A Multi-Agent System of Adaptive Production Networks*

(Extended Abstract)

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Keywords

Multi-Agent Simulation, Production networks, Firms behavior, Price mechanisms, Pattern emergence

1. INTRODUCTION

Production networks of firms linked by supply-customer relationships embedded in a geographical space are among the phenomena not yet well understood by practitioners and scientists. A production network can be defined as a network of autonomous or semiautonomous business entities collectively responsible for procurement, manufacturing and distribution activities associated with one or more families of related products. Such networks are highly non-linear and exhibit complex behavior through the interplay of their structure, environment and function, this complexity making it difficult to manage, control or even predict them. Production networks, supply chains and their management have received considerable attention from researchers in various disciplines over the past two decades. Agent-based modeling (ABM) and simulation are regarded as one of the best candidates for addressing different aspects of these networks. Indeed, ABMs allow the study of complex systems such as production networks, from a micro-macro evolutionary modeling perspective. They are able to take into account both the issue of heterogeneity and autonomy of the agents, the relevance of their temporal-spatial dynamic relations and the emergent evolutionary nature of collective phenomena.

In this paper, we present a Multiagent system for studying production networks dynamic. we propose a MAS starting with the model proposed by Weisbuch and Battiston [3], and try to understand how the behavioral styles at micro-level (agent-level) determine the proximity relations at macro-level. In W&B's Model, some strong assumptions regarding the regularity of the network, the orders from the market, the non-existence of pricing mechanisms and investment strategies, make the model very far from reality. Indeed, the firms are considered behaving uniformly, while in real market, firms are very heterogeneous, behave in different ways and scale of time and space. Our approach in this work is to start with this simple model characterizing well known stylized facts and use MAS techniques and paradigms in order to have a more realistic and flexible model allowing us to study farther issues in Agent-based Computational Economics (ACE). We investigate the dynamics between firms regarding the production firm as agent in the system. The firms are adaptive agents taking investment decisions according to their business efficiency. They adapt their prices to be competitive and get more market. Also, they adapt their business relation with their suppliers in order to reduce costs of inputs and get orders satisfied. The agent proactivity, with very simple decision mechanisms at the micro level, leads to the emergence of meta-stable business clusters and supply chains at the macro level. In this paper, first, we describe the firm model and its dynamics, second, we present the implementation of the model and a summary of simulation results. Finally, we draw our conclusions and future research directions.

Cite as: A Multi-Agent System of Adaptive Production Networks, (Extended Abstract), Samir Hamichi, Zahia Guessoum, Diana Mangalagiu, *Proc. of 8th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2009),* Decker, Sichman, Sierra and Castelfranchi (eds.), May, 10–15, 2009, Budapest, Hungary, pp. 1311–1312

2. THE FIRM MODEL

We describe our model, based on the model of Weisbuch and Battiston [3] (we call it W&B's model), as a network in which firms are involved and have Business to Business (B2B) relations.

The production network consists of a regular grid with l layers of m nodes. The network is oriented from an input layer $l-1$ (natural resources) towards an output layer 0 (supermarkets) Fig(1).

In each node of the grid we place a firm; firm $F_{k,i}$ is localized at position i in a given layer k. The network is initialized with $n = l * m$ firms. Each firm $F_{k,i}$ / $k \in [1, l-2]$ is linked to its customers in the layer $k-1$ and its suppliers in the layer $k+1$. The input to the production network enters only through the firms in the input layer. The output from the network is sold only by firms in the output layer. Orders

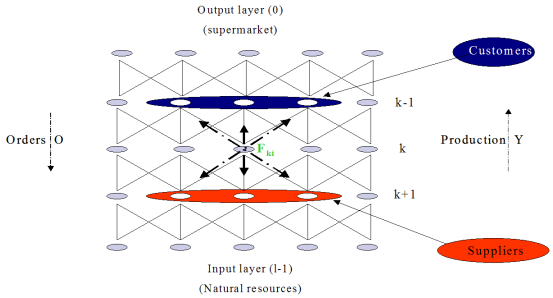

Figure 1: Network of firms

(O) flow from the output layer $(k = 0)$ to the input layer

$(k = l - 1)$; supply (Y) flows from the input layer to the output layer.

Each firm $F_{k,i}$ has capital invested in the means of production and has a production process converting Y^{in} units of inputs bought from firms in layer $k + 1$ into Y^{out} units of output. To design adaptive process of the firm in terms of investment strategies and production adjustments, we define the capital of the firm as production capacity $A_{k,i}$ which depreciate in time with a certain rate and liquid assets $L_{k,i}$ which does not depreciate. We also introduce pricing mechanisms. For the firm level, we base our model on the markup pricing mechanism where the price is calculated by adding a markup (margin) to the average unit cost of the production. For the final market (firms at the output layer), a market clearing mechanism is set to clear the market following demand/supply principle. The production process is based on B2B interactions and is executed within each time step. One time step represents a full production process: Each firm places orders. A firm receiving an order, calculates its needed inputs for production and then places orders to its suppliers. Once orders propagated down to the input layer, each firm produces according to the received inputs and delivers. After delivery, each firm calculates its profit and updates its assets and invests it in production capacity if needed. The firm is the main entity of our system. It interacts with other firms in it's environment following B2B rules. We design the two dynamic lists of suppliers and customers changing over time, depending on the firm's activity. In its B2B environment, the firm adapts the sourcing strategy by choosing the more profitable suppliers. The firm, by assessing its business exchanges adapts its relations with its partners; suppliers in its supply side and customers in its market (upstream/downstream). It reinforces the supply links with the profitable suppliers by keeping ordering inputs from them and proceeds to substitute the less profitable ones by seeking for new suppliers offering best prices. In the same dynamic, the firm as a supplier has to have competitive prices in order to get more customers. In order to get more customers, the firm adapts its fixed markup in its pricing policy to get new customers. To reach its goal, the firm has to take decisions according to strategies. This local adaptation leads to changes in the form of the organizational structure in which the firm is involved by gaining or loosing customers. Using these decision mechanisms at the firm level, we are interested on the effect of these decisions on the production regionalization and the economic performance of the whole system.

3. IMPLEMENTATION AND EXPERIMENTS

The results of simulations were obtained, using the multi-agent platform $DIMA$ [1], for a production network with 1250 nodes in five layers, run for 10000 time steps. The initial wealth is uniformly and randomly distributed among firms. Detailed simulation parameters and results are available in [2]. We studied the impact of the transportation cost and geographical reach on the network structure. We compared the economic performance of the system under different conditions and got interesting results [2]. Across the network, we studied different cases of geographical reach. First, we have considered that each customer could see and place an order with any supplier from its supply layer. In other cases, we have considered that each customer could see only a proportion of suppliers. We call this proportion the geographical limit $GeoLimit$. We observe, in all the cases we studied, that the firms self-organize into regions and spatial patterns emerge. By changing the rules at the micro level we could see different results at the macro level: the shape and the number of the patterns in the network. The number of regions we get at the end of each simulation case depends on the $GeoLimit$ parameter; The fewer suppliers a firm has access to, the higher the number of regions we get Fig(2).

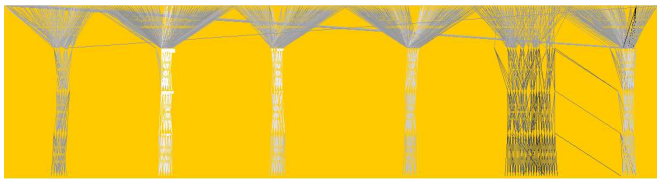

Figure 2: The network after 10000 time steps, with transportation cost $c^T = 0.1$

4. CONCLUSIONS AND PERSPECTIVES

In this paper, a MAS is introduced and preliminary simulation results are discussed. Inspired by a very simple production network model [3], the MAS is designed in a way which allows us to alleviate shortcomings of the original framework and its strong assumptions. We have integrated price mechanisms into the model and reproduced stylized facts such as the regionalization of production and wealth with heterogeneous and adaptive agents. We have modeled and simulated the impact of the transportation cost and the geographical reach on the shape of the regionalization production and wealth patterns. We also investigated various market settings market shared among numerous firms to oligopoly. The results of the simulations have shown that the individual firms, with local B2B interactions and decisions, form stable production systems based on the supply/demand and market growth mechanisms leading to the maturation of the market. From these preliminary results, we plan to investigate, using MAS concepts like stigmergy and self-organization mechanisms, various sourcing and investment policies as well as more global issues such as the vertical vs. horizontal integration and collaboration in competition. This will allow us to further investigate industrial and business cluster dynamics and to confront our findings to empirical data.

5. REFERENCES

[1] Z. Guessoum and J. Briot. From active object to autonomous agents. *IEEE Concurrency*, 7(3):68–78, 1999.

[2] S. Hamichi, Z. Guessoum, and D. Mangalagiu. A multi-agent system of adaptive production networks. Internal report, LIP6, 2008. available at http://www-poleia.lip6.fr/∼guessoum/TR01.pdf.

[3] G. Weisbuch and S. Battiston. From production networks to geographical economics. *JEBO*, 64:448–469, 2007.