

SCIENTIFIC REPORT 2020

RESONATE: *Worker flows, labor market outcomes, and agent-based modeling* (Project PN-III-P1-1.1-PD-2019-1180)

I. Summary- Stage 2020

The increasing interest in the literature in studying the flows of workers between firms at the level of the labor market creates favorable premises for using a methodological approach that specifically accounts for the behavior of the agents who interact on this market. In this context, the present research aims to build a complex network that incorporates work flows between employees and companies, in the extended framework of the labor market, using national level structures. From a methodological point of view, building a realistic and complex structure of the labor market at the regional or national level requires the use of a methodological framework that distinguishes by the standard literature in the field of the labor market in that it accounts for the heterogeneities between the agents. In this context, agent-based modeling (ABM) ensures, through the elements and tools used, a better representation of the dynamic context that describes work flows.

The research conducted in the first stage of our research, aimed at reviewing the literature in the field in order to outline the structure and the particularities of the synthetic network of work flows between companies and employees, a network that will be used in subsequent stages to test the theoretical hypotheses regarding the dynamics what characterizes the labor market. First, we carried out a detailed analysis of the research in the field, by looking at the main subjects that are related to labor market dynamics, and by studying the use and applicability of these modeling tools on the labor market related topics. Starting from the elements we identified in this first stage, we later outlined the model that describes the work flows, by including the particularities and analysis tools specific to the ABM methodology.

II. Scientific approach

Starting from the main objective of this research (which aims at using agent based modeling for describing labor market dynamics, in order to describe the nature of the interactions that take place among employers and their employees), *the objective* associated to the first stage of this research was to first analyze in depth the existent literature in the field; so as to create the premises for describing the particularities of the model that is going to be used for testing the theoretical hypotheses associated with the dynamics of labor market.

1. Literature review

The literature review was realized by following two research directions: i) the study of the main topics associated with the labor market: which allowed us to identify the main current research questions in this field, as well as ii) the identification of the methodological framework of the agent-based modeling methodology, in order to understand the particularities of this approach, as compared to the traditional approach.

Starting from the shortcomings of the neoclassical economic models (among which we enumerate the assumptions related to homogeneity, rationality and the existence of equilibrium) and those of the existent econometric models, the methodological approaches in studying the

dynamics of the labor market have evolved towards the use of agent-based modeling, so as to highlight the complexity of such an evolutionary system. The early models from the late 20th century took the first steps towards using micro-simulation to labor market field (Bergman, 1990; Elianson, 1983). Later, starting in the 2000s, the emergence and development of highly complex computational models favored the expansion of a wide range of models used for analysis, models that characterize the labor market as a complex network which is the result of the interactions that take place between employers and employees. The main approaches consisted of evolutionary and dynamic models in which the behavior of agents is considered to be: adaptive, based on game theory principles (Tsfatsion, 1998; Tsfatsion, 2001; Axtell, 2002); random (Guerrero and Lopez, 2016); selection-based mechanism (Tassier and Menczer, 2001); or rule-based (Kuhn and Hillman, 2014).

Following the ABM procedure has the advantage that enables the study of very complex labor flow networks. There is an increasing number of studies that use real data to apply these models, as for example the studies of Guerrero and his co-authors that use data on Finland (Guerrero and Axtell, 2013; Guerrero and Lopez, 2015; Axtell *et al.*, 2019), Mexico (Lopez *et al.*, 2015) or Great Britain (Tong *et al.*, 2017). All these studies use extensive data sets that model the dynamics of employee-employer networks and the existing interactions, allowing the introduction of a high degree of heterogeneity at the network level by including different topologies that characterize the mobility of agents.

From the perspective of research topics approached in the field of labor market, the studies mainly address research questions that aim at causal relationships between different variables or try to explain the effects of certain policies in the field of the labor market. To offer just a few examples of studies that use the ABM methodology in this research field, we mention studies that: analyze the structure of the labor flow network by explicitly modeling the existing links between agents (Montgomery, 1991; Montgomery, 1992, Tassier and Menczer, 2001; Tassier, 2006); study the role of unemployment benefits system (Pingle and Tsfatsion, 2004; Ricetti *et al.*, 2013) or the role of different working contracts (Lewkowicz and Kant, 2008; Goudet *et al.*, 2016), or analyze age or wage discrimination (Lewkowicz *et al.*, 2009; Tassier, 2006).

In the context previously presented, the agent-based model that we built at this stage of the project -and that will be described in the following- deepens the study in the field, taking into account modeling elements and mechanisms at the microeconomic level, to characterize the extended framework of the labor market, by taking advantage of the use of agent-based modeling.

2. Model description

In the process of studying the dynamics of the labor market, the model outlined in this project starts from the hypothesis of a structured network of agents (employees and companies) that interact within a complex system, a system that evolves over time as a result of the agents' interaction. More precisely, the labor market consists of a network of companies and employees, between which there are established links, represented by their labor relations. The complexity of the system is generated by the heterogeneity of the agents that compose it (Kühn and Hillmann, 2014), all of the agents possessing different characteristics and undertaking their own actions. Agents' behavior is continuously revised and updated if necessary, either as a result of the

outcomes generated by their previous decisions, or as a result of the information agents gather from the environment in which they act (de Marchi and Page, 2014).

The use of agent-based modeling allows for a more accurate representation of the reality, because it uses simple and intuitive rules for describing the behavior of agents (Baruffini, 2013). Among the advantages of using ABM (Sabzian et al., 2019) we can enumerate: the fact that it uses bounded rationality, it does not require a priori knowledge of the manifestation of the studied phenomenon at the aggregate level (it uses a bottom-up approach perspective); it allows a high degree of heterogeneity and interaction between agents, as well as observing the constituent elements of the system both in an aggregate manner and at an individual level.

Agent-based modeling thus includes three main elements (Sabzian et al., 2019):

- the agents -in our case, companies and workers- who possess their own properties and rules of action (if a condition is met, this generates a certain result); this heterogeneity of agents in terms of their own characteristics allows for a more realistic representation of the labor market;

- the environment or the space in which the agents interact and which includes all the conditions that can affect their behavior (for example the legislation regarding the labor market, the social protection system, the macroeconomic conditions in the respective country, etc.)

- the interaction between agents or between the agents and the environment, namely: their rules of behavior and the way in which they make decisions, starting from past experiences or from the particularities they possess.

The above mentioned structure suggests the existence of a dynamic environment, a constantly changing one, which assumes the simultaneous action of different agents. The implementation of the model thus implies running simulations in this setup to analyze different elements of the labor market, starting from the existing particularities of such a model. This is possible by calibrating the parameters of the model, using comprehensive data at the national or regional level. In practice, the implementation of this model involves populating the model with agents - companies and employees - each having a vector of attributes (properties) and characteristics (behavior rules). When the model is initialized, the attributes will be assigned values (agent's state), and by summing up all these states, the model configuration will be obtained. Afterwards, the agents are allowed to interact in time -based on the established attributes and rules- and the results of the simulation are monitored as the system evolves.

The implementation of the previously described model is computationally possible thanks to the use of programs that allow data simulation and the analysis of a large datasets. We analyzed the alternatives regarding the implementation of the model, and the analysis revealed that we need a programming software capable of both working with a large volume of data and capturing the particularities of the model in the smallest details, so that the results generated by the model to be rendered in an intuitive manner.

For this purpose, for the structuring and implementation of the model we will use the Python programming language, which is object-oriented. Despite its use on a relatively small scale in the field of economic sciences until now, in the present research the agent-based methodological approach requires the use of this programming language in order to represent the reality of the labor market as complex as possible. As an alternative to using Netlogo, Repast or MASON

programs to implement AMB, in this project we will use the Mesa modeling framework (<https://github.com/projectmesa/mesa>). It allows the creation of agent-based models by using built-in or custom core components, as well as visualizing and analyzing the results in an intuitive manner.

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