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# **An agent-based simulation of the Swiss labour market: an alternative for policy evaluation**

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## **1 Introduction**

Labour policies include measures that, in addition to acting directly on the labour market, may also refer to individuals. They aim at facilitating the matching of supply and demand and at improving the access to employment for the disadvantaged.

In this sense, a first definition (Salesi, Piras and Poggiu (eds.), 2004) can describe labour market policies as public interventions in the labour market addressed to reach its efficient functioning and to correct the imbalances. A simple classification can divide labour policies into two broad categories:

- a) passive policies, implemented to alleviate the discomfort created by unemployment (unemployment benefits, early retirement, etc.);
- b) active policies, defined to directly affect the employment opportunities of individuals. In this case they can deal with interventions for the employees (public employment services, guidance, support for job search) or firms (public sector job creation, incentives to hiring, training subsidies).

However, active policies are primarily aimed at integrating (or reintegrating) into the labour market those who are on the edge of unemployment. The long-term objective, consistent with the previous definition of active policy, is to pursue the most efficient functioning of the labour market, reducing the long-term unemployment.

For many years, this issue and the process through which firms and workers meet in the labour market has been extensively studied and the matching process that affects employment and unemployed dynamics has been a central research topic in labour economics. Most of the literature has tried to explain these phenomena on the grounds of a standard “toolbox” based on micro-foundations, which postulate hyper-rational firms and workers: the “representative individual hypothesis” is often employed to overcome difficulties entailed by aggregation of heterogeneous agents. Moreover, static equilibrium conditions are largely used to interpret macroeconomic dynamics (Fagiolo, Dosi, and Gabriele, 2004).

Following this approach Active Labour Market Policies (ALMPs) are generally analysed in the context of a macroeconomic approach or within a micro-econometric model. The latter is used among many authors: (Kluve, 2010), using a meta-analysis, based on a data set that includes 137 programs from 19 countries, shows that it is almost exclusively the program type that seems to influence the effectiveness of the program.

A critique of the usual economic analysis of labour markets states, however, that a standard economic approach does not take into account the importance of “social networks” in the labour process. Recent research, indeed, based on empirical findings (Pellizzari, 2005; Rebien, 2010; Dawid and Gemkov, 2013), highlights that social contacts like friends or relatives, organized in different types of networks (according to the average number of friends/relatives and the density of the network) have a substantial impact on the matching process. This view holds that relationships are fundamental to both employers and workers, since they are more likely to apply for jobs where they have a personal connection, and are more likely to be hired if they have “soft” skills.

The purpose of this paper is therefore to further diversify the battery of instruments used for these assessments, focusing on the regional level. We propose a different interpretative strategy based on the acknowledgement that both firms and workers live in a complex system which evolve through time and might be characterized by endogenous, persistent, novelty agents, that are heterogeneous in their endowments, wealth, behaviour and rationality (Fagiolo, Dosi, and Gabriele, 2004).

Starting from this context, agent-based computational economics (ACE) models (Testfason, 1998) identify a generic model in order to explain a complex phenomenon at a very abstract level. At the same time, this kind of models can be based on empirical data to describe a particular case study. This paper follows the agent-based models (ABMs) approach trying to link micro-level and macro-level evaluations and focusing on the interactions between economic agents. The so constructed model will actually try to describe the dynamic matching between labour supply and demand and how it is affected by specific changes in policy and social parameters.

The paper is organized as follows. In Section 2 we start by describing the convenience of evaluating Labour Market Policies with ACE. In Section 3, we present the model and we discuss its characteristics, design concepts and functional specifications, according to Dahlem ABM documentation (Wolf et. al., 2010). We next present, in section 4, two test-experiments and first results. Finally, Section 5 draws some concluding remarks and perspectives.

## **2 Labour market policy evaluation with ACE**

Recently, agent-based models have been proposed in order to support policy makers in their decisions: a similar argument holds for many policy questions, which are typically related to at least some aspects of economy, technology, and actor behaviour (Chappin, Chmieliauskas and de Vries, 2012). With agents in a computer, it becomes possible to recreate actual world on an artificial basis, to see the effects of the action and interaction. As Wiener, the actual founder of cybernetics, said<sup>1</sup>:

*“A material model is the representation of a complex system by a system which is assumed simpler and which is also assumed to have some properties similar to those selected for study in the original complex system. A formal model is a symbolic assertion in logical terms of an idealized relatively simple situation sharing the structural properties of the original factual system. Material models are useful in the following cases. a) They may assist the scientist in replacing a phenomenon in an unfamiliar field by one in a field in which he is more at home. ( . . . ) b) A material model may enable the carrying out of experiments under more favourable conditions than would be available in the original system”.*

Substituting to the “material model” idea (the actual artefact) an agent-based model (the synthetic artefact), we can have exactly the capacity of making “experiments under more favourable conditions than would be available in the original system”.

In social science, indeed, models are generally built in two ways, as a verbal argumentation or as mathematical equations, typically with statistics and econometrics. The first way is absolutely flexible and adaptable, but mere descriptions and discussion, by their nature, preclude tests and verifications of hypotheses. In contrast, the second way allows for computations and verifications, but suffers from severe limitations in flexibility and adaptation, especially with respect to how agents are expected to operate in the model and when accounting for their heterogeneity and interactions (Terna, 2013).

Computer simulation, that can be considered as a “third way”, can combine the extreme flexibility of a computer code where it's possible to create agents who act, make choices, and react to the choices of other agents and to modification of their environment and its intrinsic computability. This approach allows researchers to use the descriptive capabilities of verbal argumentation and the ability to calculate the effects of different situations and hypotheses together.

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<sup>1</sup> Rosenblueth, A., Wiener, N.: The Role of Models in Science, in “Philosophy of Science”, vol. 12, 1945, n. 4, pp. 316-321 (1945).

However, the application of agent-based models (ABMs) for policy evaluation is still limited: usually policy makers are presented with model outcomes, which depend strongly on the choice of scenarios and many other assumptions, and typically do not have access to the models themselves, as it takes technical expertise to run and interpret them. ABMs may actually be scary to policy makers, as they might confront them with the fact that for many of their objectives, they have limited control options. On the other hand, if ABMs are built with sufficient richness and organisation to be applicable to real policy questions, simulation can act as a sort of magnifying glass that may be used to understand reality in a better way.

Moreover, these new approaches are challenging, because new modelling techniques such as ABM are not established in the way that traditional ones are (Lejour et al., 2006). It is not possible, indeed, to assess the macroeconomic consequences of labour market policies using a pure micro-approach; in the same way a macro-approach does not permit to look at an individual level, making impossible to evaluate the impact of ALMPs on a precise target group. Agent-based labour market models allow the extraction of information based on aggregate outcomes, that are fully explained by the characteristics of the agents and the systemic structure of their actions.

Since these type of models simulate a complete sets of individual observations they have also an interest in addition to the micro-econometric evaluation approach *ex post*. A final advantage is that the simulation at the individual level can help to formulate hypotheses on the micro-economic agent's behaviour using simple and intuitive rules, closer to the reality than the abstraction of rational aggregate models. This greater attention to the micro-economic reality behaviour characterizes the current ACE research.

### **3 The model**

Following Dahlem ABM documentation guidelines (Wolf et al., 2010), the features of the model are structured as follows.

#### **3.1 Overview**

The proposed approach has been implemented with an integrated (micro/macro) simulation model. The model has been structured in modules (until now, two modules were implemented: Subsidized training and Job displacement effects), which let the user to enable or disable some features to explore different policy options. Following the exposed perspective, we have developed a case study to test and validate the application of the proposed methodology and framework.

The implemented ACE model considers a virtual regional labour market with firms and worker agents. Firms are assigned different sectors and have sector-specific skill requirements. The model addresses the complex issue of aggregated phenomena in the regional labour market, characterized by an environment where individual agents (firms and worker agents), their decisions at the micro-level and the policies defined at a macro level interact in a systemic way.

We are addressing some issues like connecting the economic and cellular spatial simulation models, and connecting the conventional econometric model to the developed integrated model. Specifically, this study seeks to identify traceable connections between micro and macroeconomic scales exploring the regional labour market in the southern Switzerland (Ticino and some districts of the Grisons), where the particular geographical position of the Italian-speaking part of Switzerland was an incentive to build strong relationships between the cantons and the neighbouring Italian provinces. As an example one in four workers is a trans-border commuter.

The benefits of this type of model are potentially many. The most obvious advantage is that it permits to simulate at an individual level the political impact of highly differentiated policies. This advantage has its counterpart in terms of results. Such a model that simulates a sample of individuals or firms can give messages on the evolution of a very large number of output variables, that were explicitly intended

or not by the modeller: employment rates, unemployment, labour turnover, length of stay in different states.

Let's consider a virtual world populated by a number  $nWork$  of worker agents. Each worker has assigned a nationality (Swiss or foreigner), an initial random skill  $S_i$  and an initial productivity  $P_i$ .

There are  $nSect$  sectors in the virtual world and  $nFirm$  number of firms. The number  $nSect$  has to be  $\leq nFirm$ . As in (Neugart 2009) each firm has different skill requirements. Each firm is also assigned a random number of available vacancies. The policy maker agent defines active labour market policies.

During the simulation periods firms are hit by shocks and dismiss their employees that are "too costly". The worker's "cost" depends on his productivity and his nationality. Unemployed workers have to invest in their human capital to qualify for vacancies opened in different sectors. The policy maker finances the unemployed workers' human capital investment.

At present the model doesn't consider an explicit relationship structure between agent's interaction, but depending their "upgrading decision" on vacancies, that in turn depend on firm's and agent's decision, an implicit relationship holds.

The model is programmed into NetLogo, a program specifically designed to accommodate agent-based modelling, which has a programming language flexible and easy to learn.

### 3.2 Design Concepts

When a simulation starts firms and workers are randomly allocated to sectors. If a firm is employing workers it checks if they are "too costly"; if so they are fired.

Unemployed agents decide whether or not to apply for a skill upgrading. They choose to undergo a skill upgrading in the sector  $j$  only if the following two conditions are satisfied:

- a) the vacancies in sector  $j$  are greater than a threshold;
- b) the cost of the human capital investment is less than a defined payoff, according to a particular investment strategy.

The first condition limit tries to capture the "flexibility" constraint pursued by modern labour market policies, the latter is a wealth constraint.

The investment strategy is defined according to a learning model, which takes into account the job history of the worker, and measures the average payoffs the agent has gained in the previous periods if he was unemployed.

Each firm opens vacant positions and receives applications; it then randomly chooses one applicant, which fit with the firm's skills requirement (the hiring process probability depending on the history of the applicant and on a random parameter). The worker always accepts the first offer he gets.

At present, the population level is considered stable, assuming that the simulation covers a short period of time, during that the workforce doesn't significantly change.

The level of randomness (considering the simple structure of the model) is feeble, having the user the power to precisely tune most of the aspects of the simulation.

### 3.3 Functional Specification

In conjunction to firms and worker agents, that are the most important agents in the model, there are different variables that contribute to define the simulation environment.

- Firms ( $nFirm$ ), that hire workers, assumed fixed in time and space:

Name	Type	Description	Updating	Initialization
<i>firm</i>				
region	patch	place where the firm is located	fixed	randomly assigned
Nvacancy	$N = 1 + \text{random } 10$	number of available vacancies	volatile	randomly assigned
sector	$N = [1, 2, 3]$	firm's Economic Sector	fixed	randomly assigned
Factory employed	$N \leq Nvacancy$	employed number in the firm	volatile	computed

Table 1 –firm's state variables

- Worker agents (*Nwork*), that apply for jobs;

Name	Type	Description	Updating	Initialization
<i>worker agent</i>				
nationality	$N = [0, 1]$	worker's nationality (0 Swiss, 1 foreign)	fixed	computed: 20% of them are foreign
wealth	$N = \{0, 100\}$	agent's wealth	volatile	user input
subsidized?	$N = [0, 1]$	subsidized worker	fixed	user input
skills_level S	$N = [1, 2, 3, 4, 5, 6, 7]$	worker's skills level	volatile	randomly assigned
productivity P	$N = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]$	worker's productivity	fixed	randomly assigned
worker?	$N = [0, 1]$	worker (true or false)	volatile	0
strategy	$N = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]$	agent's strategy	volatile	randomly assigned
best strategy	$N = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]$	best strategy	volatile	randomly assigned
upgrade	$N = [0, 1]$	true if the agent currently plans to upgrade his/her skill level	volatile	0
prediction	$-1.0 < R < 1.0$	current prediction of the skill upgrade	volatile	randomly assigned

Table 2 –worker agent's state variables

- Variables, that define the environment:

Name	Type	Description	Updating	Initialization
<b>strict</b>	$0 \leq R \leq 1$	"layoff" threshold	fixed	user input
<b>thrsprev</b>	$N = \{0, 50\}$	"learning" constrain	fixed	user input
<b>memory-size</b>	$N = \{0, 10\}$	agent's memory size	fixed	user input
<b>number-strategies</b>	$N = \{0, 20\}$	agent's maximum number of strategies	fixed	user input
<b>thrsflex2</b>	$0 \leq R \leq 1$	"flexibility" constrain secondary sector	fixed	user input
<b>thrsflex3</b>	$0 \leq R \leq 1$	"flexibility" constrain tertiary sector	fixed	user input
<b>employment rate</b>	$0 \leq R \leq 1$	employment rate	volatile	computed
<b>unemployment rate</b>	$0 \leq R \leq 1$	unemployment rate	volatile	computed
<b>skills level</b>	$N$	total skill level	volatile	computed

Table 3 – variables in the model

The model is initialized setting  $N_{firm}$  and  $N_{work}$ , and all the variables reported in Table 3; the model does not need external data. The simulation then runs according to the following scheme (*Pseudocode*):

Create firms and workers  
 Create sectors  
 Allocate randomly workers to sectors  
 Set initial conditions

for  $n$  periods

*Dismissal*  
 For each sector  
 For each worker  
 If worker's cost > threshold  
 Dismissal

*Human capital investment*  
 For each unemployed  
 If vacancy in sector  $i > threshold$  invest  
 else if calculate payoff  
 choose investment strategy  
 apply investment strategy

*Hiring*  
 For each sector  
 For each firm  
 If vacancy  
 If worker apply  
 Select worker  
 Else  
 Not fill vacancy

End  $n$  period

## 4 Experiments

The usual validation procedure involves multiple monte-carlo simulations and the analysis of the aggregate data (Lewkowicz, Z., Domingue, D. and Kant, J.-D. 2009). Using NetLogo the procedure is performed through the “Behaviour space” tool, that allows the user to set up experiments with multiple repetitions.

In the experiments that follow, different run-periods of the algorithm described in the Addendum paragraph are selected. The setup of two test-experiments is described below.

### *Subsidized training*

A first base test concerns the impact of an increased subsidized training: comparing a “base” and an “incremented” subsidy.

The worker agents are divided in two groups, one of “base subsidized” and one of “incremented subsidized” workers; then the simulation is run. The participation rate is checked against the base condition.

### *Job displacement effects*

A second experiment concerns the analysis of the treatment effects on the individual and the macro-economic level. ALMPs cause an increase in the size of the labour force and this involves more competition in the labour market and could produce for firms the opportunity to dismiss “non subsidized” workers and to replace them with “subsidized” workers (the simulation assumes that the subsidy “improves” the past history of the applicant, increasing his hiring probability).

As before the worker agents are divided in two groups, one of treated and one of non-treated workers; the agents from the non-treated group do not receive subsidies.

The experiment is divided in two phases. In a first simulation round no subsidies are given neither to the treated workers nor to the non-treated workers, then in a second round the agents that belong to the treated group are subsidized.

Finally, the last differences between the employment rate of treated and non-treated agents for both round are compared.

## 5 Discussion and perspectives

This model is intended as a first prototype of an agent-based regional labour market model with sector specific requirements.

The approach of evaluating labour market policies with agent-based models entails strong assumptions and some issues. The model specification is a key factor that can involve difficulties and the calibration is still imperfect. In such models some issues such as empirical initialization, the limitations of data collection, empirical validation or the role of data in the design must be addressed.

At this point, the model is still experimental and calibration is very preliminary (the initial conditions on  $nSect$ ,  $nFirm$ , nationality, skills  $S_i$  and productivity  $P_i$  are based on empirical data, coming from the regional labour market analysis), but it already allows to approximate quite a number of stylized features of the southern Swiss regional labour market. Nevertheless introducing an empirically-grounded agent-based modelling technique it will be possible to address some challenging issues in modelling of complex regional labour markets phenomena.

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