also depend on his level of experience and on the tension on the labor market (from the equation 10). Then we have :

$$S^{expected}_{j,q(p),t} = S^{base}_{j,q(p),t=crea} \times F_{\beta_q}(Experience_{i,t}) \times G(ITENS_t) \tag{21}$$

Evaluating new jobs The utility of new jobs $UTINOUV_{i,t}$ is initialized to 0 whenever an individual changes his state. It is then updated at each period with a function of the average of the prospected jobs utilities according to following equation :

$$UTINOUV_{i,t} = max(UTINOUV_{i,t-1} \times ITENS_t, \sum_{p=1}^{NPros} UTIEMP_p \times ITENS_t) \tag{22}$$

Deciding to change (or not) At this stage, the employee compares the utility of his current job with $UTINOUV_{i,t}$. In this comparison we introduce an exogenous parameter $ICHANG$, which is the *psychological cost to change* and reflects the *inertia of individuals* in their decisions against change.

If $UTINOUV_{i,t} < ICHANG \times UTIEMP_{i,t}$, the individual is satisfied with his current job and his decision-making process is over. Otherwise, he decided to begin a job search.

3.3.2 Employee (PAE) decisions

In this section, we describe the behavior of an employee i occupying the position p at qualification q in firm j at time t.

Decision to become inactive At first the employee must decide if he wants to quit and become inactive. To do so, he compares the value of his present job $UTIEMP_{i,t}$with the utility when inactive $UTINAC_{i,t}$. We have :

$$UTIEMP_{i,t} = (S^{eff}_{i,j,q(p),t} + Amen_{p,j} + Stab_{i,p})^{1-\alpha_i}(L - T)^{\alpha_i} \tag{23}$$

$$UTINAC_{i,t} = (Income)^{1-\alpha}(L)^{\alpha} \tag{24}$$

If the individual is under 25, he will not get any social welfare (RMI), but gets instead a family help $familyHelp_i$ randomly chosen in the interval $[0, MaxFamilyHelp]$: $Income = familyHelp_i$. If the individual is more than 25 years, $Income = RMI$.
If $UTIEMP_{i,t} < UTINAC_{i,t}$ then the individual quits and goes out of the labor market. Otherwise he moves to the next step.

Choice to search a new job as unemployed or as PARAE If an employee decides to seek a new job, he could do so as PARAE or as an unemployed after quitting. As job search takes time, a resignation may be advantageous. On the other side, a PARAE can avoid a drastic reduction in his leisure time by searching less intensively than an unemployed. The number of jobs observed by a PARAE per period is a fraction (defined exogenously) of the number of jobs observed by an unemployed. The expected duration is however longer for a PARAE. Therefore the individual calculates the utility for each choice.

Reservation utility update In case of resignation or transition to PARAE, the reservation utility of the individual $UTRES_{i,t}$ is computed from the list of all the jobs known during the free search :

$$UTRES_{i,t} = Param1_{UTRES} \times (1 + Param2_{UTRES} \times \frac{UMAX}{UMIN}) \times UTINOUV_{i,t} \tag{25}$$

with *UMIN* and *UMAX* the minimal and maximal utilities of known jobs.

Notice that if an employee become unemployed because of a firing, $UTRES_{i,t}$ is initialized at $UTIEMP_{i,t}$, the utility of present job : the individual has no higher requirements that finding a job with the same amount of utility as the job he just lost.

3.3.3 PARAE employee decisions

In this section, we describe the behavior of an employee i, occupying the position p, at qualification q,ă in firm j, at time t *and looking for another job.*

The individual first checks if he would rather become inactive or not. Then, at each period, the PARAE updates its reservation utility $UTRES_{i,t}$:

$$\begin{aligned} UTRES_{i,t} = UTRES_{i,t-1} - min(Param3_{UTRES}, Param4_{UTRES} \times SearchTimeInPeriod) \\ \times max(0, UTRES_{i,t-1} - UTINOUV_{i,t})); \end{aligned} \tag{26}$$

He stops to look for another job (and becomes PAE) if his reservation utility falls below the threshold value of his present job $UTIEMP_{i,t}$.

3.3.4 Inactive person decisions

The inactive person compares the utility of his present state $UTINAC_{i,t}$ (eq. 24) with the utility $UTINOUV_{i,t}$ of a new job. The utility of new jobs $UTINOUV_{i,t}$ is initialized to 0 whenever an individual changes state. It is then updated period after period as a function of the average of the prospected jobs utilities according to equation 22.

Then a psychological change factor ICHANG is applied, so that if $UTINOUV_{i,t} < ICHANG \times UTINAC_{i,t}$, the inactive stop to search. Otherwise, he decides to look for a job and become unemployed.

After assessing employability and research interest, if the inactive chooses to look for a job, he must set a level of reservation utility (aspiration level) $UTRES_{i,t}$,ă that he will compare to the utility of every job prospected to decide if he candidates or not. The utility $UTRES_{i,t}$ is computed using information already obtained during the free search. In our model we set $UTRES_{i,t}$ to $UTINOUV_{i,t}$.

Setting $UTRES_{i,t}$ ends the decision process for the inactive, and he will start to a job search, so his state switches to unemployed.

3.3.5 Unemployed person decisions

The unemployed person first calculates the utility of his present state:

$$UTICHO_i = (ALCHO)^{1-\alpha}(L - DUREC \times NBPROS(C))^{\alpha} \tag{27}$$

$ALCHO$ is the unemployment allowance he eventually gets if he meets the corresponding requirements. If so the allowance is calculated from the basic salary of his qualification level.

$UTRES_{i,t}$ is set at the time of transition to unemployment, using eq 25. At each period the unemployed person updates his reservation utility $UTRES_{i,t}$ in two steps: first he applies the equation 26 ; then he takes into account the number of application refusals[19] $NbRefus$:

$$\begin{aligned} UTRES_{i,t} = UTRES_{Temp,i,t} - min(Param3_{UTRES}, Param4_{UTRES} \times NbRefus) \\ \times max(0, UTRES_{Temp,i,t} - UMIN)) \end{aligned} \tag{28}$$

with $UMIN$ is the minimum utility encountered during the job search during this tour.

If $UTINAC_{i,t} > max(UTICHOi, t, UTRES_{i,t})$, the unemployed becomes inactive. Otherwise, he keeps searching for a job (see 3.3.7 below).

Furthermore, if the search duration of an unemployed exceeds a threshold *(*denoted *downgradeTime*), or if the number of failures experienced by the unemployed exceeds a threshold *failureThreshold*, the unemployed decides to seek at a lower qualification level (one degree below).

3.3.6 Student decisions

Given the variety of possible situations, we found difficult to model the behavior of students in this first version of WorkSim. We took a “black box” approach,simply aiming to reproduce the flow of students towards the activity on the labor market in 2007.

Students make decisions with random drawings at different ages : at 15 and 20, students have probabilities respectively 0.858 and 0.321 to stay student, otherwise they enter the labor market with the unemployed status. These probabilities allow us to reproduce the enrollment rates of the age groups 15-19 and 20-24, source INSEE[29]. At 25, we make the simplifying assumption that all students automatically enter the labor market[20].

When entering the labor market, their qualification level is randomly drawn according to a distribution that correspond to the distribution of socio-professional categories for the age group of 15-25 in 2007 (INSEE source [24]).

[19]Here, a *refusal* occurs when the unemployed persons refuses to apply for a job proposed by JobAds, finding this job not appealing (i.e. falling under his reservation utility).

[20]Although, in 2007 in France, a little less than 10% of students pursue their studies after 25 years.

3.3.7 Job search process

After describing the different decision mechanisms, let us now detail the overall job search process :

1. At the beginning, the individual asks *JobAds* for a list $NPros$ vacancies matching its qualification level *q* or a higher level of qualification (*q+1)*. Among these jobs, the proportion of jobs qualification $q+1$ is given by :

$$ProbaPosition_{q+1} = min(1, Param1_{qualif} \times Experience_{i,q,t} + isDowngraded) \quad (29)$$

   $isDowngraded$ worth $Param2_{qualif}$ if the individual seeking a new job is currently at a level of qualification below its original level of qualification, it is 0 otherwise. $Param1_{qualif}$ and $Param2_{qualif}$ are two exogenous parameters.
   The distribution of FDC and OEC jobs sent by JobAds depends on the characteristics of the individual. According to Bunel (2007) [15] "FDC are unequally distributed and are mostly offered to youth, women and workers with low job experience". To take this stylized fact into account, each OEC job *JobAds* might offer has a probability $PrDispoCDI < 1$ ăăto be actually available each period for the job seeker. Hence, the smaller this probability is, the bigger the proportion of FDC (among the *NPros* proposals) received by the jobseeker is. This probability will differ with age and gender of the individual, again according to Bunuel 's findings.

2. The individual applies each period for the best offer (i.e. with the greater utility $UTIEMP_{i,p}$, cf. eq. 20) he receives and which exceeds his reservation utility $UTRES_{i,t}$.

3. Furthermore, an employee (PAE or PARAE) whose seniority in the company exceeds a threshold $SeniorityThreshold$ will automatically apply for internal offers in their firm (promotions) at qualification level *q+1.*

3.4 Hiring phase and promotions

Now some job seekers have sent their applications, let us examine of a firm j will process them .

3.4.1 Sorting candidates and potential hiring

A two-steps process takes place. It is similar to the job sorting made by the individual in section 3.3.7. First the firm computes a score for each candidate (internal or external), then the best candidate is selected. Thereafter, the firm checks if this candidate exceeds the hiring norm. If this is the case, the candidate is hired, otherwise, the job remains vacant.

Candidate score calculation The score for each candidate i is computed as the expected profit $\Phi^{estimated}_{i,j,q(p),t}$ when the candidate is hired for the position p (whose expected productivity is $Q^{expected}_{j,q(p),t}$).

For each candidate, the human resources department calculates:

- The expected income if the individual i is hired for this job:

$$R^{expected}_{i,j,q(p),t} = P \times min\left(Q^{expected}_{j,q(p),t}, Q^{estimated}_{i,j,q,t}\right) \quad (30)$$

  with $Q^{estimated}_{i,j,q,t}$, the estimated productivity of the individual as determined by the equation 7.

- The expected cost :

$$C^{expected}_{i,j,q(p),t} = S^{estimated}_{i,j,q,t} \times (1 + PayTaxes) \quad (31)$$

  with $S^{estimated}_{i,j,q,t}$, the estimated salary of the individual determined by the equation 9.

- And finally, the expected profit of this hiring :

$$\Phi^{expected}_{i,j,q(p),t} = R^{expected}_{i,j,q(p),t} - C^{expected}_{i,j,q(p),t} \quad (32)$$

The candidate with the highest profit is selected.

Passage of the hiring norm If the profit of the best candidate exceeds the hiring norm calculated at the time of creation of the post (cf. 3.2.3) then the individual is hired.

The employee receives a message from the company and the type of contract (FDC/ OEC) is assigned to the job. The company then sends a message to JobAds to remove the publication of this offer.

Internal promotion If the best candidate hired was an internal candidate of the company, it is a promotion. The employee receives the qualification level of the job, if he does not already have this level.

3.5 Demographic Processes

Births Each year, for each woman agent, we perform a random draw according to the birth rate of her age group in order to know if there is a new birth.

This random selection is performed according to fertility rates calculated by INSEE [30].

A birth change the α factor of the agent (cf. [7, 5.2.4]), which alters the preference for leisure.

Death The mortality rate was 8.3% in 2007. When an individual dies, his job becomes vacant. We introduce a new individual at the age of 15 years in the simulation, in order to keep the same number of agent in the model.

Retirements When the agents reach the age of 65[21], they are removed from the simulation. When an individual employee retires, his position becomes vacant. We introduce a new individual at the age of 15 years in the simulation.

Entries on the labor market As see above, each time an agent leaves the simulation, we introduce one new agent at the age of 15 years.

The new agent will be a student with a probability of 0.858 [29] or on-the-job search and therefore unemployed.

New active entrants receive a qualification level, executive, middle level or employee / worker, according to a probability distribution which is the distribution of the socio-professional category age 15-25 years in 2007 (source: INSEE [24]).

Anticipated retirement At each period, the individuals over 50 years have a probability $AnticipatedRetireProba$ ăto retire early. The probability of early retirement depends on the age of the individual. It is estimated from the activity rate of seniors in 2007 (source DARES 2008 [17]).

[21]The maximum legal age to retire with a full pension in France.

4 Model calibration

4.1 Calibration objectives

The aim of this section is to determine the values of the model parameters in order to reproduce the structure of the French labor market in 2007. To do so, three distinct objectives may be selected :

1. Replicating as many as possible important characteristics of the labor market : unemployment rate by age and qualification level, wage levels, unemployment duration...
2. Reproducing flows of the labor market to get an internal dynamic of the market as realistic as possible : employment entry and exit rate by contract type FDC or OEC, quit rate, layoff rate...
3. Reaching a stochastic equilibrium to stabilize the model outputs before performing an analysis of variants around the calibrated point.

It is obviously impossible to achieve completely these three goals at the same time. For example, if one obtains a solution which reproduced simultaneously the unemployment rate and the employment entry and exit rate of the 2007 year, this solution can not be stable because the real employment entry and exit flows are not equivalent, which has the consequence of drifting the unemployment rate over time. This comes from the fact that the real labor market is never in a stochastic equilibrium.

So we choose to achieve the calibration objectives 1 and 2 mentioned above for the year 2007, without searching for a stochastic equilibrium at any cost[22]. The approach of calibration is more realistic than the one usually retained in the literature of ACE[23] labor market models which aim to get a stochastic equilibrium of the market but do not reproduce the real flows.

4.2 Two types of parameters

The WorkSim model includes two types of exogenous parameters. The first ones are given by the institutions (minimum wage level (called SMIC in France), legal trial period duration, unemployment benefits), by available statistical data (demography) or by econometric studies on the labor market.

The second type are internal parameters which have to be calibrated (see appendix B A for the list). We have 50 parameters to calibrate, including for example the initial preference for leisure (Cobb-Douglas work/leisure), or the number of job offers prospected per period by an unemployed person. For each of these parameters, admissible range of values are selected to avoid non realistic behaviors of the agents at the microeconomic level.

4.3 Minimization of a fitness function

To calibrate these parameters we minimize a *fitness* function which is the sum or the relative spreads between the outputs of our model measured after 200 periods (id. 4 years in the reality) and real targets of the French labor market in 2007. We choose 36 main targets regrouped in 5 different categories :

1. 7 targets on unemployment rate (source INSEE [27]) : global unemployment rate, by age range (15-24, 25-49 and 50-64 years old) and by qualification level (executives, intermediate professions, employees/workers)
2. 6 targets on activity rate (source INSEE [28]) : activity rates by age range (15-24, 25-49 and 50-64 years old) and by gender
3. 15 targets on wages (source INSEE [26]) : net wages by age range (less than 30, 30-49, 50-59 and more than 60 years old) and by qualification levels
4. 4 targets on long-term unemployment (source INSEE [27]) : global long-term unemployment and by age range (15-24, 25-49 and 50-64 years old)

[22]Consequently, when we will perform tests of new labor policies, we will have to correct the effects of internal model drifts on the results

[23]Agent-based Computational Economics

5. 4 targets on labor flows (source DDMO/DARES [16]) : global employment entry rate [24], employment in FDC entry rate, employment in OEC entry rate and global employment exit rate.

In addition, other targets will be retained for the model validation, but no attempt will be made to calibrate them precisely. We will simpl check that they are in the same order of magnitude as in reality :

- Net incomes of half time jobs, inactive, employment persons by age and qualification
- Detailed employment entry and exit rates : fixed-term contract (FDC) end rate, transitions rate from FDC to OEC, quit rate, layoff for economic reasons rate, layoff for personal reasons rate, end of trial period rate
- PARAE[25] agents rate in the simulation
- Unemployment length and duration of the spells of unemployment by age range and qualification
- Part-time work proportion in employment
- Average seniority and contract duration of jobs in FDC and OEC
- Yearly transition rates between inactive, unemployed and employed states

4.4 Calibration method

To minimize our fitness function, we have to resolve a continuous optimization problem. We choose the evolutionary algorithms CMA-ES [26] (Hansen & Ostermeier 2001) [22], which is currently one of the most efficient to optimization algorithm [3]. The first step is an exploration phase. We start form a set of randomly initialized parameters and use a reduced set of agents (3000 individuals and 500 firms) in order to explore the parameters space faster.

Each simulation is launched after an initialization phase of our model corresponding to a scaling of the French labor market in 2007. Then one set of parameters is tested and the corresponding simulation output is averaged on 10 simulations [27].

Each time we reach an interesting point, i;e. with a fitness around 10^{-1}, we proceed to a more refined local search with the final number of agents (13500 individuals and 2250 firms, see appendix B B for the detail of this scaling) around this point. To improve the accuracy the fitness is now measured with an average on 50 simulations.

Once the model have been calibrated, we get a curve of the unemployment rate over time like the one presented in figure 1. The different rates converge to the calibrated values at 200 periods (corresponding to 4 years in reality). We observe a small internal drift of the model after this calibrated point. In further works, we will try to correct this internal drift effect.

[24] Number of entries in employment during one year over the average number of agents employed during this period

[25] Employed person on-the-job-search

[26] Covariance Matrix Adaptation Evolution Strategy

[27] The model is stochastic, therefore at each step of model fitness evaluation by the algorithm, we have to run the model a large number of times and average the obtained fitness because the results may vary from a simulation to another due to the randomness of our model.

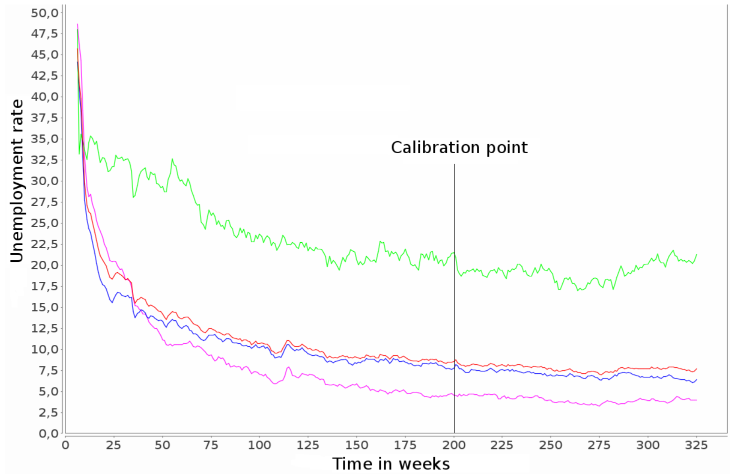

Figure 1: Time variation of unemployment rate during one simulation. In red, global unemployment rate, in green, 15-24 years old unemployment rate, in blue, 25-49 years old unemployment rate and in pink, 50-64 years old unemployment rate

4.5 Model validations

4.5.1 Calibration on priority targets

Table 6 in appendix A below displays the results for priority targets by performing calibration over 200 periods with 13500 individuals and 2250 firms, and an average of 50 simulations (rate below are in %). Calibrated parameters values can be found in the appendix B.

These outputs of the model are overall close to the targets values (13.9% relative spread in average) and no one differs more than 40% from the target. The less accurate outputs concern employees/workers wages, the lowest qualification of the model, with salaries below 35% far all age range. These wages are overall too close to the minimum wage (985 in 2007). A way to improve this could be a more refined modeling of the different qualification levels by adding for example a new level of "skilled worker", because these skilled workers earn usually a salary well above the minimum wage.

Another limit of the current calibration is related to long-term unemployment. The long-term (> 1 year) unemployment is realistic and young people stay unemployed less time than seniors, but we nevertheless observe not so much differences between age ranges.

Seniors (50-64) unemployment rate is less than the reality (-35%). This might be because we lack a discrimination mechanism from the firms towards seniors with long-term unemployment. We do not model neither senior human capital obsolescence, nor a reduction of their productivity as manual laborers, nor a possible decrease of their capacity for innovation and adaptability in intellectual professions.

Furthermore, less than 25 years old long-term unemployment rate is greater of 34% than in reality. Here we might lack a internships in the mode, and also agency work that concern mainly these young people excluded from FDC and OEC.

4.5.2 Comparison of simulated flows with DMMO survey

It is also of interest to verify whether others types of outputs, which were not in our fitness function, are accurate or not. Therefore, we compare workforce turnover by age range calculated by WorkSim with the same turnover calculated by DARES and based on *Déclarations mensuelles des Mouvements de Main-d'Oeuvre (DMMO)* and *Enquête sur les Mouvements de Main-d'Oeuvre (EMMO)* [16].

These entry and exit rates are ratios between global entry or exit number during the 2007 year over the number of employed persons at the beginning of the year.

	WorkSim outputs				Source : Dares, DMMO/EMMO			
	Global	< 30	30 to 49	> 50	Global	< 30	30 to 49	> 50
Turnover rate	**41.6**	**109.6**	**38.4**	**22.3**	45,7	104,2	30,5	23,1
Entry rate	**42.2**	**116.2**	**39.8**	**18.7**	46,3	110,6	30,8	18,6
Entry in FDC rate	**27.8**	**82.4**	27.1	**7.9**	30,3	78,9	17,9	11,7
Entry in OEC rate	**14.4**	**33.8**	**12.7**	10.7	12,0	26,0	9,4	4,2
Exit rate	**41.3**	**103.5**	**37.2**	**26.1**	45,0	97,7	30,2	27,6
Exit for FDC end	**21.5**	**58.6**	21.6	**7.0**	23,5	65,8	15,0	10,7
Quit rate	4.7	**22.6**	3.1	1.1	7,9	17,2	6,4	2,2
end of trial period rate	7.8	18.1	7.5	4.4	2,0	5,1	1,3	0,5
layoff for eco. reasons rate	0.18	0.2	0.19	0.14	0,6	0,3	0,6	0,8
layoff for other reasons rate	4.7	4.0	4.9	4.6	2,5	3,1	2,3	2,4

Table 1: Comparison of turnover rates by age range WorkSim/Dares

It is remarkable to note that most work flows calculated by WorkSim are very close to DMMO (data in bold), which make our model quite consisternt.

We notice however some gaps which suggest improvement recommendations of our model :

- The excess of end of trial period rate indicates either a too rapid information gain on employee real productivity or that the decision taken by firms to stop a contract after the trial period should be more costly, lowering the threshold of acceptable benefit for this employee. We might for example include training costs already spent since the beginning of the contract.
- There are also seniors with a too small rate of redundancy and a rate of recruitment in OEC too high. As already discussed above this might come from seniors who are not sufficiently penalized by firms in our model. Currently productivity increases with experience, and the salary in proportion, while in reality productivity is likely to decline at the end of a carrier.

4.5.3 Comparison of annual transition rates with *Enquête Emploi* (employment survey)

We now compare the annual transition rate of individuals calculated by the model with those obtained empirically from the employment survey *Enquête Emploi* (Jauneau 2011) [31].

These transitions from this employment survey are based on questionnaires by comparing individual states a year n and a year $n+1$. These numbers are divided by the total number of individuals questioned in order to get the annual transition rates [28]

	Simulated by WorkSim transitions	2007 Transition from employment survey
Unemployment into Employment	**2.46%**	**2.4%**
Employment into Unemployment	**1.31%**	**1.6%**
Inactivity into Employment	1.16%	2.9%
Employment into Inactivity	0.85%	2.1%
Unemployment into Inactivity	0.16%	1%
Inactivity into Unemployment	0.41%	1.4%
Employment into Employment	**59.43%**	**60.8%**
Unemployment into Unemployment	4.27%	2.3%
Inactivity into Inactivity	29.94%	25.6%

Table 2: Comparison of annual transition rates WorkSim / employment survey

The transition rates between the employment and unemployment obtained with our model are very similar to the 2007 rate obtained from the employment survey. Transition rates associated with inactivity are however

[28] One can notice that these flows capture the transitions between two dates separated by a full year, but do not capture the intermediate transitions that have been there during the year, unlike those calculated from DMMO rates. Therefore they underestimate the mobility.

rather poorly matched. One reason for explaining this difference is the absence of households in WorkSim, which have a significant role in the decisions of transition to inactivity for individuals in reality. To improve the model the decisions should be taken at the household level. In that case, an inactive person could, for example, make the choice to look for a job if his spouse loses his own and becomes unemployed, even if his preference for leisure is high.

4.5.4 The characteristics of unemployment

The WorkSim model allows to compute detailed data on the characteristics of unemployment by age range and qualification level :

	Global	15 24 years	25 49 years	50 64 years
Long-term unemployment - more than 1 year	42.2%	38.07%	44.2%	44.5%
Long-term unemployment - more than 2 years	33.8%	26.3%	35.6%	35.8%
Average Unemployment length (in month)	18,2	15.8	19.6	19.8
Average duration of unemployment spells (in months)	2.9	2.5	2.72	4.74

Table 3: Characteristics of unemployment by age in WorkSim

First we note that the average duration of unemployment spells is much lower than the average unemployment length. This reflects both a *composition effect* (the most employable of the unemployed individuals find a job quickly) and a decrease of exit rate when unemployment seniority increases. The statistics of *Pôle Emploi* confirm this hierarchy if we consider that the duration can be measured by the average registration duration of job seekers in categories A, B, and C removed from the lists during the previous month. It is then 8 months in 2007 against 13.9 months for unemployment length [27]. In the simulation we found a shorter average duration (2.9 vs 8), mainly because in our model, an unemployed person who gets discouraged and becomes inactive just one week in the model closes a period of unemployment, whereas this is not the case in statistics of *Pôle Emploi.*

The long-term unemployment is very well reproduced as a proportion of total unemployed persons. On average, in our model, 42.2% of the unemployed persons have been unemployed for more than 1 year (which is very close to the 40% rate obtained by using the employment survey [25]), with more than half of them for more than 2 years. 35.8% of unemployed persons above 50 years old look for a job for more than two years (38% rate obtained by using employment survey [25]).

In table 4 below, we study the impact of qualification on unemployment.

	Employees/Workers	Intermediate professions	Executives
Long-term unemployment - more than 1 year	47.8%	21.4%	14.6%
Long-term unemployment - more than 2 years	38.9%	7.4%	2.0%
Unemployment length (in month)	21.0	8.2	6.0
Average duration of unemployment spells (in months)	2.8	3.6	3.2

Table 4: Characteristics of unemployment by qualification in WorkSim

The lowest level of qualification is the most affected by long-term unemployment with the longest length of unemployment (21 months in average), but shows the shortest average duration of unemployment spells (2.8 months). This is not contradictory and can be explained by the fact that some of the unemployed persons are significantly excluded from employment, while others are unemployed intermittently between two short fixed-term contracts, for example, which lowers average duration of unemployment spells.

5 First characterizations of the French labor market with simulated flows

In this final section, we aim to analyze the structure of the labor market based on the stock-flow diagrams for the individuals, then try to explain what could be the factors affecting unemployment by performing variants analysis.

5.1 Flow Diagrams of individuals and characterization of the French labor market

In this section, we present the flow diagram for all individuals and by age range (15-24, 25-49 and 50-64 years old). Each type of flow is measured in two ways. The percentage in brackets indicates the proportion of agents of a group who change state. This is actually a probability of transition to a state per period for a given agent. These probabilities are very low because they are calculated on a weekly basis but they show perfectly the relative probabilities to change state. The numbers associated with the arrows indicate the average number of agents who move from one state to another each period. The thickness of the arrow in the diagram shows the "flows strength" compared to the other flows.

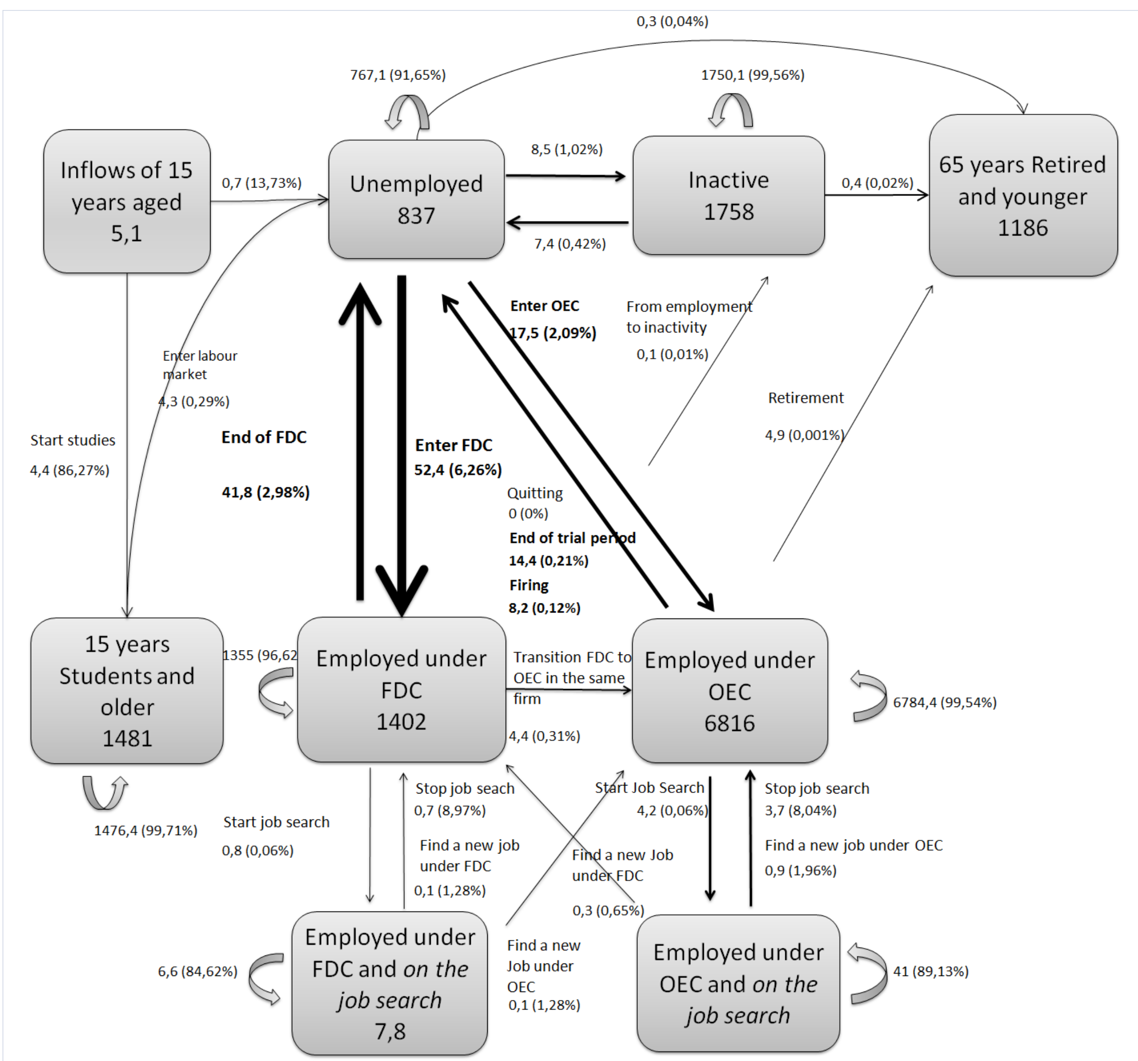

Figure 2: All individuals

In the diagram of all individuals (Figure 2), the labor market is characterized by high rates of rotation between the status of "unemployed" and "Employee in FDC". Entry rates in FDC are about two times greater than the rate of direct entry in OEC. Exit to unemployment is also a major stream, the second in size. The conversions of FDC into OEC represent only 10% of the exits, the others persons go to unemployment. Therefore, an important part of agents alternate short periods of temporary work with periods of unemployment. Besides these "precarious" status, the majority of employees are employed in very stable OEC, even if some of these permanent employees are always looking for another more attractive job in OEC (transition to the PARAE state [29]).

One of the most important question of characterization of the labor market is the existence of a *segmentation* (or *dualism*) into a precarious part and a stable part. If so, another issue is whether this segmentation is durable for individuals or temporary. Durable segmentation has serious effects in terms of well-being on the cycle of life and risk of exclusion. A temporary segmentation is a long-term integration after a difficult period for a more or less fraction of young people and has very different effects on the life cycle [30].

To answer, we need to split the diagram by age groups for further analysis, as depicted in the following Figures 3 and 4 below.

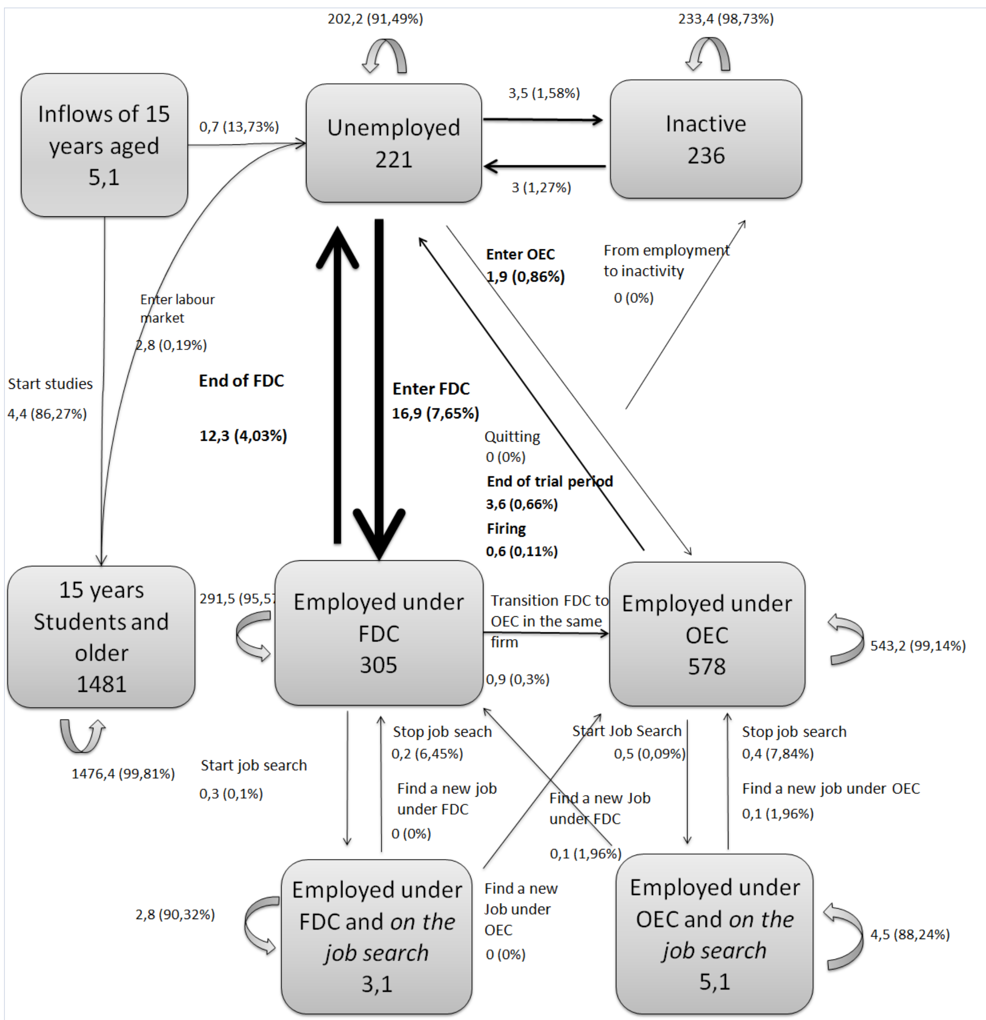

Figure 3: 15-24 years old individuals

[29]The number of PARAE is very underrated in the simulations, but we have not considered that it was a priority to take into account this stock in the fitness function

[30]This distinction would call developments for which we do not have space in this paper, as well as an extensive explanation of the results. See Ballot (2002) , p.72, who distinguishes static and dynamic segmentation.

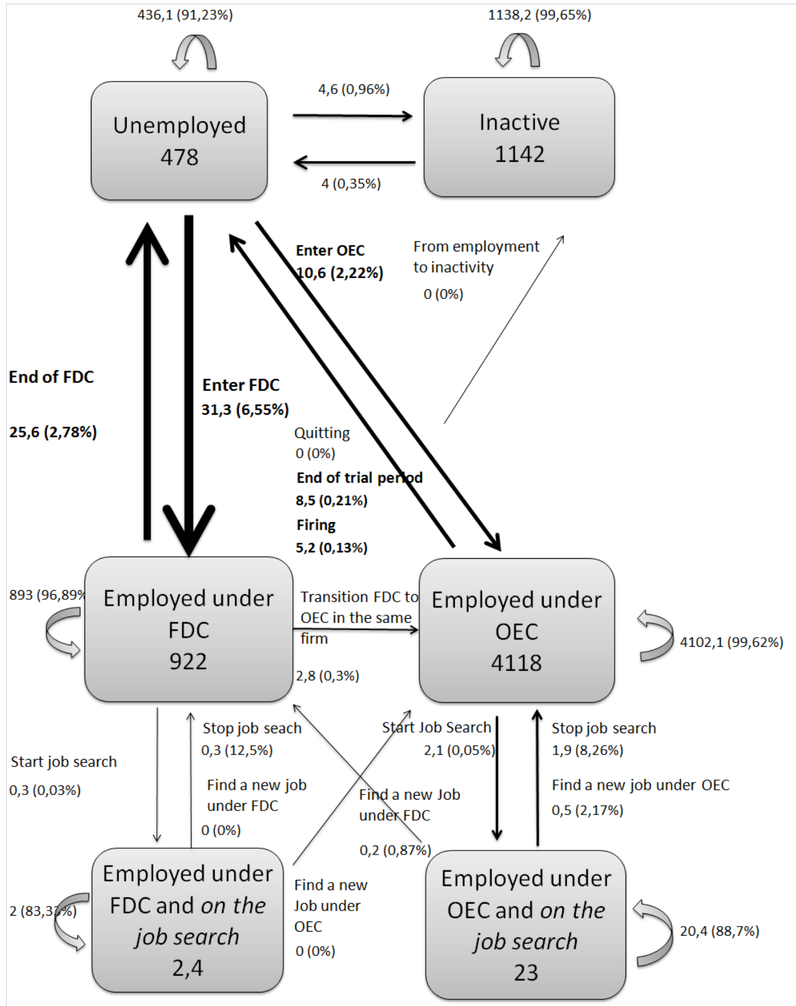

Figure 4: 25-49 years old individuals

The flow diagrams appear very different between the three age classes. 15-24 years old people (Figure 3) are much less stable than the other categories of agents (figures 4 and 5).

The flow diagram of the young people is characterized by two mobilities that distinguish them from the flows of the other age ranges. The first one is a double flow between unemployment and FDC. This flow is more important than the average. The second mobility consists of transitions between unemployment and inactivity which are more frequent than the average. The mobility diagram is then characterized by an instability of a fraction of youth, the others finding OEC which are stable (less than 1 layoff for 15 ends of fixed-term contracts).

The flow diagram of 25-49 years old people is characterized by a significantly higher stability. The double flow between unemployment and FDC remains significant but weaker and the double flow between inactivity and unemployment is low. The present model results suggest[31] then a persistence of segmentation in the transition from youth to middle age. The conversions of FDC in OEC rate are not very strong and recruitment in OEC neither, so that precariousness does not disappear.

[31] For the moment, we "suggest" the permanent segregation because to confirm this result, we will have to follow cohorts of 15-24 years old people during their career between 25 and 49 years age to see if the young people who alternate between FDC and unemployment do the same when they are older. This will require to run the model over a period of about 25 years.

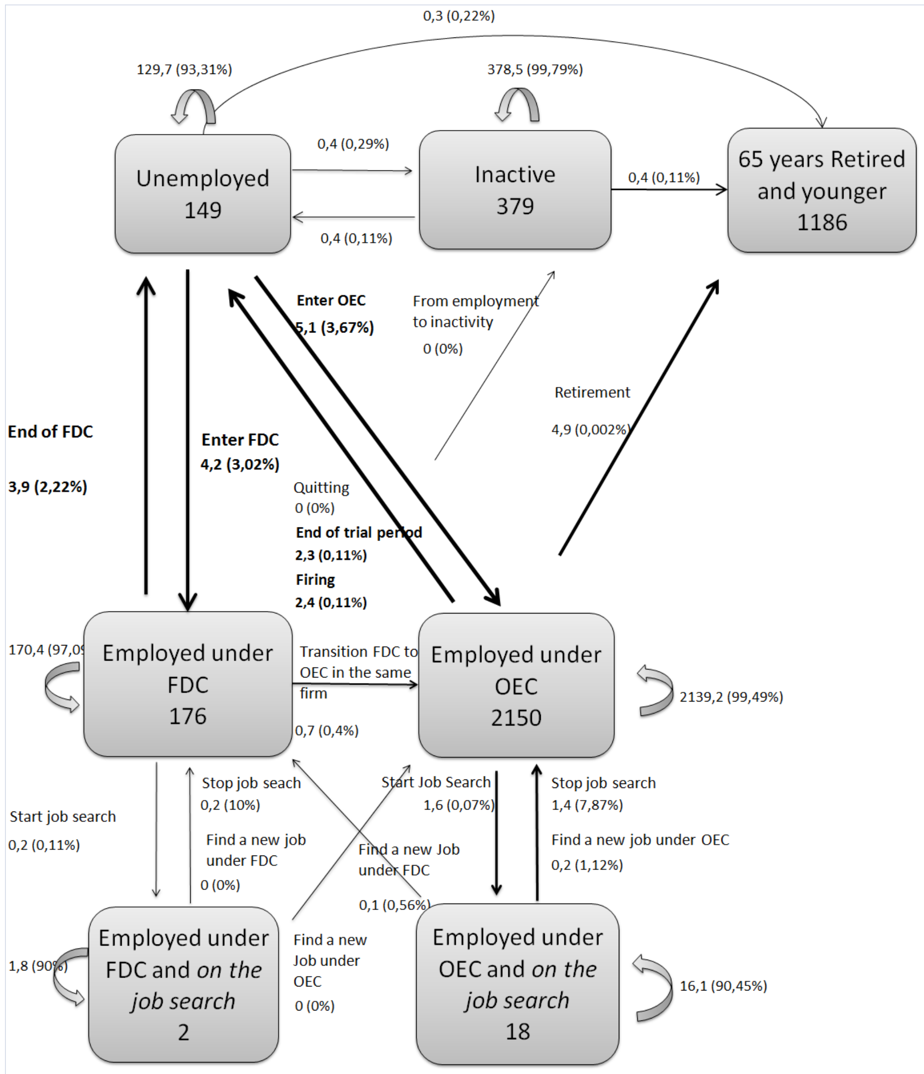

Figure 5: 50-64 years old individuals

In contrast, the market of seniors (Figure 5) is more stable than the one of 25 - 49 years old people. It is characterized by work flows really less important, with employment entry and exit rates very low due to the weak flows between unemployment and FDC. Unemployed person of this age range have the lowest probability to enter into employment (about 7% of the unemployed person find a job each period), which is the explanation of a high level of long-term unemployment in the 50-64 age group. A distinctive flow appears : the main reason of employment exit (in absolute terms) is the transition to retirement (36% of the exit reasons).

A disaggregated analysis by qualification levels of workforce will not be detailed here because of the lack of space. Its main conclusion is that the flows between FDC and unemployment are concentrated on workers and employees without disappearing into the other categories.

5.2 Variants analysis

Another benefit of ACE models is that one can easily study the *sensitivity* of each parameter on the microscopic behaviors of agents and the outputs of the models. To do this, we run a set of simulation by changing each time the value of a given parameter, the others remaining to their calibrated values (see appendix B A).

These analyses variants allow us to understand more precisely the mechanisms of our model.

We present in this section studies of some sensitivity analyses that have relevant impacts on microscopic behaviors of individuals and firms :

1. sensitivity parameter ζ, the margin taken on base productivity to compute net wages. This margin is used by the firm to pay social charges, production taxes, dividends etc. (see equation 9 of the model)
2. sensitivity to the standard deviation of the productivity core of individuals, σ_{Prod} (see equation3)
3. sensitivity to α_0, the base preference for leisure of individuals (see equation 19)

5.2.1 Sensitivity to the margin taken on base productivity to determine net wages

The sensitivity curve of the unemployment rate to ζ, the the margin taken on base productivity to determine the net wages, is whosn in figure 6 to the left. It has a U-shape, with a minimum around the calibrated value. If the margins on salaries are too small ($\zeta < 0.5$), unemployment increases because firms create fewer jobs. Jobs have indeed less chance to be profitable. Conversely, if the margins on salaries increase ($\zeta > 0.7$), the wages proposed to individuals decrease and the jobs become less and less attractive for individuals, which results in a decrease in activity due to lack of incentive to work, and then an increase in unemployment rate, (reservation utility never satisfied). We notice however that when ζ approaches 1, that is to say that the firm margin is theoretically 100%, wages must remain equal to the minimum legal net wage of 985 per month (figure 6 right) limiting the expansion of inactivity and unemployment.

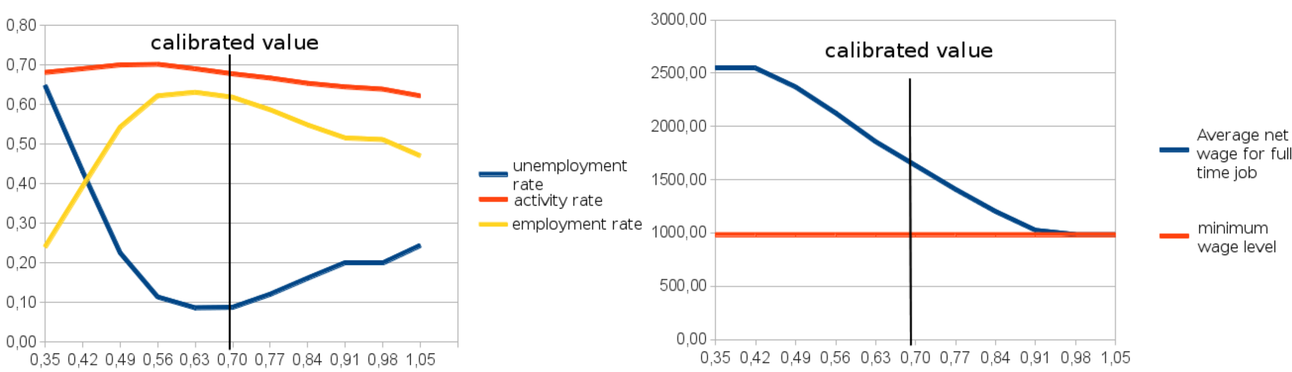

Figure 6: Sensitivity of model outputs to ζ

5.2.2 Sensitivity to the standard deviation of the individual productivity core, σ_{Prod}

When the standard deviation of the distribution of individual base productivity increases, the global unemployment rate increases slightly at the aggregate level from figure 7 (left), because the larger the spreads of productivity between individuals, the higher proportion of individuals with low levels of productivity. This accentuate at the same time the exclusionary effects on the labor market and the long-term unemployment increases (Figure 7 right). This phenomenon is more sensitive for 25-49 years old people and even more important for seniors, but it is the opposite for young people under 25 years old who see their unemployment rate decrease if the standard deviation of the distribution of productivity increases. This is explained by the fact that young people are less productive (as they have accumulated less human capital because of shorter experience) and therefore are often eliminated by recruiters when they compete for a job with older (more experienced) job seekers. When the standard deviation of their productivity core increases, it gives to a fraction of them a greater chance to be more competitive with others workforce categories. This sensitivity analysis thus highlights what we might call an "unemployment of insertion" of young people into the labor market.

Overall, unemployment rates of all ages tend to merge (the right tail of the curves in Figure 7) if the "innate" productivity distribution of individuals is high because the human capital factor has a relatively smaller weight than the productivity core in the competition for jobs between different workforce categories.

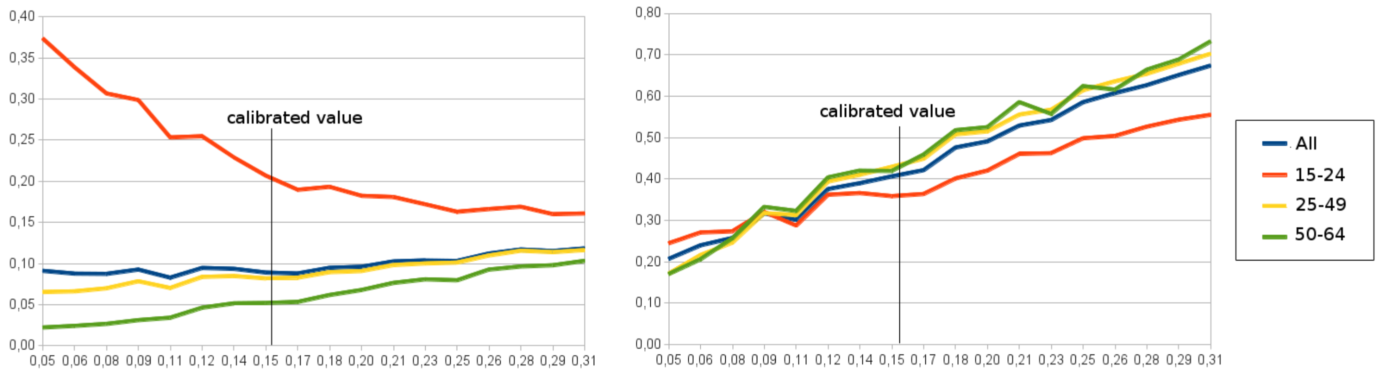

Figure 7: Sensitivity of unemployment (left) and rates of long-term unemployment (right) to σ_{Prod}. The calibrated value is 0.154.

5.2.3 Sensitivity to the basic preference for leisure

The parameter α_0 represents the basic preference for leisure individuals in the computation of the leisure parameter α (c.f. section above), which is between 0 and 1 and reflects the individual preferences for leisure. The higher α_0 , the higher is the preference for free time compared to wages and non-monetary job characteristics. As displayed in figure 8, an increase in the parameter α_0 results in a decrease in activity rates and employment rates. The long-term unemployment also decreases because the long-term unemployed persons become discouraged faster and stop their job search to become inactive. The opposite effects of the decline of activity and employment rates lead to a slight increase in unemployment rate. However, if α_0 decreases, the greater participation of workers in the labor market contribute to increase the unemployment rate, because the market can not absorb all these new active persons when the global demand remains the same.

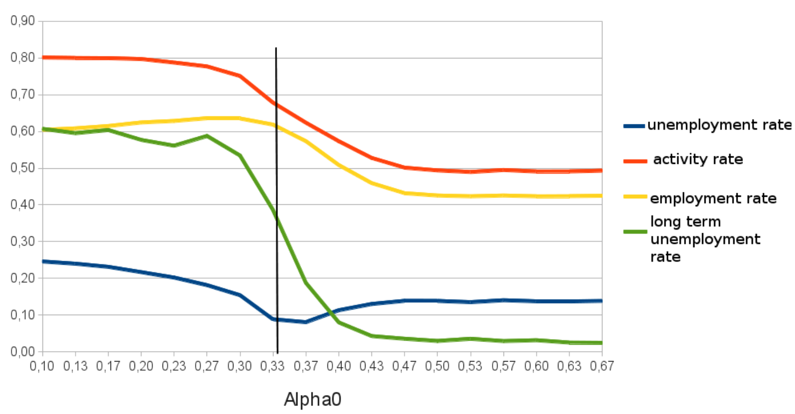

Figure 8: Sensitivity of the main outputs of the model toα_0, basic preference for leisure of individuals

5.3 Study of an exogenous shock of aggregate demand

In the previous sections, we studied the effects of variation of endogenous mechanisms of our model of the labor market. Finally, we illustrate the impact of an *exogenous* change in aggregate demand. To do so, we run the model during 200 periods with the calibrated parameters and the standard aggregate demand calculated at the initialization of the model. Once the simulation reach 200 periods we apply a multiplicative factor on the demand (demand shock) and observe the response of the model after 400 periods.

5.3.1 Response of the model to aggregate demand shock

If the demand shock is positive (aggregate demand factor greater than 1), the unemployment rate decreases, which highlight an unemployment by lack of demand in our model. The unemployment rate does not decrease to zero, while the vacancy rate becomes very important. There is thus a persistent structural unemployment (3%) due to the mismatch between supply and demand labor in terms of productivity (Figure 9).

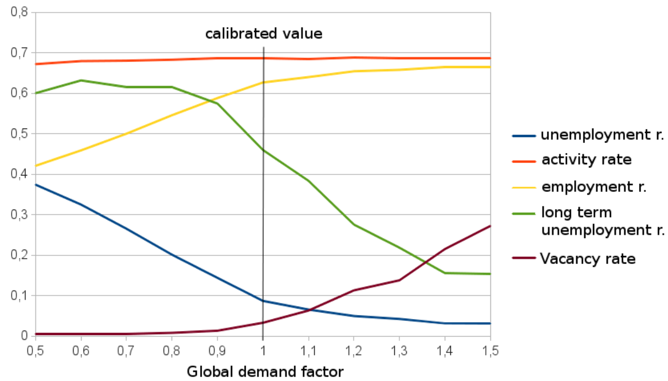

Figure 9: Model outputs after 400 periods function of global demand factor

5.3.2 Beveridge curve

These variations in aggregate demand allow us to get some couples of points of unemployment and vacancy rates to draw the Beveridge curve (Figure 10). The shift of the curve with the axes is a measure of the unemployment rate in our labor market related to the frictions in the model due to the search for information and the diversity of characteristics and requirements of agents.

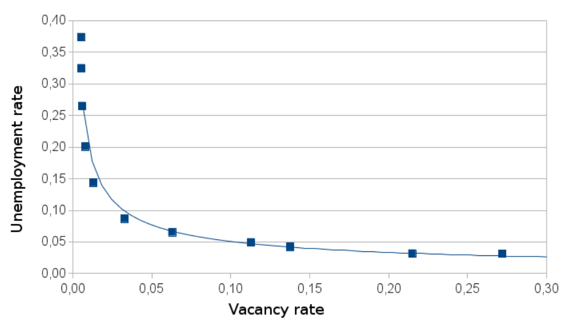

Figure 10: Beveridge curve. Unemployment rate function of vacancy rate

6 Conclusion

In this version presented here, the WorkSim model provides a comprehensive theoretical framework of the labor market. Following ARTEMIS, WorkSim is the first to bring together a number of elements, which we consider jointly essential to characterize precisely the nature of a labor market, in order to have a tool for employment policies analysis :

1. the **stock-flow accounting** of individuals is complete, and it is accompanied by a stock-flow accounting of jobs (and even positions within the company).

2. the **institutional environment** is modeled and based on labor law, which forces decisions, but may not always be respected, and it must be taken into account (e.g. for FDC).

3. the mobility is modeled through **decision-making based on bounded rationality with learning**. These decisions are decisions made by the firms **and** the individuals, both heterogeneous. They are based on a unique intellectual framework which is the search theory, theory based on the consideration of the cost of state change in a decentralized market, and extended to a general theory of mobility. This theoretical framework provides an intellectual coherence to the many decisions modeled. It also appears to have a higher analysis potential than the matching model.

WorkSim is calibrated on a large number of targets of the French labor market in 2007, by using a powerful algorithm which has not already been used in this context. It reproduces well enough these targets, so that economic analyses may be conducted. Moreover, it reproduces well and sometimes very well the gross flows measured by different statistical sources and with different types of measures, which is an important element of validation since *most of these variables are not the calibration targets*. It reproduces well gross flows of labor of the DMMO and annual transitions calculated by the Employment Survey ("enquête emploi"). Theses statistics are widely used in analyses and debates on the French labor market.

This article presents a number of preliminary analyses to characterize the French labor market. It suggests a **segmentation or dualism between workers**, some are stable in OEC because layoffs are low, some are rotating between FDC and unemployment. This dualism persists between the 15-24 years old group and the 25-49 years old group, so the paper suggests that *this dualism is permanent*, at least for a fraction of the workers. A fraction of young people do not seem to switch from FDC to OEC when they get older, contrary to the assumption of a gradual integration mechanism of young people involved by this temporary dualism. This conjecture should be refined by subsequent longitudinal analyses from simulated careers.

The sensitivity variants to some parameters show reactions of unemployment which seem to be consistent with what could be expected by economic reasoning, even if the results may be sometimes unexpected *ex-ante* because of complex interactions. For example, the share of productivity taken by the firm before the wage distribution has a non-monotonic effect on unemployment. It has a U-shape.

The labor market is very complex, and the model must be completed before studying employment policies. Naturally, the key factor is the job creation, and the model reproduces well the massive effect of a sharp increase in aggregate demand on the reduction of unemployment. However, the primary objective of a model of the labor market is to study the effects of structural policies at given global demand, although *in fine* these effects can influence demand.

Future works Our research program is currently focused on a number of modules (extensions) to be integrated. The first aims to model (endogenously) the choice between FDC and OEC made by the firms. This is a complex issue that has not been solved to our sense in a formalized framework. This module will integrate the continuous training which is one of the explanation factors and a fundamental element in the labor market. Secondly, the modeling of households seems necessary in order to represent the individuals decisions, and to calculate income and income inequality. A third module will focus on a more detailed analysis of retirement to better analyze the senior market. A fourth module focuses on the analysis of careers. The characterization of the labor market requires an understanding of careers, as it was mentioned, by distinguishing temporary segmentation and permanent segmentation. Empirical analyses are very useful and can serve as a benchmark, but will never be able to reproduce full career in a cohort, due to the lack of individual data (weekly!) over such a long period (Briard 2007) [14]. The multi-agent modeling seems to be an essential tool in this area, and this is a key reason for their construction, if one want to really understand the nature of the labor market.

More ambitious extensions could be considered later in order to take into account macroeconomic relationships in our analysis. It is necessary when policies involve high financing costs, and aim to increase aggregate productivity. Relatively simple models including banks and good market with consumers have already been developed by Eliasson (1977) [18] and also in recent years. Moreover, the differentiation of firms on the goods market would be a useful step to better reproduce the dynamics of job creation and destruction, which is the primary source of the dynamics of individuals gross flows. This differentiation is done notably by taking into account physical capital and innovation, and then the investment in R & D. Finally the employment search is random in the model while social networks have a particular importance in France, and although some models have been developed in recent years, the study of network effects on careers and also on macroeconomic performance

remains to be done.

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Appendix A : Calibration results : comparison with the targets

	WorkSim outputs		Comparison with source INSEE/DARES		
	Average	Standard deviation	Target	Absolute spread	Relative spread
Global unemployment rate	8,24	1,7	8,00	+0,24	+5,21 %
15-24 unemployment rate	19,96	3,6	19,30	+0,66	+3,31 %
25-49 unemployment rate	8,15	1,5	7,30	+0,85	+10,43 %
50-64 unemployment rate	5,24	1,2	5,40	-0,16	-3,05 %
Executive unemployment rate	4,06	0,84	3,20	+0,86	+21,18 %
Middle level unemployment rate	5,86	1,5	4,6	+1,26	+21,5 %
Employee/Worker unemployment rate	10,62	2,3	10,6	+0,02	+0,19 %
15-24 men activity rate	47,87	1,4	38,10	+9,77	+20,41 %
25-49 men activity rate	98,85	0,4	94,90	+4,05	+4,09 %
50-64 men activity rate	69,38	0,7	62,10	+7,28	+10,49 %
15-24 women activity rate	32,38	1,3	31,90	+0,48	+1,48 %
25-49 women activity rate	68,99	1,5	82,80	-13,81	-20,02 %
50-64 women activity rate	54,24	0,7	54,90	-0,66	-1,22 %
$<$ 30 Executive monthly net wage in	2144	192	2200	-56	-2,61 %
30-39 Executive monthly net wage in	3124	100	3192	-68	-2,18 %
40-49 Executive monthly net wage in	3868	132	4024	-156	-4,08 %
50-59 Executive monthly net wage in	4568	80	4296	272	+5,96 %
$>$ 60 Executive monthly net wage in	5044	56	5656	-612	-12,20 %
$<$ 30 Inter. professions monthly net wage in	1684	60	1532	148	+9,02 %
30-39 Inter. professions monthly net wage in	2032	48	1792	240	+11,86 %
40-49 Inter. professions monthly net wage in	2276	40	1984	292	+12,87 %
50-59 Inter. professions monthly net wage in	2480	68	2092	388	+15,67 %
$>$ 60 Inter. professions monthly net wage in	2656	56	2272	384	+14,43 %
$<$ 30 Workers monthly net wage in	984	10	1172	-188	-19,23 %
30-39 Workers monthly net wage in	992	9	1312	-320	-32,41 %
40-49 Workers monthly net wage in	1012	6	1380	-364	-36,23 %
50-59 Workers monthly net wage in	1040	10	1448	-408	-39,16 %
$>$ 60 Workers monthly net wage in	1068	13	1464	-396	-36,95 %
Global long-term ($>$ 1 year) unemployment	42,2	6,2	40,0	+2,2	+5,5 %
15-24 long-term unemployment	38,1	6,3	25,0	+13	34,21 %
25-49 long-term unemployment	44,2	6,6	40,6	+3,6	8,14 %
50-64 long-term unemployment	44,5	7,1	60,4	-15,9	-35,73 %
Entry rate	42,2	3,5	46,3	-4,1	-9,72 %
FDC entry rate	27,8	1,8	30,3	-2,5	-8,99 %
OEC entry rate	14,4	1,7	12,0	+2,4	+16,67 %
Exit rate	41,3	3,3	45,0	-3,7	-8,96 %

Table 6: Comparison with the targets

Appendix B : Calibrated exogenous parameters of the model

Parameter	Description	Calibrated value
$\mu_{Executive}$	Mean of the distribution of base productivity of executive positions in firms	722.19
μ_{ML}	Mean of the distribution of base productivity of middle level positions in firms	689.05
$\mu_{Employee/Worker}$	Mean of the distribution of base productivity of employee/worker positions in firms	334.18
P	Price of the good in euros	1.65
σ_D	Standard deviation of weekly demand shock	0.00129
ζ	Part of the salary the company take on productivity for profit	0.699
$\beta_{Executives}$	Increase factor of general human capital with experience of executive positions	9.82×10^{-4}
β_{PI}	Increase factor of general human capital with experience of middle level positions	3.36×10^{-4}
$\beta_{Employ/Ouvrier}$	Increase factor of general human capital with experience of employee/worker positions	2.43×10^{-4}
ω	Factor for the calculation of tension on the labor market	0.02011
σ_{Prod}	Standard deviation of the distribution of individual core base productivity	0.1536
σ_0	Standard deviation of initial productivity estimation	0.05168
δ_σ	Sensitivity to seniority in productivity estimation	0.004
η_σ	Sensitivity to number of evaluations in productivity estimation	0.004
$profitThreshold$	Threshold below the firm plans to fire employees	0.0925
N_1	Parameter for hiring norm calculation	0.9013
N_2	Parameter for hiring norm calculation	0.1
N_3	Parameter for hiring norm calculation	0
N_4	Parameter for hiring norm calculation	2.84

Table 7: Calibrated exogenous parameters of the section A of the model

Parameter	**Description**	**Calibrated value**
$ProbaExecutive$	Probability to draw an executive position when the firm choose to create a new position	0.3362
$ProbaML$	Probability to draw a middle level position when the firm choose to create a new position	0.1983
$ProbaEO$	Probability to draw a employee/worker position when the firm choose to create a new position	0.4655
$ProbaFDC_{Executive}$	Probability to draw a position in FDC for an executive position	0.2504
$ProbaFDC_{ML}$	Probability to draw a position in FDC for a middle level position	0.3631
$ProbaFDC_{EO}$	Probability to draw a position in FDC for a employe/worker position	0.8535
$ProbaFDC1week$	Probability to draw a one week FDC for an executive position in FDC	0.3041
$ProbaCDD1month$	Probability to draw a one week FDC for an executive position in FDC	0.2698
$ProbaCDD2months$	Probability to draw a two months FDC for an executive position in FDC	0.064
$ProbaCDD6months$	Probability to draw a six months FDC for an executive position in FDC	0.1257
$ProbaCDD12months$	Probability to draw a twelve months FDC for an executive position in FDC	0.2272

Table 8: Calibrated exogenous parameters for the decision of new jobs creation

Parameter	Description	Calibrated value
$FDCUtility$	Maximum value of the stability criteria for a 24 months FDC	148.90
$SensiStabAge$	Sensitivity to the stability criteria of OEC	0.00688
$employabilityThreshold$	Employability threshold behond which individuals consider themselves employable	152.70
$PrLossXP$	Percentage of loss of general experience each tick after 6 months without job	1.28×10^{-3}
$PrPerteXP_q$	Percentage of loss of level q experience each tick after 6 months without job at the qualification level q	0.004
$ICHANG$	Psycological cost for change	1.143
$failureThreshold$	number failures threshold beyond which the unemployed lowers his qualification level for its search	45
$refusalThreshold$	number refusals threshold beyond which the unemployed get discourage and becomes inactive	131
α_0	Base parameter for the calculation of α parameter of individuals	0.3313
$child1_\alpha$	Parameter for the calculation of α of women	1.51
$child2_\alpha$	Parameter for the calculation of α of women	0.88
old_α	Parameter for the calculation of α of individuals	3.27×10^{-4}
$ProbaOEC_{15-24}$	Probability that a job offer in OEC proposed by JobAds is effectively available for a 15-24 years old individual seeking for a job	0.191
$ProbaOEC_{25-49}$	idem for 25 -49 years old individual	0.327
$Param1_{UTRES}$	General factor for initial UTRES calculation	2.61
$Param2_{UTRES}$	Sensitivity of UTRES to the UMAX over UMIN ratio in new jobs utilities evaluation	0.0712
$Param3_{UTRES}$	minimal value of UTRES decreasing factor each period	2.22
$Param4_{UTRES}$	Sensitivity of UTRES to the number of refusals. Parameter for UTRES evolution equation	0.0748

Table 9: Calibrated exogenous parameter of the section B of the model