Networks between markets and hierarchical structures: an agent based simulation framework

Marco Lamieri
Università degli Studi di Torino,
Facoltà di Economia,
Dipartimento di Matematica e
Statistica applicata alle scienze
umane "Diego De Castro"
E-mail: *lamieri@econ.unito.it*
(Presenting Author)

Daniele Ietri
Università degli Studi di Torino,
Facoltà di Economia,
Dipartimento Interateneo
Territorio
E-mail: *ietri@econ.unito.it*

[EXTENDED ABSTRACT]

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A remarkable amount of economic literature brings to our attention the fact that market is not the only result of the behaviour of agents, as we can find other forms of contact and communication. Many of them are determined by proximity conditions in some kind of space: in this paper we pay a particular attention to relational space, determined by the relationships between individuals or between firms.

Our aim is to build up a general framework used to create, in an easy and fast way, simulation models suitable for experimenting different theoretical foundations regarding economic theory of the firm starting from a network structure of the market.
The paper starts from an account on theoretical literature on networks. Networks, and social networks in particular, represent people and their relationships focusing on nodes (individuals or agents) and ties (relationships between individuals).

The second part of the paper describes which kind of network structure is considered by the simulation framework. This framework may be used to represent forms of exchange in a sort of half-way condition between markets and hierarchies. In markets, exchanges are based on discrete relations, lasting only for the time needed by the transaction itself (barter exchange is a clear example of this condition). In hierarchies, the typical form of relation is otherwise shaped by administrative exchanges. In networks, relationships involve reciprocity and trust, as "the members are linked by ties that extend well beyond the very brief moment when the act of exchange is being accomplished" (Durkheim, 1893)

In the model presented the simulation framework is implemented for the study of diffusion of a product's innovation among a population of firms. In the third part of the paper we give a definition of innovation and we present an overview of innovation's theories. Innovation "concerns the search, discovery, experimentation, development, imitation, and adoption of new products, new production processes and new organisational set-ups" (Dosi, 1998). It has been argued (Lundvall e Borràs, 1997) that innovation is an interactive process with a strong social nature: interaction takes place between different steps of the innovation process, between departments of the same firm and between different organisation. Moreover, Schumpeter (1934) believes that the innovative decision of a firm arises from the competitive strength of the market.

In order to introduce the use of agent based simulation to study networks and markets, we present a brief summary of the simulation techniques in social science and economics as a way to investigate complexity. According to Langton (1992) one of the fundamental aspects in the analysis of complex phenomena is the distinction between linear and non-linear systems. Dealing with linear systems the behaviour of the whole system exactly corresponds with the sum of its constituting parts. Obeying to a principle called by Langton principle of superposition, linear systems may be studied with a reductionistic method while non linear systems do not respect the superposition principle: even if the observer has understood how each part works, it won't be possible for him to understand the system as a whole. This

kind of system is complex. According with Parisi (2001) simulation models are proposable as a method to comprehend reality halfway between models expressed by language and mathematical symbols. For the use of agent based simulations in social science, and economics in particular, we refer to Gilbert and Terna (2000), Tesfatsion (2002) and Parisi (2001) for a discussion about simulation methods and their applications on social system.

In the applied part of the paper we present our market simulation framework based on networks and realised in Java Swarm. Our aim is to investigates the dynamics of a population of firms (potential innovators) and consumers interacting in a space defined as a network. Consumers are represented in the model in order to create a competitive environment that pushes enterprises into the innovative process: from interaction between consumers and firms, innovation emerges as a relational good. The focus of the model is the enterprise which is the potential innovator: consumers define a competitive environment in order to push firms into an innovative process. Consumers are modelled with heterogeneous preferences and bounded rationality. Each firm produces one product, represented by a numeric array of a defined length. Each value of the array represents a technological feature of the product. The firm has a basic accounting capability: an initial asset is defined and for every tick of the simulated time costs and revenues are accounted. Firms have also an innovation strategy: they can have a vocation to imitate or to be engaged in internal research. The innovative strategy is the peculiar part of the model and some different theory have been implemented. This simulation model may be useful to understand the innovation process from two different points of view. From a micro perspective it is possible to investigate: why firms decide to innovate, how the innovation process affects the enterprise's activity and how innovation spreads via imitation. From an aggregate perspective it is possible to look for emergent phenomena from the interactions of the simple agents described in the model, the firms, and investigate the effects of innovations and imitations on the economy as a whole, business cycles dynamic of the simulated economy. Finally an analysis of technological progress dynamic at a macro level is proposed, first of all in order to study if it is constant or shows discontinuities, i.e. when radical innovations are followed by incremental ones. For future development of the framework we would like to take into account the role of institutions devoted to the creation and diffusion of knowledge, as university, research and technology transfer centres.

The technical part of the paper describes how the simulation framework is implemented. We decided to use Swarm (http://www.swarm.org) as agent based simulation framework to develop the model and implement it in Java (http://java.sun.com). Swarm has been chosen because of its diffusion and the presence of a strong community of users; we believe is very important to create a model easily understandable by other scientist and Swarm is somehow a base framework. In order to implement the concept of social network within the simulation model JUNG, Java Universal Network/Graph Framework, library is used (http://jung.sourceforge.net/). JUNG is a software library that provides a common and extendible language for the modelling, analysis, and visualisation of data that can be represented as a graph or network. It is written in Java and has been integrated within the JavaSwarm model considering each agent (both firms and consumers) as nodes of the network. From a technical point of view we consider the agent as a vertex of the graph: all the graph-specific information and feature are separated from the agent-specific definition and behaviours. The integration between Swarrm and JUNG includes also the use of Swarm's probe that can be called just clicking on the vertex visualised by JUNG.

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