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## A multi-agent model of the French Labor Market : WORKSIM

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### Motivation

The model WORKSIM is conceived to simulate the French labor market, with two main objectives, namely to explain how the market functions at the aggregate level and the level of different categories of manpower, and to measure the impact of various public policies.

The present version is a much-improved version of a preliminary version (Lewkovicz, Domingue and Kant, 2009) and is inspired by the model ARTEMIS (Ballot, 1981, 2002). ARTEMIS was a pioneer multi-agent model of the labor market that modeled the flows between the main stocks (employed, unemployed, non participant), as well as the flows of jobs (filled, vacant) and aimed to characterize the main features of the French labor market before and after the 1973 oil crisis. WORKSIM keeps many general features of ARTEMIS, **modeling individually both the firms and their own jobs and the workers**. Yet it is more complete and precise in the description of the legal and institutional aspects of the French labor market, and in the modeling of the decisions. For instance the degree of imperfection of the employer's information on a worker's productivity is modeled, and the employer improves the precision of his information on an individual employee's productivity as the tenure increases. Cohorts of individuals are followed over their labor market career. Moreover, WORKSIM fully exploits the capacities given by multi-agent systems, and is made of heterogeneous agents that are autonomous, pro-active, and engaged in many interactions.

ARTEMIS and WORKSIM are built on the concept of search theory (Phelps et al., 1970), which gives them intellectual coherence, yet they implement a generalized search theory that applies to all voluntary mobility decisions by workers, and takes also into account firms decisions based on profitability and demand that impose involuntary mobility to workers. **Search is on both sides. The models are anchored into a double stock-flow accounting for workers and for jobs**. Moreover they distinguish different types of contracts, namely for WORKSIM fixed-term contracts and permanent contracts.

Our version of search theory is broader than the canonical model that models both sides of the labor market (for instance Mortensen and Pissarides, 1994) since the agents take into account not only the dispersion of firms' wages (workers) and the dispersion of workers productivities (firms), but also present or anticipated rationing. Rationing means that workers can see all their applications rejected within a period and use this information to adjust their reservation wage (or rather utility) for the next period, the choice of the level of jobs searched, and their decision to stop participation when unemployed, or search on the job when employed. Firms may receive no application for their vacant

jobs, and then adjust their hiring standard, or may end up suppressing them. It is possible for a worker that the wage is higher than his known marginal productivity as a result of a negative shock on demand to the firm and the downward rigidity of the wage (the Keynesian dimension is present). WORKSIM is not a complete macroeconomic model, and firms face an exogenous demand for the good they produce, with exogenous shocks with a random walk while the mean of the shocks for the aggregate market is zero in the reference simulation to obtain a statistical equilibrium.

Decision algorithms could in principal be computed by dynamic programming, but a perfect rationality with infinite horizon and many states between which heterogeneous agents move would make an analytical solution non computable. However the analytical solutions of search models obtained in simple settings have repeatedly taught us that optimal decisions take the simple form of a threshold: reservation wage (or utility) and hiring standard. Therefore, in WORKSIM, these thresholds are computed through algorithms based on **bounded rationality**, hence according to a decision rule taking into account the main determinants as they appear in economic reasoning and empirical evidence. For instance the reservation utility of an unemployed worker decreases as his tenure in unemployment increases, and the hiring standard increases when the labor market becomes slack. Parameters are obtained by calibration or taken from microeconomic evidence (see below).

The intellectual contributions are twofold and complementary. The first contribution is a better characterization of the nature of the labor market under study through the simulated mobility schemes of the main categories of agents (age, gender, skill category) during a year period. The mean and distribution of the unemployment spells and the mean and distribution of the cumulated unemployment and non-participation spells during a year period are also important features often not computed and of high interest. Then variants in the reference model are introduced such as changes in labor market policy and external macro shocks and their effects on the labor market can be carefully described with the outcome measures mentioned above.

An essential component of this contribution relies first on the integration of the **competition between categories of workers but also between firms** (that can fail). This crowding out effect occurs endogenously and no functional form has to be assumed. Microeconomic studies have shown that it is very important, but must specify a functional form, while it is likely to be highly non linear. Secondly **the interactions between heterogeneous agents on both sides of the market can lead to a more or less important inefficiency in matching** (easy to graph as a Beveridge curve), and we do not have to assume an arbitrary and stable functional form for the matching relation, as in the analytical models.

The impacts of labor market policy, including institutional changes, and aggregate demand or technology shocks is then the emerging outcome of a complex system of interacting agents and institutions, presumably highly non linear.

The second contribution, which will not be developed in the present paper, is the computation of the agents' trajectories over their labor market career, and the construction of a typology of trajectories through data analysis methods. The fine characterization of a given labor market implies the synthetic description of the workers' careers. What proportion of precarious workers on the life cycle, are the young workers slowly integrated, what determines the exclusion of some but not all seniors?

The model is an on-going and open ended enterprise, blocks and algorithms will be progressively added and improved, and the paper will present a version that does not intend to capture all the main components of the French labor market, but captures more mechanisms than the models known to us.

### The model

The agents are as follows:

- **Individuals** in one of the exclusive *states*: non participant, unemployed, employed (private sector), retired, student, civil servant
- **Firms** with its jobs individually modeled
- A **Government** agent, that recruits civil servants and sets labor market policies

To these, we add:

- An artifact **Jobads** that centralizes job offers and applications of job searchers (unemployed, on the job searchers)
- A **demographic** module that manages the demographic processes (births, aging, deaths, retirements...)

The present legal/institutional features integrate laws relative to the labor contracts (fixed term and permanent), firing rules, government rules (for instance the replacement rate for civil servants who retire), minimum wages and welfare (RMI), parents' transfers to their children.

The decisions are not given by statistical laws. The decision algorithms are based on **bounded rationality**, and take future time into account. They can be considered as approximations of reduced forms of optimal decisions, in the complex world that the model is for the agents. However they **learn, and adjust their decisions as a result of experience**.

#### **A period (tick) in a simulation has four steps:**

- A.** Firms decisions: management of vacant jobs (setting hiring standard), management of contracts (wage setting), evaluation of incumbent employees (productivity), creation or destruction of jobs as a response to a microeconomic shock on its demand.
- B.** Workers decisions: entry in the labor market, exit, search on the job, unemployed search, applications
- C.** Filling jobs: hiring process, promotions within the firm
- D.** Demographic block

The period is set to one week, in order to account for the very short fixed contracts, very frequent in France. A short period also allows to reproduce correctly the short spells in the distribution of unemployment spells.

An important feature is the process of **initialization**. We have an algorithm for setting the scale, in order to reproduce the distribution of firms by size, and the demographic characteristics of individuals. We have chosen to simulate the year 2007 because we have for this period a large database. Moreover, it takes place before the financial crisis, and allows us to study the labor market

before this crisis, before undertaking to introduce this shock. In our simulations, we have 13500 individuals and 2250 firms after scaling.

### **Model calibration**

WORKSIM has two types of exogenous parameters. The first type comprises those given by institutions (minimum wage, duration of probation period, redundancy payment, unemployment allowances...), demographic statistics or taken from French microeconomic studies. The other type comprises parameters that have to be calibrated. There are around 30 of them presently, among which the initial preference for leisure in the Cobb-Douglas utility function, the number of jobs on which the searcher gathers information within a period, the maximum number of rejections by a applying unemployed before he exits the labor market, etc.

In order to calibrate these parameters, we minimize a fitness function obtained by computing a weighted average of the differences between the real and the simulated value for a set of important variables. We want to reproduce correctly for the years 2007-8 variables such as the aggregate unemployment rate, the unemployment rate disaggregated into 3 age categories (15-24, 25-49, 50-64). We add the transition rates from employment to unemployment and from unemployment to employment, as this imposes to the model to reproduce in a realistic manner the dynamics of entry in employment and exit from unemployment. In order to solve this problem of continuous optimization, we have chosen to use the CMA-ES evolutionary algorithm (Hansen & Ostermaier, 2011), one of the best performing algorithms to solve this type of problem. The first phase of optimization is an exploration phase. We start with a set of parameters with random values. We choose to take the mean of 5 runs for a test, which reduces the precision of the measures, without being too penalizing in an exploration phase. Each time a point is obtained with a sufficiently satisfactory fitness (in the order of  $10^{-4}$ ) we implement a finer local search around the point to improve the precision of the computations taking the mean over 50 runs for each set of the tested parameters.

### **First results obtained**

- WORKSIM reproduces the stocks and flows on the French labor market in 2007-8, and offers the tools to analyze the sensitivity of these stocks and flows to the main behavioral parameters. Other fundamental variables such as duration of spells in the states (or stocks), unemployment, employment, non-participation... shed more light on the nature of the French labor market, for instance the unequal burden of unemployment on the young workers.
- Possible institutional changes on the French labor market are studied, specially the replacement of the dual contract system by a unique contract, and the effects of wage taxes.

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