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## Dynamic Cost Reduction Through Process Improvement in Assembly Networks

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We consider a decentralized assembly system in which a buyer purchases components from several first-tier suppliers. We examine the dynamics of suppliers' investments in cost-reduction initiatives over the life cycle of a product under different procurement approaches. We model the suppliers' investment decisions under cost-contingent contracts, with wholesale prices determined on the basis of the prevailing component costs, as a dynamic game in closed-loop strategies. We show that there always exists an equilibrium in which the suppliers' investments are synchronized, that is, in each period either all suppliers invest in process improvement or no supplier does. We also consider target-price contracts, under which the assembler announces the rate of component cost reduction to be achieved over the product's life cycle at the beginning of the contractual relationship. We show that target-price contracts lead to higher investment levels and profits if the rates are properly specified. In general, the equilibrium investments of the suppliers are lower than those under centralized control the buyer can eliminate this inefficiency by subsidizing a certain fraction of the costs of investments. We extend the model to a setting with two competition are suppliers and knowledge spillover at the suppliers. We find that the level of inefficiency under decentralized control decreases with increased competition and spillover rate.

Key words: assembly systems, process improvement; dynamic games; procurement; supplier management. History: Received Decomber 15, 2006; accepted October 17, 2006, by Candace A. Yano, operations and supply chain management. Published online in Articles in Advance January 5, 2009.

#### 1. Introduction

Process innovation plays a major role in reducing production costs over the life cycle of a product (Hatch and Mowery 1998). Original equipment manufacturers (OEMs) and their suppliers invest time and money in process-improvement activities such as lean production initiatives, inventory optimization, and quality-improvement projects. As a result, production costs typically decrease over the life cycle of a product. Some of this cost reduction is reflected in the suppliers' selling prices to the OEMs. This paper explores the dynamics of suppliers' investments in cost reduction over the life cycle of a product and how the extent of cost-reduction activities and the resulting firms' profits depend on the procurement strategy of the OEM.

We consider a decentralized assembly system in which a manufacturer purchases components from several first-tier suppliers over a finite horizon representing the life cycle of a product. We model the effect of cost-reduction initiatives by a learning model that is parameterized by a learning rate: the cost of a component in a given period is a decreasing convex function of the cumulative investment in process improvement achieved by its supplier. Specifically, we consider gradual investments in process improvement (as in Fine and Porteus 1989), a practice that is central to Lean Production and Six Sigma Programs, rather than a one-time large investment in technology resulting in radical change. Baily and Farrell (2006) investigate productivity growth in the U.S. auto industry from 1987 to 2002 and find that 45% of the growth was attributable to process improvement at assembly plants, notably the adoption of lean manufacturing practices. Andersson (2006) gives an example of cost reduction from a supplier of General Motors (GM). The supplier of a door hinge simplified the hinge design, allowing for a stamped hinge that did not need to be welded. This resulted in 35% savings in the cost of the hinges for GM. As in these examples, process improvement usually requires investment in the form of engineering hours and other managerial DOSOURCES.

OEMs use different approaches for specifying how purchase prices should change over the years. Baron and Besanko (1984) identify two of these approaches one in which the buyer adjusts the price it pays to its suppliers each year in response to the achieved cost improvements and another in which the buyer announces in advance the time path of target cost reductions based on a prediction of a "reasonable" rate of innovation and then keeps to this path. We refer to the first approach as cost-contingent contracts and to the second approach as target-price contracts. They

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