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Competitive investments in cost reducing process improvement: The role of managerial incentives and spillover learning

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ABSTRACT

We study the rivalry between two firms and consider the effect of spillovers when the firms' operations and technology managers are given bonuses for cost reduction. We model a game in which the firm owners independently offer their manager a bonus to stimulate cost reducing process improvement before the process improvement and production stage, and draw a comparison with the game in which these bonuses are not used. Several outcomes contrast strongly with existing literature. We find that cost reduction bonuses are generally only positive in equilibrium when spillovers are less than 50%. In case spillovers are higher, cost reduction bonuses are only positive when a firm's process improvement capability is relatively high. Also we find that the sensitivity of process improvement levels in the spillover parameter crucially alters when cost reduction bonuses are introduced. Prisoner's dilemma occurs in case spillovers are less than 50%, or when spillovers are higher and process improvement capability is relatively high.

1. Introduction

An important decision for many operations and technology managers is how much to invest in cost reducing process improvement, for instance by acquiring new manufacturing technologies (e.g. Hayes et al., 2005; Li and Rajagopalan, 2008). In order to stimulate managers to be aggressive in terms of effectuating process improvement, many firm owners employ bonuses for realized cost reductions (Masternak and Camuso, 2005). As process improvement decisions are typically chosen in a competitive landscape, recent research (e.g. Veldman et al., 2014) has addressed the interplay between the process improvement decisions of firms in rivalry, and the effect cost reduction bonuses might have in such settings. However, as cost reduction bonuses stimulate managers to conduct more process improvement, thereby altering the competitive dynamics between firms, it is important to also look at the factors that might influence the effectiveness of cost reduction bonuses. In particular, it is well-known from practice that firms have problems keeping the knowledge gathered from process improvement projects to themselves, especially firms that are spatially close to each other (Autant-Bernard et al., 2011). These so-called process improvement spillovers, which refer to "involuntary leakage or voluntary exchange of useful technological information (De Bondt, 1996: 2)" may demotivate a manager to invest in process improvement, as a percentage of the investment will leak away freely to a rival firm. They can occur when an industrial firm is unable to keep its technological knowledge that is the result of innovative activities all for himself (for instance when a rival is conducting corporate espionage or makes use of competitor analysis systems), or when firm employees leak information to the outside world. Firms can also set up horizontal or vertical process improvement collaboration in order to facilitate spillovers. Much research has been done on spillover learning in buyer–supplier relationships (e.g. Mesquita et al., 2008; Perols et al. 2013), firm-end customer relationships (Clark et al., 2013) and the relationships between competitors. The focus of this paper is on the latter category, as it arguably may be the most important spillover source (Czarnitzki and Kraft, 2012). In particular, the main objective of our research is seeing how the use of cost reduction bonuses in equilibrium changes when spillovers are considered, and discussing the profit implications.

Our work is based on Overvest and Veldman (2008) and Veldman et al. (2014) who model a two-stage setting of firms in rivalry. In the first stage, firm owners independently determine the cost reduction bonuses they offer to their operations and technology managers for realized process improvements. In the second stage, the managers decide on the process improvement investment levels, and simultaneously engage in Cournot competition. In both papers the assumption is made that there are always zero spillovers between the firms in rivalry. In the current paper we

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extend their models by considering spillovers. We find that the size of the cost reduction bonus crucially depends on the spillover parameter. More importantly, we find that when spillovers are larger than 50%, it is generally not optimal to use cost reduction bonuses. In this case, positive cost reduction bonuses are only used when process improvement capability is relatively high (i.e. the process improvement cost parameter is low) compared to the spillover parameter. Another finding is that the sensitivity of process improvement levels with respect to the spillover parameter crucially alters when cost reduction bonuses are introduced. Finally, whereas these delegation games typically lead to a prisoner's dilemma (Sengul et al., 2012), we find that in our framework that this does not necessarily occur. More precisely, when spillovers are larger than 50% and process improvement capability is relatively high, cost reduction bonuses are strategic complements, and prisoner's dilemma will not occur.

This article is organized as follows. In Section 2, we discuss the literature and how it relates to our work. In Section 3 we give the basic set-up of our model. In Section 4 we provide the study's main results. Conclusions and further avenues for future research are given in Section 5.

2. Related literature

Our work lies at the cross-section of two streams of literature. The first stream uses game-theoretic frameworks to model process improvement competition between firms. Most of the work in this area considers output spillovers: the leakage of technological knowledge of one firm directly lowers the cost per product of the other firm. The work by d'Aspremont and Jacquemin (1988) often serves as a basis. They model a simple two-stage game in which two rival firms chooses production quantities after a process improvement competition stage where a certain percentage of process improvement outcomes spills over to the rival firm. Several extensions to this model have been made. De Bondt et al. (1992) investigated how the model behaves when the number of firms in an industry and the degree of product differentiation in a Cournot market are varied. De Bondt and Henriques (1995) consider a duopoly with asymmetric spillovers (i.e. the spillovers from one firm to the other is larger than the other way around). They explicitly link spillover asymmetry to the sequence of which firms execute process improvement investments (i.e. which of the firms is a leader or follower in the process improvement stage). De Bondt (1996) provides an insightful overview of the literature on spillovers and innovative activities. Recent work has considered principal-agent approaches to this model. Lacetera and Zirulia (2012), for instance, model a duopoly game in which a firm's researcher determines his cost-reducing scientific efforts by maximizing a wage schedule with incentives for realized cost reduction. In a subsequent stage, the firms compete on the end market by choosing production quantities, whereby a firm's production is influenced by that firm's researcher efforts, as well as the efforts by a researcher from the other firm. Although the paper addresses the incentives given to the researcher for process improvement effort, the researcher's pay depends only on his own realized cost reduction, and not on the decisions made by his rival researcher. Therefore the incentives given to the researcher are only strategic in the sense that they influence product market competition in a subsequent stage.

The second stream we consider concerns strategic incentives. Fershtman and Judd (1987) were among the first to analyze the strategic effect of publicly observable incentive structures. They model a two-stage game where in the first stage, two rival firm owners determine the bonus weights linked to sales, after which Cournot competition takes place. They find that firm owners set positive sales bonuses in a Nash equilibrium, even though the collective use of these incentives is done at the expense of firm profits. Combining the work of d'Aspremont and Jacquemin (1988) and Fershtman and Judd (1987), Overvest and Veldman (2008) analyze a setting where firm owners can give managers a bonus for cost-reducing process improvement. Veldman et al. (2014) considered a case where two firms differ in terms of their abilities to reduce costs and find that the use of cost reduction bonuses typically (but not always) makes firm owners worse off in terms of profitability compared to the case where firms owners cannot commit to using such bonuses. Veldman and Gaalman (2014) investigated the interaction between cost reduction and product quality bonuses.

To the best of our knowledge, Chalioti (2015) has been the first to study strategic cost reduction bonuses in cases with non-zero spillovers between firms. She considers two rival firms, each consisting of a principal (i.e. firm owner) and an agent (i.e. the manager). Each principal makes a take-it-or-leave-it offer to the agent with regard to an incentive contract consisting of a base salary, an incentive for that firm's reduction of marginal cost (whereby marginal cost is comprised of the manager's research efforts, a fraction of the rival manager's research efforts and a noise term), as well as an incentive for the rival's reduction of marginal cost. She termed the latter incentive the 'pay-for-rival performance' incentive. After that, the agents simultaneously decide on cost reducing process improvement levels, based on the incentives given to them in the previous stage. As their payments not only depend on their own process improvement decisions, but also on the decisions made by the rival manager, the managers are in process improvement competition here in a way similar to the model of d'Aspremont and Jacquemin (1988). In the final stage, the principals simultaneously decide on production quantities.

The main differences between our model and the model by Chalioti (2015) are as follows. In contrast to her model, we let process improvement and production take place simultaneously instead of letting the process improvement stage serve as input of the production stage (a decision which we motivate in the next section). Furthermore, whereas the agents in Chalioti (2015) only make process improvement decisions, we let the managers choose both process improvement and production levels. Also, as we are primarily interested into the structure of the cost reduction bonuses given by a firm owner, we let the manager's compensation depend on only the cost reductions he/she realizes instead of being dependent on rival performance as well. Finally, we will refrain from incorporating agency issues such as moral hazard, as the consideration of information asymmetry makes the underlying models much more complex. Veldman et al. (2014) demonstrate that information asymmetry not fundamentally alters the provision of cost reduction bonuses.

3. The model

We consider a duopoly consisting of firms i and j ($i, j = 1, 2$; $i \neq j$). The firms are in Cournot competition with homogeneous goods and face an inverse demand function $p = a - b\sum_{i=1}^{2} q_i = a - b(q_1 + q_2)$, where p indicates the price of the good, q_i represents the production quantity of firm i, and $a, b > 0$ represent the demand parameters. Marginal costs are given by $C_i = c - y_i$, where c is the constant marginal cost and y_i is the realized cost reduction due to technological developments within and outside the firm. As is argued in Veldman et al. (2014), the terms $(a - c)$ and b can both be normalized to 1 without loss of generality. Similar to d'Aspremont and Jacquemin (1988), define $y_i = x_i + \beta x_j$, where x_i is firm i's realized cost reduction due to its

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