Endogenous choices of contract types in an agent-based model of the labor market

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Abstract

The Fixed Duration Contracts (FDC) have taken an importance place in the European labor markets, notably in France and Spain. They represent a dominant share of the hires, although most workers hold an Open Ended Contract (OEC) at any given date. There is then a permanent coexistence of the two types of contract that we explain through a trade-off that firms compute between their costs and benefits when deciding to open a vacancy. For the first time are taken simultanously into account for the OEC the firing costs, the advance notice costs, and the losses when the firm is unable to meet the legal requirements to initiate economic dismissals. For the FDC, the specific costs are the termination costs and the waiting cost when a new FDC cannot be opened immediately after a termination. Training and vacancy costs are common to both contracts and included but they are amortized over very different durations among the two contracts and these costs influence the trade-off.

We extend WorkSim, an agent-based model of the French labor market which reproduces the gross flows of workers between the different states, employment (FDC and OEC), unemployment and inactivity. The theoretical framework is the costly search by the heterogenous agents, firms and individuals, who interact on the market, taking rationally bounded decisions but learning from their mistakes. The competition takes place in a labor stock-flow consistent framework, taking into account crowding out effects. The model is scaled and calibrated through a poweful algorithm to reach a steady state which reproduces the main observed variables in the labor market in the year 2011 with a correct fit. We generate the main effects of FDC, churning, screening, stepping stone, but also model in detail the buffer effect which is built on an option into an intertemporal decision framework with idiosyncratic anticipations of firms demand. The results of the sensitivity analysis show that pessimistic anticipations and the volatility of demand shocks raise the recourse to FDC but also unemployment. Increasing firing costs also raises unemployment but not in very significant way. Forbidding FDC does not change the employment significantly since the opposite effects of FDC seem to compensate each other. While the model puts into a unified framework the main theoretical ideas that yield the trade-off between FDC and OEC, and can be applied to different countries, it also offers sufficent detail to allow for labor market policy discussion in a given country.

1 Introduction

In this paper, we extend WorkSim, an agent-based model of the French labor market to account for the choice by employers to open vacancies either as Open Ended Contracts (OEC) or Fixed Duration Contacts

(FDC). The FDC have taken an important place in the labor market of numerous European countries, and it is specially true in France and in Spain[Bentolila et al., 2012]. The share of FDC in employment was 10% in the French private sector in 2011, while the share of FDC in hires was 80%. A better understanding of this choice is necessary to assess the effects of the nature of labor contracts on unemployment, and throw light on the interactions of these contracts with institutions of the labor market such as firing costs. There is indeed the question in many countries whether and how labor market institutions should be reformed, a concern revived by the European Commission, the OECD, and the IMF. However, the interactions between the institutions of the labor market are complex and understanding their effects requires detailed formal and calibrated models with endogenous choice of contracts, and these models are rare. In fact, our model WorkSim is the first one to account for all these effects and their consequences. A first characterization of the difference between OEC and FDC is that the former entail substantial firing costs that cannot be compensated by lower wages because part of these costs are not severance costs but red tape costs that are lost for workers. The FDC entail low termination costs. This difference in termination costs if the only one would entail that firms expecting the slighest negative change in demand would only hire on FDC, and one or several problems with FDC are necessary to explain that FDC do not crowd out OEC. These problems will be reviewed below. However avoiding costly firing costs is not the only important feature of FDC. Hiring a worker on a FDC allows the employer to obtain a better estimate of her productivity. It is a cheap way to screen workers before offering them an OEC. Moreover such a decision on giving a permanent contract (or dismissing the worker) is made compulsory in a number of countries at the end of the FDC, since renewal is often limited or forbidden. In our view, this screening role leads the employers to be less demanding in terms of required observed productivity (or hiring standard) when hiring on a FDC, since the duration is limited, and they economize on higher vacancy costs implied by a higher hiring standard. Moreover the workers hired through accumulation of experience raise their productivity during their spell on the FDC jobs and improve their probability to pass the higher hiring norm of permanent jobs after. The effect of a lower hiring standard raises the chance to obtain an OEC in the screening firm, and we call it the *screening effect*. The rise in productivity increases the probability to obtain an OEC in many firms, and we call this the *stepping stone effect*.

The FDC have then several effects on both global unemployment and on the careers of those who work on these contracts over a long period of their life. The effects on unemployment go into opposite directions. The use of FDC to avoid the firing costs of OEC entails often that at the termination, the worker is unemployed for some time before finding a new job, since she has to search and find an acceptable job, and then to be selected for hire. This is the *churning effect* exposed by [Blanchard and Landier, 2002a] and FDC hence raise unemployment. However there is the second effect of the possibility to avoid firing costs by recurring to FDC. Since employers know that they will terminate jobs at low cost if the demand falls in the future, they are more prone to hire when demand rises, than if these do not exist. The inter-temporal profit is higher. This is the *buffer effect* and it lowers unemployment. This is the effect that employers advocate most. Third the *screening effec*t allows workers whose observed (with error) productivity was too low for an OEC to be temporarily employed. Their productivity is then progressively better measured, and they have a chance to be offered an OEC in the firm. This lowers unemployment. Fourthly the *stepping stone effect*, by raising the productivity of some workers who would not have passed the higher hiring standard of OEC, lowers their risk of unemployment in the future. Normally this stepping stone effect does not entail a crowding out phenomenon, since there are some new OEC which can be opened and filled if more workers are more productive. Theoretical analysis is then not likely to sign the net effect of FDC on unemployment, and we expose here a model which takes all the four effects listed into account and is calibrated on real data to bring some light on the net effect. A detailed model is all the more necessary that the link between the existence of FDC and unemployment which emerges from econometric evidence is not clear [Alonso-Borrego et al., 2005].

The distributional effects of FDC on careers is also potentially considerable. The coexistence of the two types of contracts implies a contrasted situation between workers in fairly stable OEC, with a median duration of their job of 2 years (in France), while workers have a median duration in FDC of 2 weeks [Barlet and Minni, 2014]: Workers often undergo spells of unemployment between two FDC, and this is increased in some countries by the interdiction to renew such a contract. This dualism has important social consequences such as low yearly income and moreover, the difficulty of precarious workers to obtain a lease or borrow to buy a home. These FDC are specially concentrated on the youths (28% of the employed youths have a FDC contract, leaving apprenticeship aside, against 7% for the 25-49 age class), and additional adverse long run consequences occur if they alternate between FDC and unemployment, namely a low accumulation of experience, and the possibility of exclusion of the labor market[1].

It is therefore an extremely important issue to understand why employers recur to two types of contracts and not one. The FDC termination costs are very low compared to the firing costs on OEC, since if the FDC contract is not transformed into an OEC the employer has to pay 10% of the salary during the total contract. The main question is: why OEC still exist? They not only exist but even remain the dominant type of contract under which employees work at a given date (87% in France in 2011). We have already mentioned the legal limitations on the use of FDC. In France they are allowed to replace absent workers, but also to face a temporary increase in demand or seasonal demand. This is a substantial part of the story. There has however been a considerable increase in the proportion of FDC on the period 1984-2000 (it doubled in France), but stability over the period 2000-2011. Yet there is a considerable increase in the proportion of short FDC versus longer FDC since 2000. It hints to the desire of employers to have a substantial and higher share of employees who can be used as a buffer. The stable share of FDC may be interpreted as a ceiling imposed by the legal restrictions. In Spain, where the law has not been enforced, the rise has continued [Bentolila et al., 2012]. Another reason for the ceiling story not to be anyhow a full story for France is that some firms use a lower proportion of FDC than others, and it seems unlikely that all go to the maximum legal number, which is allowed by their own situation (absent workers, temporary rise in demand, etc), although empirical evidence at the micro level would be welcome.

To put it in a more theoretical way, in this paper our first contribution is to build a multidimensional trade-off between FDC and OEC costs, which leads firms to open some jobs as OEC and some other jobs as FDC. We can mainly concentrate on gross costs in the discussion since we consider that the job base productivity is the same for the two types of contracts and the hiring wage is the same for an identical job (a legal constraint in France). To be more precise on OEC costs, expected firing costs are not the only costs, since economic firings must be justified by a serious economic risk for the firm if the contract is not terminated, and there is some uncertainty on the judges decision if the worker sues, which can raise the cost of firing to the cost of retaining the worker. Therefore some workers on unprofitable jobs may be retained and losses occur. Moreover advance notice has to be given by the employer before firing, and this represents several months during which the worker provides a low or even zero productivity if the employer allows the worker not to work. If firing costs, costs of retaining unprofitable workers, and advance notice costs are specific to the OEC, some sunk costs occur for both types of jobs and training is the one we will emphasize. Many jobs require that the worker when starting the job, has a sufficient human capital, complementary to the technology of the job, to be productive. The employer has to pay a training fee which raises the worker's human capital to the required level[2]. While human capital theory still debates about the possibility to pass the costs of general training to the worker, it is clear that part of the specific training is not passed. When choosing the type of contract, the employer computes an expectation of these training costs. They are amortized on a much shorter duration for a FDC than for an OEC since the ratio of median duration is 1 to 50. This training cost is therefore a potential factor in the choice of contract and justifies in some cases the opening of an OEC. There is some evidence that workers on OEC are more trained than workers on FDC, and this can be taken as hint (not a proof) that employers select an OEC when training requirements are high [Booth et al., 2002]. However the amortization on a short period of the cost of training is not the only sunk cost of FDC. When a FDC is terminated, and the law does not allow for its renewal, the employer has to expend vacancy costs while searching for a new worker. Moreover some countries such as France impose, after termination, a period during which the job cannot be filled by a new FDC, that we will name "waiting period" (in French "délai de carence"). This rule is precisely in order to limit the number of FDC. Like the training cost, these costs are amortized on the short period during which a FDC is filled. Therefore the total of these costs compared to the profits obtained during the short period where the job is filled may be very high, in fact sometimes higher than these profits, and this is one explanation of why FDC do not crowd out OEC. The trade-off we build considers the four costs (training, waiting, vacancy, termination cost) for FDC, and the training, firing costs, losses caused by the impossibility to fire if the employer cannot justify that they are serious enough, and advance

[1] Junod [Junod, 2012] suggests that while being a year in a FDC raises the probability to find an OEC, two years in succession in FDC lowers this probability. More evidence is needed on this topic.

[2] Some evidence for France is given by [Lambert et al., 2009]

notice costs for the OEC.

If we consider in more depth the expected firing costs on OEC, these are not an exogenous risk for a firm when forecasting sufficiently forward its demand, but the consequence of the choice to hire (or not) an OEC today. Only those workers hired today on OEC risk to be fired at the forecasting horizon. Firing is therefore endogenous, and not (or at least partially not) the mechanical consequence of a fall in demand. The choice of one type of contract is then greatly influenced by the computation of the risk to have to fire OEC at the horizon of the anticipations of the firm on its demand. The interesting point is that this risk depends on the size of the buffer that the firm has at this horizon in terms of FDC with a low cost of termination. To hire today FDC influences the buffer at the horizon. In other words, and this will be our second contribution, we consider that the trade-off involves inter-temporal computations with an evaluation of the future options. We model a choice which rests on the computation of the cost/benefits of its consequences on the costs of adjustment at the forecasting horizon. Firms have their own anticipations on their idiosyncratic demand and they do not make only a mean scenario, since different realizations bring asymmetric consequences on the size of firing costs. They construct different scenarios about the future, optimistic and pessimistic, neutral, and weight them (possibly differently). The results will be that some firms will have more FDC in their mix of contracts than others. We will then study the main factors which affect the shares of the two types of contracts at the aggregate level and the consequences on unemployment.

[*Note: this section is preliminary and will be revised for the workshop*] There is a significant literature on the effects of FDC when coexisting with OEC. However most of these models make assumptions to obtain the coexistence which otherwise would not exist, or leave aside some of the major effects that we listed. Most of the models use a matching framework with Bellman value equations. [Blanchard and Landier, 2002b] base their argument on the rise of turnover when FDC exist. If there are firing costs (which are a waste) higher on OEC, then the employers find it often profitable not to transform the FDC into OEC at the (stochastic) end of the FDC, and to let the worker become unemployed, while they hire a new worker on FDC. The model then displays the churning effect which raises equilibrium unemployment. FDC constitute a trap of precariousness, not a stepping stone. The model assumes exogenously that entrants can only be hired on FDC, and also that permanent jobs are more productive than FDC, otherwise they would disappear. In the real labor markets it is however the case that workers can be directly hired on OEC, specially non beginners, and only a minority of workers get their FDC transformed into OEC[3]. Several papers focus on the screening role of FDC. [Faccini, 2014], [Bucher, 2010] and [Berson and Ferrari, 2013] justify the coexistence by the transformation of FDC into OEC but fail to explain why most hires in OEC concern unemployed or employed workers who quit their job for a new job. Moreover this explanation cannot be a sufficient explanation of FDC, for two reasons. First 62% of the FDC last one week or less. This is too short to learn the productivity of a worker at a sufficient level of confidence and offer her an OEC. Second the OEC have a probationary period which is imposed by the law of 2 to 4 months, increasing in the qualification of the worker. It can even be renewed once under some conditions. The employer can dismiss the worker during this period at no cost, but there is always some risk that the worker appeals to the judges if she wants to argue that the breach is not based on the lack of competence. The buffer effect is taken into account in a general equilibrium model by [Alonso-Borrego et al., 2005] with incomplete markets. When hiring, a firm takes into account the effect on the profit function in the future, with the expectations of shocks distributed according to a first order Markov process. When solved for stationary recursive competitive equilibrium, and calibrated on Spanish data during the 90's, the results display that prohibiting FDC lowers unemployment. The mechanism is a decrease in productivity which raises employment. FDC allow for a better allocation of resources since labor is adjusted at lower cost. This effect overtakes the negative effect of FDC on productivity caused by the higher rotation. Finally the effects on welfare are uncertain since there are winners and losers. Another paper by [Cahuc et al., 2012] sets a trade-off between FDC and OEC when there are idiosyncratic productivity shock arrival rates on jobs. The cost of terminating an OEC is the firing costs, while the cost of a FDC after the adverse shock is the wage until the end of the contract. When firing costs are sufficiently large, the equilibrium entails both FDC and OEC. Job protection by firing costs leads to a small decrease in the number of jobs. If the model explains the coex-

[3]Very few studies measure the ratio of transformation of FDC into OEC. [Bunel, 2007] finds that 19% of the workers are in an OEC the next month (France, period 1990-2001. However they may have passed through unemployment an found an OEC in another firm. He however displays some other statistics which point to a transformation.

istence of the two types of jobs, one may wonder if it does not mainly explain that employers recur to very short FDC if facing high shocks probabilities to avoid the cost of unproductive FDC workers. Finally another research track explains the coexistence by the preference of workers for permanent jobs while firms prefer more flexible FDC [Berton and Garibaldi, 2012]. This leads to an equilibrium with the two types of contracts. The model implies that given the faster job finding rate by workers of temporary jobs, these workers are indifferent between the two types of jobs. Our view is that workers indeed prefer permanent jobs, but that it is not an essential element in the coexistence of the two types of jobs. Labor demand is the driving force. None of the former models accounts for all the mechanisms we listed: churning by non renewal, buffer, screening and stepping-stone.

We propose such a model as an extension of [Goudet et al., 2013, Goudet et al., 2015], which builds itself on the experience of model ARTEMIS [Ballot, 2002]. The WorkSim model reproduces the gross flows of individuals between the main states, employment, unemployment and inactivity. Employment is subdivided into the FDC and the OEC. The flows are generated by the interaction of the rational decisions of heterogeneous agents of each type, firms and individuals who belong to households (around 10000 agents in total in our simulations and a scale of 1/4700). We construct complete accounts of the stocks and flows of workers (and also of jobs), and this makes analysis of changes such as policies or laws coherent and precise. A change of state of an individual in the model is a unit in a gross flow, and it has a corresponding cost which can for instance be the severance costs paid by the firm if fired, or a higher wage if she is promoted. Our choice is different from the transition matrices between discontinuous dates, the more standard framework that is used in labor economics, since the observed data tend to take the form of transitions rates between states. However the latter framework does not allow to compute costs corresponding to decisions, hence the agents cannot compute expected costs correctly. To obtain gross flows, the period must be as close to the real unit period which is the day on the labor market, so we choose the week, since the day would computationally too cumbersome. The individuals age and evolve as a closed and stationary population.

The theoretical framework for the decisions is costly search by the individuals and by the firms, but decisions are based on bounded rationality since the heterogeneity makes a rational expectations system based on Bellman equations intractable and unrealistic. However searchers make adaptive anticipations and correct their decisions when they discover their mistakes, for instance if their reservation utility is too high to find an acceptable job offer, they lower it. They learn. We then model the decisions as comparisons of utility, for each state, between the different states they can reach or try to reach. This allows to model naturally the matching of workers to jobs. The workers decide to apply (or not) to vacancies posted by firms. Each employer sets a reservation productivity and selects the best candidate if any passes the reservation productivity. This is much more precise than using a matching function since it makes possible to represent the competition between workers and between firms. We want no *a priori* segmentation in the labor market, and we then obtain endogenous non linear crowding out effects on the heterogeneous workers (young, intermediate age class, seniors, more or less experienced, more or less qualified), when aggregate demand or some important institutions change. We view this treatment of crowding out effects as an important contribution of this type of model. Costly search gives a unifying basis for building and extending the model. It is necessary to distinguish unemployed and inactive individuals, as is done in the ILO definition of unemployment. It is a permanent element of a large cost/benefit analysis for decisions. On this basis employed workers decide also to search or not, or to quit to search. Search is done on both sides of the markets as firms decide whether to create a vacancy, with which type of contract, and with which reservation productivity. It is also an element of the decisions on personal and economic dismissals.

The model is a partial equilibrium model, since we want to focus on the role of institutions, specially labor law, which we model in some detail, as well as the welfare system related to the labor market. In our economies in which growth has become very low, our interest is to look at the decreases in unemployment that can be obtained by institutional policies, given the existence of an exogenous aggregate demand, and a number of vacancies that exist endogenously or can be induced by these policies. We are also interested by the distributional effects of policies. In the present paper, the role of firms ' anticipations will also be emphasized. The demand share then follows an idiosyncratic process for each firm while aggregate demand is stable. The model then distinguishes demand shocks which lead the firm to create or suppress jobs and productivity changes which are endogenous, being based on the hiring decisions and the experience of the incumbent workers. Finally the extension proposes the trade-off which has been described in a preceding paragraph between OEC and FDC amortized expected costs, and models the different anticipation scenarios which integrate the buffer effect as a result of inter temporal choices. The universe of unknown parameters is fairly large (48) and a powerful evolutionary algorithm is used to set them to minimize the distance with a weighted set of 51 targets of interest (unemployment by age class, the stocks of contracts, the distribution of wages...). This provides a basis for the analysis of policies such the change in firing costs or the interdiction of FDC.

The presentation of the paper will be as follows. The section 2 describes the model. Section 3 summarizes the calibration process. Section 4 displays the results and section 5 concludes.

2 Model Description

2.1 The agents in WorkSim

In WorkSim, the agents are heterogeneous. They have specific attributes determined once and for all at their creation and internal variables which evolve all along the simulation. The agents attributes and variables are shown in Appendix A. There are two types of agents: *Private Firms* and *Individuals*. At its creation, each firm starts with at least one worker to run the company, denoted in this paper as the managing director. The *Individuals* are grouped in households and the simulation evolves in a closed population. The individuals can marry each other, have children, and therefore the decisions of one member of the household may have an impact on the other members.

The agents under 15 or over 65 years belong to these household but are not *instantiated* as full agents and do not take decisions in the model. However, these *non-instantiated agents* indirectly participate through the economic decisions of the other members of the household (eg. the number of dependent children is taken into account in decisions of transition to inactivity, the retirement pension is included in household income). The individuals under 15 years become full agents in the model at the age of 15, and some remain in the school system while others enter the labor market.

2.2 Environment

In addition to these agents, the model uses three *artifacts* [4]:

- *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 (see sections 2.6.5 and 2.7), according to the principles of search theory.
- a "*statistical institute*" that calculates all the statistics from a simulation model and disseminates some information (e.g. tension on the labor market). The information is imperfect for agents, and we could specify what information is being broadcasted.
- a *Public Sector* that recruits (exogenously) employees, collects payroll taxes on businesses.

2.3 Institutional Framework

Moreover, it also includes one *institutional module*. 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*)[5] and *open ended*

[4] *Artifacts* in multi-agent systems are the passive (non-proactive) entities providing the services and functions that make individual agents work together [Omicini et al., 2008], and must be distinguished from proactive autonomous entities like the individuals or the firms.

[5] Main FDC Features: maximum duration of 18 months including the possibility to be renewed once, small probationary period, allowance at the end of the contract: 10 % of total gross salary. Cannot be broken without heavy penalties (paying the remaining salary part).

contracts (*OEC*),[6] dismissals on personal and on economic grounds, redundancy payments, …). and (2) government decisions (minimum wages, welfare benefits, ...). The parameters of the institutional framework are shown in Appendix B.

2.4 Demand

In our economy, there is one good, and each employee produces a certain amount of a variety of this good which is unique to the firm but different from other firms variety by the heterogeneous preferences of the consumers for this variety, and the random fluctuations of these preferences (horizontal differentiation) [Salop, 1979]. The price P is then unique and fixed at the arbitrary value of 1. The only production factor is the labor, like in many labor market models. Moreover, the firm production is linear additive in terms of hours of work, and some employees only work part-time.

Each firm of the N firms in our model responds to a demand of this good $D_{j,t}$, which fluctuates randomly due to variations in consumers preferences. However, the global demand D^{tot} is held constant because we aim to study our economy in a steady state.

At time $t = 0$, the market share of a firm j is given by $MS_{j,t} = \frac{D_{j,t=0}}{D^{tot}}$.

We assume that the distribution of this global demand varies between firms. Then we apply a stochastic shock on this market share for each firm at each period (random walk) :

$$\forall t,\ MS_{j,t} = Max(0, MS_{j,t-1} \times (1 + \mathcal{N}(\mu_{MS,j,t}, \sigma_{MS,j,t})))$$

with $\mu_{MS,j,t}$and $\sigma_{MS,j,t}$, two parameters of trend and deviation of this market share specific to each firm. These coefficients are randomly drawn every year for each firm according to normal laws $\mathcal{N}(0, \sigma_{trend})$ and $|\mathcal{N}(0, \sigma_{deviation})|$. The first date of revaluation for a firm is random, then the revaluations take place every year after this date.

The demand of each firm j is recalculated each period according to the evolution of this market share [7] :

$$D_{j,t} = \frac{MS_{j,t}}{\sum_{k=1}^{N} MS_{k,t}} \times D^{\text{tot}}$$

A firm is composed of a manager and employees of 3 different occupation levels (1 = blue collar or employee, 2 = middle level job, 3 = executive).

Each firm has a specific organization and needs labor for each of occupation level q :

$$D_{j,q,t} = D_{j,t} \times \psi_{j,q}$$

with $\psi_{j,q}$ the share of productivity of the firm j allocated to the occupation level q. When creating a firm these shares are randomly drawn from a standard normal distribution with a mean μ_{Ψ_q}, which depends on the occupation level of the job, and a standard deviation σ_{ψ}.

2.5 Simulation cycle in the WorkSim Model

The **simulation cycle** includes four main steps, as shown in Figure 1 below:

1. Firm decisions: contracts and vacancies management, evaluations, job creation / destruction ;
2. Individual decisions: labor market entrances and exits, job search ;
3. Firm decisions: applications and promotions management;
4. Demography: household dynamics, retirements, aging.

[6] Main OEC Features: no duration limit, probationary period, no firing costs for the first year, no termination costs if quitting, variable firing costs when firing.

[7] It can be noticed that this equation of demand of each firm allows to hold the sum of the firm demands always equal to D^{tot}

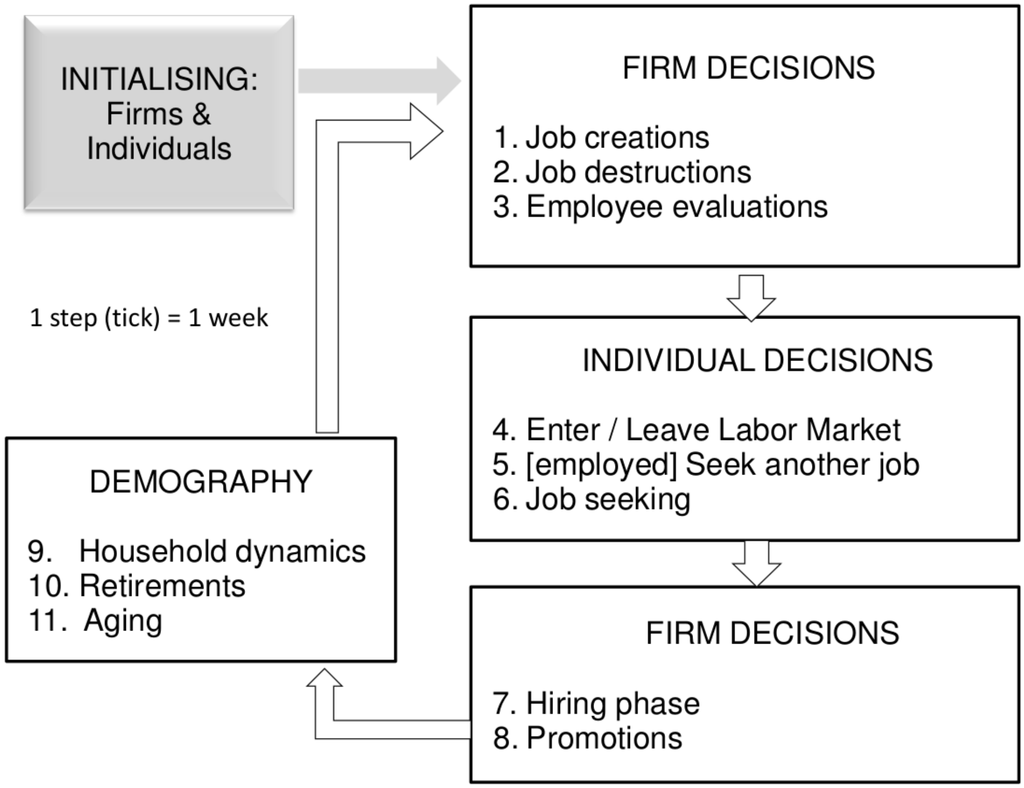

Figure 1: The simulation cycle in WorkSim

The length of one period in the simulation cycle corresponds to *one week* in the real world, in order to take into account the many very short term contracts that are found in the French labor market, 46% of all hires are on Fixed duration contracts that last one week or less in 2010 [Berche et al., 2011]. Moreover, when statistics are needed, we took 2011 as a reference year, for which we could find the most recent and complete statistical data and sources.

2.6 Firm decisions

We have regrouped in Appendix B the main economic computations a firm has to perform during one simulation period : benefit, job features including the production base and the salary base, employee productivity (that will depend on its human capitals) based on imperfect information, cost of an employee.

Before describing the job creation process, let us describe the demand anticipation mechanism that is the core of these job creation process and the endogenous choice between the different contracts : FDC and OEC.

2.6.1 Demand anticipation

Impact on firm demand In section 2.4 above, we decribed how the demand of each firm is determined through its market share evolution. However we suppose that the firm does not know the coefficients $\mu_{MS,j,t}$ and $\sigma_{MS,j,t}$ involved in this mechanism. The firm only observes the evolution of its demand period after period. From its history of demand during the last year (52 periods of one week in the model), the firm learns the coefficient of trend and deviation of its demand $\widehat{\mu}_j$and $\widehat{\sigma}_j$. These two coefficients are estimated from a linear regression on its demand history according to this model :

$$D_{j,t} = \alpha_j + \mu_j \times t + \epsilon_t$$

with ϵ_t the random error with mean 0 and standard deviation σ_j.

Once the firm has estimated these coefficients $\widehat{\mu}_j$ and $\widehat{\sigma}_j$, it anticipates that its demand will be modified by a random shock $\delta \sim \mathcal{N}(\widehat{\mu}_j, \widehat{\sigma}_j)$ each period. Then the firm can deduce a modification of its demand at a horizon d as the sum of these d small independent shocks :

$$\triangle \sim \mathcal{N}(d \times \widehat{\mu}_j, \sqrt{d} \times \widehat{\sigma}_j)$$

This impact at horizon d has 99% chance to be in the interval $[d \times \widehat{\mu}_j - 3 \times \sqrt{d} \times \widehat{\sigma}_j,\ d \times \widehat{\mu}_j + 3 \times \sqrt{d} \times \widehat{\sigma}_j]$.

To simplify the calculations of our agent *firm*, we assume that the firm only evaluates 3 scenarios of its demand evolution corresponding to the lower limit, the center, and the upper limit of this interval :

$$I^{tot}(\theta, d) = d \times \widehat{\mu}_j + 3 \times \theta \times \sqrt{d} \times \widehat{\sigma}_j$$

with $\theta = -1$ in the pessimistic scenario, $\theta = 0$ in the neutral scenario and $\theta = +1$ in the optimistic scenario.

The firm deduces a potential impact after d period on its demand per occupation level q in the scenario θ, $I_q^{tot}(\theta, d) = \psi_{j,q} \times (d \times \widehat{\mu}_j + 3 \times \theta \times \sqrt{d} \times \widehat{\sigma}_j)$, with $\psi_{j,q}$ the share of productivity of the firm j allocated to the occupation level q.

Demand margin calculation At each period and for each occupation level, each firm has to create new jobs or destroy existing ones, depending on an exogenous demand (cf. section 2.6.3 below). Then, it manages its employees through evaluation, eventual firings, and manages the fixed duration contracts (cf. section 2.6.4 and 2.6.4 below). For each occupation level q, we define the demand margin $G_{j,q,t} = D_{j,q,t} - (Q_{j,q,t}^{eff} + Q_{j,q,t}^{*})$, the difference between:

- the amount of good demanded to the firm $D_{j,q,t}$, which varies stochastically among firms, and
- the sum of the current total effective production of the firm $Q_{j,q,t}$ and the current expected production of vacancy jobs (to be filled) of the firm $Q_{j,q,t}^{*}$

Each period the firm evaluates its "buffer" for the occupation level q at horizon d. This is the additional demand margin potentially available for the occupation level q after d periods, noted $D_{j,q,t}^{buffer}(d)$. This demand margin potentially available is the sum of the estimated productions of the jobs in the firm whose contrats have an expected duration shorter than d :

- FDC with a fixed term shorter than d
- expected retirement of employees in OEC before d periods

With the evaluation of demand margin at time t, the potential impact on demand and the evaluation of its "buffer", the firm deduces a potential maximum demand margin after d period in the scenario θ :

$$G_{j,q,t}(d, \theta) = G_{j,q,t} + I_q^{tot}(\theta, d) + D_{j,q,t}^{buffer}(d) \tag{1}$$

2.6.2 Employee Profit Evaluation

We present here the evaluation algorithm used by the firm to evaluate an employee i on a job p with a contract c with a set of potential duration $D_c^{possible}$. This set of possible durations represents the different options of duration a firm may have with a contract. For example for a contract with an initial duration of D^{init}, but renewable once with the same duration, the set of possible duration is $D_c^{possible} = \{D^{init}, 2 \times D^{init}\}$, and during the anticipation with a given scenario of demand evolution the firm will only retain the best option.

This unique algorithm will be used at different moments in the model :

- during the job creation process to assess the expected profit with a potential candidate on a job with a new contract (cf. section 2.6.3 below)

- during the evaluations of employees already in the firm : end of probationary period, personal and economic firing (cf. section 2.6.4)
- during the hiring process to evaluate the hiring norm and the expected profit with the candidates (cf. section 2.6.5)

The algorithm will be implemented with different parameters depending on the type of contract (see appendix D for the detailed implementations with FDC and OEC).

Three possible scenarios The central idea that governs profit estimation relies on the way the firm will estimate the future demand. If the demand is forecasted to increase, that a new job might be profitable, but not if there is a decrease in the demand.

Hence, the firm will compute three scenarios ($\theta \in \{-1, 0, +1\}$) that are depicted in the Figure 2 below. We see on this Figure that in the pessimistic scenario of demand evolution ($\theta = -1$) and after a certain time the demand of the firm is below its production with the new job. As the firm cannot sell more good than its demand, it may result in a loss because the firm has to continue to pay a salary. In this example, we see that it may be more profitable for the firm to choose a contract with a shorter expected duration like a 3 months FDC. Indeed, the firm will have the option to end this contract after 3 months in case of a negative scenario or to renew it if it goes well. However with a shorter contract it is more difficult to amortize the cost of hiring and training a new employee. It therefore appears a trade-off depending on the level of uncertainty of future demand and how the firm perceives the risks.

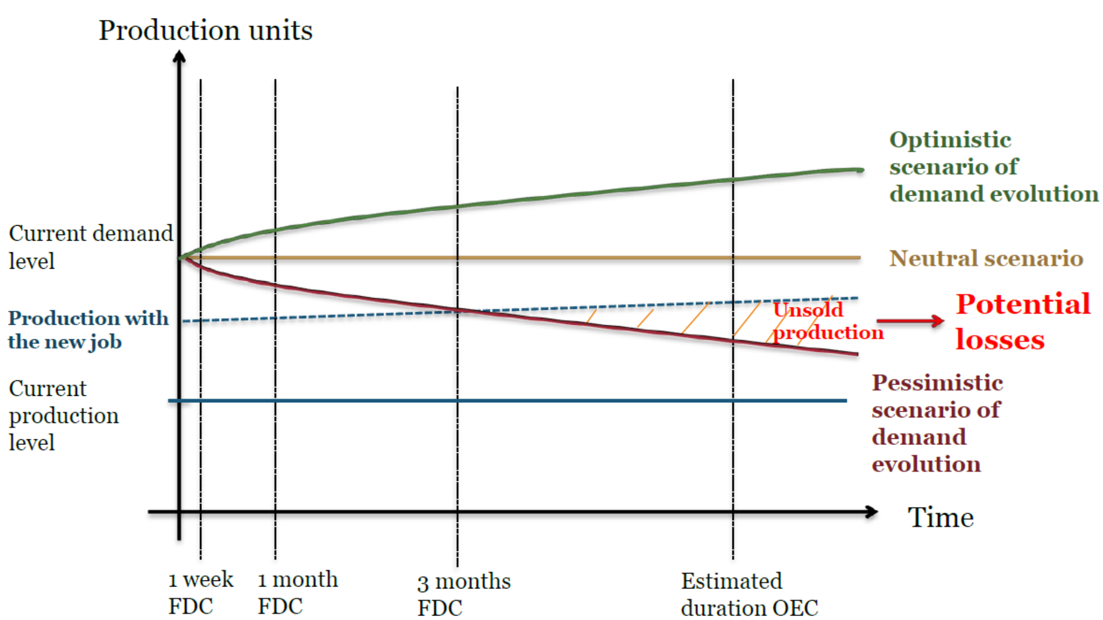

Figure 2: Demand and risk anticipation

Evaluation of an average profit with a employee i on a job p with a contract c : $\Phi^{avg}_{i,j,p,q,c,t}$ In order to evaluate this profit, the firm takes into account up to 4 phases :

1. A possible phase of hiring if the employee evaluated is not already on the job. The job is vacant during a period d_v and the firm has to pay a vacancy cost c_v. When the firm evaluates the profit with an employee already on the job, we have $d_v = 0$ and $c_v = 0$.
2. The actual phase of the contract from the period d_v to $d_v + d_c$. During this period the firm receives a profit $\phi^{estimated}_{i,p,q,t}(\theta, d_v, d_v + d_c)$ equals to the profits realized during the whole duration of the contract (cf. section 2.6.2 in appendix D).

3. A possible waiting period d_w in the case of a temporary contract. During this phase, the job is in the state *pending* and the firm does not perceive any profit.
4. A possible advance notice period of the duration d_n if the contract is an OEC and the firm needs to fire the employee. During this period, the employee does not produce, but the firm continues to pay a salary for the employee. It results to an additional cost c_n.

From this profit we deduce additional costs that we note $A_{i,p,q,c}$ including training cost of the employee (if not already on the job) and specific end costs related to the type of contract evaluated :

$$A_{i,p,q,c} = TrainingCost^{general}_{i,p,q} + TrainingCost^{occup}_{i,p,q} + TrainingCost^{spec}_{i,p,q} + EndCost_{i,p,q,c} \tag{2}$$

The training costs depends on the difference between the human capitals of the individual and the required human capitals of the job and is expressed as a ratio of the job base salary. They are computed for each of three human capital types, following the generic equation :

$$TrainingCost^{CT}_{i,p,q} = PrTrainingCost^{CT} \times S^{base}_{p,q} \times Max(CH^{CT}_{req,p} - CH^{CT}_{i,t},\ 0) \tag{3}$$

with $CT \in \{general, occup, spec\}$ the different types of human capitals.
The total profit per period for a contract c with a duration d_c in scenario θ is then :

$$\Phi^{tot}_{i,p,q,t}(\theta, d_c) = \frac{\phi^{estimated}_{i,p,q,t}(\theta, d_v, d_v + d_c) - c_v - c_n - A_{i,p,q,c}}{d_v + d_c + d_w + d_n} \tag{4}$$

For a contract c with a set of $D^{possible}_c$ duration and in a scenario θ, the firm chooses the duration d_c which offers the best profit :

$$\Phi^{tot}_{i,p,q,c,t}(\theta) = \max_{d_c \in D^{possible}_c} (\Phi^{tot}_{i,p,q,t}(\theta, d_c))$$

Finally, the firm computes an average profit for the 3 scenarios of demand $\theta \in \{-1, 0, 1\}$:

$$\Phi^{avg}_{i,j,p,q,c,t} = \omega_{-1} \times \Phi^{tot}_{i,j,p,q,c,t}(\theta = -1) + \omega_0 \times \Phi^{tot}_{i,j,p,q,c,t}(\theta = 0) + \omega_{+1} \times \Phi^{tot}_{i,j,p,q,c,t}(\theta = +1) \tag{5}$$

with ω_{-1}, ω_0 and ω_{+1} the weighting coefficients of the firm for each of the 3 scenarios. $\omega_{-1} + \omega_0 + \omega_{+1} = 1$. The values of these coefficients represent the greater or lesser pessimism of the firm during the evaluation process.

Evaluation of a profit $\phi^{estimated}_{i,p,q,t}(\theta, d_v, d_v + d_c)$ with an employee i on a job p from the period d_v to the period $d_v + d_c$ for a scenario θ of demand evolution

In this section we develop how the firm evaluates the profit anticipated from a period d_v to a period $d_v + d_c$ in a scenario θ of demand evolution used in the step 2 of the algorithm presented in the last section 2.6.2.

According to equations 17 and 18, the estimated production of an employee i after d periods on the job p is

$$Q^{estimated}_{i,p,q,t}(d) = {\sigma^{eval}}_{i,p,q,t} \times Q^{base}_{p,q} \times CProd_i \times F_\beta(CH^{general}_{i,t}(d), CH^{occup}_{i,q,t}(d)) \times F_\lambda(CH^{spec}_{i,p,t}(d)) \tag{6}$$

with $CH^{general}_{i,t}(d)$, $CH^{occup}_{i,q,t}(d)$ and $CH^{spec}_{i,p,t}(d)$, the human capital of the employee after d periods on the job. As we have seen in section B.3, these human capitals are at least equal to the human capitals required on the job (with the training when the individual is hired) and increase by 1 each period. Then we have :

- $CH^{general}_{i,t}(d) = Max(CH^{general}_{i,t}, CH^{general}_{req,p}) + d$
- $CH^{occup}_{i,q,t}(d) = Max(CH^{occup}_{i,q,t}, CH^{occup}_{req,p,q}) + d$

- $CH^{spec}_{i,p,t}(d) = CH^{spec}_{req,p} + d$

Similarly the firm can also evaluate the cost of the employee after d periods on the job with the equations 20 and 21:

$$C^{eff}_{i,p,q,t}(d) = max(SMIC, S^{base}_{p,q} \times F_\beta(CH^{general}_{i,t}(d), CH^{occup}_{i,q,t}(d)) \times F_{\lambda^*_q}(CH^{spec}_{i,p,t}(d)) \times G(U_{q,t})) \times (1 + PrCharges) \quad (7)$$

With this production, this salary and the potential demand margin (cf. equation 1), the firm deduces the profit during one period at this horizon d and for a scenario θ of demand evolution :

$$\phi^{estimated}_{i,p,q,t}(\theta, d) = P \times min(Q^{estimated}_{i,p,q,t}(d), G_{j,q,t}(d, \theta)) - C^{eff}_{i,p,q,t}(d)$$

With $G_{j,q,t}(d, \theta)$ the potential demand anticiapted by the firm at horizon d in a scenario θ of demand evolution and including the *buffer* of the firm, which is the demand margin potentially available if the firm terminates all its contracts which have an expected duration shorter than d (cf. equation 1 and figure 3 below).

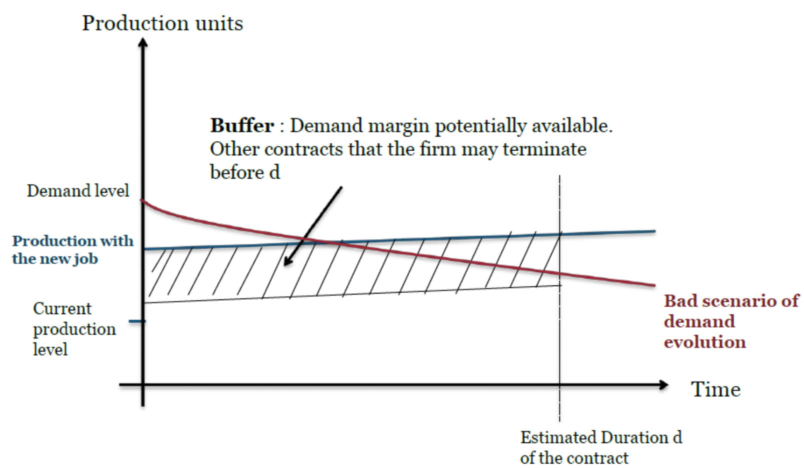

Figure 3: Demand and risk anticipation

To reduce the number of operations performed by the agents *firm* in the model, we approximate the cumulated profit perceives by the firm from the period d_v to $d_v + d_c$ by $\phi^{estimated}_{i,p,q,t}(\theta, d_v, d_v + d_c) = \frac{\phi^{estimated}_{i,j,p,q,t}(\theta, d_v) + \phi^{estimated}_{i,j,p,q,t}(\theta, d_v + d_c)}{2} \times d_c$. [8]

2.6.3 Job creations (step 1 in Figure 1)

If $G_{j,q,t} > DemandThreshold$ and if the firm has jobs in the state *pending* in the occupation level q, the firm considers to recreate a contract for this job, which changes its state and becomes *vacant*. $DemandThreshold$ is a fixed parameter.

If $G_{j,q,t} > DemandThreshold$ and the firm does not have jobs in the state *pending* in the occupation level q, the firm considers to create a new job p of the occupation level q. The characteristics of this new job are randomly drawn as mentioned in the section B.2.

The firm compares two types of contract for the job : OEC or FDC. If the job is in the state *pending* with a waiting period at the end of a contract in FDC (cf. section 2.6.4), the firm can only consider the creation of an OEC contract.

The FDC contracts are evaluated with different fixed terms : 1 week, 1 month, 2 months, 6 months, 12 months, 18 months.

[8] We compared this approximation with the cumulated profit and we do not observe significant changes in the results of the model.

Evaluation of a contract To evaluate a contract, the firm receives information about $NPros$ job seekers of the occupation level q , who have applied to a job with a FDC and $NPros$ job seekers of the occupation level q who have applied to a job with a OEC during the last period. For each type of contract c the firm evaluates the average profit for all the $NPros$ potential candidates.

The expected profit $\Phi^{avg}_{i,j,p,q,c}$ for a candidate i on a job p with a contract c is evaluated with the algorithm presented in section 2.6.2. Then the firm chooses to create the contract c with the best average profit greater than 0.

In addition, a small share of the firms (in a limited number of sectors like in the catering sector or the live performance sector) have the additional option to create a customary FDC (cf. annexe C), which represents the best possible contract for the firm, and then only create this type of contract.

If the job is created, the average expected production of the job $Q^{estimated}_{p,q,t,avg}(0)$ at time of hiring for the $NPros$ job seekers (cf. equation 6) is deducted from the demand margin at time t of the firm : $G_{j,q,t} = G_{j,q,t} - Q^{estimated}_{p,q,t,avg}(0)$ and the firm considers to create other jobs as long as $G_{j,q,t} > DemandThreshold$.

2.6.4 Job destruction (step 2 in Figure 1)

By contrast, when there is a significant reduction in its demand in one occupation level (in our model, this is when $G_{j,q,t} < -DemandThreshold$), the firm reacts in the short term by trying to remove its vacancies. In the medium run (on a yearly basis), if this low cost adjustment is not sufficient, the firm considers the possibility to dismiss workers (see 2.6.4 below).

Moreover, independently of the demand level, the vacancies that remain unfilled and have a vacancy duration greater than a fixed threshold – a parameter that will differ for FDC and OEC – are destroyed.

Short-term adjustment: vacancy removals In each period, when $G_{j,q,t} < -DemandThreshold$, the company randomly draws one of its vacancies and removes it. $G_{j,q,t}$ is increased by $Q^{estimated}_{p,q,t,avg}(0)$. This process is repeated for all the remaining vacancies as long as overproduction remains (i.e. as long as $G_{j,q,t} < -DemandThreshold$ and there are still vacancies to be removed).

Medium-term adjustments: economic dismissals An evaluation of the financial viability of the company is performed on a yearly basis (52 periods in the simulation). The first date of the balance sheet is drawn randomly, then this financial reporting occurs every year from this date. The company calculates its yearly return that is computed as the ratio of the yearly profit over the total labor cost[9]. If this return falls below a certain *profitability threshold* (a fixed parameter PT, that will be calibrated), the firm can justify an economic dismissal procedure:

- All remaining vacancies are removed.
- The company performs economic evaluations for all employees. In order to decide whether the employee should be kept, the firm calculates a profit for each scenario:
  - First scenario: the firm keeps the employee. The company computes the demand margin it gets without this employee, and evaluates as in section 2.6.2 the interest it would now have to create this job with this employee.
  - Second scenario: the firm does not keep the employee and evaluates a dismissal cost (specific to a firing for economic reasons)

If a company has no employee anymore, and if the managing director left alone does not make a sufficient return, the firm is considered to be bankrupt and is removed from the simulation. The managing director becomes unemployed. However, we want to *keep the number of firms constant.* Hence, when a bankruptcy has occurred, we randomly select an active agent in the simulation to create a new firm and manage it. He will be the only producer in the firm (until he starts to recruit).

[9]The labor cost represents here the capital funds the firm has to pay in advance. Hence, the return is the ratio of the profit over this capital.

Employee evaluations (step 3 in Figure 1) In each period, the firm examines if some employees have to be evaluated. This individual evaluation may occur:

1. At the end of the probationary period for FDC and OEC ;
2. Every year, at the anniversary date of the contract, for OEC employee. The firm may consider to fire the employee for personal reasons;
3. At the end of FDC contract to decide if it should be renewed ;
4. At the end of FDC contract, if the transformation of FDC to OEC is to be considered ;

This process takes place in two steps. First the firm has to provide a legal justification if needed, and then the firm evaluates from an economic point of view if it has an interest to dismiss the employee.

1) Need of legal justification

1. To dismiss an employee at the end of a probationary period, the firm must prove that the inherent skills of the employee are insufficient to realize the tasks required by its job [Cour de cassation, 2008]. We assume that the firm can justify an end of probationary period if $Q^{estimated}_{i,p,q,t} < Q^{required}_{p,q}$. With $Q^{estimated}_{i,p,q,t}$ evaluated with equation 18 and $Q^{required}_{p,q} = Q^{base}_{p,q} \times F_\beta(CH^{general}_{req,p} + T, CH^{occup}_{req,p,q} + T) \times F_\lambda(CH^{spec}_{req,p} + T)$. $(CH^{general}_{req,p}, CH^{occup}_{req,p,q}, CH^{spec}_{req,p})$ is the vector of human capitals required by the job and T the time spent by the employee on the job.
2. To fire an employee in OEC for personal reasons after the probationary period, we assume that the firm can dismiss an employee is it has at its disposal more evidence that the skills of the employee are insufficient. That is to say if $Q^{estimated}_{i,j,p,q,t} < \rho \times Q^{required}_{p,q}$, with ρ an exogenous parameter lower than 1.

2) Economic evaluation In order to decide whether the employee should be kept, the firm calculates a profit for each scenario (as in section 2.6.4)

- First scenario: the firm keeps the employee. The company computes the demand margin it gets without this employee, and evaluates as in section 2.6.2 the interest it would now have to create this job with this employee. Thanks to learning, the firm knows better this time the employee's actual productivity.
- Second scenario: the firm does not keep the employee. If the employee is under OEC, the firm evaluates specific dismissal costs related to a firing for personal reasons.

The firm compares the total profits associated with each scenario. If the firm chooses to dismiss the employee (end of probationary period, end of FDC contract, OEC firing on personal ground), the job becomes in the state *pending*. If the contract for the job was an FDC, there is a waiting period before the firm can create a FDC again on this job.

If the contract on the job was an OEC, there is an advance notice period for the firm before the employee is effectively fired. According to French labor law, this advance notice period lasts for one month in the case of the seniority of the employee is lower than two years, and for 2 months otherwise. During this advance notice period, we assume that the employee does not produce, but the firm continues to pay a salary.

2.6.5 Hiring phase and promotions (step 7-8 in Figure 1)

First of all, the firm must define its *hiring norm*, that is the profitability threshold below which it prefers to refuse a candidate. To do so, it uses the expected profit $\Phi^{avg}_{i,j,p,q,c}$ calculated for each of the $NPros$ candidates during the job creation process for the job p with the best contract c (cf. section 2.6.3), and evaluates among those which are positive, the average Φ_{Moy}, the minimum Φ_{Min} and the maximum Φ_{Max}.

The hiring norm of the firm is given by:

$$\text{HiringNorm}_{j,p,q,t=crea} = \text{N}_0(\Phi_{Moy} + \text{N}_1 \times (\Phi_{Max} - \Phi_{Min}))\frac{N(d_p)}{H(ITENS_{q,t=crea})} \tag{8}$$

with N_0, N_1 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_2 for a very short FDC (duration below one week) and a maximum at 100% for an OEC contract. $ITENS_{q,t=crea}$ is the tension on the labor market at the time of job creation and is given by $ITENS_{q,t} = \frac{V_{q,t}}{U_{q,t}}$ with $V_{q,t}$ the vacancy rate and $U_{q,t}$ the unemployment rate at time t for the occupation level q. The higher this tension, the more the firms have to lower their requirements if they hope to find a candidate. H is a logistic function with values between 0.8 and 1.2 and given by $H(x) = 0.8 + \frac{0.4}{1+20\times e^{-3x}}$.

This hiring norm is then decreased by a percentage N_3 in each period until the job is filled, but never drops below 0.

Hiring takes place in three steps:

1. *Receiving applications* – Firstly the firm receives applications from external applicants. and applications of internal candidates[10].

2. *Selection and potential hiring* – A two-steps process takes place:

   (a) First, the firm computes a score for each candidate (internal or external). The score for each candidate i is computed with the algorithm presented in section 2.6.2 as the expected profit $\Phi^{avg}_{i,j,p,q,c}$ if the candidate is hired for the job. Then the best candidate (highest score) is selected.

   (b) 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.

3. Internal promotion – If the best candidate hired is an internal candidate of the company, it is a promotion. The employee acquires the occupation level of the job.

2.7 Individual decisions (step 4-6 in Figure 1)

The individuals take decisions in 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 and not searching for another job (denoted ENS), employed and seeking a new job (denoted $OTJS$, for On-The-Job Searchers), 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).

Utility functions Each individual uses a utility function, to decide whether she should stay in its current state or move to another one. The utility function has the generic form of a Cobb-Douglas function:

$$U = (Income + Amenity + Stability)^{1-\alpha}(Free\,Time)^{\alpha} \tag{9}$$

It is a weighted aggregation of four factors:

1. *Income*: weekly income of the household in euros, divided by the number of consumption units (an adult counts for 1, a child 0.5)

2. *Amenity*: non-monetary features perceived by the individual (social recognition, working environment, job hardness...). [11]

[10] Internal candidates are employees of the firm with a seniority greater than a certain threshold (*SeniorityThreshold*), and whose occupation is strictly one level lower to the occupation level of the job.

[11] 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 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 probationary period is too short to reveal the real productivity).

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 job (OEC). 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 heer working hours and her search time. Our definition is a broad one since it includes time devoted for instance to sleep, eating, washing, domestic duties, and notably caring for the children.

The parameter $\alpha \in [0,\ 0.99]$ encodes the preference of the individual for free time or work. First, there is an effect of age, which increases the disutility of time spent at work. Hence α will evolve according to the following equation :

$$\alpha = Min[0.99,\ \alpha_{base} * (1 + \alpha_{old} * (age - 15))] \tag{10}$$

With α_{base} drawn at the creation of the agent according to a normal distribution with mean α_0 and standard deviation σ_{alpha} (and with a minimum of zero).

Moreover. as in the ARTEMIS model [Ballot, 2002], α is different between men and women with children, because gender roles in the household has some impact[12]. We model this difference by multiplying the woman's alpha by a factor F_w depending on the number of children in the household : $F_w = 1 + \alpha_{child} * \#children$. For women under 25 and having children, this alpha is further multiplied by a factor $(1 + \alpha_{youngWomen})$. This modified alpha cannot be above 0.99.

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. Each reachable state will be evaluated using the relevant values of income, amenity, stability and free time in the utility function, the difficulty to reach it, and the cost of changing state (ICHANG). The agent can then decide whether it is better for him to stay in her current state or to move to another one, as we see on figure 4. In this case, the individual stops her decision process and changes state, as prescribed by Simon's *satisficing heuristics* [Simon, 1956].

Every month, an individual in *the inactive* or *the employed* state 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 occupation of the individual. On the basis of these information she receives on these jobs, she evaluates $UTINOUV$, which represents the interest to start looking for another job .

Reservation utility calculation for the unemployed and On-The-Job-search states The reservation utility of the unemployed evolves according to the following equation :

$$UTRES_{i,t} = UTRES_{i,t-1} \times (1 - Param3_{UTRES}) + Param4_{UTRES} \times (UTICHO_{i,t} - UTICHO_{i,t-1}) \tag{11}$$

With $Param3_{UTRES}$ and $Param4_{UTRES}$ two calibrated exogenous parameters. If a worker becomes unemployed by quitting, or has a job but considers looking for another job, the initial reservation utility of the individual $UTRES_{i,0}$ is computed from the list of all the jobs known during the free search: If an employee becomes unemployed because he is fired, $UTRES_{i,0}$ is initialized at $UTIEMP_{i,t}$, the utility of the job lost: the individual has no higher requirement. The reservation utility decreases with the seniority in unemployment. $UTRES_{i,t}$ depends also on her myopic utility $UTICHO_{i,t}$. This myopic utility reflects the income per unit in the period (unemployment benefit, RSA[13]...) and free time reduced by the time spent to search a job every week. This means that this myopic utility can rise (or fall) and $UTRES_{i,t}$ accordingly. [14]

In the case of an On-the-Job-Search (OTJS) worker, her utility is given by :
$UTRES_{i,t} = UTRES_{i,t-1} \times (1 - Param3_{UTRES})$.

[12] In fact, and even if societies are constantly evolving on that issue. French women in 2011 have devoted more time than men for housework and the education of children. According to INSEE's enquiry on time use, on average, women devote 45mn daily to care for children, while men spend only 19mn on such an activity. Indeed, in 2011, the full-time employment rate of French women living in a couple with three children or more was 39.8% and 87% for men in the same situation [INSEE, 2011b]

[13] As for "Revenu de solidarité active". In France, this a minimum income for people without resources. In 2011, the RSA was 467 € per month for a single person aged 25 or more.

[14] We distinguish this myopic utility to be unemployed $UTICHO_{i,t}$ from the dynamic reservation utility $UTRES_{i,t}$ according to

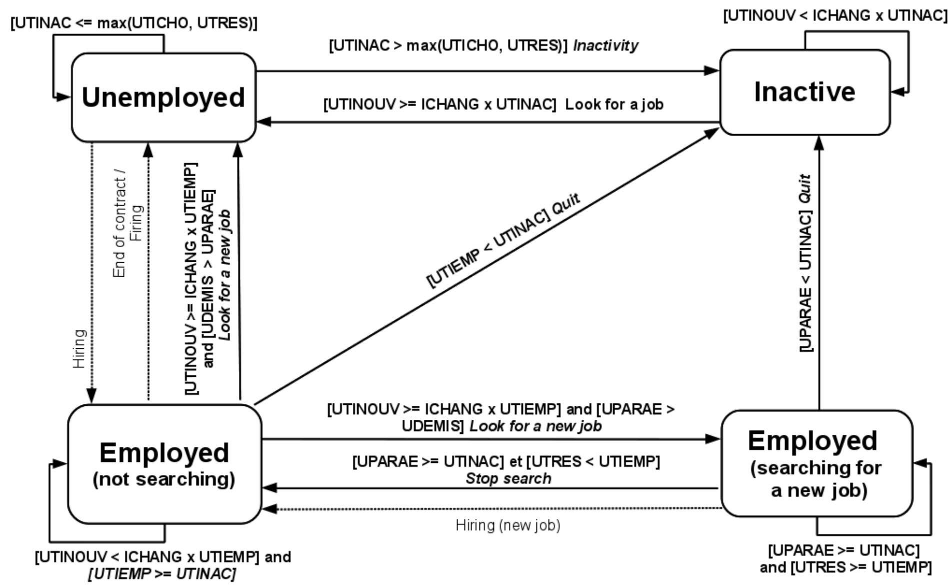

Figure 4: State diagram describing the main transitions of individuals and their decision-making process. Each utility is calculated according to the equation 9. Legend: UTINAC: utility to be inactive. UTINOUV: utility of a new job, estimated through prospecting. UTICHO: utility to be unemployed. UTRES: utility of reservation. UOTJS: utility of the OTJS (On-the-Job-Search) state. UTIEMP: utility to be employed. UDEMIS: utility to quit. ICHANG psychological cost to change state (calibrated exogenous parameter). Dotted arrows represent decisions that do not fully depend on the agent (i.e. taken by the firm.)

Decision of student and public servant agent 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 activity on the labor market in 2011.

Furthermore, the public servant agents (21.3% of the agents) do not take decisions and are just present in order to reproduce demographic and employment statistics. When they retire, they are replaced according to a rate 1:1 (to be in a steady state) by youths who are finishing their studies and are randomly drawn in their cohort.

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

1. Each period in the model (one week in the reality), a job seeker receives from JobAds a list of NPros vacancies matching her occupation level or a level above. At time t, this number of vacancies NPros is determined according to a Poisson distribution with parameter $\lambda_t = NPros_{Avg} \times H(ITENS_{q,t})$.

   (a) $NPros_{Avg}$ is the average number of vacancies received by the unemployed each week and set at the value of 3.

   (b) $ITENS_{q,t}$is the tension on the labor market at time t for the occupation level q. The higher the vacancy rate and the lower the unemployment rate, the more the job seekers receive vacancies each period. H is a logistic function with values between 0.8 and 1.2 and given by $H(x) = 0.8 + \frac{0.4}{1+20\times e^{-3x}}$.

2. The individual applies each period for the first offer she receives with a utility at least as high as her reservation utility $UTRES_{i,t}$.

search theory which takes into account the expectation to get a job with an expected salary. This dynamic reservation utility remains based on bounded rationality, since searchers do not anticipate the possible break of the contract they look for, and the values of the many states beyond.

3. At each step, if the individual looking for a job does not receive any job offer corresponding to her occupation level or if all of her application are rejected, he lowers her reservation utility $UTRES_{i,t}$.

3 Model calibration

3.1 Scaling

We start from the real firm distribution by size (i.e. number of employees) in France in 2011[INSEE, 2011a]. We scale up this distribution by a reduction factor of 4700[15] and obtain 808 firms, for a total of 4411 employees. Then, we add public servants in a proportion of 21.3% (INSEE Source [INSEE, 2013b]), and the numbers of "inactive", "unemployed", "retired" and "student" agents corresponding to 2011 statistics [INSEE, 2011d]. We obtain a total of 8 713 individual agents and it corresponds to the 40.79 million individuals in the age range 15-64 with a reduction factor of 4 682 (which is well in line with the reduction factor for the firms). Finally, we have then 8713 individuals and 808 firm agents, for a total of 9 521 agents in the simulation.

3.2 Minimization of a fitness function

To calibrate the model parameters (48) we minimize a *fitness* function which is the weighted sum or the relative spreads between the outputs of our model and the real targets of the French labor market in 2011 (source INSEE/DARES/ACOSS). We have chosen 51 main targets grouped in 7 different categories:

- 7 targets on unemployment rate by age group and by occupation level [INSEE, 2011c]
- 6 targets on activity rate by age group and by gender [INSEE, 2011b]
- 14 targets on wages by age group and by occupation levels, and annual wages distribution per decile on the global population [INSEE, 2013a]
- 12 targets on labor flows [DARES, 2012]
- 4 targets on share of FDC in employment and hires [Berche et al., 2011, INSEE, 2011d]
- 3 targets on share of long term unemployment in unemployment by age group (INSEE Source [INSEE, 2011d])
- 5 additional targets on part-time job proportion in employment ([INSEE, 2011d]), vacancy rate (COE 2013 [COE, 2013]), the ratio of employed "looking for a new job" (OTJS) in the simulation [INSEE, 2008] and average specific and global training cost in euros.

3.3 Calibration method and results

This fitness function is minimized at a horizon of 200 periods (each period corresponds to one week). To minimize our fitness function, we choose the evolutionary algorithm CMA-ES [Hansen and Ostermeier, 2001], which is one of the most powerful algorithms to solve this kind of problem [Auger and Hansen, 2012].

CMA-ES means Covariance Matrix Adaptation Evolution Strategy. The principle of this evolutionary algorithm, inspired by biology, is to test step by step new generations of points in the parameters space. Each new generation of points is drawn stochastically according to the results obtained with the previous generation of points. The mean and the covariance matrix of the distribution of the new randomly drawn points is updated incrementally in order to move towards the best results obtained by previous generations.

We obtain the results shown in Appendix C for the main targets of our calibration in a steady state (the different rates are expressed in %), the outputs are averaged over 200 simulations. We obtain an average relative difference between all the outputs of our model and the real targets of 10.9%. This deviation can be deemed satisfactory for such a large non-linear model. It should be emphasized that the aim of

[15] This factor is chosen to get a total around 10 000 agents at the end of the process.

the model is not to obtain precise fits on the variables but reproduce the processes that, by their interactions, reproduce the workings of the labor market in a way that brings economic understanding of these processes. This model is neither a microsimulation model, with observed and large data bases, nor an économétric model. These are more precise but much more partial and also much less detailed on the processes. We now look at the detailed parameters and variables.

The values of the calibrated parameters are shown in Appendix F. Some deserve some comments but others have values determined by the specificities of the initialisations and should not be compared to parameters estimated on econometric studies. Let us look at the parameters concerning the individuals' behavior. The preference for free time α has a negligible sensitivity to age. The psychological cost level of moving is 6% of the utility, which reveals a market in which individuals ask for little compensation to move for a better state, which does not mean that they will always move since it also depends on finding a desirable job and be recruted. The rises in the productivity in response to the human capital stocks are biased upward since young workers enter in the market with no experience. Taking into account that the profiles are quasi-linear, we only note that the hierarchy of the profiles is as observed, steeper for executives than for middle workers and steeper for middle workers than for blue collars and employees. If we look at the parameters of the firms. The share of the base productivity value that is kept by the firm is 73%, in a context in which the costs are only labor costs. Goudet, Kant & Ballot (2013) show that the employment has a U shape response to this share, but that the calibrated value does not entail a strong change in employment around the calibrated point since it close to the maximum employment. As for the balance between pessimism and optimism, we get a striking result. The best fit of the model is obtained for a high domination of pessimism (80%) while the neutral scenario weights 18% and the optimistic scenario is only 2.6%. We will examine below the sensitivity to the changes in these weights. Worthy to note is also the parameter for personal dismissal legal justification, which is 99%. It means that employers feel they can fire as soon as they observe a productivity which is less than 99% of the required productivity, meaning a quasi total absence of fear to make a mistake and loose in courts if the worker sues for unjustified personal dismissal.

The appendix E displays the simulated and the observed targeted variables. The model reproduces well the unemployment rates for all and for the two age groups. It underestimates by 3 points (on 22) the unemployment of the youths, and this can be explained by the complexity of the entry period, with multiple moves between studies, work, inactivity (or black labor) among the youths, a subject which could not be dealt in detail in the model. However we have the main qualitative result, which is that the unemployment rate among the youths is more than twice the average unemployment rate, a major feature of the French labor market. The share of long term unemployment (unemployed for more than one year) is correctly reproduced, highlighting the importance of this phenomenon which strikes the young (28%), the 25-49 age class (41%) and the seniors (57%) (table 14). The rise of the share with the age and the figures themselves are well approximated. It indicates that the inequality towards unemployment is well taken into account in the model, an important objective of a model focused on understanding this type of inequality. The targets on activity rates are good, except again for the youths, which we overestimate for the same reasons (table 10) . If we disaggregate employment into FDC and OEC, we obtain very good estimates with the 8.74% of FDC (table 13).

The gross flows are fairly well reproduced, which is an important point since they are at the core of the model and the sensitivity and policy analyses in this paper. Again, we have some underestimation of the entry of rate of the youths, since we do not mesure perfectly their changes of state (table 12). The different exits of the firm, computed as a percentage of employment, always show some difference between simulated and observed data, but the hierarchy of exits is reproduced, with end of FDC the main exit with 40%, while quits are the second with one degree of magnitude less (8%), then end of probationary period and dismissals for personal reasons come third, with 2.4%. Economic fires are a degree of magnitude less again, with 0,7% yearly rate, close to the 0,5% in real data. This is in fact what really matters to understand the characteristics of the French labor market: to reproduce these three orders of magnitudes, which makes for instance economic fires 2% of the end of FDC. If we go into more detail to distinguish short and long FDC, we find some important results (table 13). The share of the FDC of one week in the entry of FDC is 35%. This is less than in the observed data (54%) since these comprise the FDC of less than one week. The share of simulated FDC of less than one month is 29% against 21% in the French labor market. Although not precise, these results represent the main qualitative facts about the distribution of

FDC by duration, i.e. the domination of short and very short contracts. Finally the monthly net salaries are somewhat underestimated, but the distribution by deciles is correct (table 11). In order to better compare the results with observed statistics, we now look at variables which have not been included in the targets but are very important to evaluate the quality of the validation, since they are sets of variables regularly published and used by economists to analyse the French labor market.

4 Simulation analysis and results

We first undertake a sensitivity analysis on some important parameters related to the choices between FDC and OEC, to explore the model results, showing that the results can be interpreted through economic mechanisms that make sense. Again, each result corresponds to an average over 200 simulations.

4.1 Sensitivity Analysis

In order to perform the sensitivity analysis, we run a set of simulations by changing the value of a given parameter step by step, the others remaining to their calibrated values. For each consecutive point, we measure the outputs of the model after 200 periods (4 years in reality) and average these results over 200 simulations in order to eliminate the stochastic effects. In the following we evaluate :

1. The sensitivity to the weight of the pessimistic scenario ω_{-1} in profit evaluation (cf. equation 5).
2. The sensitivity to the specific training cost (cf. equations 2 and 3)
3. The sensitivity to demand volatility $\sigma_{deviation}$ (cf. section 2.4).

4.1.1 Sensitivity to the weight of the pessimistic scenario in profit evaluation

We study here the impact of the firm manager "animal spirits", that are modeled as weights on optimism and pessimism about his future demand. To do so, we first vary the pessimist weight ω_{-1}, the other remain set at their calibrated values and then all the three values are re-normalized to get a total sum equal to 1.

The pessimistic scenario, as soon as its weight is higher than zero, has a very strong influence on the unemployment rate (cf. Figure 5). The employers start early to be scared by the risk of future fires and lower the hires of OEC, and substitute hires of OEC by hires of FDC as figure 6 shows. Then, if the weight of the pessimistic scenario continues to grow over 20%, the substitution takes place between FDC: shorter FDC substitute to longer FDC. The constraints on the hires of FDC (payment of the wage until the term of the contract, waiting period proportional to the termination of contract), explain this new substitution. A possible explanation of the two sequential evolutions we mentioned in the introduction, the rise of the FDC share in the 80's and 90's followed by the shortening of FDC in the 2000's could be be an increased fear of bad outcomes in a more open and competitive world, although other factors than this "animal spirits" interpretation may play.

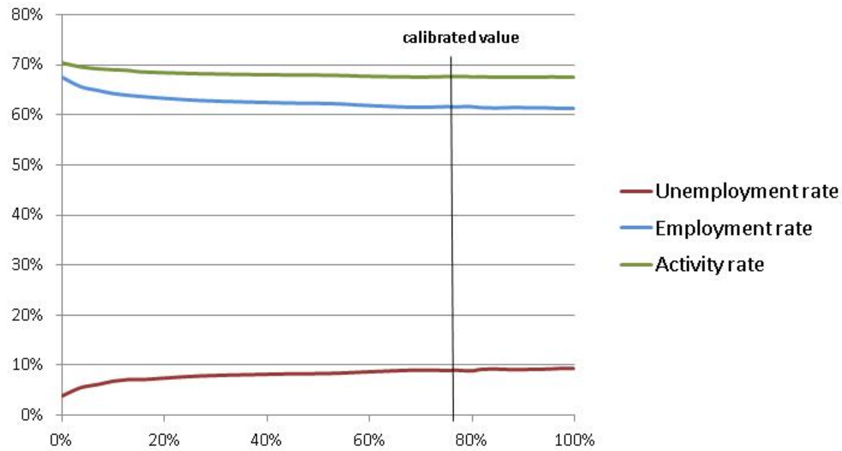

Figure 5: Sensitivity to weight of the pessimistic scenario ω_{-1} in firm profit evaluation

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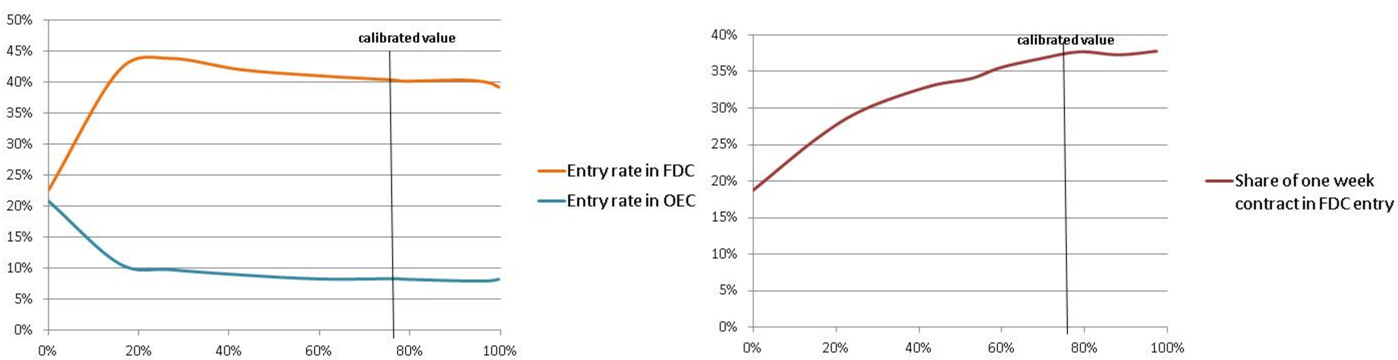

Figure 6: Sensitivity of entry rates to weight of the pessimistic scenario ω_{-1} in firm profit evaluation

We evaluated the sensitivity to the optimistic scenario and we obtain symetric results. This is not surprising because when the weight of the optimistic scenario grows, the weight of the pessimistic scenario decreases and vice versa.

4.1.2 Sensitivity to specific training cost

We established the trade off between the training costs and the firing costs as a possibly important element of the choice between hires on OEC and on FDC. In this sensitivity analysis, we change only the costs of the training specific to a job to fulfill the specific skill requirements, which is a simpler story than the consequences of raising general and occupational skill level requirements. Each worker has a zero level in job specific skills when hired. The costs do not depend on who is hired, and there is no selection involved on this basis. The figure 7 shows that the rise in the specific training costs decreases strongly the hire of FDC, and among them, particularly the short FDC (figure 8). Employers substitute hires in OEC which rise. The net effect on unemployment is close to zero (figure 9). An implication of the importance in training costs in the substitution of OEC to FDC could be that firms should not be subsidized for the training costs, specially when hiring on FDC. However this subsidy should be studied in a more global context than we can do in the present model.

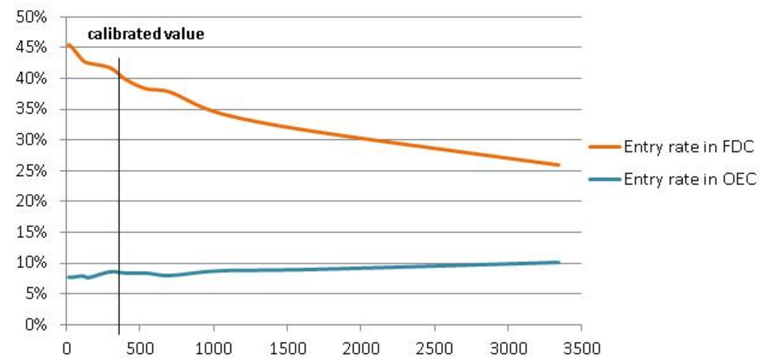

Figure 7: Sensitivity of entry rates to average specific training cost

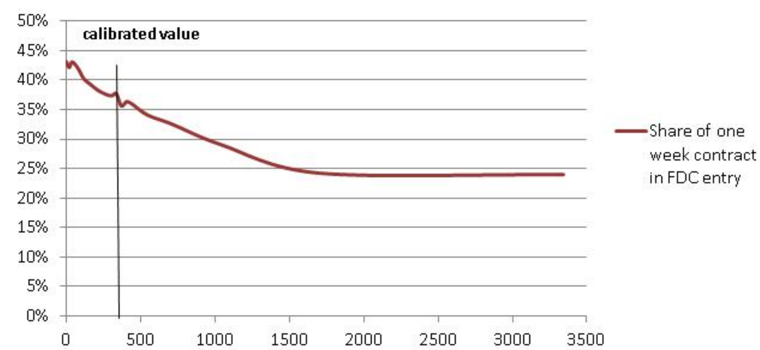

Figure 8: Sensitivity of the share of short FDC to average specific training cost

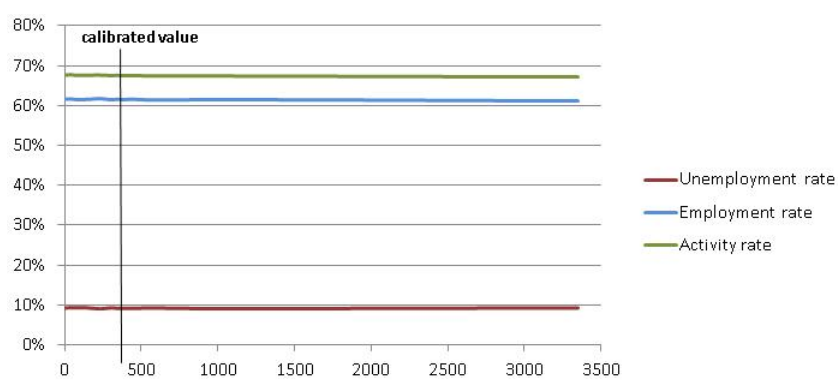

Figure 9: Sensitivity of unemployment rate to average specific training cost

4.1.3 Sensitivity to demand volatility

Demand volatility around the trend of the firm demand has an important effect on the unemployment, which rises with this volatility because of turnover (figure 10). Clearly the entry rate in FDC rises (figure 11 on the left) in order to avoid costly fires on OEC (figure 12 on the left). However, when volatility is low and rises, OEC hires start by declining, then when volatility continues to rise above twice the calibrated volatility, they rise again since the firm cannot avoid fires and has to re-hire OEC workers when demand rises (figure 11 on the right). The entry rate in OEC then has a U shape. Fires also rise when volatility is not low. FDC cannot be a perfect buffer when volatility is high since they have their own costs (badly amortized training costs, waiting costs, and vacancy costs). While unemployment rises, we get the paradox that the share of long term unemployed decreases since the turnover becomes so high (figure 12 on the right).

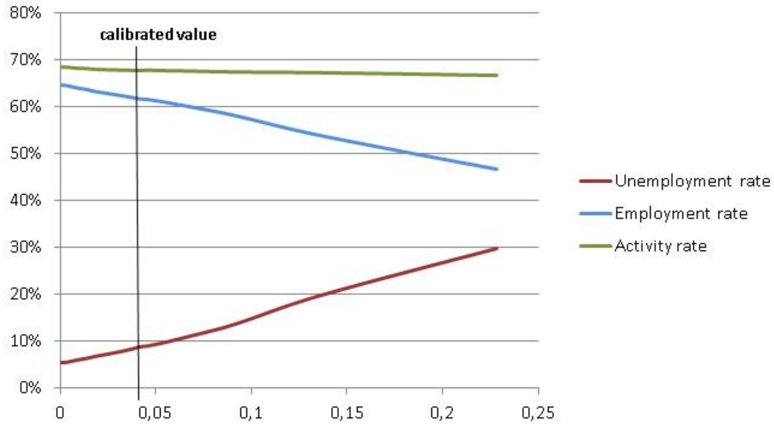

Figure 10: Sensitivity to firm demand volatility $\sigma_{deviation}$

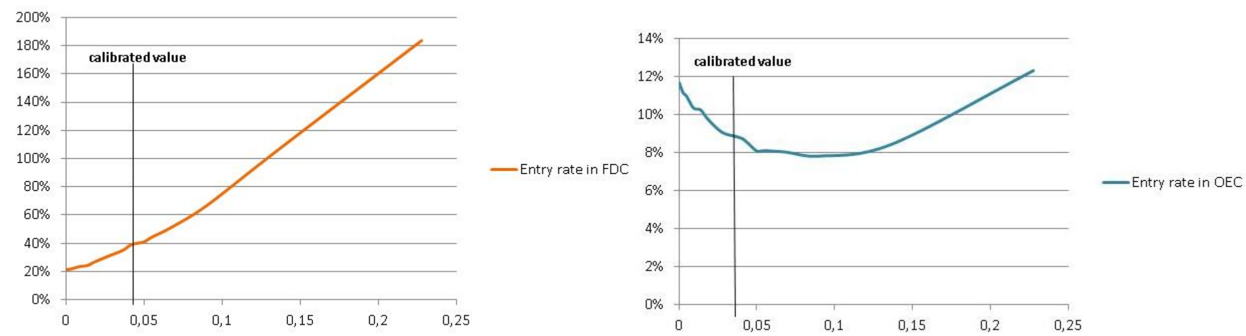

Figure 11: Sensitivity of entry rates to firm demand volatility $\sigma_{deviation}$

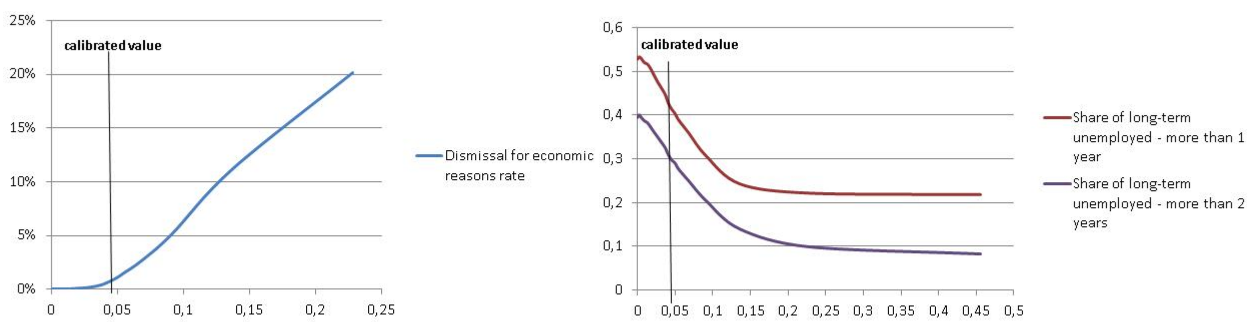

Figure 12: Sensitivity to firm demand volatility $\sigma_{deviation}$

4.2 Analysis of some policies

4.2.1 Increasing firing costs

The rise of unemployment in response to the increase in total firing costs (including advance notic

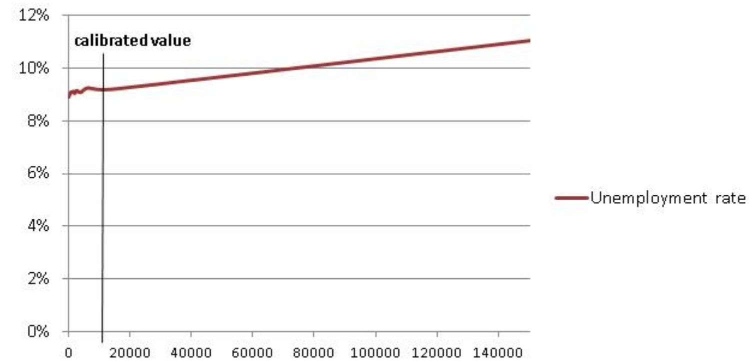

Figure 13: Sensitivity of unemployment rate to firing cost

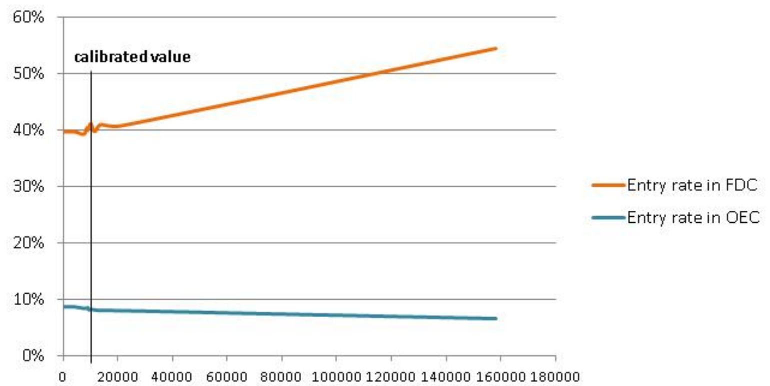

Figure 14: Sensitivity of entry rates to firing cost

4.2.2 Removal of the waiting period of FDC

The French law imposes a waiting period during which a terminated FDC cannot be proposed again on the labor market. If this constraint is suppressed, the result goes against intuition. The unemployment rises. There is more entry in FDC, and even a little more in FDC of one week. The entry rate in OEC decreases a little also. These changes entail an increased churning and higher unemployment.

[16] An experiment on the suppression of this difficulty ot fire has not been done in this first version, and is of course necessary to assess its role

	With waiting period	Without waiting period	Deviation
Unemployment rate (global)	9.07	9.38	+0.31***
Unemployment rate (15-24)	19.14	19.43	+0.29*
Unemployment rate (25-49)	8.16	8.46	+0.3***
Unemployment rate (50-64)	6.17	6.51	0.34***
Employment rate	61.47	61.25	-0.22***
Activity rate	67.61	67.61	+0.0
Entry rate	48.84	52.59	+3.75***
Entry rate in FDC	40.49	44.65	+4.16***
Entry rate in OEC	8.35	7.94	-0.41*
Share of FDC in employment	8.74	9.36	+0.62***
Share of FDC of 1 week in employment	1.41	1.49	0.08***

***Statistically significant at 99.9%

*Statistically significant at 95%

Table 1: Removal of the waiting period of FDC

4.2.3 Forbidding fixed duration contracts

Finally we assume that FDC are forbidden, and that the only contracts are the OEC and the customary FDC contracts who are limited in number. The global unemployment rate decreases, but only by half a point . We have seen that theory cannot predict the net effect of such a suppression of FDC since the churning effect predicts a rise in unemployment while the other three effects, buffer, screening and stepping stone, predict the reverse. For a model calibrated on the French data of 2011, the apparent conclusion is that the churning effect dominates slightly the others. The story is however more complex than this. The employment rate do not increase significantly since some unemployed find it very difficult or impossible to pass the hiring standards of OEC. They become more often long term unemployed, and exit the labor market so that the activity rate declines by 47/100 of a point. . The disappearance of the buffer effect, and of the screening and stepping stone effects of the FDC explain this discouragement. Finally individuals play a role in the net effect of the suppressionof FDC. As a combined result of the churning effect and this decrease in activity the global unemployment declines. One should be very careful about the robustness of the net effect, which depends on so many factors. The interest of the policy experiment is first to show that the opposed effects of suppressing FDC are likely not to yield the important rise in unemployment that is often predicted. Second the model is here able to (tentatively) display the complexities of the effects of a policy.

	With FDC	Without FDC	Deviation
Unemployment rate (global)	9.07	8.39	-0.68***
Unemployment rate (15-24)	19.14	18.98	-0.16
Unemployment rate (25-49)	8.16	7.34	-0.82***
Unemployment rate (50-64)	6.17	5.59	-0.58***
Share of long-term unemployed - more than 1 year	41.71	61.38	+19.67***
Share of long-term unemployed - more than 2 years	30.12	47.69	+17.57***
Employment rate	61.47	61.49	+0.02
Activity rate	67.61	67.14	-0.47***
Entry rate	48.84	21.49	-27.35***
Entry rate in FDC	40.49	4.75	-35.74***
Entry rate in OEC	8.35	16.74	+8.39***

***Statistically significant at 99.9%

Table 2: Forbidding fixed duration contracts

5. Conclusion

We have extended a agent-based model of the French labor market with heterogeneous firms and jobs and heterogeneous workers and households to endogenize the choice by the firms between OEC and FDC when deciding to open a vacancy. This model takes into account the main costs that each type of contract generates. Some are common, such as the training cost and the vacancy cost, although they have to be amortized on a much shorter period for FDC. Some are specific to one type of contract such as the firing costs, the losses involved when firing is impossible because the courts would not admit it, and the advance notice cost for an OEC on the one hand, and the waiting cost and the precarity bonus for a FDC on the other hand. These costs generate the main effects mentioned in the literature, namely the churning, buffer, screening and stepping stone effect. We model all these mechanisms together for the first time. Some such as the buffer effect require an inter-temporal framework into which fires become an endogenous variable, since a hire on an OEC today leads a firm with several jobs to make scenarios on the future to forecast the risk and cost of having to lay her off, which may lead to prefer a FDC.

Our modeling methodology allows to take into account the crowding out effects since the decisions of the competing agents determine the complete gross flows within a labor market with coherent stock-flows accounts. Calibration by a powerful algorithm allows us to fit the model to the French data with a reasonable mean error, and reasonable errors for most of the important variables of interest for the study of the choices between OEC and FDC. The model then displays the results of sensitivity analysis. The volatility of idiosyncratic shocks on firms demand as well as the weight of pessimistic anticipations raise the unemployment, and explain changes in the mix of the types of contracts. These appear to be strong effects. Consequences of changing a number of policy variables such as the firing costs, training costs or the waiting delay also have sometimes unexpected net effects on the unemployment. For instance firing costs seem to have only a small effect on hires in OEC and unemployment since the difficulty to fire remains an obstacle to such hires. The suppression of the FDC has opposed effects, and the net effect on unemployment seems to be low. It is an empirical issue and the result depends on the quality of the calibration, which can be improved. Finally workers choices, while not being the driving force in the mix of jobs, may play a role in the net effects of some policies through their participation decision.

The model goes beyond the more partial models that have been built on the choice between OEC and FDC. It brings a blend of two contradictory but necessary contributions. It keeps generality since the costs and benefits of FDC versus OEC exist in the other countries, with more or less weight. The importance of the animal spirits of employers is a major determinant of the buffer effect, showing the interest of taking them into account in a model, as Nobel prizes Akerlof and Schiller (2009) (Akerlof G., Schiller R. (2009), Animal spirits, Princeton University Press, Princeton.) have advocated researchers. Many countries other than France have some of the legal mechanisms that are built into the model. Yet it has enough institutional detail and fit to the data to allow for a study of the net changes of the interactions of the institutions for the French unemployment.

The present analysis can be pursued further, since it has been short on productivity and welfare. Firms also have two other types of contracts with a smaller share in their employment that they can use: apprenticeship and temporary help. The latter is an additional but costly mean to adjust to demand shocks. Work is in progress on integrating this latter contract in the model.

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Appendixes

A List of WorkSim agents characteristics

Individuals

Specific attributes of individuals

- gender
- base alpha parameter (preference of the individual for free time or work when entering the labor market)
- initial occupation level when enter the labor market

Internal variables of individuals

- age between and 65, which evolves during the simulation
- current occupation level (which can change if the individual receive a promotion)
- the state on the labor market: employed, OTJS (person employed and looking for an other job), unemployed. inactive, student, retired
- the firm, the job, the contract and the salary if employed
- salary history during all the career
- matrimonial status
- list of information about states and incomes of the other members of her household (partner and children). The model evolves in closed population, then the others members of the household are agents in the model.
- current alpha parameter (preference of the individual for free time or work), evolving during the simulation
- human capital, general experience on labor market and specific experience in a job of a firm

Private Firms

Specific attributes of private firms

- base productivity and base salary of its jobs by occupation level
- amenity of its jobs by occupation level: non-monetary characteristics evaluated imperfectly by the employed (e.g. working conditions....)
- share retained by the firm on employee's productivity value

Internal variables of private firms

- lists of employees, jobs and contracts
- list of vacancies
- yearly balance of profit and loss
- demand margin

B Key Economic Computations in the WorkSim Model

We describe here some key economic computations in WorkSim on the firm side.

B.1 Firm Benefit

At each step of our simulation – one week in the reality, we suppose that each firm j with $n_{j,q}$ employees at the occupation level cannot sell more goods than its demand quantity $D_{j,q,t}$ and its production $Q^{eff}_{j,q,t}$. $Q^{eff}_{j,q,t}$ is the sum of the production of all these $n_{j,q}$ employees. The good is produced before the firm knows its demand, so that the firm pays the wages and the other costs even if the good is not sold. The good cannot be stored and any excess of offer is lost. The income of the firm j at time t is given by:

$$R^{eff}_{j,t} = P \times \sum_{q=1}^{3} min(Q^{eff}_{j,q,t}, D_{j,q,t}) \quad (12)$$

The regular global cost of the firm is:

$$C^{eff}_{j,t} = \sum_{i=1}^{n_j} C^{eff}_{i,j,p,t} \quad (13)$$

where $C^{eff}_{i,j,p,t}$ is the effective salary cost of the employee i in a job p in the firm j at time t and n_j the total number of employees.

The profit of the firm at time t is given by:

$$\Phi^{eff}_{j,t} = R^{eff}_{j,t} - C^{eff}_{j,t} \quad (14)$$

This profit is stored in the history of the firm in order to perform a yearly balance (cf. section 2.6.4).

B.2 Job features

Each firm j has a specific job of managing director noted p_0 and a list $(p_{q,1}, p_{q,2}, ..., p_{q,m_{j,q}})$ of $m_{j,q}$ jobs per occupation level q. A job can be in 3 different states : *filled, vacant* or *pending*. In the model we distinguish between the job and the contract, and the contract assigned to the job can change if for example the firm transforms a FDC into a OEC for the same employee on the same job.

Each job p of the occupation level q is characterized by specific attributes determined once for all at its creation :

- a vector of required human capitals $(CH^{general}_{req,p}, CH^{occup}_{req,p,q}, CH^{spec}_{req,p})$. These human capitals represent the minimum skills required to work on this job and they are randomly drawn according to uniform distributions respectively between 0 and $MaxCH^{general}_{req}$, $MaxCH^{occup}_{req}$and $MaxCH^{spec}_{req}$. We will see in the next section that an individual can acquire these skills with experience and training.

- The number of hours required on the job, $NbHoursPerWeek_p$. This number of hours is randomly drawn at the time of creation of the job. It has a probability $ProbaHalfTime$ to be equal to 17.5 hours (part-time job) and $1 - ProbaHalfTime$ to be equal to 35 hours (full-time job).

- A hourly base production equals to the hourly base production for all jobs in the firm at occupation level q. It is randomly drawn at the creation of the firm j within bounds from a standard normal distribution with a mean μ_q, which depends on the occupation level of the job, and a standard deviation σ_Q:

  $$Q^{base}_{j,q} = Max(0, \mu_q \times \mathcal{N}(1, \sigma_q))$$

  Then the weekly base production of the job is given by :

  $$Q^{base}_{p,q} = Q^{base}_{j,q} \times NbHoursPerWeek_p \quad (15)$$

- A hourly base salary determined from the base production in the job for all jobs in the firm at occupation level q :

$$S_{j,q}^{base} = Q_{j,q}^{base} \times P \times (1 - \zeta_j) \tag{16}$$

with $P = 1$ the exogenous price of the (unique) good and $\forall j,\ \zeta = \zeta$, an exogenous parameter that represents the share of the base productivity value kept by the firm (in order to pay expenses, taxes, interests, dividends, etc.). The weekly base salary of the job is then :

$$S_{p,q}^{base} = S_{j,p,q}^{base} \times NbHoursPerWeek_p$$

- A level of amenity. This represents non-monetary features perceived by the individual on the job (social recognition, working environment, job hardness...). A hourly base amenity randomly drawn at the creation of the firm as a percentage of the base salary for all occupation level q according to $Amen_{j,q} \sim \mathcal{N}(0, PrA \times S_{j,p,q}^{base})$. PrA is an exogenous parameter. The weekly base amenity of the job is then $Amen_{p,q} = Amen_{j,q} \times NbHoursPerWeek_p$.

B.3 Effective production of an employee i in a job p : $Q_{i,p,q,t}^{eff}$

There is a base productivity attached to each job, and the employee's characteristics and effort will modulate its value. Moreover, the employer has only an imperfect and evolving information on individual productivity [17].

The effective productivity of an individual i at job p is given by :

$$Q_{i,p,q,t}^{eff} = Q_{p,q}^{base} \times CProd_i \times F_\beta(CH_{i,t}^{general}, CH_{i,q,t}^{occup}) \times F_\lambda(CH_{i,p,t}^{spec}) \tag{17}$$

The effective productivity is based on four complementary factors : (1) the base production in the job, (2) the core productivity of the employee, (3) the general human capital and the human capital of the employee in the occupation level of the job he holds, and (4) the specific human capital in the job [18]:

1. The base production $Q_{p,q}^{base}$ for the job p in occupation q is given above by equation 15

2. $CProd_i$ is the core productivity of the individual i. $CProd_i \sim Max(0,\ \mathcal{N}(1, \sigma_{Prod}))$ with standard deviation σ_{Prod} is determined once for all when the individual enters the labor market. It encodes the initial skills and motivations of the individual.

3. $F_\beta(CH_{i,t}^{general}, CH_{i,q,t}^{occup}) = 1 + \beta \times CH_{i,t}^{general} - \beta' \times (CH_{i,t}^{general})^2 + \beta_q \times CH_{i,q,t}^{occup} - \beta_q' \times (CH_{i,q,t}^{occup})^2$. β, β', $\beta_q$and β_q' are exogenous parameters. $CH_{i,t}^{general}$ and $CH_{i,q,t}^{occup}$ are the stocks of general human capital and human capital in the occupation level q of the job detained by individual i at time t. Each period spent in employment, $CH_{i,t}^{general}$ and $CH_{i,q,t}^{occup}$ increase[19] by 1 but are reduced by a percentage respectively $PrLossXP$ and $PrLossXP_q$ in each period spent out of employment [20]. This decrease will start respectively only after $TLossXP$ and $TLossXP_q$ periods after leaving employment. These human capitals may also increase if the individual receives a training by the firm when he is hired. With this training, $CH_{i,t}^{general}$ and $CH_{i,q,t}^{occup}$ rise until they reach the human capitals $CH_{req,p}^{general}$ and $CH_{req,p,q}^{occup}$ required by the job.

[17] In this productivity differentiation, we find 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 with the previous version of WorkSim [Lewkovicz and Kant, 2008], the present version introduces experience factors and imperfect information.

[18] These complementarities are justified by various economic studies. The complementarity in terms of performance between a technological level of a job (related to implicit physical capital associated) and a level of human capital used is a common accepted fact [Leiponen, 2005], 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 her specific knowledge [Ballot and Taymaz, 1997, Acemoglu and Pischke, 1998]

[19] These increases in productivity correspond to the *learning by doing* phenomena highlighted by Arrow [Arrow, 1962] and represent increases in productivity without training costs for the firm.

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

4. $F_\lambda(CH^{spec}_{i,q(p),t})$ is the job-specific production factor, given by $F_\lambda(CH^{spec}_{i,p,t}) = 1 + \lambda \times CH^{spec}_{i,p,t}$. λ an exogenous parameter. $CH^{spec}_{i,p,t}$ is the specific human capital of an individual i in the job p in the firm j and depends on the seniority of the employee on the job $Senior^{spec}_{i,p,t}$. This seniority is increased by 1 each period spent in the job p. The specific human capital also increases if the individual receives a training when he is hired. In this case, it reaches the specific human capital $CH^{spec}_{req,p}$ required by the job. Notice that if the individual receives a promotion and changes her occupation level in the company, the seniority in the job will be reset to 0. The specific human capital in the original definition of Becker [Becker, 1975] represents the skills acquired by an individual in a firm and only useful in this firm. However, the seniority factor appears to have little impact (at least on wages) in France since the 90s [Beffy et al., 2006]. In our model, we distinguish jobs by occupation and each level in the hierarchy of occupations allows to acquire specific skills (technological and social) in this occupation[21].

B.4 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, 1979], 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 about the precise levels of real productivity for each of its employees. Therefore, it is only able to assess a level of *estimated productivity*:

$$Q^{estimated}_{i,p,q,t} = Q^{eff}_{i,p,q,t} \times \sigma^{Eval}_{i,p,q,t} \quad (18)$$

$\sigma^{Eval}_{i,p,q,t}$ represents the degree of uncertainty of the company in the evaluation of its employees. It depends on the seniority of the employee at her job p in the firm and is drawn from the following distribution when the employee is hired, and also at each employee evaluation :

$$\sigma^{Eval}_{i,p,q,t} = Max(0, \mathcal{N}(1, \sigma_0 \times (1 - \delta_\sigma \times Senior^{spec}_{i,p,t}))) \quad (19)$$

with σ_0 and δ_σ two exogenous parameters[22].

B.5 Cost of an employee i in a job p : $C^{eff}_{i,p,q,t}$

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

$$S^{eff}_{i,p,q,t=hiring} = Max(SMIC,\, S_{p,q} \times F_\beta(CH^{general}_{i,t}, CH^{occup}_{i,q,t}) \times F_{\lambda^*_q}(CH^{spec}_{i,p,t}) \times G(U_{q,t=publish})) \quad (20)$$

SMIC [23] is the minimum hourly wage in France, net of the employee's contribution to social security. The starting salary is the weekly base salary of the job $S_{p,q}$ modulated by the factors of human capitals of the employee. Due to important considerations of equity in terms of human resource management (e.g. [Adams, 1963]), the employer cannot discriminate between employees who have the same experience. A feeling of unfairness could generate decreases in effort and productivity for the employees who feel unequally treated (efficiency wage concept)[24]. $F_{\lambda^*_q}(CH^{spec}_{i,p,t})$ is the productivity gains factor related to her

[21] We have made the choice to discard the notion of firm human specific capital by creating instead two types of specific capitals. The first is the occupation human capital, which corresponds to the professional skills acquired in the educational system and subsequent experience acquired in a given occupation level. This type of human capital is obviously important and distinct from general human capital in the model (see [Gibbons et al., 2005], [Kambourov and Manovskii, 2009] for evidence) . In the model it is specific to a broad aggregate of occupations i.e. qualification q . The second is the job specific human capital. It covers possibly some required training given when entering the job but in any case the experience by learning on the job. It is assumed to be so specific that it will not have any use in other jobs. It notably contains some social skills specific to the job.

[22] Note that when the firm only has one employee, the firm knows its global production $Q_{j,t}$ and does not have any doubt on her effective production; therefore $\sigma_{i,p,q,t} = 0$.

[23] as for "Salaire minimum interprofessionnel de croissance". In 2011, the monthly net minimum wage for a full-time job was 1 072 €.

[24] Moreover, in terms of theoretical consistency, it is necessary to choose a posted salary and not a salary negotiated on the basis of the match value. 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 them (or not).

experience in the job in the firm which affects her salary. It is assumed here that the company gives to the worker only a part of the productivity gains related to specific human capital on wages, hence $\lambda_q^* < \lambda_q$. 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 [25]. A final factor affecting wages is the global unemployment rate $U_{q,t=publish}$ at the time of publication and at the level of qualification q of the job offer by the firm.
We consider that the relation G is isoelastic, according to the literature on the wage curve [Blanchflower and Oswald, 1994], and take $G(x) = k_q \times x^{\omega}$, where ω is an exogenous parameter, set as its standard value of -0.1, and $k_q = (\frac{1}{U_{q,ref}})^{\omega}$. $U_{q,ref}$ is set as the global unemployment rate for the reference year we study for the level of qualification q.

This weekly salary of employee i in firm j is reviewed annually at her birthday date of her arrival in the company according to the same equation 20.

Effective cost of an employee The effective cost of an employee i on a job p, $C^{eff}_{i,p,q,t}$ include her salary $S^{eff}_{i,p,q,t}$ and payroll charges .

$$C^{eff}_{i,p,q,t} = S^{eff}_{i,p,q,t} \times (1 + PrCharges) \tag{21}$$

$PrCharges$ is the ratio of social security charges to salary.

[25] See e.g. [Lindbeck and Snower, 1988]. Note that very strong recessions like the current crisis might justify to qualify this hypothesis

C Parameters of the institutional framework

Parameter	Description	Value for France in 2011
$FDCbonus$	Percentage of the gross wage given to the employee at the end of a FDC	10%
$FiringCost$	Firing cost of an employee in OEC depending on his/her salary and seniority	cf. paragraph below
$NoticePeriodOEC$	Legal dismissal notice period for an OEC	1 month if employee's seniority is below 2 years. 2 months otherwise.
$EmployerCharges$	Percentage of employer's social security contributions on net wage	54%
$EmployeeCharges$	Percentage of employee's social security contributions on net wage	28%
$ReductionCharges_{>20}$	Reduction of employer's charges at the SMIC level for firms with 20 employees or more	26% of gross wage
$ReductionCharges_{<20}$	Reduction of employer's charges at the SMIC level for firms with less than 20 employees	28.1% of gross wage
$SMIC$	Monthly net minimum wage for a full-time job	1 072 €
RSA	Minimum income for people without ressources	467 € per month for a single person aged 25 or more
$ALCHO$	Unemployment benefits	See [Public, 2011] for the calculation
$ProbationaryPeriodFDC$	Probationary period of a FDC	One day per working week with a limit of 2 weeks in the expected duration of the contract is below 6 months. 1 month if the expected duration of the contract is over 6 months.
$ProbationaryPeriodOEC$	Probationary period of a OEC	2 months for blue collars. 3 months for middle level positions. 4 months for executives.
$WorktimePerPeriod$	Legal work time per week for a full time job	35 hours
$AgeRetirement$	Minimum retirement age for a full-rate pension	65 years

Table 3: Parameters of the institutional framework

Firing Costs for OEC In 2011, according to the article R. 1234-2 of the Labor Code in France in 2011, the severance pay for an employee dismissed is one fifth of one month's salary per year of seniority. For employee with at least ten years of seniority, this severance pay is one fifth of one month's salary plus two fifteenth of one month's salary per year of seniority over ten years (Labor laws \$L.1234-9\$, \$R.1234-2\$ et \$R.1234-4\$). The reference salary used to calculate the severance pay is the maximum between the average of the gross wages in the last 12 months and the average of the gross wages in the last 3 months.

There are additional costs if the employee appeals to the public employment court (in French "Prud'hommes"). The rates of use of court in the case of firing for economic and personal reasons are estimated by [Serverin and Valentin, 2009] respectively at the values 1.12% and 17%.
According to [Munoz Perez and Serverin, 2005], the probability that an employee succeed with this procedure is 64.5%. If an employee conduct a legal proceeding and succeed, the employer has to pay an additional compensation at least equal to the salaries of the last 6 months (Article L1234-9 of the Labor Code). The employer has also to reimburse to the public institutions the unemployment benefits paid to the employee during the procedure. We assume in the model that the global additional costs correspond to one year of salary of the employee.

If firm has more than 50 employees, it must consider additional costs related to a job-saving plan. We assume that the cost of this job-saving plan for each employee is equal to 10 times its monthly gross wage.

D Profit evaluation algorithms

D.1 Profit evalulation of FDC with initial fixed term d_{FDC}^{init}

Renewal option of a FDC In the French labor law, a FDC is renewable once in the limit of 18 months (Article L1242-8 of the French Labor Code). To simplify, we assume that this renewal is always of the same duration that the initial duration of the contract, but with the limit of 18 months. Thus a FDC with an initial duration d_{FDC}^{init}can be seen as a contract with a duration $d_{FDC}^{renew} = Min(2 \times d_{FDC}^{init}, 18\, Months)$, with an option to end it at d_{FDC}^{init}. Furthermore, it is not rational for an employer to dismiss an employee before d_{FDC}^{init} or between d_{FDC}^{init} and d_{FDC}^{renew} because the employer will have to pay all the unpaid salary until the end of the contract (Article L1243-4). Then for a FDC with an initial duration d_{FDC}^{init}, the set of possible durations is :

$$D_c^{possible} = \{d_{FDC}^{init}, d_{FDC}^{renew}\}$$

Expected vacancy duration d_v and vacancy costs c_v These values are internally learned by the firm. The firm stores the duration of the vacancies with a FDC and an initial duration d_{FDC}^{init} which have terminated during the last 3 years and evaluates an average duration. If the firm does not have enough information to calculate this duration, it asks the *statistical institute* of the model. The cost of a vacancy per period is expressed as a percentage of the weekly base salary of the job : $PrVacancyCostFDC \times S_{p,q}^{base}$

Waiting period d_w When a FDC comes to its end, it is not possible for the firm to hire an employee in the same job with a new FDC before the end of a legal waiting period. This waiting period d_w is equal to $1/3$ of the duration of the contract (including a renewal) if the duration of the contract is more than 14 days and $1/2$ of the duration of the contract if the duration is less than 14 days (Article L1244-3 of the French Labor Code).

Specific end costs for a FDC At the end of the contract, the employer has to pay to the employee a short term contract bonus $FDCbonus$ This amount is 10% of the total gross wage paid during the contract (Article L1243-8). $EndCost_{i,p,q,c} = FDCbonus$

Special case of the *customary FDC* One part of the firm are allowed to create customary FDC as mentioned in section 2.6.3 (Article D. 1251-1 of the French Labor Code). These contracts are evaluated like FDC with a duration of 1 week, but with $d_w = 0$ and $FDCbonus = 0$. Notice that there is also no training costs because the human capitals required for these jobs are set to 0 (cf. section B.2).

D.2 Profit evaluation of OEC

Duration of an OEC A OEC does not have any predetermined duration. The maximum duration corresponds to the retirement age of the employee. However in practice, the employee may quit the job at any time. The firm can also find a professional inadequacy of the employee and then dismiss her at the end of the probationary period, etc... Then we assume that the firm estimates a potential average duration of an OEC by learning. For each occupation level q, the firm computes the average duration $d_{OEC,q}$ of its OEC that have terminated during the last 3 years and $D_c^{possible} = d_{OEC,q}$.

Expected vacancy duration d_v and vacancy costs c_v These values are internally learned by the firm. For each occupation level q, the firm stores the duration of the vacancies with a OEC that have terminated during the last 3 years and evaluates an average duration. If the firm does not have enough information to calculate this duration, it asks the *statistical institute* of the model. The cost of a vacancy per period is expressed as a percentage of the weekly base salary of the job : $PrVacancyCostOEC \times S_{p,q}^{base}$

Firing costs If in a scenario θ of demand evolution, the firm evaluates a negative profit after the duration $d_{OEC;q}$, that is to say if $\phi^{estimated}_{i,j,p,q,t}(\theta, d_{OEC,q}) < 0$ (cf. section 2.6.2), the firm has to take into account a potential additional $FiringCost$. The calculation of this firing cost is detailed in annexe B.

Advance notice period d_n In the case of firing, there is a notice period d_n for the firm before the employee is effectively fired. According to French Labor Code (Article L1234-1), this notice period last for one month in the case of the seniority of the employee is lower than two years, and for 2 months otherwise. During this notice period, we assume that the employee does not produce, but the firm continues to pay a salary. Then the cost is $c_n = d_n \times C^{eff}_{i,p,q,t}(d_{OEC;q})$. With $C^{eff}_{i,p,q,t}(d_{OEC,q})$ determined as in equation 7.

Specific end costs related to personal firing cost The firm has also to consider an additional cost if the OEC ends with a dismissal for personal grounds (if the employee skills are shown to be insufficient for the job) :

$$EndCost_{i,p,q,c} = AvgPersonalFiringCost_q \times ProbaPersonalFiringCost_q$$

with $AvgPersonalFiringCost_q$ the average cost of a firing for personal reasons registered by the firm during the last 3 years and $ProbaPersonalFiringCost_q$ the probability of this event learned by the firm.

E Calibration Results

	All	15-24	25-49	50-64	Executives	Middle Level jobs	Employee/Workers
WorkSim Outputs	9.07	19.14	8.16	6.17	4.89	6.38	9.51
INSEE Source	9.2	22	8.4	6.3	3.8	5.0	11.4

Table 4: Targets on unemployment rate by age group and by socio-professional categories

	Men			Women		
	15-24	25-49	50-64	15-24	25-49	50-64
WorkSim Outputs	42.44	92.01	61.17	38.28	80.9	52.78
INSEE Source	37.90	94.4	61.9	34.5	83.6	54.60

Table 5: Targets on activity rates by age group and gender

	Executives		
	15-24	25-49	50-64
WorkSim Outputs	1706	2755	4221
INSEE Source	2079	3558	4485
	Middle level jobs		
WorkSim Outputs	1382	1713	2519
INSEE Source	1603	2143	2496
	Employee/Workers		
WorkSim Outputs	1197	1220	1618
INSEE Source	1336	1624	1745

Table 6: Average monthly net salaries in euros by age group and by socio-professional categories

	1er Decile	1st Quartile	Median	3rd Quartile	9th Decile
WorkSim Outputs	1072	1189	1560	2231	3213
INSEE Source	1201	1412	1773	2380	3349

Table 7: Monthly net salaries in euros distribution

	Employment entry					
	Entry rate	Entry in FDC	Entry in OEC	Entry rate 15-29	Entry rate 30-49	Entry rate 50-64
WorkSim Outputs	48.17	40.13	8.04	96.51	40.3	26.54
DMMO Source	51.0	40.0	11.1	115	36.6	23.7

	Employment exits					
	Exit rate	End of FDC	Quit	End of probationary period	dismissal for eco. reasons	dismissal for other reasons
WorkSim Outputs	48.92	31.03	8.87	2.61	0.71	2.4
DMMO Source	49.4	35.2	6.5	2.0	0.5	3.2

Table 8: Workforce turnover

	Share of FDC in employment	Share of customary FDC in employment
WorkSim Outputs	8.74	0.096
ACOSS	9.9	0.099

	Share of FDC of less than 1 week in entry in FDC	Share of FDC of less than 1 month in entry in FDC
WorkSim Outputs	35.93	29.22
ACOSS	54.8	21.4

Table 9: Share of FDC in employment

	15-24	25-49	50-64
WorkSim Outputs	31.6	42.3	56.0
INSEE Source	28.4	41.9	57.8

Table 10: Long term unemployment (more than 1 year) share in unemployment

	Half-time job share in employment	Vacancy rate	OTJS rate
WorkSim Outputs	14.72	4.2	3.5
INSEE Source/COE	17.9	4.4	4.3

	Average specific training cost in euros	Average global training cost in euros
WorkSim Outputs	373	1212
Targets	400	1300

Table 11: Additional targets

F Calibrated exogenous parameters of the model

Parameter	Description	Calibrated Value
α_0	Average base factor for individual preference for free time	0.447
α_{old}	Increment of the factor for individual preference for free time every year for an individual	2.09×10^{-5}
α_{child}	Sensitivity parameter to the preference for free time of women depending on the number of children in her household	0.088
$\alpha_{youngWomen}$	Specific sensibility parameter to the preference for free time for young women under 25 having children	3.71
$ICHANG$	Psychological cost face of change	1.06
PT	Profit threshold under which the firm initiates a redundancy plan	-55%
σ_{trend}	Distribution parameter of trend on demand for firm	0.0063
$\sigma_{deviation}$	Distribution parameter of standard deviation on demand for firm	0.046
N_0	Parameter in hiring norm calculation	0.79
N_1	Parameter in hiring norm calculation	0.096
N_2	Parameter in hiring norm calculation	0.0093
N_3	Parameter in hiring norm calculation	0.11
ζ	Share of base productivity value kept by the firm	0.73
$\mu_{\Psi,Executives}$	Mean share of the firm demand allocated for executive positions	0,354
$\mu_{\Psi,MiddleLevel}$	Mean share of the firm demand allocated for middle level positions	0,298
β	Sensitivity factor to general human capital	2.22×10^{-3}
β'	Sensitivity factor to general human capital	2.73×10^{-8}
$\beta_{Executives}$	Sensitivity factor to human capital in the occupation level : *Executive*	2.54×10^{-3}
$\beta'_{Executives}$	Sensitivity factor to human capital in the occupation level : *Executive*	5.44×10^{-8}
$\beta_{MiddleLevel}$	Sensitivity factor to human capital in the occupation level : *Middle Level*	8.05×10^{-4}
$\beta'_{MiddleLevel}$	Sensitivity factor to human capital in the occupation level : *Middle Level*	4.31×10^{-8}
$\beta_{EmployeeWorker}$	Sensitivity factor to human capital in the occupation level : *Employee/Worker*	5.54×10^{-5}
$\beta'_{EmployeeWorker}$	Sensitivity factor to human capital in the occupation level : *Employee/Worker*	1.31×10^{-7}
σ_{Prod}	Standard deviation of the distribution of individual core productivity	0.14
σ_0	Initial standard deviation of employee productivity estimation by firms	0.35
δ_σ	Decrease factor of σ_0 with employee seniority	0.0033
$ProbaHalfTime$	Probability for a new job to be a part-time job	0.203
$\mu_{Executives}$	Average hourly base productivity of executive jobs	13.25
$\mu_{MiddleLevel}$	Average hourly base productivity of middle level jobs	11.73
$\mu_{EmployeeWorker}$	Average hourly base productivity of employee/worker jobs	9.77
$MaxCH^{general}_{req}$	Maximum general human capital required for a job	1580
$MaxCH^{occup}_{req}$	Maximum human capital in occupation level required for a job	509
$MaxCH^{spec}_{req}$	Maximum specific human capital required for a job	116
$PrTrainingCost^{general}$	Parameter in training cost calculation	0.091
$PrTrainingCost^{occup}$	Parameter in training cost calculation	0.061
$PrTrainingCost^{spec}$	Parameter in training cost calculation	0.073
ω_{-1}	Weighting coefficient for pessimistic scenario	78.7%
ω_0	Weighting coefficient for neutral scenario	18.8%
ω_{+1}	Weighting coefficient for optimistic scenario	2.6%
$param1_{UTRES}$	Parameter in reservation utility calculation	0.906
$param2_{UTRES}$	Parameter in reservation utility calculation	0.083
$PrVacancyCostFDC$	Parameter in vacancy cost calculation for FDC	0.24
$PrVacancyCostOEC$	Parameter in vacancy cost calculation for OEC	5.75
ρ	Parameter for personal firing legal justification	0.99
$TimeLossCH^{general}$	Time in period before loss in general human capital	29
$TimeLossCH^{occup}$	Time in period before loss in occupation level human capital	52
$PrLossCH^{general}$	Share of general human capital lost each period after $TimeLossCH^{general}$ period out of employment	2.3×10^{-4}
$PrLossCH^{occup}$	Share of human capital of level q lost each period after $TimeLossCH^{occup}$ period out of employment in level q	0.0019