WorkSim, an agent-based model to study labor markets

Jean-Daniel Kant[1,2], Gérard Ballot[3,4] and Olivier Goudet[1,2]

[1] Sorbonne Universitées, UPMC Univ Paris 06, UMR 7606, LIP6, F-75005, Paris, France
[2] CNRS, UMR 7606, LIP6, F-75005, Paris, France
jean-daniel.kant@lip6.fr, olivier.goudet@gmail.com
[3] Université Paris 2, CRED EA-7321, Paris, France
[4] TEPP FR CNRS 3435
gerardballot@wanadoo.fr

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Abstract. In this paper, we introduce the WorkSim model, a novel agent-based framework to study labor markets. The first objective of the model is to reproduce the gross flows of individuals between the important states: employment (distinguishing fixed term contracts and open ended contracts), unemployment and inactivity, and the ratios of individuals in these states. French legal Institutions of the labor market are modelled in some detail. The decisions are taken on the basis of the bounded rationality since firms and individuals are heterogeneous, and employers form anticipations. One novelty of the model is that we consider multi-jobs firms and shocks on the firm's demand so that the employer can take into account anticipated shocks when he decides on the types of contract. Once the model is calibrated, the second objective is to characterize the nature of the labor market under study, and notably the roles of the two types of contracts. This is done, first by examining the patterns of flows and stocks at the aggregate level and at the levels of different categories of labor, and second by sensitivity experiments, modifying some exogenous parameters and variables such as total demand. We then uses the model as a tool for experimenting labor market policies, including changes in the labor law in France. Several contributions to the literature on dual labor markets are then offered.

1 Introduction

WorkSim is a novel agent-based framework to study labor markets (Goudet et al., 2016). The multi-agent methodology is the perfect tool for such a research program, since it can model institutions precisely, and account for heterogeneity and individual interactions. Simulation results enable us to compute aggregate variables such as the flows and the stocks of both jobs and workers, and finally the individual careers and the main types of trajectories.

Agents are autonomous and there is then no need for an auctioneer, an assumption in many orthodox models, implemented either through centralized wage setting or through a matching function, which has consequences since a centralized labor market has different outcomes from a decentralized labor market[5]. The agents take decisions based on their information and the calculation of costs and benefits, and the profit (for the firms) or utility (for the individuals) they expect. The environment is very complex because of the institutions and the interactions, and changing, and their rationality is bounded in the sense of Simon (1956). Therefore, when in a given state, they choose the best of a few possible solutions (see below for examples). They make mistakes when deciding, but in

[5] the real labor markets have some intermediaries such as Employment Agencies and temporary help firms, but they should be introduced in a decentralized environment with their specificities

WorkSim, they can learn and revise their requirements in the future. The institutions and legal rules that constrain the decisions are modeled precisely. The model allows for non-linear consequences of policy or behavioral changes, and notably crowding-out effects, often important in labor markets, and source of distributional changes. The computed effects of the law El-Khomri will bring a resounding example.

We build a partial equilibrium model, with a exogenous total demand for the good. Then we assume that each firm produces a variety of a unique good with horizontal differentiation, and that there is a unique exogenous price. However, *Each firm faces stochastic shocks on its demand share*, which can be seen as fluctuations of consumers' preferences.

1.1 Extending Search Theory

WorkSim is grounded in the concept of *search* (Phelps, 1970). Search Theory studies how economic actors find a partner for their transactions (here workers look for a job in a company, and employers a worker for a vacant job)[6]. In WorkSim the basic concept of search is developed in several directions, some new, in order to build the complete framework of job and workers' flows that is needed:

1. *Matching emerges from bilateral meetings on a decentralized labor market.* Employers post vacant jobs with wages that workers will apply for (or not). Employers select among those who are high in the productivity distribution. They prefer to keep a job vacant than hire a worker with a poor productivity. A stopping rule taking the form of a minimum productivity requirement or hiring standard follows. Moreover agents have an imperfect evaluation of the future match value: workers do not know the amenity of the job (conditions of work) before being hired, and the employer has an uncertain information of the worker's productivity). No matching function is then used, which distinguishes the model from the matching models (Mortensen and Pissarides (1994). The matching function introduces an unrealistic intermediary, and has weaker microeconomic foundations than the sequential double search framework which can cope with heterogeneity and informational differentiation[7]. However the main problem is that it is not robust to large changes in the labor market and does not reproduce crowding out affecting some categories of workers.[8].
2. *Firms are multi-jobs.* This is new to search literature, and is a major feature that is key to the contribution of the model to the analysis of the employers' choices between the two types of contracts. We consider that shocks are on demand to the firm, a realistic assumption, rather than on individual jobs productivity, as in the search literature.

[6] The search concept is first necessary to distinguish the two states of "unemployed" and "inactive" on the basis of rational decisions of agents. There is indeed a flow from unemployment to inactivity, because the value in terms of unemployment utility (expected gains from search minus time foregone) may become lower than the utility of inactivity (including welfare and free time). In that case, the individual stops search and becomes inactive. This is distinct from the fact that part of the inactive persons do not want to work because they have some other resources and value non-working time (caring for children)

[7] for instance an employer has more information on a worker he has had in FTC than on external candidate

[8] For evidence of the bias introduced by a matching function as a result of an employment policy, see (Neugart, 2008).

The firm faces a yearly idiosyncratic random trend (on its share of the market), and random weekly variations around that trend. The employer forms anticipations on future demand, and, if present demand rises, takes into account future cost and benefits of each type of contract before deciding to create a job. On the one hand employers can offer short Fixed term contracts (FTC) and some of them reach their termination as the time demand falls. On the other hand economic dismissals of Open Ended Contracts (OEC) take administrative delays - generating hoarding costs- and severance pay. Hence hiring FTC can be a good choice for an employer who is uncertain about his future demand. However FTC have their own problems such as limited renewal and a bad amortization of training costs. Considering firms with multiple jobs and demand shocks then makes possible to model the choice by each firm of a profitable mix of the two types of contracts. Productivity changes in each job-worker match are modeled as improvements in workers productivity, a non random mechanism, which is based on general experience and on-the-job learning with seniority, and some productivity random variations over time (due to health for instance) are also added. We add an assumption of wage rigidity to shocks that means that demand shocks cannot be solved by the employer by changing the wages. Equity and motivation justifications based on efficiency wage theory can be invoked to give microfoundations to this behavior. Entry wages are flexible to the labor market conditions, but incumbent wages are rigid, with rises depending on human capital accumulation. As a consequence of the multi-jobs feature, finally we needed to model anticipations carefully and in some detail, and these include a novel feature in labor market modeling, with the introduction of subjectivity, in the line of Kahneman et al. (1982) and Akerlof and Shiller (2010). All these features put together yield a coherent search model which differs deeply from existing models.

3. *The search calculus is extended and integrated in most other decisions on the labor market which involve more than search costs.* First workers take other voluntary decisions than applying for a job, such as quits and on-the-job search (i.e. looking for a new job while remaining employed). Search calculus in terms of utility is also done about decisions of entry and exit of workers, but we include some elaborate features such as taking into the psychological cost of starting to search, and the total income of the household, the latter assumption brings non market interactions between individuals, an empirically observed behavior on the labor market. Second firms also take into account the search costs of replacement when they consider firing a worker, for lack of productivity.

   Demand shocks and workers'productivity changes allow us to explain the flows: Demand shocks explain job creations and hires, part-time, economic dismissals, while productivity changes explain personal dismissals, promotions and transformations of FTC into OEC, since FTC can be also used as screening devices.

Moreover a major difference between WorkSim and the analytical search models relies on our utilization of the concept of Simon's **bounded rationality** to model the decisions (Simon, 1955). Two major arguments can be given:

1. First, dynamic programming algorithms used to solve the decision problem in analytic search theory cannot be used in a model in which heterogeneous agents move sequentially into many states over time, build a differentiated CV, and compete.
2. Second, according to bounded rationality theory, real agents have limited capacities in terms of computation and memory. They might therefore use simple rules, but a very important behavioral addition in our approach is that they can revise their decisions or even their rules thanks to **learning** and collecting information. This continuous learning is in fact very coherent with search theory. However, in order to compute equilibrium, analytical models assume perfect rationality and individuals have a lot of information such as the true distribution of wages, and firms the true distribution of productivities. By contrast, in WorkSim, we model "simple" decision rules - that comply with bounded rationality, partial information and learning processes.

1.2 Related Agent-based models

Our model takes place in a multi-agent literature on labor markets which is thin but has a long history. Bergmann (1974) has developed a simple search model by both sides of the market and obtained simultaneously vacant jobs and unemployment. Eliasson (1977) has built a Keynesian and Schumpeterian micro-to-macro model which treats only firms as individual agents but the number of workers in a firm can vary and unemployment is computed. ARTEMIS (Ballot, 1981, 2002) , the ancestor of WorkSim, is based on search decisions by individuals and multi-jobs firms. It is the first multi-agent model to have modeled the gross flows of individuals between the three main states, with the addition of on-the-job search as a state. This was also done within an institutional framework, notably with workers either in OEC in internal labor markets, other workers in OEC without careers, and others in a temporary help firm. The model generates a temporary segmentation of the young workers. Then, a negative demand shock affected the male workers of intermediate age in OEC very little but was concentrated on the other categories of labor, precluding the progressive integration of young workers in the internal labor markets. This led to a permanent segmentation with serious life cycle consequences for some individuals.

The years 2000 have mainly seen multi-agents models aiming at theoretical research (see Neugart et al. (2012) for a recent review), such as introducing networks, a logical way to consider search in some contexts (Tassier and Menczer, 2001). Richiardi (2004) modeled the matching process between workers and firms with on-the- job search, entrepreneurial decisions and endogenous wage determination. Neugart (2008) developed an agent-based labor market model with sector-specific skill requirements. Barlet et al. (2009) simulate the French labor market for year 2006. They distinguish individuals and jobs, but not firms as such although there is labor demand side, with creations and destructions of jobs based on a desired margin and demand.

WorkSim goes beyond the existing multi-agent literature on the labor markets on three dimensions:

1. It is the only ABM labor model to be grounded in a **double stock-flow accounting**, one for the individuals, one for the jobs, and most of the important flows are considered. This accounting is the equivalent of the financial stock-flow accounting for ACE macroeconomic models, a guarantee of coherence. It also allows for a easy description of the labor market dynamics at the aggregate and any disaggregation level of interest, and the highlighting of the competition between categories of labor (young, adults, seniors....).
2. It models the **institutions and the labor law** at their level of direct impact (the microeconomic level), since they are rules of the game that agents know and take into account in their decisions. The diverse forms of labor contracts, with very extreme differences, are probably the major feature of the French labor market, and they are at the heart of the model, since they modify the flows [9].
3. The model aims at reproducing the stocks and flows during a year, and assumes it is a steady state - an approximation, but the year chosen, 2014, is not a year of great aggregate change. Then the model is calibrated by a powerful algorithm on a large number of targets, aggregate of by category of workers (63) and 60 parameters.

The paper is organized as follows. In section 2, we describe the main features of the model. In section 3, we present our validation method – through calibration – and in section 4 a brief characterization of the simulated French labor market and some simulation experiments. We will show how WorkSim could be used to assess labor policies, including the recent "Labor Law" that attracted most of the attention recently in France, and generated vivid debates among politicians and economists. Section 5 will conclude and open the discussion.

Note that if the current version WorkSim is primarily designed to account for the French Labor Market (denoted FLM in this paper), most of its components and mechanisms could be re-used to describe labor markets in other countries. In fact, mainly the elements specific to the French institutions (labor law) must be adapted when dealing with another country.

2 Model Description

2.1 The agents in WorkSim

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, representing the *managing director*[10] 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

[9] The diversity of contracts exists in many other countries and our model could be adapted to simulate other labor markets.

[10] The managing director works full time for the firm, and at the three occupations. The director never leaves the firm, except to retire or when the firm goes bankrupt.

one member of the household may have an impact on the other members. In WorkSim, the agents are heterogeneous. They have specific attributes determined once and for all at their creation (e.g. gender, amenity, ...) and internal variables (e.g. age, salary, number of employees, ...) that evolve all along the simulation.

The agents under 15 or over 65 years belong to these households 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. Finally the period corresponds to a week, in order to capture very short spells on many FTC, and be as close as possible to real gross flows. 46% of all hires are on Fixed-Term Contracts that last one week or less in 2010 (ACOSS, 2011). Having the day as the period appears computationally too costly and does not fit the ILO definition of unemployment (an unemployed is a person who has not worked even an hour during the week).

2.2 Environment

In addition to these agents, the model uses three *artifacts* [11]:

- *JobAds*, which receives job offers from the firms and job applications from the job seekers. Dissemination of information, however, is based on the costly job search process described in more detail below (see sections 2.8 and 2.9), according to the principles of search theory.
- a *Statistical Institute* that calculates statistics from the simulation and disseminates some information (e.g. tension on the labor market). The information is imperfect for agents, and we 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-Term contracts* (FTC[12]) and *open ended contracts* (OEC[13]), dismissals on personal and on economic grounds, redundancy payments, ..., and (2) government decisions (minimum wages, welfare benefits, ...).

[11] *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.

[12] Main *FTC* (CDD) 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).

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

2.4 Individuals

In WorkSim, the individuals i are characterized by the following attributes :

- *Gender* : female or male.
- *Age*, denoted age_i and counted in weeks (a tick represents one week in the simulation).
- Preferences for *free time* : see section 2.9 below.
- *State* in the labor market. The possible states are : 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.
- *Occupation*, denoted q in this chapter. The number of possible occupations is denoted n_q. In our simulations, we consider 3 levels : 1=blue collar or employee, 2 = middle level job, 3 = executive. Of course, an individual can change his/her occupation during the simulation (upward or downward).
- *Productivity kernel* $kProd_i$: it represents the "innate" abilities of the individual i. $kProd_i \sim Max(0, \mathcal{N}(1, \sigma_{coreProd}))$[14] with standard deviation $\sigma_{coreProd} \in [0, 1]$ is an exogenous calibrated parameter.
- *Condition factor* $cond_i, t$ that represents the physical condition, the motivation and satisfaction for i. It evolves with time following a random walk :

$$cond_{i,t+1} = Max(minC,\ Min(maxC, cond_{i,t} + \mathcal{N}(1, \sigma_C))) \tag{1}$$

  Hence $\forall t,\ cond_{i,t} \in [minC,\ maxC]$. $minC$ et $maxC$ are two exogenous parameters and $\sigma_C \in [0, 0.3]$ is calibrated.
- *Human capitals (HC)* $HC^{gen}_{i,t}, HC^{occ}_{i,q,t}, HC^{spec}_{i,p,t}$, respectively for the *general*, *related to the occupational level* q, and *specific to the firm* and job p *human capitals*[15].
  The general HC represents the abilities useful for all jobs, like problem solving or knowledge of a foreign language. It increases with experience (one more unit per period) and also with training. It decreases at each tick i is unemployed by a percentage Lxp after Txp periods (loss of skills). $Lxp \in [0, 0.1]$ and $Txp \in [0, 100]$ are two calibrated parameters.
  The occupational HC is related to the occupational level, and represents abilities specific to this level: machinery or team leading for instance. Like the general HC, it increases with experience (one more unit per tick) and also with training, and decreases at each period i is unemployed by a percentage Lxp after Txp ticks.
  The specific HC is related to the position and the firm. It represents abilities specific to the job in the firm, like a particular process or a software to use. It equals the number of periods the employee spends in the job. It is reset to zero when s/he leaves the job.

2.5 Demand

The only production factor is the labor, like in many labor market models. As mentioned, there is one good, and each firm produces a certain amount of its own variety of this good.

[14] In this chapter, $\mathcal{N}(\mu, \sigma)$ denotes a normal law distribution, with mean μ and standard deviation σ.

[15] There are many evidences that support all these three types of human capitals (e.g. Kambourov and Manovskii, 2009; Crook et al., 2011).

The price P is assumed unique (horizontal differentiation) and fixed at the arbitrary value of 1. Each firm of the N firms in our model responds to a *quantity demanded* 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 $D_{j,t=0}/D_{tot}$. We assume that the distribution of this global demand varies between firms. Then we apply a stochastic shock which defines the trend of this market share for each firm each year and another stochastic shock each period (random walk) using a normal law.

2.6 Jobs

Each firm has a managing director and a list of jobs per occupation. A job can be in 3 different states : *filled, vacant* or *pending*. A *pending* job is typically an FTC contract that ended, but cannot be renewed immediately, because of the waiting period[16].

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

- a vector of *required human capitals* $[HC^{gen}_{req,p}, HC^{occ}_{req,p,q}, HC^{spec}_{req,p}]$, respectively for the *general*, *related to the occupational level* q, and *specific to the firm* and job p *human capitals*. They represent the minimum skills required to work on this job and are randomly drawn according to uniform distributions respectively between 0 and $MaxHC^{gen}_{req}$, $MaxHC^{occ}_{req}$and $MaxHC^{spec}_{req}$. We will see in the next section that an individual can acquire these skills with experience and training.
- The *duration of work* HpW_p, measured by the number of hours required per week for the job p.
- A *hourly base production* $QH^{base}_{j,q}$ that equals to the hourly base production for all jobs in the firm at occupation q. It is randomly drawn at the creation of the firm j, to account for the differences in production efficiency (technology, organization...) between the firms.
- A *hourly base salary* determined from the base production in the job for all jobs in the firm at occupation q :

$$SH^{base}_{j,q} = QH^{base}_{j,q} \times P \times (1 - \zeta) \tag{2}$$

  with $P = 1$ the exogenous price of the (unique) good and $\zeta \in [0, 1]$, 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 will be simply given by

$$S^{base}_{j,p,q} = SH^{base}_{j,q} \times HpW_p \tag{3}$$

- A level of *amenity*. This represents non-monetary features perceived by the individual on the job (social recognition, working environment,...). A hourly base amenity ran-

[16] The firm does not want to destroy the job, if there is still a potential demand margin for it, so it becomes a pending job, until the waiting period will be finished. So we have here an important feature of WorkSim: unlike other models, *we distinguish the job and the contract*, several employees (and therefore several contracts) may have occupied the same job since its creation.

domly drawn at the creation of the firm as a percentage PrA of the base salary for all occupation level q.

2.7 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.

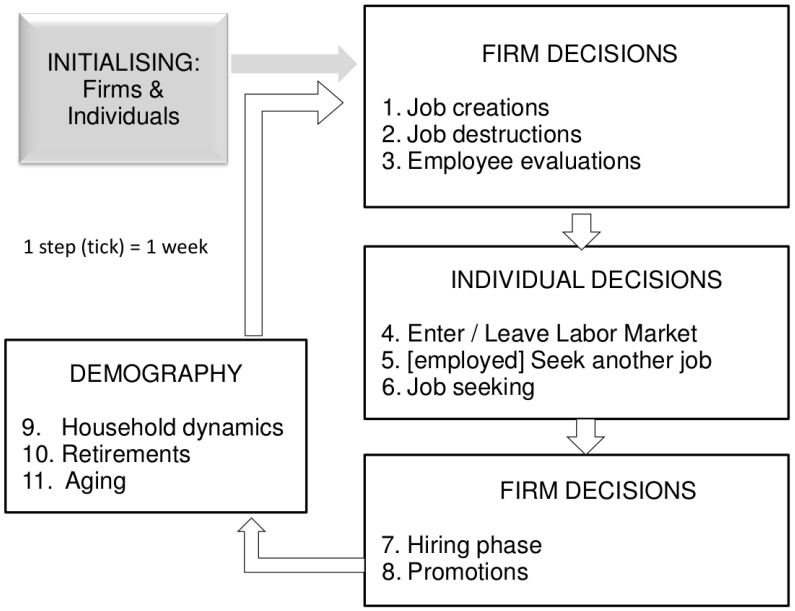

Fig. 1: The simulation cycle in WorkSim

2.8 Firm decisions

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

Demand anticipation The central idea that governs job creation relies on the way the firm will estimate the future demand. If the demand is going to increase, a new job might be profitable, but not if there is a decrease in the demand.

Hence, the firm will compute three scenarios – *bad*, *neutral* and *good*, which are depicted in the Figure 2 below. We see in this Figure that in the bad scenario of demand evolution,

the demand of the firm is below its production with the new job after a certain time. As the firm cannot sell more than its demand, it may result in a loss because the firm has to continue to pay a salary until dismissal is allowed. 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 FTC. Indeed, the firm will have the option to end this contract after 3 months in case of a bad 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 objective level of uncertainty of future demand (variance is known) and how the employer perceives the risks.

Because of bounded rationality, the firms anticipates with a *finite* horizon only. The decision process combines all the three possible scenario into a multi-criteria weighted profit, and the weight of each scenario is automatically calibrated.

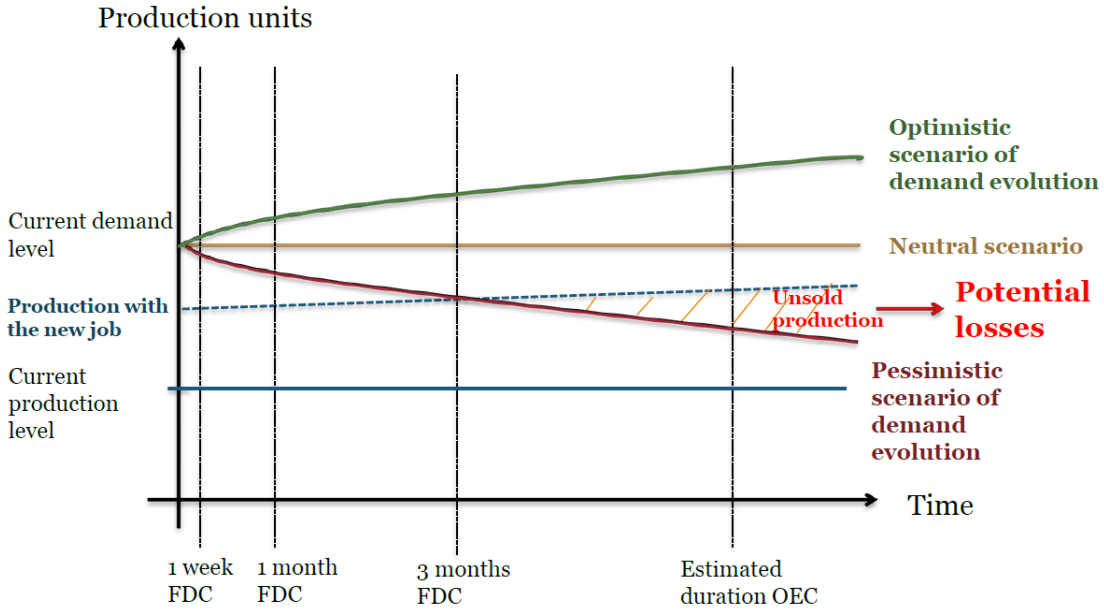

Fig. 2: Demand and risk anticipation of the firms

Job creations (step 1 in Figure 1) The job creation proceeds in three steps:

1. First, the firm checks if there is a sufficient demand margin to create a new job. Here it considers the actual (not anticipated) demand margin $DM_{j,q,t}$ for firm j and occupation level q at time t: if it exceeds the demand margin threshold DT (calibrated parameter), then the firm moves to the next step. Otherwise, no job is created.
2. If there is in the firm a *pending* job in the occupation q, the firm considers to hire a new person for this job (taking into account the eventual grace period). Therefore the pending job becomes a *vacant* job. Otherwise, it moves to the next step.
3. Here, $DM_{j,q,t} > DT$ and there are no pending jobs in occupation q. Hence, the firm considers to create a new job p of the occupation q. The characteristics of this new

job are randomly drawn. From these job features, the firm must decide which type of contract suits better.

Evaluation of a contract

1. During a prospecting phase, the firm receives information about $NPros$ job seekers of the occupation q , who have applied to a job with a FTC and $NPros$ job seekers of the occupation q who have applied to a job with a OEC during the last period. The expected profit per period $\phi^{per}_{i,j,p,q,c,t}$ for a candidate i on a job p with a contract c is then computed for each contract : the OEC contract is compared with several FTC with different fixed terms : 1 week, 1 month, 2 months, 6 months, 12 months, 18 months.
2. Then the firm chooses to *create the contract* c with the *best average positive profit*, calculated along a set of potential candidates. These candidates are job seekers and *JobAds* sends to the firm their productivity level and human capitals. The firm will choose the contract c^* that give the highest positive profit ϕ^{avg}. If all the profits are negative, no new job is created.
3. The firm continues to consider creating new job as long as $DM_{j,q,t} > DT$.

Job destruction (step 2 in Figure 1) By contrast, when there is a significant reduction in its demand in one occupation (in our model, this is when $DM_{j,q,t} < -DT$), 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.

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 FTC and OEC – are destroyed.

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[17]. 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. This is the formal implementation of our interpretation of the French jurisprudence before the El-Khomri law over the serious economic difficulties that allow to dismiss. However, owing to the diversity of judgments and penalties inflicted in case of unfair dismissal, an employer, even though he aims to respect the serious economic difficulty conditions, may be condemned in industrial courts. Therefore he anticipates penalties on the base of the rates of litigation and loosing the case, which are added to the severance costs (see section 4 for details) :

– All remaining vacancies are removed.

[17] 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.

– After all the vacancies being removed, if $DM_{j,q,t} < -DT$ still holds, the firm consider to dismiss employees. It selects one employee, computes the associated profit $\Phi^{tot}_{i,j,p,q,c,t}$ and the firing cost EFC. If $\Phi^{tot}_{i,j,p,q,c,t} < -EFC$, the firm dismiss the employee. This process is repeated until $DM_{j,q,t} > -DT$ or if all employees have been evaluated.

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*[18]. Hence, when a bankruptcy has occurred, we randomly select an active agent in the simulation to create a new firm and manage it. S/he will be the only producer in the firm (until s/he starts to recruit).

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 FTC and OEC ;
2. Every year, at the anniversary date of the contract, for OEC employee.
3. At the end of FTC contract to decide if it should be renewed ;
4. At the end of FTC contract, if the transformation of FTC to OEC is to be considered.

Dismissal for personal reasons The process takes in two steps :

1. First, the firm evaluates if there is a case for considering the dismissal. That could be the case if the employee's production is below the firm's requirement. Thus, there is a chance that the firm considers to fire this employee for personal reasons if the annual production of the employee $Q^{eval}_{i,j,p,q,t}$ satisfies : $Q^{eval}_{i,j,p,q,t} < \rho \times Q^{required}_{p,q}$ where $Q^{required}_{p,q}$ is the required level of production and ρ an exogenous parameter in $[0.7, 0.9]$. ρ encodes the tolerance the firm has with underproduction, or the maximum margin risk it accepts to take[19].
2. Then the firm decides whether such a dismissal is profitable (on economic grounds).

Hiring phase and promotions (step 7-8 in Figure 1) Once the firm has chosen which contract c to create, a hiring norm must be computed to evaluate the candidates. This *hiring norm* is the profitability threshold below which it prefers to refuse a candidate. To do so, it uses the *positive* expected profits $\Phi^{avg}_{j,p,q,c,t}$ calculated for each of the $NPros$ candidates during the prospecting phase and compute the average Φ_{Moy}, the minimum Φ_{Min} and the maximum Φ_{Max} values.

The hiring norm of the firm is given by:

$$HNorm_{j,p,q,t=crea} = (\phi^{per}_{Moy} + N_1 \times (\phi^{per}_{Max} - \phi^{per}_{Min}))\frac{N(d_c)}{H(TIGH_{q,t=crea})} \quad (4)$$

[18] We keep the number of firms constant for two main reasons. First, we do not aim to model the determinants of firm creation, way too complex and out of the scope of WorkSim. Second, we are looking for a steady-state with a scale-up for year 2014, to apply and assess policies, and this will not be possible if the number of firms evolves constantly.

[19] If ρ is too high, it will create a lot of dismissals and the firm will have a higher chance to face litigation and a higher chance to loose if it underestimated the real employee's productivity.

- N_1 will be calibrated in $[0, 1]$. The hiring norm increases with $\phi^{per}_{Max} - \phi^{per}_{Min}$, so the firm favors a large dispersion of candidates' qualities in order to increase the probability to get better candidates, as prescribed by search theory.
- $N(d_c) = N_2 + N_3 \times d_c$, an increasing function of the duration of the contract d_c proposed for the job. N_2 et N_3 are two calibrated parameters in $[0, 1]$. We assume that the firm will be more demanding for longer contracts, as they imply to keep the employee for a longer time.
- $TIGHq, t = crea$ is the tightness on the labor market at the time of job creation and is given by $TIGHq, t = \frac{V_{q,t}}{U_{q,t}}$ with $V_{q,t}$ the vacancy rate and $U_{q,t}$ the unemployment rate at time t for the occupation 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_4 in each period until the job is filled, but never drops below 0.

Hiring takes place in three steps:

1. *Receiving applications* – The firm receives applications from external and internal applicants.
2. *Selection and potential hiring* – A two-steps process takes place:
   (a) First, the firm computes a score for each candidate (internal or external), given by the expected profit per period $\Phi^{per}_{i,j,p,q,c,t}$. 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.

2.9 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, employed and seeking a new job , student or retired. The transitions between these states can be caused by individual choices (for example: to look for a job, to quit a job...), by external events (firing, death...), or eventually by a sequence of multiple decisions (e.g. applying for a job, and the firm hires the candidate).

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

$$U = (Income + Amenity + Stability)^{1-\alpha}(Free\ Time)^{\alpha} \tag{5}$$

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...), cf. section 2.6 above.
3. *Stability*: criteria reflecting the preference of the individual for stability, i.e. for a job with the long 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 her/his working hours and 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 $\alpha_{i,t} \in [0, 1]$ encodes the preference of the individual for free time or work.

Overview of the individual decisions The decision-making process of individuals is sequential and summed up in the state transition diagram depicted in Figure 3. At each period, the individual agent computes the utility of its current state and the utilities of each reachable state. Each utility is evaluated using the generic form given by equation 5 above, and instantiated with the relevant values of income, amenity, stability and free time. For some transitions, a factor $ICHANG \in [1, 2]$ is applied that represent the psychological cost facing change (calibrated parameter). When $ICHANG > 1$, the new state's utility must be even greater to win the decision.

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

1. Each period in the model, a job seeker receives from JobAds a list of $NV_{i,t}$ vacancies matching her occupation or a level above. We assume that these incoming job offers occur at a mean frequency that is known and independent of the time elapsed since the last offer. Therefore, we model the arrival of new job offers with a Poisson law : at time t, this number of vacancies $NV_{i,t}$ is drawn from a Poisson distribution with parameter $\lambda_t = NSJ_U \times H(TIGH_{q,t})$, where NSJ_U is the average number of vacancies received by the unemployed at each period, and H is the same function of tightness as above.
2. The individual sends an application for the first offer whose utility is above his/her *reservation utility* $UTRES_{i,t}$[20]. If there is no job offer corresponding to her/his occupation or if all of her/his applications are rejected, s/he lowers her/his reservation utility $UTRES_{i,t}$. Thus, at the end of each period, the reservation utility is updated :

$$UTRES_{i,t} = UTRES_{i,t-1} \times (1 - Ru_3) + Ru_4 \times (UTUEM_{i,t} - UTUEM_{i,t-1}) \quad (6)$$

[20] Reservation utility is an important concept in labor economics. It is the equivalent of the hiring norm, for the individual, as it represents the minimum level of utility to make it acceptable to an agent. It does not remain constant, but dynamically evolves during the agent's life, to adapt to situation changes. So, the equation will vary, depending on the agent's state (see eq. 6).

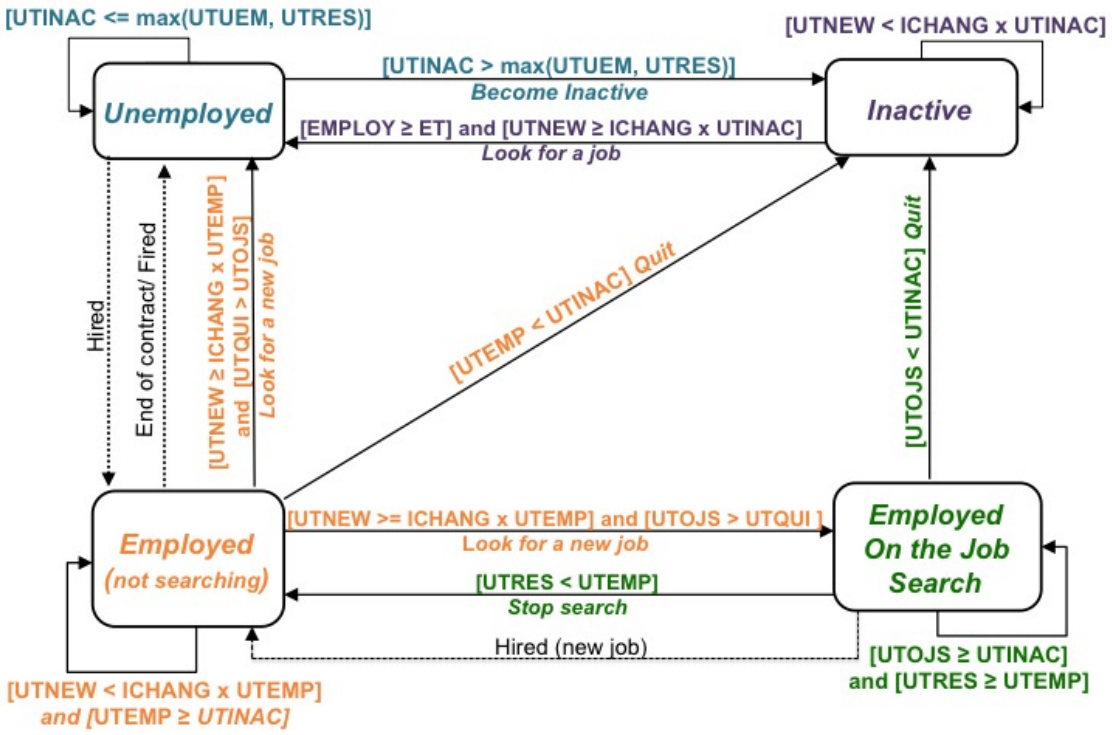

Fig. 3: UML State diagram describing the main transitions of individuals and their decision-making process. UTINA: utility to be inactive. UTNEW: utility of a new job, estimated through prospecting. UTUEM: utility to be unemployed. UTRES: utility of reservation. UTOJS: utility of the OJS (On-the-Job-Search) state. UTEMP: utility to be employed. UTQUI: utility to quit. ICHANG psychological cost to change state (calibrated exogenous parameter). EMPLOY measures the employability of the inactive. Dotted arrows represent decisions that do not fully depend on the agent (i.e. taken by the firm.)

where $Ru_3 \in [0, 0.005]$ is a calibrated parameter and Ru_4 a fixed parameter (0.5). The first term of the equation accounts for the diminution with time and the second is driven by a modification of $UTUEM$, that is the utility for the unemployed (for instance a decrease of revenue will lower $UTUEM$ and therefore $UTRES$, as the urge to find the job increases). We do not set different reservation utilities for the two types of contracts since the workers search for the two types of jobs simultaneously. Yet we take into account the lower return to search provided by the FTC in terms of utility since they offer shorter contracts, by including the stability parameter. This information is known to the searcher before contracting for a FTC. For an OEC the mean duration is known. This method ensures that searchers prefer OEC *ceteris paribus* but may accept to apply to FTC when their research does not meet success and they lower their reservation utility.

3 Validation process

3.1 Methodology

The WorkSim methodology uses a validation process at 2 levels :

1. *model building* : the way we design the model, and especially the agents' decision rules is rooted as much as possible in empirical data and facts. Following the *psychomimetism* methodology Kant (1999), we ensure that these decision processes do not violate the cognitive principles we build our model on (e.g. bounded rationality).
2. *data reproduction*. We want our simulation to account for most of available data on the labor market we aim to study. To do so, we use an automatic procedure to calibrate the model parameters for which we do not have an empirical value (see below).

3.2 Calibration

Scaling First of all, we must set the number of agents in the simulation. It must be large enough to account sufficiently for real behaviors, but not exceed our computational power[21]. For the first set of experiments (sections 4.1 and 4.2), we used a reduction factor around 5400 and obtained 7484 individuals and 797 firm agents, for a total of 8281 agents in the simulation. The simulation of the "Labor Law" required 20 000 agents to ensure we have sufficient large firms since the new law states different rules according to size class (see section 4.3 below).

Calibration procedure To calibrate the 60 model parameters, we have to minimize a *fitness* function that is the weighted sum of the relative spreads between the outputs of our model and the real targets of the French labor market in 2014 (source: INSEE/DARES). We have chosen 63 targets grouped in 10 different categories : unemployment rates (7 targets), activity rates (6), salaries (14), job flows (12), FTC (4), long-term unemployment (3), mobility (between occupations; 12), additional (part-time, vacancies, on-the-job,training costs). In most cases, we have a target per occupation or age range.

To minimize this fitness function, we apply 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 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 are updated incrementally in order to move towards the best results obtained by previous generations.

At each *iteration*, the CMA-ES algorithm sets the values of all the 60 parameters. Then, to cope with the stochasticity we have in the model, 48 simulations are run (they are usually called *replications* in a calibration process) with a different seed for the random

[21] As we show below, the simulation itself does not take too much time and power to run. The critical point is the calibration as it has to launch thousands of simulations to reach an acceptable solution.

generator, and the outputs are averaged over these 48 simulations to obtain the fitness value of the iteration. We stop the calibration when the fitness does not improve (same minimum value) for 500 iterations.

Computational power needs The calibration process is very costly in terms of computational resources, because the total number of simulations could be very high : it is given by the product of the number of iterations by the number of replications. With WorkSim, it took 2000 iterations to converge, and as stated above each iteration is made of 48 replications. Each simulation takes about 1-2 minutes overall and the whole calibration process takes one or two days to be completed.

Results of the calibration on the main targets We obtain an average relative spread between all the outputs of our model and the real targets of 7.9 %. This can be deemed satisfactory for such a large non-linear model. We deal with a multi-objective optimization problem with many targets and parameters, and these problems are known to be hard to solve.

4 Results and policy experiments

In this section, we summarize the main results from a first set of prior simulations we conducted with WorkSim. In this set, the model was calibrated to account French data in 2014. Then we present results on the most recent labor law reform in France. Note that each simulation result is averaged over 196 simulations.

4.1 A brief characterization of the French Labor Market

The model generates some important specific characteristics of the French Labor Market such as the very important share of FTCs in terms of flows, 81 % and the contrasting fairly low figure of the share of the workers employed in such contracts: only 9 %. The unemployment of the young is also much higher than the unemployment of the older workers. This confirms the dualism in the French Labor Market, which is displayed by the differences in the patterns of gross flows of the categories of workers. The model computes all the simulated flows, but allows for comparison with those which can be measured by the published statistics, and the results fit roughly. Most workers are stable in their OEC, while a minority undergoes short spells of employment in FTC and spells of unemployment between them. Moreover this dualism persists for part of the young workers when they age while the others obtain more stable OEC, either through the experience gained in FTC, or through direct recruitment in OEC as the result of a screening process. Many more results, some of them novel are obtained but will not be detailed here, since they are not the core of this paper.

4.2 Assessment of some labor public policies

We have conducted several simulation of labor policies, and most of them were new (never implemented). In fact, one of the major purpose of WorkSim is to aid political decision on employment and labor, by simulating ex-ante and understanding the effects of one particular policy.

Removal of Fixed-Term contracts Because of the strong segmentation in the French Labor market, with high flows between FTC and unemployment and few workers to enter rapidly into a more stable OEC, one might want to permanently remove the FTC and have only OEC contracts. We experimented this removal in WorkSim, in an experiment where only OEC and a few *customary* FTC contracts remained. We measured the impact after 2 and 4 years. Two years after the removal, there is a significant rise of the unemployment rate (+1.1), especially among young people and employees or workers. After 4 ans, the unemployment rate decreases, and equals the baseline simulation (with FTC), because part of the individuals get hired on a OEC. But the unemployment rate decreases also because of the discouragement of 290 000 who leave the labor market (a decline in the activity rate by 1 point). Moreover, the long-term unemployment strongly increases (by 29 points after 2 ans, and still 24 points more after 4 years). After 8 years the employment remains low. The diminution of hires has generated a decline in human capital in the population, and this has irreversible effects on employment in the model. Thus, not only the abolition of FTC failed to reduce the segmentation but it actually increased it[22]. The extreme case of forbidding FTC shows that at that limit FTC and OEC are net complements, not substitutes in their effects on employment and unemployment. However this result should not extend to intermediate mixes since individual employers, when allowed, often choose a mix of the two types of contracts which yields the highest production and profits.

Reduction of charges The level of social charges on employment are frequently discussed, especially by employers' syndicates. In fact, in 2003, the minister F. Fillon has passed a law that reduces the charges paid by the firms on employment, for salaries lower than 1.6 times the minimum wage (SMIC)[23]. The decrease will be 26 % for firms with 20 employees or more, and 28.1 % for the others. To study the effect of this measure, we compared the results of the baseline simulation[24] with a new simulation where these charge reductions are removed. We measured a drop of 0.72 points in the unemployment rate, and a gain of 233 000 jobs, thanks to the charges reduction. The firms also increase their benefits.

[22] There are several processes involved in FTC, and they have opposing consequences on unemployment: first the diminution of the risk of paying OEC termination costs they offer when uncertainty is high (or buffer role) should lower unemployment. The screening and experience accumulation (also called the stepping stone role) are likely to lower unemployment, while churning (the fact that workers are sent to unemployment frequently because FTC cannot be renewed without limit) is negative. It is very difficult to quantify these effects. WorkSim is the first agent-based model to account for all these effects. Our results for the FTC removal could be explained by the fact that the reduction of churning is not large enough to compensate the loss of buffer stock and stepping stone effects (for definitions and more details, see Goudet et al., 2014).

[23] these results are based on a calibration on year 2011, but there should not be qualitative changes

[24] As noted above, the baseline simulation is performed with parameters set to their calibrated values.

However, it might be more efficient to target the policy on lower wages. Therefore, we vary the maximum wage to benefit from the policy, from 1.2 SMIC to 2.2 SMIC. The results are displayed in the Table 1 below. It appears that the 1.2 SMIC target gives the most effective policy: the smallest unemployment rate (9.55%), 298 000 more jobs, 253 000 less unemployed and also the lowest costs.

Indicators	**1.2 SMIC**	**1.3 SMIC**	***1.6 SMIC***	**2.2 SMIC**
Unemployment rate (%)	9.55	9.66	*9.78*	9.83
Number of created jobs (in thousands)	298	266	*233*	217
Number of avoided unemployed (in thousands)	253	228	*192*	180
Gross cost per created jobs (in euros)	86138	94361	*110 729*	119 816
Gross cost per avoided unemployed (in euros)	101 581	110 088	*134 375*	144 445

Table 1: Charge Reductions. The baseline simulation corresponds to the 1.6 SMIC column (in italics).

Firing costs and removing legal justification Another option to reduce unemployment consists in making the creation of OEC (instead of FTC) easier. Many firm leaders and employers' syndicate complain about the level of firing costs and the difficulty to fire employees when the demand becomes insufficient. Therefore we conducted two experiments to study these issues.

In a first experiment, we vary the severance pay schedule (the number of months of salary), and multiply it by a factor between 0 and 50. Surprisingly, we find a very small effect on unemployment. The unemployment rate increases only by 1 point when we multiply the severance pay by 50. The low sensitivity to severance pay is predicted in the theoretical literature since both fires and hires should increase. However another phenomenon takes place. When the cost increases, the firms replace OEC hirings by FTC hirings[25]. Moreover, when the cost is null, the unemployment remains around 9.5%, because hiring in OEC remains low.

Therefore, we conduct a second experiment, where we remove the legal justification attached to firings. When demand decreases over one week, the employer may fire some workers. He still has to pay the severance pay and advance notice, but no longer undergo a year of losses before firing nor provision indemnities for unfair dismissal. This change of costs is integrated into the anticipation mechanism that is part of the decision process to create an OEC job. The results are shown in Table 2, after 2 years following the change of the law. With this variant, the unemployment rate drops by 1.62 points, and the decrease is particularly important for the youth, with a drop of 10.67 points. However, we observe an increase of 1.64 for the seniors. When we look at the unemployment rate per occupation, we find the policy to be quite beneficial for the blue collars/employees category (-3.26 points) at the detriment of the two other occupations (+0.75 for middle levels and +1.64 for executives). The global benefit could partly due to the fact that the firms mainly use OEC to hire: the entry rate in OEC goes from 11.4 % to 27.24 %; while

[25] For recent econometric evidence see (Hijzen et al., 2017) in the case of Italy, and (Tejada, 2017) in the case of Chili.

the entry rate in FTC drops from 45.38 % to 7.22 %. The share of FTC drops from 8.77 to 1.89 %. As a counterpart, the OEC become more precarious: the economic firing rate jumps from 0.58 % to 16.74 %, the average seniority in OEC decreases from 5.86 to 3.55 years, and the probability to loose a job increases by 65 % (from 8 % to 10.33 %).

Indicators	**Reference**	**Variante**	**Impact**
Unemployment rate (%)	9.81	8.19	-1.62***
Unemployment rate 15-24 ans (%)	24.66	13.99	-10.67***
Unemployment rate 25-49 ans (%)	8.89	7.65	-1.24***
Unemployment rate 50-64 ans (%)	5.42	7.06	+1.64***
Activity rate (%)	69.84	70.01	+0.17***
Number of employed individuals (in thousands)	25 694	26 1218	+523***
Number of unemployed individuals (in thousands)	2794	2340	-454***
Entry rate in OEC (%)	11.4	27.24	+15.84***
Entry rate in FTC (%)	45.38	7.22	-38.16***
Average individual's utility	226.5	225.2	-1.3***
Average weekly firm benefit (in euros)	4133	4728	+595***
Long-term unemployment rate (%)	32.12	41.94	+9.81***
Economic firing rate (%)	0.58	16.74	+16.16***
Probability to loose one's job within a year (%)	8	10.33	+2.33***

Table 2: Removal of legal justification in case of firing.

If we compare the suppression of the severance pay and the suppression of hoarding costs, the latter appears much more efficient globally to lower unemployment, even though it has also distributional effects detrimental to some categories and increases the precarity of OEC. Since the opposed effects on hirings and firings can take place in the two cases, the lack of sensitivity of flows when severance pay are suppressed can also be explained by the very low rate of economic dismissal in France, around 0.5%, which leads to an expected severance cost too low to influence the hiring rate. [26].

4.3 Evaluation of the dismissals facilitation in the El Khomri Law

The El Khomri law project has been presented in March 2016 by the French government as the major labor law of François Hollande's presidency. This law has set the war not only

[26] The expected severance cost is the sum of two elements in the model: the first is the expected severance pay, which is learned by the employer. The second is the litigation costs. It is the product of the probability to pay litigation indemnities by the expected amount. The judge intervenes only if the fired workers sue, which happens in 1% of cases of economic dismissals. However the workers win in 64% of the litigations. We have then considered average indemnities. The model does not consider the cost of the true uncertainty over these indemnities. The variance between courts is high and the subject has raised a hot debate in France. A ceiling has been debated but not introduced in the EL-Khomri Law. However such a ceiling has been introduced in the 2017 Ordonnances with some exceptions. (Chéron et al., 2011) shows that a higher variance reduces hirings under high intertemporal elasticity of substitution. However the firing rate is exogenous. The integration of the variance of indemnities deserves future work in WorkSim, provided better data become available on real indemnities paid.

on the French political scene, but also between French economists who do not hesitate to take a categorical position in favor or against it. Its final version was voted on July 21, 2016. There are many articles in the law, and several are impossible to model at this stage. Here we focus on the facilitation of the economic dismissals, as it is likely to have an important impact on the labor market, although the results presented above warn us of the complexity of the effects.

With the ELK law, article 30 (denoted as "ELK law" in the remaining of this paper)), the conditions to allow economic dismissals are explicitly specified. They are allowed in case of a decline either in firm's demand or its turnover computed over a certain period, which depends on the firm's size. For firms under 11 employees, the period is 1 quarter, for those between 11 and less than 50 the period is 2 quarters, for firms between 50 and less than 300, the delay is 3 quarters, and for firms with 300 employees or more the delay is 4 quarters.

Effects under a stable aggregate demand At first we simulate[27] the ELK law for a steady state of the exogenous aggregate demand. ELK law yields effects which change over time after the introduction of the law. They evolve during the first 3 years to stabilize generally after 4 years. The first can be termed short run effects and the latter long run effects. This comes from the fact that it takes time for the firing conditions to be filled even under the new law. The immense majority of French firms are small or very small and it takes time for such firms to face a cumulated change large enough to be allowed by the new law to fire at least one employee.

The law does not change the unemployment rate not the employment rate. However it is favorable to the young (15-24), both in the short and the long run, with a decline in unemployment of 148,000 after 4 years (drop over 5 points). The impact is not significant for the age class (25-49). After 2 years, there is a small decrease in unemployment (-53,000) and an increase in employment (+71,000). However after 4 years the law has no significant effect on this age class. Finally the seniors (50-65) undergo a substantial rise in unemployment (+101,000), rising from 6.6 to 8%, i.e. 1.4 points, and a decrease in employment (-121,000).

Moreover, the mobility on the labor market is found to change very deeply, and the nature of the labor market is transformed. The share of FTC in the hires falls from 77% to 30%. The OEC becomes the dominant hiring contract. The proportion of FTC in ongoing contracts falls from 8% to 2.3%, with a decrease of the mean duration (renewal not included) from 3.6 weeks to 1.9 weeks. This double change means that FTC are now used mainly when future demand forecasts are bad and no training is required. However the integration of the remaining FTC employees improves since the turnover on OEC is higher. The economic dismissal rate jumps from 0.6% to 19%, a major change in a French labor market which has been characterized by a very low and decreasing economic dismissal rate during the present century. As a consequence the OEC become shorter (the median duration of OECs falls from 4.8 to 2 years) and more precarious, as the probability

[27] these simulations are done with a population double of the previous experiments in order to have more firms in each class size

to loose one's job within a year jumps from 8.17 to 13.13 (+4.9 points, + 60 % relative increase).

Indicators	**Reference**	**Variante**	**Impact**
Unemployment rate (%)	10.37	10.26	*ns*
Unemployment rate 15-24 yr (%)	27.75	21.89	-5.86***
Unemployment rate 25-49 yr (%)	9.1	9.24	*ns*
Unemployment rate 50-64 yr (%)	6.62	8.03	+1.41***
Activity rate (%)	59.29	59.09	-0.2**
Number of employed individuals (in thousands)	25 591	25681	*ns*
Number of unemployed individuals (in thousands)	2960	2937	*ns*
Entry rate in OEC (%)	11.88	28.24	+16.36***
Entry rate in FTC (%)	40.95	12.45	-28.51***
Average individual's utility	229.2	222.72	-6.48***
Average weekly firm benefit (in euros)	4133	4728	+595***
Long-term unemployment rate (%)	34.72	33.26	-1.47***
Economic firing rate (%)	0.61	19.55	+18.94***
Probability to loose one's OEC within a year (%)	8.17	13.13	+4.86***

Table 3: Results for ELK Law after 4 years. *ns = non significant*.

Two major conclusions can be drawn. First a significant substitution of the young to the seniors takes place, although it declines with time. Second the new load of adjustment set on the OEC has the logical effect of making the FTC an almost useless tool of flexibility for the employers except for very short expected durations. The explanation of the opposed effects over the young versus the other categories is clear. The young were much more often than the others in FTC (22% against 7.6% for the 25-50 and 4.9% for the seniors) and benefit from their fall. The effect then goes much beyond the higher flexibility of OEC. It raises the integration of the young in (more precarious) OEC, and this shows that the screening and experience enhancing roles of FTC before the ELK were not a sufficient factor of integration. This mechanism, the substitution of OEC to FTC, and its consequence, the substitution of young workers to seniors, have been overlooked or underestimated by non quantitative analysis of the law. However a caveat on these substitution results is in order. We have assumed that any job can be a FTC or an OEC, even if we take into account that employers should be deterred from FTC when training costs are high. In the real world some jobs require trust and/or long experience and cannot be FTC, so that substitution is overestimated in the model. Finally if the results are compared to the experiment on the suppression of the legal justification on economic dismissals, it comes as no surprise that the effects on total unemployment of the latter are much more important. The hoarding costs in the former high important for many firms, because the large firms must still wait for a year of demand decline, although this is a less demanding requirement than (substantial) losses.

Sensitivity of adjustment to aggregate demand We now change exogeneously aggregate demand in order to examine if the ELK law influences the effect on unemployment. Figure 4 gives values after 2 years. It shows that the adjustment of the labor force is predicted to be more important after the law. First when demand declines under its value in the reference simulation, economic dismissals are more important, the suppression of the hoarded labor is more complete, and unemployment rises more under the law El-Khomri. The effect reaches 4 points if demand was to fall by 25%. Second when demand rises above the reference value, the employers hire more easily on OEC, and unemployment decreases more under ELK law. For a symmetric increase in demand the decrease is 2 points. The responses are not symmetric for large (and somewhat unrealistic) changes since if demand is very high, there always remains some search unemployment by workers who raise their reservation utility.

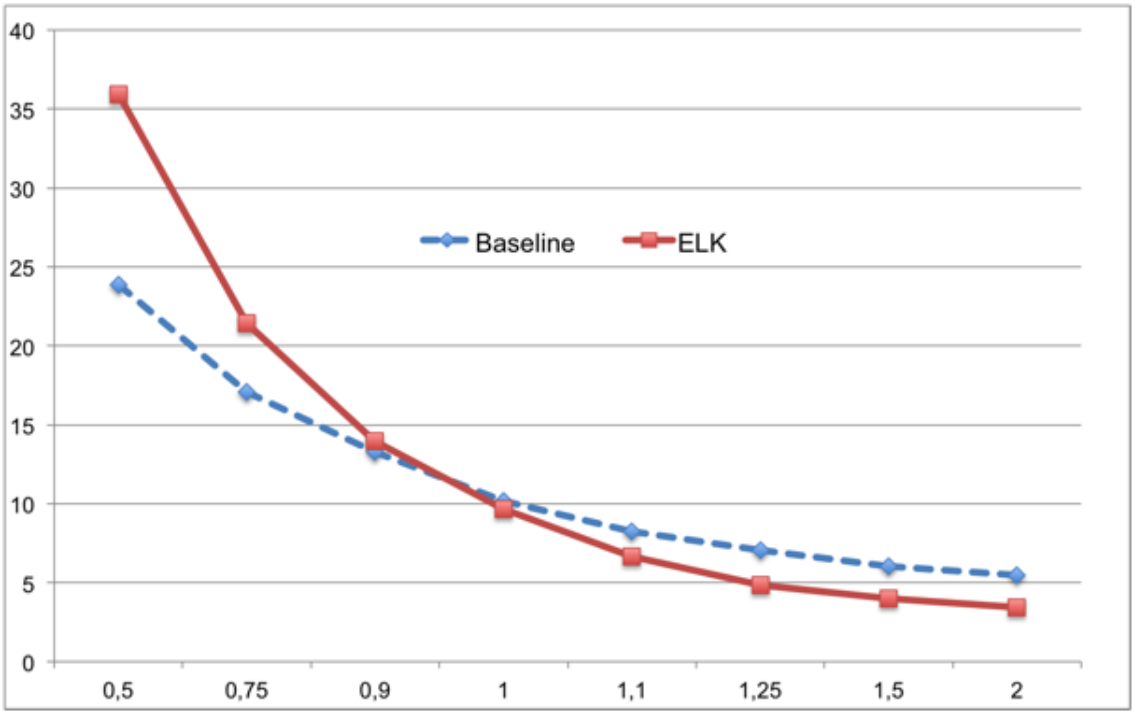

Fig. 4: Sensitivity of employment rate to demand shocks. x-axis displays the demand factor $df \in [0,5; 2]$, where the total demand D_{tot} becomes $df \times D_{tot}^{ref}$

5 Discussion

In this synthetic paper, we present the WorkSim framework, a comprehensive model of the labor market. It implements numerous mechanisms that were not integrated together before within a single labor market model: search on both sides of the market with multi-jobs firms, intertemporal decision processes under bounded rationality, anticipations of demand shocks and the possibility of loss aversion, learning, endogenous contract choices, different

types of human capital, endogenous salaries and productivities. The stock-flow accounting of individuals, based on gross flows, is complete and endogenous. It is supplemented by a stock-flow accounting of jobs for further analysis. The institutional environment is modeled and based on labor law, which sets constraints on the possible decisions at the microeconomic level, taking into account the specific characteristics of each agent, worker or employer.

WorkSim is calibrated on a large number of targets of the French labor market, by using a powerful algorithm which has not already been used in economic models. It reproduces well enough these targets to conduct some economic analyses. Moreover, it reproduces well the gross flows measured by different statistical sources and with different types of measures. This gives us an estimation of the model accuracy, and is part of the model's *validation process*.

We conducted several analyzes and policy evaluations. These helped us to identify core mechanisms in the French Labor Market : segmentation, screening by FTC, importance of firms' pessimism, among others. Labor policies appeared to have contrasting results in terms of employment improvements, benefits and costs. The complexity of the labor market has naturally led us to omit some more or less important institutions, and the number of targets remains small compared to this complexity. The results are meant to suggest new mechanisms, and the possibility of some new effects of policies. The main conclusion is that institutions seem to matter. However quantitative effects should be considered as highly tentative. Yet they refer to the computation of ex ante effects. The real data simply do not exist in this case.

Future directions The model can be extended in several directions : adding temporary employment agencies, social networks, and training (more detailed) for instance. We can also integrate more organizational elements, including tasks, and the monitoring role of the hierarchy.

Second, WorkSim needs to be plugged into an agent-based macro-economic framework, in order to have consumption, production and financial effects as well. The experiment outcomes in wages and profits have effects which in turn modify aggregate demand and employment again. One way to look at this is to assume that they are second order effects, but this may not be true. Third, tools to help analyzing and explaining the simulations are still to be developed further : visualization (improving the graphical interface in WorkSim), analyses of the agents ' decisions, automatic classification of agents' trajectories to study individuals' careers (cohort analysis). Another issue is the link with econometrics, to improve the agents' micro-foundation and enhance the validation process.

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