Chapter 99

A Multi-Agent System for Production Networks Simulation:
Toward a Pheromone-Based Model for Agents' Coordination

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ABSTRACT

In this chapter, the authors present a multi-agent model aimed to investigate emergent organizational structures in production networks and their reification by means of pheromone-based algorithms. The model considers agents (firms) embedded in a production network, interacting among them through business-to-business relations. The evolution of the network structure is endogenous, as it takes into account the individual behavior of the firms and their interactions. The firms are adaptive agents taking investment decisions according to their business efficiency. They adapt their prices to be competitive and get a larger share of the market. Also, they adapt their business relations with their suppliers in order to reduce costs of inputs and get orders satisfied. The agent's 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. Pheromone-based algorithms reify dynamically these clusters as explicit graphs. The results of the authors' simulations show the impact of the transportation cost and the geographical reach on the regionalization of production and on wealth patterns. 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.

INTRODUCTION

Over the last decade, the complex dynamics of supply chains (SC) and production networks of firms had received considerable attention in the literature [Carbonara et al. (2002); Dyer et al. (2000); Harland et al. (2001); Swink et al. (2007)]. The complexity of such systems comes from the large number of heterogeneous actors they involve and from the spatial distribution and interdependence of these actors. However, a particularly interesting aspect received little attention in the literature: the exploration of the dynamics at the firm level in the particular context of a supply/production network.

In a production network, firms' interaction (through buying and selling transactions) may take several forms, produce several types of benefits and lead to increased competition and possibly increased economic performance. This forces firms to adopt new strategies such as privileging partnerships and distributed production approaches and leads to interesting emergent behaviors at a macro level. The emergence of hybrid organizational forms such as clusters of firms in industry is one of the observed macro-level behaviors, which is the focus of the present chapter.

This chapter is organized as follows: after a brief introduction describing the general perspective and objective of the chapter, we first provide the background of the production networks of firms and emergence of supply-chains as distributed systems. We review the literature and the current issues on the interaction between firms through simple business-to-business (B2B) relations leading to the emergence of production districts. We introduce different views on the efficiency and robustness of these networks and on how they relate to organizational performance. Then we discuss the insight agent-based modeling approach brings to the understanding of these issues. We briefly review agent-based models of self-organization in production network issues and coordination mechanisms, which could lead to a better performance for the firms within a distributed framework.

In the second part of the chapter, we present the Multi-Agent System (MAS) of adaptive production networks we have developed combining both micro->macro and emergent-macro->micro approaches simultaneously. In the model, at the micro level, the firms interact locally, leading to the emergence of some macro level structures of supply-chains. We use a pheromone-based mechanism to develop explicit graphs that capture the endogenous emergent macro level structures (emergence of efficient supply chains). The firms capture these emergent macro level effects, which affect their behavior. This reproduces the real world behavior, where the agent (the firm, in our case) observes and interprets what it sees. These new structures influence the local firms and the interactions between them, changing the cooperation and the coordination of the production. Finally, we provide concluding remarks and future research directions.

BACKGROUND

In this section we introduce the main definitions and concepts needed to understand the interactions taking place between organizations in order to capture complex dynamics, structures, routines and performance of organizations and organizational arrangements such as industrial clusters.

Theories of Industrial Districts and Clusters

Alfred Marshall, in the nineteenth century, coined the term 'Industrial Districts' when remarking that industries tend to concentrate in specific geographical areas [Marshall, (1890)]. As examples of industrial districts, Marshall referred to straw plaiting in Bedfordshire and cutlery in Sheffield, pointing out that geographical proximity provides specialized labor, nurtures subsidiary industries,

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