

NumJobs

How digital and AI will impact economy and jobs ? A multi-agent simulation approach

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Issues and objectives

The aim of the NumJobs project is to provide to firms and organizations an **innovative tool to simulate the impact of digital and AI technologies on economies and societies**.

Digitalization, automation, robotization, rise of artificial intelligence (AI), as many movements and factors which constitute the digital revolution, often founded on innovations of rupture.

The bigger issue (or fear depending on point of view) here concerning these digital innovations is that of the **impact on employment. Are they sources of job creation, or will they involve destruction – possibly massive – of employment ?** If there is job creation, is it through new types of occupation ? And which actual professions would be threatened of extinction? Moreover, beyond the question of creation or destruction, **how this digital revolution will modify the nature of work**, the actual tasks, the work conditions, the place of work in the life of the individuals and the society ?

Thus, the impact of digitalization about employment not only concerns the economy but also the whole society. Admittedly, the question of the impact of technical progress on employment is not new. On the one hand because the labor market is strongly dynamic, with thousands of jobs being destroyed and created each day. In addition, technological progress is divided according to two distinct directions, but which can be simultaneous and also correlated : *innovation of the processes* of production and *innovation of product*.

Innovations thus lead destructions of existing employment and creations of new jobs. Among them, disruptive innovations create new sectors, and could trigger waves of innovations that are potentially engines of wealth creation by diffusion of purchasing power to the other sectors of the economy. They have however destroying effects on certain types of jobs.

Previous industrial revolutions have not induced a net negative effect on the number of jobs. Productivity and new products have raised incomes and demand for products. The key issue we aim to tackle is whether the digital technology has similar effects or may involve negative effects on the number of jobs and their structure.

Why current studies are insufficient ?

This question is the object of a great interest these last years and several studies sought to measure the impact of digital on employment. The first study is Frey & Osborne (2013) who estimates that 47% of employment in the USA and 35% in the United Kingdom have a high probability of automation within 20 years. Applied to the French case, 42% of employment at the risk (Roland Berger, 2014) is obtained. However these studies relate to the occupations , whereas an analysis – finer – by tasks is necessary to give an account of the heterogeneity of the occupations. A study of OECD (Arntz and al., 2016) based on tasks but at an aggregate level (?) (considers the risk with 9% of employment (for the USA and on average in 21

OECD countries), while another of France Strategy (Ru, 2016) is based on an investigation DARES into the work conditions and estimates the risk at 15% for France.

A recent report of the COE (the French Council of Orientation for Employment) recently synthesized these studies (COE, 2017) and underlines their limits rightly. They are focused on the potential destruction of employment due to digitalization and automation, but do not allow to measure the creation opportunities related to these technologies. They are based on current technologies, and do not take into account the evolution of the innovations. The social, institutional and economic brakes - that can limit automation - are also not considered. The COE proposes its own study while being based on the investigation work conditions of the DARES, in order to work on the level of the individual terms of employment, and is also interested in employment likely to evolve (not only their disappearance). Their conclusion for France is that 10% of existing jobs are threatened, and that the half of this employment is likely to evolve in an important way.

These studies highlight the difficulty of the subject. Depending on the method, they lead to rather different results, even if the last seem to converge towards a risk of disappearance of employment between 9% and 15%, and 50% of employment that would be concerned with deep change. *None of these studies gives the impact on unemployment.* Concerning the upgrading capability of employment, the COE gives results on the occupations, but not on their contents (tasks). In addition, *the studies are static, in the sense that it are not able to study the evolution of these innovations.* Lastly, *these studies take primarily the point of view of the individuals (work conditions) and not that of companies* (in particular their organization, their strategy, economic constraints, etc).

Our approach

Our analysis is that a tool is lacking to model and simulate the impact of the digital innovations on employment and work. With NumJobs, we aim to build such a tool, **the first to cover all the necessary dimensions** of this problem. This tool will allow to :

- **Simulate the impact of a technology on work** (organization, tasks,...) **and employment** (creations of new jobs, destruction, unemployment,...)
- Take into account all the main elements of the job market, with its **two sides: individuals and firms**
- Account for **all the economic aspects**, thanks to a macroeconomic looping of the job market
- Model the **processes of innovation** (processes and products) , via a competition between companies, in order to account for the dynamics of digital innovations, and to measure the evolution of their impact over time.

Based on our experience in the field of simulation using multi-agent systems¹ applied to labor market and innovation, we can now propose a method to build such a tool successfully.

We propose to base our tool on 2 models of simulation multi-agents we have developed for several years:

- **WorkSim** (<http://worksim.lip6.fr>) is a **multi-agent model of labor markets**, created by J.-D. Kant and G. Ballot. These agents (individuals and companies) make decisions

¹ Multi-agent systems come from distributed artificial intelligence. They are composed of a large number of data-processing agents in interaction, in order to model at the same time individual behaviors (by giving to the agents varied cognitive behaviors) and collective ones (emerging from the interactions). In particular, they are used to study and simulate economic systems (e.g. Tesfatsion & Judd, 2006; cf and social systems (cf. Gilbert & Troitzsch, 2005; see also <http://jasss.soc.surrey.ac.uk/JASSS.html>).

based on microeconomic analyses, under bounded rationality. For example the decision for a company to create or not a new job distinguishing open ended contracts and short fixed duration contracts, according to the request; or the decision for an unemployed to apply or not with a job offer, or to leave the job market.

WorkSim scales down the French Labor Market at a scale factor of 1/2000 and is calibrated on more than hundred important variables such for example as the unemployment rate or the wages by broad occupation (coming from INSEE, of the DARES, etc.). It reproduces the important stylized facts of the French job market and has been published in international publications (e.g. Goudet and al., 2016). It already allowed us to carry out the first quantitative evaluation ex-ante of the recent law work “El Khomri” and several other policies of the job market (reduction in charges, contract of generation, etc.).

- **A multi-agent model of endogenous growth** with multiple firms in competition to study the **dynamics of innovation** in new consumer goods and quality for each one of these new goods (allowing new activities, with associated innovations of process), is being developed per G. Ballot (e.g. Ballot & Huynh, 2016). Certain goods may disappear, high qualities eliminate from low qualities when the standard of living increases in an endogenous way, the worker-consumers also being represented individually. The model of production rests on a triplet: competences (R & D, to produce), tasks (organization of work) and alliances in R & D between companies, which are a source of diffusion and accumulation of competences. Moreover, for the first time, a computational model of the innovation is buckled by an endogenous competition of the companies which position on a market differentiated (dynamically) in goods and qualities, but can also go bankrupt. The nature of each market emerges at the same time as a macroeconomic state of growth of long run.

Thus, we propose with the NumJobs tool to combine a detailed model of the job market coupled with a model of dynamics of innovation with many competing firms. This tool – not yet developed by other researchers– will simulate how the innovations of associated product and process appear, how they first of all impact work in terms of competences and tasks necessary for the production of these digital innovations, in terms of employment (creations or destruction of jobs, recruitments,...) and then at the macroeconomic level.

This tool will be **flexible** in order to study different scenarios and emphasizes **dynamics** in order to take into account:

- the **evolution of the digital innovations**;
- the **evolution of** occupations by modifying **competences** requested and the **tasks** associated with employment;
- the **organization** of the companies, their **strategies** (of innovation, recruitment).

For the first time it will integrate and account for all the major factors of the impact of digitalization and automation on employment:

- **dynamics** of the **innovations**, transformation of the contents of occupations , creation of new employment, adaptation of the agents to technology;
- **socio-demographic** factors (demography, education), training (role and impact);
- **microeconomics**: supply and demand (duality work - consumption), production, several sectors, organisation of work;
- **macroeconomics**: effects of short-term, long-term looping;
- **environment**: labor law, institutions, economic conjuncture.

Who are we ?

This ambitious project will draw part of the complementarities and the multidisciplinary which have us successfully building permit the WorkSim simulator.

Jean-Daniel Kant is a computer scientist, researcher in artificial intelligence, and knows the digital innovations well. He has carried out for 15 years a multi-disciplinary research (combining computer science, mathematics, economics, psychology and social sciences), and is a recognized specialist in agent-based simulation in economics².

Gérard Ballot is a recognized specialist in labor and innovation economics, and a pioneer in agent-based simulation of labor markets³. He is also the co-designer of the training and innovation modules in the agent-based model MOSES, which combines micro and macroeconomics.

Project overview

At first we must select the country the model will be designed for. Later on it could be applied – through adaptations – on other countries for cross-country comparison studies.

We identified the following principal workpackages :

[WP1] Extending WorkSim

First, we need to adapt WorkSim to the country of interest if not France. Then we extend WorkSim to meet the needs for NumJobs:

- **Multiple industries**, including digital economy (AI, robotics,...)
- **Competences and tasks** associated with the jobs (requirements for hiring and for production)
- **Dynamics of occupations and jobs** (creation and destruction), in interaction with the innovation model

[WP2] Macroeconomic loop

- Modeling the **demand** for three types of goods : **final consumer goods**, **intermediate** goods, and **capital** goods
- Modeling the **goods market** with **endogenous** prices
- Addition of a **simplified banking system** (loans for households and companies)
- Macro loop with **stocks and flows consistency**

[WP3] Coupling with the innovation model

- Dynamics of **innovation**, **R & D** investment , **product and process** innovation, introduction of **new** products
- Dynamics of occupations (new competences and tasks)
- **Co-operation** and **competition** between firms, alliances (R & D)

[WP4] Simulating the impact of digital on jobs and employment

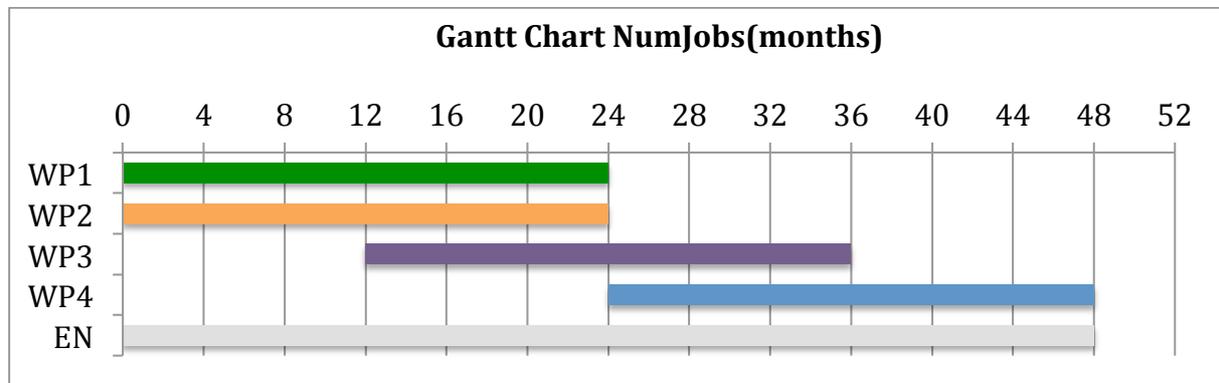
- Identification of the **case studies**, in co-operation with the partners
- Data collection for these cases
- Implementation of the cases

² See <http://www-poleia.lip6.fr/~kant/>

³ See <http://cred.u-paris2.fr/ballot>

- Simulations, experiments, analyses and conclusions

WP1 and WP2 must be synchronized, before carrying out WP3. WP4 will conclude to get the first results. In addition, several cross-sectional studies [EN] on the digital economy will be led at the beginning of the project, in order to define the sectors to be studied and their uses. A Gantt chart over 48 months is depicted below :



Resources estimation

As an indication, one could consider at least 1 PhD students to carryout WP1 and WP4, 1 year of post-Doctoral to be supplemented after the thesis to finish WP4 , 2 post-docs (each 2 years) to carry out WP2 and WP3. To be added the collaboration contract for faculty advisors, and the means affected to cross-sectional studies EN.

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