Agent Based Modelling Approach of Migration Dynamics

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Abstract. We propose an agent-based model to simulate internal migration of workers. The model is based on mathematical equations describing the socio-economic characteristics of the agents and their behaviors. The main assumption of the model is the objective of individuals to find decent (formal) employment.

The model simulates the migration of agents from a rural-type region of origin to a destination region with more important economic activities. The model consists of two main stages: before and after migration. In the first stage, potential migrants and migrants are determined. The second stage involves job search and demographic and socio-economic updates. The model is divided into several modules: (i) Initiation and migration, (ii) Job search module, and (iii) Module of economic and demographic transitions.

Keywords: Agent-based model · Internal migration · Mathematical equations labor market

1 Introduction

Thanks to the evolution of computers in the late eighties, computational and simulation methods have invaded all fields of research from robotics to ecology and from medicine to geography. Among these methods, Agent Based Models (ABM) represent a (relatively) new branch of artificial intelligence with a continuously growing interest. ABMs use metaphors inspired from biology and sociology to implement intelligent artificial systems to model real processes.

ABMs consider the basic elements constituting a process and allow analysing the emerging global dynamics of this system. This ability to reconcile the analysis' levels microscopic and macroscopic, is one of the most important advantages of their use in studying heterogeneous systems. In addition, ABMs allow the integration of new agents and the test of different hypotheses without attempting real experiments.

R. Silhavy et al. (eds.), *Applied Computational Intelligence and Mathematical Methods*, Advances in Intelligent Systems and Computing 662, DOI 10.1007/978-3-319-67621-0_31

The facilities that ABMs offer, make them a powerful tool used in various disciplines, notably in economics.

For economic analysis, ABMs have gained notoriety and interest in recent years. ABMs allow for more flexibility in economic modelling and more realistic analysis than conventional methods. ABMs were used in economic modelling at the end of the seventies with the model of [1] on spatial segregation. The model was realized with a chessboard and pieces were moved by hand. Nether less, this model highlights the individual preference of agents to have a majority of neighbors belonging to the same ethnic group.

Generally, ABEMs use a bottom-up approach to explain the emerging global dynamics of an economic system from the individual dynamics of autonomous and heterogeneous agents that act and interact according to certain rules in a particular environment [2].

The economic models based on agents overcome several limits of standard economic modelling. If conventional economic models adhere to an infinite maximization of individual utility, a complete information and a perfect rationality of individuals, the ABEMs allow us to overcome these simplistic and restrictive assumptions by taking into account agents' heterogeneity in terms of characteristics, behavior and objectives. So agents in ABEMs live their own experience, have a limited perception of their environment and learn from their previous actions.

ABEMs constitute an extension of conventional economic approaches and contribute to their renewal. They are also closer to experimental and behavioral sciences than deductive logic methods.

ABEMs have a wide range of applications ranging from labor market modelling and employment policies [3, 4] to simulation of financial market dynamics [5].

Recently, migration movements have been modeled by ABMs. Generally, Migration ABMs are based on behavioral theories (random utility and planned behavior) and their decision to migrate depends mainly on maximization of expected utility.

Some models integrate the individual's life cycle by taking into account some life events (marriage, divorce, graduation or retirement) that change the status of the individual and thus his objectives. Given the impact that migrations can have on individuals' trajectories, studies taking simultaneously into account migration and the life cycle have known a growing interest.

Even if the use of ABEMs in migration analysis still in its early stages, it allows migration model to be more and more realistic. Few authors have been interested in modeling the decision to migrate by minimalist models or more sophisticated models. For example, the work of [6] who takes into account the expected benefits, wealth, age and migrants' network in the migration decision. Naqvi and Rehm [7] considers migrations resulting after natural disasters and leading to a decrease of incomes and an increase of food prices. Hassani-Mahmooei and Parris [8] made a model in which the decision to migrate takes two steps: selection of potential migrants then determination of migrants. Espındola et al. [9] and El Saadi et al. [10] translate an economic model [11] into ABM.

Unlike the majority of ABM of migration that are based on its demographic aspect, we propose an ABEM of internal migrations of workers. The model differs from conventional economic migration models by: (i) taking into account factors other than

economic factors in the decision to migrate such as the socio-demographic characteristics of Agents; (ii) considering individuals' heterogeneity; (iii) and by introducing the selective character of migration (little exploited in the literature). Compared to ABEM of migration, this work introduces the evolution of individuals throughout their life cycle. In fact, the proposed model simulates the main events they will face throughout their lives (studies, marriage, divorce, etc.), allowing perpetuation of individuals' heterogeneity.

The structure of the paper is as follows. Section 2 introduces the proposed model. Section 3 presents the results of the simulations. A conclusion summarizing the essentials of the work done and model's prospects finishes the article.

2 The Agent Based Migration Model

The aim of this work is to model the process of labor migration using agent based model. The main assumption of the model is the objective of individuals to find decent (formal) job and we opt for the maximization of income in the job search process. Decisional processes and agents' characteristics are described by mathematical equations.

The model involves two main stages: before and after migration. In the first stage, potential migrants and migrants are determined. The second step involves job search process and updating demographic and socio-economic characteristics.

For each step, a system of relations presenting different behaviors of the agents is defined. The model is decomposed into several modules: (A) Initiation and migration module, (B) Job search module, and (C) Module of economic and demographic transitions.

2.1 Initiation and Migration Module

Initiation

The model includes two types of agents: Agent Individu and Agent Region.

Agent Individu

We consider the person and not the household as the main actor of the model even if the new migration theory rejects the individualistic character of the neoclassical models (like the model of [11]) and places the decision to migrate within a wider societal context taking into account the impact of household support [12]. From this point of view, the model developed here is a step back from this theoretical advance, but it is a deliberate simplification. Modelling household support remains difficult in practice. Also, the main objective of the model is to describe individual dynamics of labour migration and therefore mainly concerns the job seeker. Agent Individu may be either an employee affiliated to the social security system, an employee who is not affiliated to the social security system, an unemployed person or an inactive person. He is described

by a set of socio-economic characteristics such as age, marital status, employment status and educational attainment.

Agent Region

Agent Region represents the firms through the creation and destruction of employment. Two types of regions are considered. An origin region with a low rate of decent job creation, a large dispersion in incomes, an undeveloped formal sector, and a destination region with more potential (more important economic activities). These characteristics generally describe the two environments rural and urban.

Each Agent Region is described by the unemployment rate, the tension of the labour market, the probability of finding a job, wages and a set of demographics transitions rates. Firms are not explicitly simulated, but jobs are created according to a job creation rate specific to each region. As the first objective of the model is to analyze the migration of workers and not the recruitment process within firms, it seems preferable to simplify this dynamic by creating and destroying employment within the regions.

Migration Process

Decision to migrate takes place in two stages. Initially, potential migrants are determined on the basis of certain socio-economic characteristics. Next, potential migrants estimate the expected profit of migration by taking into account wages and the probability of finding a job.

Determination of Potential Migrants

The decision to migrate depends strongly on the individual characteristics of migrants. This is called self-selection that determines the ability to migrate for different categories of people.

In this model, the individual characteristics chosen are age, gender, employment status, educational level, marital status and the existence or absence of migratory networks. All these variables have a great selective influence in the propensity to migrate.

The determination of potential migrants is based on the calculation of a discriminant function relatively to these variables for unemployed or informally employed individuals aged between 16 and 59 and living in the rural. This function is presented as a linear combination of these variables ($F_j(t)$). A worker is considered as a potential migrant if he satisfies the following condition:

$$F_j(t) \times u \times \theta > Threshold \tag{1}$$

With Threshold a constant determining by user.

Once potential migrants are determined, they will have to choose between migrating or staying.

Decision to Migrate

Potential migrant individuals now have to calculate the expected gains with or without migration. These gains are weighted by the probability of finding formal job, which depends on agent's qualification. Skilled workers may apply in contrast to unskilled workers for skilled and unskilled job positions, increasing their chances of having a formal job:

$$G_i^j = \pi_i^j \times W_{i,j}^e \tag{2}$$

Where

- G_i^j is the expected gain for individual i in region j;
- π_i^j is the probability of finding a decent job in region j;
- $W_{i,j}^e$ is the expected wage for individual i in region j. The expected urban and rural wages are calculated as follows:

$$W = SNMG \times Q + \sigma W \times R(0,1) \tag{3}$$

With

- *SNMG* the National Minimum Wage;
- Q Individu's qualification;
- σW Wage Dispersion;
- $R(0,1)$ Realization of the uniform law (0, 1).

Wage differentials between the region of origin and destination regions are calculated. If wage differential is greater than zero, then the potential migrant will decide to migrate.

After determining the migrants, job prospecting is the next step in the model for migrants and non-migrants.

2.2 Job Searching

All unemployed or informal workers aged between 16 and 59, are concerned by job search. Those who are qualified can apply for skilled and unskilled job positions and those who are not qualified will have to settle for unskilled job positions.

In each region and every year, a number of jobs are released following retirements, others are created and some can be destroyed.

Individuals with the highest probability of finding formal employment will be the first to be hired.

However, individuals will not be able to remain indefinitely in a situation of unemployment, they will be discouraged after a certain number of attempts.

We suppose that the probability to be required increase with the qualification and the time spent on the search. This probability is defined by [13]:

$$P_i^j(\mathrm{t}) = P_i^j(t-1) + (1 - P_i^j(t-1)) \times \pi_i^j(t) \tag{4}$$

Where

- $P_i^j(t)$ is the probability to be required for agent i in region j at time t,
- $\pi_i^j(t)$ is the probability to find a job for agent i in region j at time t.

Once the job search process is completed, an update of the demographic and socio-economic variables begins. The module starts a new cycle.

2.3 Demographic and Economic Updates

The individuals' state evolves in time and changes throughout their life cycle. Since our model depends largely on individual characteristics of the population and on the current and expected demographic changes, a particular attention is made to the sociodemographic updates. The main simulated demographic events are births, deaths, marriages, divorces, promotions and school dropouts.

First, death individuals are removed from the database and the age of the remaining individuals is increased by one year. Then new agents are created, others divorce while some get marry. Children who have reached the age of six are enrolled in school. Some students (primary, secondary or high school) and students (university or vocational) drop out of school and become inactive. The rest of the students move on to the next higher level. At the end of each model cycle, students complete their studies. Some of them start looking for work and become unemployed and others become inactive.

Economic transitions of individuals are also simulated. Unemployed persons who have spent a long period seeking employment, will abandon and become inactive while a part of the inactive persons will undertake a job search and become unemployed. Some more ambitious unemployed will embark on the entrepreneurial adventure, while some of the entrepreneurs will be forced to give up their business and will be among the new unemployed.

3 Simulation and Results

3.1 Simulator

The migration model proposed is realized on GAMA platform.[1] GAMA is a free modelling and simulation development environment dedicated to agent-based modelling. GAMA allows the modelling and simulation of several processes of different fields ranging from epidemiology, land use to urban mobility or reconstruction of geo-historical events. The development environment offered by GAMA includes a GAML code editor that facilitates the writing of templates (auto-compilation of models, auto detection and correction of errors, etc.). GAML is an agent-oriented programming language that is simple to use and assimilate and even allows novice modellers to create templates. The GAMA platform has been enriched since its creation in 2007 and incorporates many powerful tools for space management, 3D visualization, or geographic data integration.

The simulator realized is an experimental tool for visualizing evolution of rural and urban labour market under labour migration. Two databases are necessary to model such evolutions. The first database is relative to individuals and regions. The second base regroups the set of probabilities of transitions between states as well as the probabilities of occurrence of the events. The simulator performs the following tasks for each agent:

[1] gama-platform.org.

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Migration process
For each unemployed (or informal) worker in the rural
area
     Calculate the score;
     Is it a potential migrant?
       Yes
         Add to the collection of potential migrants.
For each agent in the collection of potential migrants
     Calculate the expected salaries (rural and urban);
     Calculate the wage differential.
       Is wage differential > 0
         Yes
          Define as a migrant;
          Initialize job search time;
          Migrate
          Delete agent from rural population;
          Add the agent to the list of unemployed agents
in the urban area.
Job Search Process
For each unemployed (or informal) worker in the two
regions
     Calculate the probability to find a job;
     Classify the unemployed by the probability of
recruitment
     Assigning these unemployed persons to vacant posts
as follows:
     Assign qualified individuals to qualified positions
first;
     Assign the rest of qualified individuals to
unskilled positions;
     Assign unskilled individuals to the remaining
unskilled positions;
     Increment the search time
       Search time > maximum search time
        Set Employment Status = inactive
Demographic Update
For each region
    Delete death Agents;
    Increase ages of remaining agents;
    Add new agents;
    Get divorced a part of married agents;
    Get married a part of single agents
    Let a proportion of students leave school;
    Promote the remaining students
    Do the Economic transitions between different
employment statuses.
    Update global variables
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3.2 The Scenarios Tested

The proposed agent-based migration model allows simulations for a large set of parameters (economic or demographic parameters). We chose to focus on those related to job creation in presence and absence of workers' migration. The realized simulator considers two regions:

- Origin Region representing Rural. The agricultural employment predominates the labor market. Employment in this region is therefore mostly seasonal and precarious;
- Destination region with urban character and preponderance of services and industrial activities.

The number of individuals considered in each region is 9900. The evolution of unemployment and employment are studied according to three rates of job creation: 3%, 5%, and 10%. For demographic characteristics, the table below summarize the most important (Table 1).

Table 1. Demographic settings

Variable	Rural	Urban
Birth rate	0.02478	0.02478
Death rate	0.00441	0.00441
Marriage rate	0.01	0.01
Divorce rate	0.001	0.0015
Success rate baccalaureate	0.455	0.554

3.3 Simulations Results

By looking at the evolution of the unemployment rate in the urban area, we can see that developments with or without migration are similar in terms of trend. In fact, for a job creation rate (UJC) of 3%, the unemployment rate remains very high with or without migration (69.1% with migration and 66.7% without migration). For UJC values of 5 and 10%, the rate of unemployment decreases and stagnates around 3% (in the presence or absence of migration). However, it converges faster towards this value for an UJC of 10% in the absence of migrations (Fig. 1).

Concerning urban employment, we find that the higher is the UJCs, the higher is the occupancy rate. When considering migration, the proportions are more important for UJCs above 3%. For an UJC of 3%, the proportion of the occupied is greater without migration. This is certainly due to the fact that an UJC of 3% does not allow the absorption of urban unemployment (native + migrants) and therefore decreases the proportion of the population occupied (Fig. 2).

For a Rural Job Creation rate (RJC) of 3%, rural employment decreases. This rate of job creation does not allow for the expansion of the rural sector either in the presence or in the absence of labour migration. For a RJC of 5%, there is a stabilization of rural employment in the absence of mobility of workers and a decline with migration. The RJC of 5% lets the population's occupancy rate around 20%.

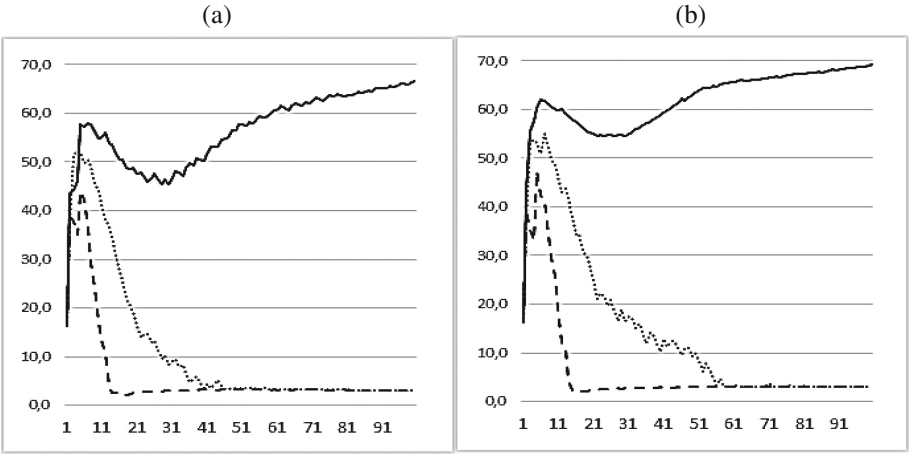

Fig. 1. Variations of unemployment rate in urban area for different values of UJC: UJC = 0.03 (solid line); UJC = 0.05 (dotted line) and UJC = 0.1 (dashed line). (a) In presence of massive labour migration, (b) in absence of labour migration

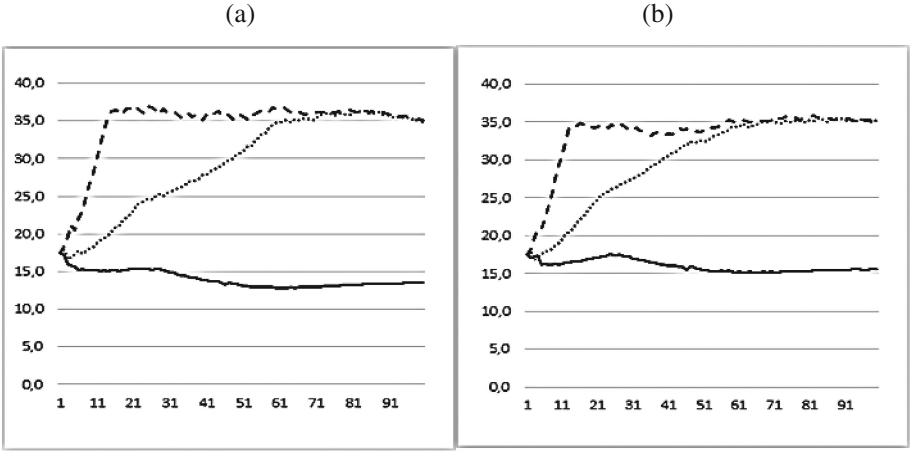

Fig. 2. Variations of employment in urban area for different values of UJC: UJC = 0.03 (solid line); UJC = 0.05 (dotted line) and UJC = 0.1 (dashed line). (a) In presence of massive labour migration, (b) in absence of labor migration

When considering migration, this RJC decreases the occupancy rate less rapidly than for a RJC of 3%. The chances of finding a formal rural job with a 3% RJC are lower than in urban area. This incites the rural unemployed to migrate and deprives the rural sector of a potential workers. For a RJC of 10%, the rural sector develops more

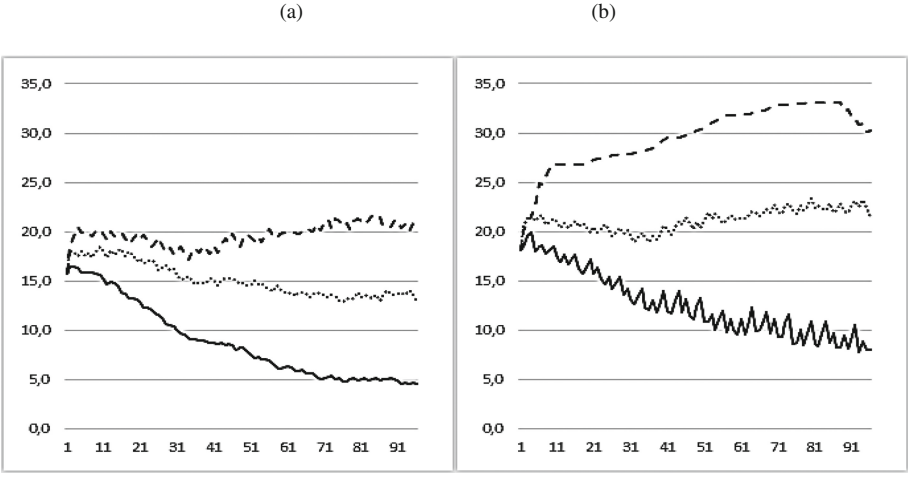

Fig. 3. Variations of employment in rural area for different values of RJC: RJC = 0.03 (solid line); RJC = 0.05 (dotted line) and RJC = 0.1 (dashed line). (a) In presence of massive labor migration, (b) in absence of labour migration

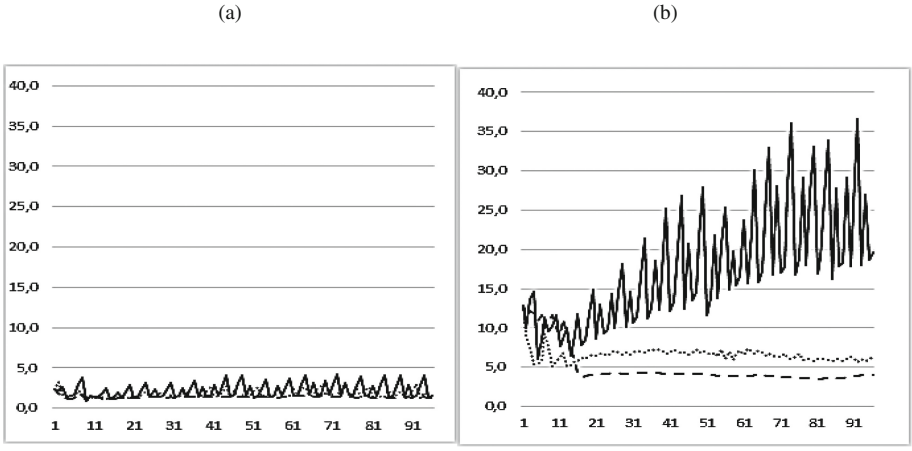

Fig. 4. Variations of unemployment in rural area for different values of RJC: RJC = 0.03 (solid line); RJC = 0.05 (dotted line) and RJC = 0.1 (dashed line). (a) In presence of massive labour migration, (b) In absence of labour migration

markedly in the absence of migration (occupancy rate in the presence of migration is 21%, and in their absence 32%) (Fig. 3).

For rural unemployment, the higher is the RJC, the lower is the unemployment rate. In the absence of migration and for a RJC of 3%, the unemployment rate exceeds 35%, and for RJCs of 5 and 10%, unemployment rate decreases and stabilizes around 7 and 4% respectively. However, in presence of migrations, the unemployment rate remains at a very low level and does not reach 5% (Fig. 4).

These results show the importance of migration flows and their effects on the two regions of departure and arrival in terms of employment and unemployment in particular for rural area which is deprived of a potential labour force by migration.

For Urban area, the incidence of migrations is more important in terms of volume than in terms of trends.

4 Conclusion and Perspectives

The proposed model represents a first prototype of an agent based labour migration model with heterogeneous agents. We attempt in this first version to introduce the agents' heterogeneity in the decision to migrate to reflect the selective nature of migration and in the job search through hiring probabilities and searching times. The model allows us to identify the incidence of migration on labour markets of origin and destination areas and their evolution through several scenarios in contrast to the most migration models (conventional or agent based models).

The simulation results show an impoverishment of the origin area in favour of destination's region. We have also remarked the existence of thresholds in terms of Job creation rates (rural or urban) above which rural workers do not migrate.

We notice also that despite very high job creation rates, residual unemployment persists. This is certainly due to a bad matching between jobs and agents qualification.

Some results of the model are not exploited because of the lack of pertinence of data (such education and creation of firms).

A second version of the model is in progress improving the process of job searching. Workers will have the choice between integrating an informal job and remaining unemployed. We will introduce also the effect of social network in the job search.

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