Chapter XIX
Modeling the Firm as an Artificial Neural Network

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ABSTRACT

The purpose of this chapter is to make the case that first a standard artificial neural network can be used as a general model of the information processing activities of the firm; second, to present a synthesis of Barr and Saraceno (2002, 2004, 2005), who offer various models of the firm as an artificial neural network. An important motivation of this work is the desire to bridge the gap between economists, who are mainly interested in market outcomes, and management scholars, who focus on firm organization. The first model has the firm in a price-taking situation. We show that increasing environmental complexity is associated with larger firm size and lower profits. In the second and third models, neural networks compete in a Cournot game. We demonstrate that they can learn to converge to the Cournot-Nash equilibrium and that optimal network sizes increase with complexity. In addition, we investigate the conditions that are necessary for two networks to learn to collude over time.

INTRODUCTION

The purpose of this chapter is two-fold: (1) to make the case that a standard backward propagation artificial neural network can be used as a general model of the information processing activities of the firm, and (2) to present a synthesis of Barr and Saraceno (BS) (2002, 2004, 2005), who offer various models of the firm as an artificial neural network.

An important motivation of this work is the desire to bridge the gap between economists, who are mainly interested in market outcomes, and management scholars, who focus on the

internal components of the firm. The topic of optimal firm organization in relation to its environment has been extensively studied in the management literature (Lawrence & Lorsch, 1986; Burns & Stalker, 1994; Gailbraith, 1973; Chandler, 1980), but remains largely unexplored in industrial organization and in economics in general.

In spite of the path-breaking work of Coase (1937) and Williamson (1985), the internal nature of the firm continues to be seen by most economists as a black box production function. The few exceptions are within two streams of research: the area initiated by Nelson and Winter (1982), which studies the firm's activities from an evolutionary point of view, and more recently, the *agent-based* literature, developed to better understand the information processing behavior of the firm (see Chang & Harrington (2006) for a review of agent-based models of the firm). These papers define an *organization* as a group of boundedly rational individuals that pursues a common objective, transcending the individuals' objectives, in order to process information and make decisions. These models study the costs and benefits of different organizations.

Our models of the firm fit within this agent-based literature by modeling the firm as a type of artificial neural network (ANN). Typical uses of ANNs in economics include non-linear econometrics (Kuan & White, 1992) and game theory applications, where simple neural networks (perceptrons) are used, for example, to distinguish which strategies should be played given the history of strategies (Cho, 1994). Our approach is different and unique in that the neural network is used as a model of the firm itself. Sgroi (2005) discusses the use of neural networks for modeling boundedly rational agents in economics.

ARTIFICIAL NEURAL NETWORKS AND THE FIRM

In the 1950s, ANNs were developed as simple models of the brain.[1] The brain can be characterized as a massively parallel and decentralized information processing machine, which controls the operations of the body and sees to its normal, routine functioning. In a similar sense, the mangers of a firm serve as "the brains of the operation," and without management a firm cannot exist. In its most basic description, a neural network is a type of non-linear function that takes in a set of inputs, and applies a set of parameters (weights) and a transformation (squashing) function to produce an output. The network can be *trained* to *learn* a particular data set; training is an iterative process where the weights are adjusted via a learning algorithm to improve the performance (reduce the error) of the network over time. After the network has learned to map inputs to outputs, it is used to *generalize*—that is, to recognize patterns never seen before on the basis of previous experience.

Management scholars have documented several activities of the firm that bear close resemblance to the activities of a brain (see Simon, 1997; Cyret & March, 1963; Lawrence & Lorsch, 1986; Gailbraith, 1973):

- **Decentralized Parallel Processing:** The firm is a coordinated network of agents (nodes) which processes information in a parallel and serial manner in order to make decisions.
- **Embedded Decision Making:** Organizations have some form of a hierarchical structure. Decisions are made within decisions.
- **Learning by Experience:** Agents become proficient at activities by gaining