



## Agent learning in supplier selection models

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Available online 29 November 2003

### Abstract

We use agent-based modeling to study the performance of a supplier selection model, originally proposed by Croson and Jacobides [Small Numbers Outsourcing: Efficient Procurement Mechanisms in a Repeated Agency Model, Working Paper #99-05-04 Department of Operations and Information Management, The Wharton School of the University of Pennsylvania (1999)], which displays a complicated reward and punishment profile under incomplete information. We document the dynamics and convergence to equilibrium of the interactions of a single buyer with a heterogeneous group of sellers, which results in both *separation* of sellers capable of producing high-quality goods from those incapable of doing so, and *continuing incentives* for high-quality-capable sellers to produce at the maximum quality possible. We model two methods of determining exploration reference points—an “auction-style” model focusing on probability of success and a “newsvendor-style” model focusing on profitability. Our simulation shows that (1) the tournament structure suffices to reach convergence at high-quality levels whenever the number of suppliers exceeds three, (2) punishment length and number of suppliers are substitutes, and (3) shorter punishments improve learning speed of convergence. Moreover, we show that it is strictly better for the buyer to transact with relatively few suppliers—a conclusion generated endogenously inside the model as a tradeoff between exploration and exploitation, rather than through assumptions that explicitly penalize supplier proliferation.

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**Keywords:** Supplier management; Reinforcement learning; Agent learning; Moral hazard; Incomplete contracts

### 1. Introduction

The twin challenges of how to choose capable suppliers and of how to motivate capable suppliers once they have been chosen are central problems in the management of the modern firm. In this paper, we study a game-theoretic supplier selection model ori-

ginally proposed by Croson and Jacobides [1] where neither the suppliers nor the buyer possesses full information. We use agents to model suppliers who learn to produce at their optimal quality levels through a prespecified system of rewards and punishments administered by the buyer. We also demonstrate how the process of repeated optimality-seeking updates to the actions of the heterogeneous suppliers results in the sellers capable of producing high-quality goods distinguishing themselves from those sellers incapable of doing so (addressing adverse selection), while producing at the highest possible level of quality (addressing

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moral hazard). Furthermore, using multiple related simulation environments, we can address the question of “how many suppliers is it optimal to employ?” Supporting both previous theoretical literature [6,7,10,28] and corroborating evidence from the Japanese automotive market [1–3], we show that it is optimal for the buyer to transact with relatively few suppliers, a conclusion generated endogenously inside the model rather than forced to happen through assumptions which penalize supplier proliferation *per se*. We also evaluate the results from the perspective of benefit to society and the costs incurred by the sellers.

In Section 2, we discuss the intersection of the IS and supplier-management literatures. In Section 3, we present our motivation for carrying out an agent-based approach on a solved game-theoretic problem. Section 4 provides an overview of the specific outsourcing model on which we focus. In Section 5, we describe the precise agent-based technique we employ. Our experiments and results are summarized in Section 6. Section 7 concludes and provides suggestions for future work.

## 2. Literature review

Over the past 15 years, IS researchers have been trying to predict the net effect of IT on the attractiveness of outsourcing. Malone et al. [22] reason that by reducing coordination costs proportionally, whether producing in-house or using the market, IT would encourage a greater shift of firms to make use of markets, where coordination costs’ as a percentage of total costs in markets is higher than in firms. Gurbaxani and Whang [20] study the effect of IT from a transaction-cost and agency-theory perspective, but no claim is made about the direction of the shift for either in-house production or use of markets. Although reduction in coordination costs due to IT has paralleled a tremendous increase in outsourcing, they [20] note that the shift has empirically been in the direction of long-term contracting with only a few suppliers, rather than continuous recontracting on the spot market.

Bakos and Brynjolfsson [6,7] both document and explain this seeming paradox by combining coordination costs with the incentives for suppliers to make non-contractible relationship-specific investments. They illustrate the relationship between the number

of suppliers and the intensity of noncontractible investments by suppliers, showing that increases in the supplier base reduce the bargaining power of suppliers and thus decreases the incentive of each supplier to make investments in the continuation of the relationship. When these noncontractible relationship-specific investments play a large role in value creation, the buyer has an incentive to limit the proliferation of suppliers even though he must thereby pay higher prices. Their analysis is restricted to observable but unverifiable variables. The authors claim that to provide strong investment incentives for the suppliers, the number of suppliers the buyer should contract with should be small. However, the question of providing incentives comes after the decision of which suppliers to hire: if product quality is unobservable, the buyer’s first concern must be to determine the suppliers capable of (and willing to) produce high-quality products.

Dyer et al. [16] describe the supplier-management practices in the automobile industry in the US, Japan and Korea. Traditionally, the practice in the US has been that of an arm’s length relationship, where a company contracts with several suppliers, thus minimizing dependence on any particular supplier and maximizing buyer bargaining power. In Japan, however, the practice has been of maintaining close relationships with suppliers in “partner”-type relationships. In fact, Japanese automakers maintain three tiers of suppliers. Tier I consists of direct suppliers providing strategic components, in whom the buyer generally holds large equity stakes. The suppliers comprising Tier II provide customized components, where the buyer has a small equity stake, and those suppliers that provide competition for the first-tier suppliers. Finally, Tier III consists of suppliers who make more standardized parts such as tires, spark plugs, etc. where presumably cost and continuous predictable supply play a more important role than the provision of noncontractible quality. Recent years have seen a convergence of supplier-management practices in the US, Japan, and Korea to a mixture of partnerships and arm’s length relationships. The authors conclude that to achieve advantages of the two kinds of relationships, the suppliers should be segmented into different groups based on the inputs they provide, whether strategic or standard. The different groups can then be managed optimally

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