

An Agent-Supported Simulation of Labour and Financial Markets for Migration Processes

Nancy Ruiz, Vicente Botti, Adriana Giret, Vicente Julian, Oscar Alvarado, Victor Perez, and Rosa M. Rodriguez

Abstract The Migration Process is a phenomenon that includes a variety of actors, societies and political issues at different levels. In the migration problem it is then possible to observe complex interactions among different entities: there are links among economics, politics, social, commercial, labour, health, culture, and safety areas. Migration movements may also influence and be influenced by the effects of policies and norms of both sending and receiving countries. One of the key factors that influence the Migration Process behavior is the Labour Market, which is simultaneously affected by Financial Markets. These interactions have been traditionally represented by mathematical approaches that do not allow including flexibility, autonomy, adaptive and pro-activity features that are present into the dynamic and complex real life migration scenarios. On the other hand, the Multiagent System (MAS) paradigm has been successfully applied in studies related to mass movement in complex environments. In this paper a MAS simulation approach is proposed to simulate the migration process and to model micro-level interaction protocols that link Labour and Financial Markets to Migration Processes (MP-LM&FM) in order to observe dynamic behaviours that may emerge at macro level.

Nancy Ruiz, Vicente Botti, Adriana Giret, Vicente Julian, Oscar Alvarado
Universidad Politecnica de Valencia, Camino de Vera s/n, 46020, Valencia, Spain
e-mail: {nruiiz, vbotti, agiret, vinglada, oalvarado}@dsic.upv.es

Victor Perez, Rosa M. Rodriguez
Boeing Research & Technology Europe, Cañada Real de las Merinas, 1-3 Building 4 - 4th floor
28042 Madrid, Spain
e-mail: {victor.perezvillar, rosamaria.rodriguez}@boeing.com

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1 Introduction

Migration is a phenomenon that may influence policies and norms of both sending and receiving countries. Furthermore, Labour and Financial Markets behaviors are also affected by migration. Thus, the study of migration processes and their interactions with Labour Markets, the influence of the Financial Markets (MP-LM&FM) at micro-level, and the global behaviour that emerges at macro-level are key issues in managing migration problems.

The Migration Process includes a variety of actors, societies and political issues at different levels. There are links among economics, politics, social, commercial, labour, health, culture, and safety areas. Then, in the migration problem it is possible to observe complex interactions among different entities. The behaviour patterns can be defined as complex because there are n dynamic variables, where the participants are people with autonomous and intelligent behavior, and the environment constantly evolves. Therefore, as some researchers point out [20, 10], one of the key factors that influences the Migration Process behaviour is the Labour Market. Moreover, Labour Markets are simultaneously affected by Financial Markets. However state of art research studies on the migration problems and their relation with the Labour and Financial Markets are based on mathematical models [2, 19, 23] in which it is difficult to include flexibility, autonomy, adaptive, heterogeneity, self-interested behaviors and pro-activity features that are present into the dynamic and complex real life migration scenarios.

The Multiagent paradigm allows to define adaptive, autonomous, interdependent, networked entities like “social agents”. A social agent acts according to inputs, decision rules and protocols in response to the influence of its environment. The agent population dynamics depend on the network properties like clustering, hubs, and patterns. A social agent can influence his neighbors in response to the local influence that it receives. Then, Multiagent theory allows to represent actions and interactions (as behaviour patterns) of autonomous entities in an environment. In a Multiagent System (MAS) the global behaviour emerges from the interactions and the properties of the agents. Thus, a MAS model allows to simulate simultaneous behavior of multiple agents to show and predict actions of complex phenomena. The Agent-based Social Simulation (ABSS) studies the social phenomenon by using computational models. These models may represent people and their interactions as agents [9]. The ABSS is focused on the emergence properties of large agent groups that react to its environment following a set of rules. The MAS paradigm has been applied in studies related to mass movement by defining agent-based models to simulate the rural-urban movement according to social learning [18, 7]. Many models have been developed in this field, such as the Ethnic Migration Model (EMM) [13] and the Schelling Segregation Model (SSM) that shows the emergence of socio-spatial patterns [17]. Then, it is possible to observe that MAS approaches allow to represent the behavior of the interactions and influence among complex environments like the Migration Process, the Labour and Financial Markets at micro-level and observe the global behavior that may emerge at macro-level.

As a result of a study related to the migration process and their relation with the Labour and Financial Markets from the point of view of MAS, we have identified behaviour patterns that can be represented using agent-based models. This approach allows to use predictive techniques to represent the complex environment of links among the Migration Process, Labour Market and Financial Market models. These processes have been translated into simulation models that can be used to predict and react to emergent situations. In this paper a MAS simulation approach is proposed to simulate the migration process and to model micro-level interaction protocols that link Labour Market, Financial Market, and migration processes (MP-LM&FM) in order to observe dynamic behaviours that may emerge at macro level.

In this paper representative models of MP-LM&FM influence are presented. Therefore, a proposal of an agent-supported model of MP-LM&FM influence into an agent-based architecture is presented. Finally, the features of an agent-based simulation environment that was developed as a technological Demonstrator to validate the agent-supported architecture are shown.

2 Labour and Financial Market Models

The Labour Market behavior according to Neoclassical Economic Theory [14] (where migration occurs as a response to regional differences in income opportunities, such as job opportunities) is a key factor that influence the Migration Process behavior. The Labour Market behavior can modify not only the target country but also the migration routes. People make decisions based on different factors such as distance, price, risk, and mainly the labour requirements. When a Labour Market requires a large number of people and offers “good” payment in a specific place, people will try to go to that place instead of another. At the same time, Labour Market is linked to the Financial Market behavior. The external supplies of an Industry take into account the required inputs of other industries or sectors and, at the same time, the internal supplies consider the labour resource requirements (inter-industry flows). Thus, the labour resources required by the Industry are provided by the Labour Markets and Financial Market is composed by Industries that influence the Labour Market behaviour. Therefore, any change (increment or decrement in demand or production) in the Financial Market behavior will be reflected at the Labour Market level. The behavior of Migration Process, Labour Market and Financial Market represents the system behaviour at micro-level and from their interactions the system behaviour at macro-level emerges (see Sect. 3 and Fig. 2). In this work, Labour Market is graphically depicted as a layer below the Financial Market because of its dependence on the Financial Market behaviour.

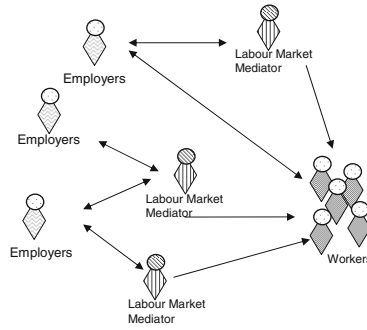


Fig. 1 Labour Market entities

2.1 Labour Market

Labour economics seeks to understand the functioning and dynamics of the market for labour. Labour markets run through the interaction of workers and Labour Resource Providers (Employers) [5, 3]. Labour economics observes the suppliers (workers) and the demanders (employers) of labour services and attempts to understand the resulting pattern of wages, employment, and incomes. In this section a representative model of a Labour Market is presented. Human capital is created and put into use in Labour markets. The structure of the Labour market is therefore critical for the quantity and quality of human capital that is created and for the uses to which it is put. Under dynamic efficiency of the Labour market the emphasis is shifted to the efficiency of the Labour market in the provision of adequate resources for education and training and to the recruitment of enough people for these purposes. According to Todaro and Harris [20, 10] the probability of eventually finding a job in a specific sector is a key factor that influences the migration to specific places (Industries) or sectors [22]. Thus, the Labour Market requires people with specific skills to meet their needs and thus the Labour Market requirements influence people when they want to migrate during their making decisions process.

A Labour Market model (Fig. 1) includes at least two main entities: Employers and Workers. Labour demand is a derived demand; in other words the employer's cost of production is the wage at which the business (or firm) benefits from an increased output or revenue. The process of allocation of vacancies to fill the labour demand usually is done by Employers that can request help to Mediators to get their labour resources. Mediators are specialized people that search and select the better labour resources according to the employer requirements (skills, payment, age, gender, etc.).

2.2 *Financial Market*

Computable General Equilibrium (CGE) models are probably the most utilized tool for development planning and macro policy analysis [15]. Bandara [1] and Jorgenson [11] both recognize that the beginnings of CGE (or ‘empirically estimated economy-wide’) modeling started with the work of Leontief in the 1930’s. The Leontief Model has been selected due to the fact that it is a reference model in economics research environment. It is worth to highlight its flexibility, simplicity and the successful results obtained in economic and social studies. In this section a brief description of a Financial Market based on Leontief Model is presented. Leontief created an accounting system that encompassed “all branches of industry, agriculture, and transportation (and) also the individual budgets of all private persons” [12]. Leontief set up his own structure for a ‘national account’ of the economy wherein all sectors produced goods or services that were fully consumed by another sector. Input-output Analysis was partly inspired by the Marxian and Walrasian analysis of general equilibrium [21] via interindustry flows. The goal of the model is to allow the Economists to predict future production level of each industry and satisfy future demand of a variety of products.

3 Agent-Supported Simulation Architecture

Based on the models and interactions previously described (Sect. 2), this section presents an agent-supported simulation architecture that represents the MP-LM&FM influence. The agent-supported architecture translates all the actors of the Migration Process, Labour Market and Financial Market into Agents to represent their micro-level behaviour. Thus, from the interactions among them the macro-level behavior of the global system will emerge (Fig. 2). At micro level, the migration process is directly influenced by the Labour Market behavior. The Labour Market manage the available vacancies that can be filled by migrants. Labour Markets interact with Financial Markets due to the available vacancies offered per Labour Market. Thus at macro level, it is possible to observe the global behavior of the system as a result of the agent interactions at micro-level.

The Agent-supported Simulation Architecture simulates the Migration Process, Labour and Financial Markets like a complex social system with dynamic behaviour patterns of their participants in specific regions. To this end, the region includes specific places called “nodes” in which it is possible to observe migration activities like departure/arrival of Migrants, Labour Market Management, Security Patrols, and Financial Market Management. The simulation includes predefined routes that Migrants can use. The routes connect specific region nodes. Thus, the architecture includes communication protocols that the agents use according to specific scenarios. The main scenarios that can be simulated include: a) Search of transportation to move along migration routes done by Migrants, b) Negotiation among Transportation Service Providers and Migrants, c) Movement of migrants with different

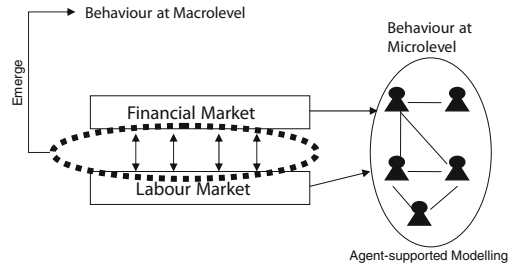


Fig. 2 Agent-representation of behaviour at micro and macro level

transportation mechanism, d) Search a job to earn money done by Migrants, e) Execution of negotiations processes to link position vacancies to workers managed by Labour Market Mediators, f) Patrol of arrived transports at specific places done by Security Forces, g) Capture of migrants that arrive to a specific place done by Security Forces, h) Verification of documentation of captured Migrants done by Security Forces, i) Control of the required inputs (supplies) of the Industries for their production according to their demand done by Industry Agents, j) Supply Labour Resources to Industries through Labour Resources Providers and Labour Market Mediators, and k) Supervision and management (done by the manager of financial markets) of changes in inputs and outputs requirements, demand and production of all industry agents.

The Agent-supported Simulation Architecture also allows the user to track the behaviour of agents in specific nodes by storing data that show arriving/departing migrants, position vacancies and dynamic payment by capabilities, results from the security patrol execution (migrants that have been captured and released), and management of the Financial Market. Moreover, the Agent-supported Simulation Architecture allows the generation of simulation data that can be post-processed with external tools. This data can be used to analyze previous situations and predict future actions. The main issue of this architecture is therefore the integration of Labour and Financial Market into the migration process. Next sections detail its main features.

3.1 Agent-Supported Labour Market

In the Agent-supported Labour Market it has been defined three types of roles: Labour Resource Providers, Workers, and Labour Market Mediators.

Labour Resources Provider Agent. Labour Resource Providers offer a number of vacancies that require a specific skill and a minimum grade of skill, gender and age. Each vacancy offers a given payment per hour and a defined contract duration. Then payment is the maximum amount that Labour Resource Providers offer.

Labour Market Mediator Agent. A Labour Market Mediator manages the allocation of vacancies offered by the Labour Resource Providers according to the vacancy requirements and the available Workers. Labour Market Mediators use negotiations mechanisms to link vacancies to workers. Thus, Labour Market Mediator uses as inputs: a) Vacancies offered by Labour Resource Providers, and b) Worker Requests. These inputs are stored and managed during allocation process. The Labour Market Mediator manages outputs related to links between offered and requested vacancies and informs Labour Resource Providers and Workers about these links.

Worker (Immigrant) Agent. Workers are looking for vacancies according to their presumed skills and a minimum requested payment.

The vacancy allocation process is the key activity in the Labour Market. It is guided by negotiation processes among the Labour Resource Providers and Workers and is controlled by the Labour Market Mediators. The multiagent paradigm makes possible to use any negotiation protocol for automating negotiation in an easy way (i.e. double-auction mechanism [8]). These protocols define the rules that all participants must follow during the vacancy allocation process. In this paper, the Labour Market definition is focused on specifying a negotiation mechanism during the vacancy allocation process. This mechanism can vary according to the features of the node (i.e. management of regular or irregular job vacancies, fixed or dynamic salary, etc.).

3.2 Agent-Supported Financial Market

This section presents the Financial Market Model presented in 2.2 (Leontief Model [12]) using the agent paradigm. Industries of Financial Market require to control inputs and outputs to cover demand and production. The industries are represented like agents that request inputs to other agents. In the Financial Market relations among industries are represented like complex interactions thanks to the agent paradigm. The Agent-based Financial Market is composed of three type of actors:

Industry Agent. This Agent specifies the coefficient inputs required according to the input-output matrix of Leontief Model. The requirements are linked to the production and demand levels. Thus, the Industry Agents supervise if the inputs required are affected by changes on production according to the current demand. When a change occurs, this agent will modify the required inputs according to its coefficient inputs (Leontief Model). The Industry Agent informs both the Labour Resources Provider Agent about the change of Labour requirements and the Manager of Financial Market which adjusts the input-output matrix.

Labour Market Mediator Agent. This Agent searches and supervises that the Labour requirements requested by the Industry Agent are fulfilled. Then, this agent interacts with the Labour Market. The Labour Market Mediator Agent requests a number of vacancies of a specific skill and expertise grade, duration and

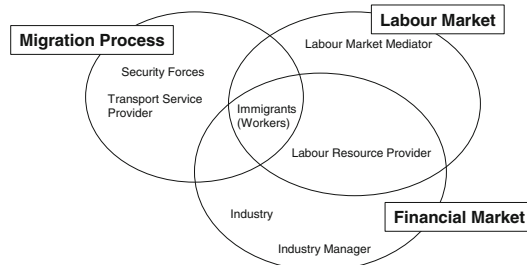


Fig. 3 Agent-interaction among Migration Process, Labour and Financial Markets

payment per hour (acting like a Labour Resource Provider). If Industry Agent informs on a change of Labour requirements, the Labour Market Mediator Agent updates the new requirements. Labour Market Mediator Agents participate at Labour Markets and Financial Markets doing different activities.

Manager of Financial Market. This Agent supervises the Industry Agents behavior. If some Industry Agent changes its Demand or Production, the Manager of Financial Market informs the Industry Agents about the changes of input requirements according to the Matrix inputs defined in the Leontief Model.

Due to the continuous influence between the Agent-supported Labour Market and the Agent-supported Financial Market (Section 2), the internal behavior of the Financial Market triggers a reaction in the internal behavior of the Labour Market (Fig. 3). At the same time, changes at Labour Market trigger a reaction at the Migration Process.

4 ARGOS: An Agent-based Demonstrator

An agent-based Demonstrator called ARGOS has been developed to simulate and validate the Agent-supported Architecture presented in Section 3. The simulation validates the scenarios included into the architecture by defining an initial state of the migration process. Thus, the migration problem has been bounded in a specific region. The initial state includes: a) specific routes to connect places, b) a given number of immigrants with specific profiles that allow to identify clusters of immigrants, c) Labour Markets that influence the preference of immigrants to select specific migration routes in specific places, d) the negotiations processes (to link position vacancies to workers) based on auction mechanisms [6] (the double-blind auction), and e) the use of strictness level that Security Forces apply when supervising the documentation of captured immigrants. ARGOS has a web interface that includes three modules (Fig. 4): a) Argos Control (a module that allows controlling the simulation execution of the behaviour of the agents), b) Argos Player (a module that allows playing current and previous simulations with a flexible and easy-to-use interface), and c) Argos Data (a module that allows analyzing the generated data

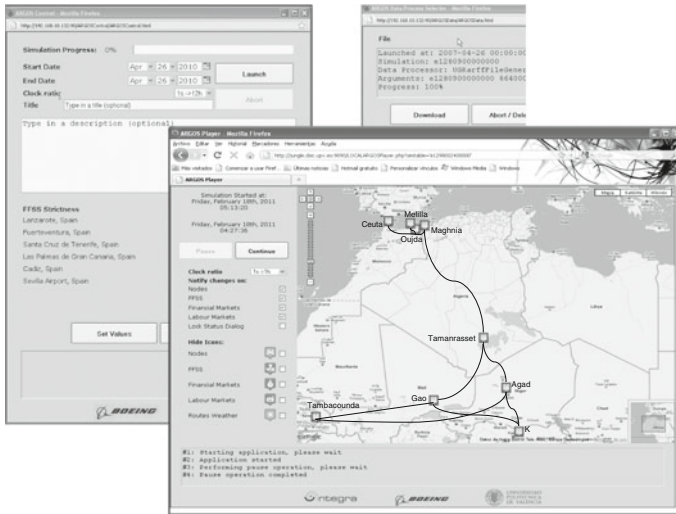


Fig. 4 ARGOS Control - Argos Player - Argos Data

during simulation executions). ARGOS also allows the User to track the behaviour of agents in specific nodes by using graphic data that show among others arriving/departing Migrants, position vacancies and dynamic payment by capabilities, changes on Financial Markets and their influence translated as available vacancies that manages specific Labour Markets and results from the security patrol at nodes. Argos Control also generates simulation data of the behavior Migration Process, and Labour and Financial Markets for external analysis. This generated data can be used to analyze previous situations and to predict future actions. Then, Argos Data allow the analysis of the historical data generated by Argos Control.

Argos Player displays the behaviour of Migration Process and the influence of the Labour and Financial Markets using the data generated by the Argos Control module (Fig. 4). Argos Player allows to observe how changes of Financial Market Demand in a node (that appears at specific time) generate requests of human resources to cover its production and demand. The required human resources are requested with specific skills to the Labour Market. In this way, it is possible to observe how the level of immigrants in that node increases due to the availability of vacancies.

5 Experimentation

ARGOS has been used to simulate the migration process in a specific region where the main source of migrants is Senegal and Nigeria and the main goal of these migrants is to reach Spain. The region includes specific places called "nodes" in which it is possible to observe migration activities like departure/arrival of Migrants, Labour and Financial Markets Management, and Security Patrols: Tambacounda

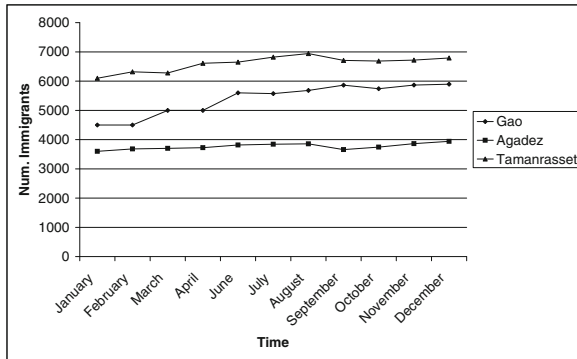


Fig. 5 Migration behaviour according to Labour Markets

(Senegal), Gao (Mali), Kano (Nigeria), Agadez (Niger), Tamanrasset (Algeria), Maghnia (Algeria), Oujda (Morocco), Melilla and Ceuta (Spain). These nodes are connected by migratory routes see Fig. 4. There are Labour Markets at Gao, Agadez, Tamanrasset and Oujda. There are Security Forces at Maghnia, Oujda, Ceuta and Melilla. Financial Markets are located in Oujda. The scenario shows one of the migration routes chosen in the late 90's by sub-saharan Africans to reach Europe. Before reaching destination, many migrants remain in transit countries for months or even years to earn money for their own subsistence, and for financing the rest of the trip to Europe. ARGOS also shows climate changes at the region. Migrants take into account the climate when they select a transport. The Labour and Financial Markets has been limited to five representative economic sectors: agriculture, livestock farming and fishing, energy, industry, building, and services. During simulation, Labour and Financial Markets at nodes are composed by different economic sectors [16]. Agriculture, labour livestock farming and fishing sector has a demand calendar that is linked to the product type (i.e. orange, grape, tuna, etc.). Financial Markets manages Input-output matrixes that include the active economic sectors at each node. Thus, for the simulated scenario, the Labour Markets are composed as follows: in Agadez there are agriculture, and industry sectors, in Gao and Tamanrasset there are agriculture, industry, and services sectors. Moreover, the Financial Market at Morocco has agriculture, livestock farming and fishing, energy, industry, building, and services as the more representative economical sectors. The Financial Markets used are based on the Leontief Model [4].

During simulation execution Migrants query the Labour Market conditions at different nodes, when they search the best route to get money and reach to their final node (i.e. cities in Spain). Migrants select the best migration route taking into account some data: price, duration, risk of the route (linked to geographical features), the successful probability to reach the target node related with climate data and their knowledge about the target node. Two important features drive the migrants' choice about the node to be reached: the existence of a labour market and the presence of job opportunities that match their skills. In order to evaluate the Labour and

Financial Markets influences over the migration routes we have conducted 100 executions of the simulation scenario described above. These executions simulate the migration behaviour from January 1999 to December 1999. Figure 5 shows the average number of Migrants that move through the defined routes during that year. It is also possible to observe that in Tamanrasset and Gao during summer time, when their sector of services increase their labour resources demand migrants select more migration routes that reach to these nodes than Agadez, which does not have service sector. This behaviour allows to validate that the migrants preference those routes in which nodes offer more job opportunities.

6 Conclusions

In this paper a MAS simulation approach has been presented, the proposed approach allows to model micro-level interaction protocols in order to simulate migration processes. The main focus of this paper is the integration of a labour and a financial markets into an Agent Based Migration architecture. This integration allows to simulate the influences of these two markets into migration processes. Finally, the features of an agent-based simulation environment called ARGOS which allows the validation of the agent-supported architecture has been described. The simulation approach has been successfully used as a tool for migration model analysis. Furthermore, the models of migration processes, Labour and Financial Markets have been translated into simulation models that are used to predict and react to emergent situations.

Agent Technology has been used to support the decisions process during migration management. In order to validate this analysis, it has been included the Labour and Financial Markets behaviour into the agent-based simulation environment previously developed. ARGOS has been used to validate the use of the multiagent paradigm to represent the complex social interactions at micro-level and observe the global behavior that emerge at macro-level as a result of the interactions among the MP-LM&FM. The simulation environment called ARGOS includes the following key entities of the migration problem: Migrants, Transport Service Providers, Security Forces, Labour Market Mediators, Employer Services Providers, and Financial Market Managers. These entities are implemented by means of agents with complex behaviour. Several tests have been made using ARGOS in order to analyze the behaviour of the Labour and Financial Markets (MP-LM&FM) and their influence over the migration process. Thus, it is possible to observe the influence of Labour and Financial Markets over changes on migration routes. Some future work includes: the definition of more specific profiles of migrants, increase the migrant knowledge of the environment in order to takes into account more attributes to select the best migration routes, add more nodes with labour and financial markets, and define metrics to manage the influence at micro and macro level.

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