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# A model of strategic product quality and process improvement incentives

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ABSTRACT

In many production firms it is common practice to financially reward managers for firm performance improvement. The use of financial incentives for improvement has been widely researched in several analytical and empirical studies. Literature has also addressed the strategic effect of incentives, in particular what the effect of certain incentive structures would be on the behavior of a firm's competitor (s). Most of these studies, however, focus on sales incentives. In this paper we investigate the effects of strategic incentives for product quality and process improvement using a game theoretic model that considers two owner–manager pairs in competition. We find that if one of the managers is told to only maximize firm profits (which in fact is similar to profit incentives), the other manager will be offered positive incentives for product quality and process improvement. These product quality and process improvement incentives result in increased profits, at the expense of the profits of the other firm. Also we find that if both firm owners have the possibility to offer incentives for product quality and process improvement, they will both do so. However, this equilibrium essentially entails a prisoner's dilemma, in which the two firms earn lower profits compared to a situation in which the owners instruct their managers only to maximize firm profits. Insights into the normalization of the problem and the aggregation of multiple product quality and process improvement variables are also discussed.



## 1. Introduction

### 1.1. Research motivation

In this paper we study the managerial incentives firm owners use to stimulate their managers who make decisions in a competitive context. More specifically, we focus on both the internal and external effects of incentives for process improvement and product quality, which are generally seen as important variables in the production strategy arena. The use of incentives for process improvement and product quality is not uncommon, as empirical research (e.g. Ittner and Larcker, 1995; Murphy, 1999) and many annual firm reports indicate. However, whereas the effect of those incentives on the 'internal' decisions of firm owners and managers is relatively well understood (for instance by studying it using principal-agent theory), the external effects of these incentives (e.g. how incentive structures may directly influence the behavior of a firm's competitor) have hardly been the object of research.

Whereas the competitive effect of incentives for variables typical for production economics is underexposed in the literature, there exists a great wealth of research on competitive sales incentives. This stream research took off with the work of Fershtman and Judd (1987) and Sklivas (1987). They showed that owners will almost never tell their managers to maximize firm profits in a competitive situation. They find that firms rather offer their managers observable sales incentives to stimulate them to sell more. Their main explanation was that observable incentives serve as a strategic commitment device towards competitors. Competitors will interpret these incentives as a sign of aggressive sales behavior, inducing them to alter their production decisions in a way which is beneficial to the firm offering sales incentives. However, since all firm owners have the possibility to act as such a Stackelberg leader towards the rival firm's manager, in equilibrium both firms will stimulate their managers to focus on sales maximization. In this paper we investigate whether the same results hold when process improvement and product quality incentives are concerned.

### 1.2. Background literature

Our work combines two research streams: (1) research on the strategic interaction between firms, (2) research on strategic incentives. The first research stream mostly consists of non-cooperative game theory models. Bonanno and Haworth (1998), for instance, investigated when firms opt for process improvement and product improvement, defining product improvement as the investment in product quality. Banker et al. (1998) investigated how equilibrium

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levels of quality change as competition intensifies. Tseng (2004) and Waller and Christy (1992) studied firms' investments in manufacturing flexibility in the light of several industry characteristics.

The second research stream considers what kind of incentives firm owners give to their managers to stimulate profit maximizing behavior, and how these incentives influence the behavior of the firm's rival(s). Many papers on this topic depart from the work by Fershtman and Judd (1987) and Sklivas (1987). Ishibashi (2001), for example, investigated whether their results (which are based on Cournot competition) also hold when firms compete in product quality and price. In later work researchers addressed the effects of incentives for market share (e.g. Jansen et al., 2012) and relative performance evaluation (e.g. Asseburg and Hofmann, 2010). In a noteworthy paper, Balasubramanian and Bhardwaj (2004) compared a perfect coordination situation, in which firm owners instruct their managers to maximize profits by making pricing and product quality decisions, with the situation in which an operations manager bargains with a marketing manager before entering the product market.

Two recent papers have extended previous research by focusing on incentive contracts that more explicitly capture the decisions of the production manager. Overvest and Veldman (2008) studied quantity (i.e. Cournot) competition in a situation where managers are directly rewarded for process improvement. They find that in equilibrium, the bonus that is given to process improvement is always positive. In Veldman et al. (2013) this model has been extended in several directions. In particular, in this paper it is found that the results of Overvest and Veldman (2008) also hold for competing firms that significantly differ in terms of their underlying cost structure. The study shows that uncertainty in the success of process improvement decisions dampen, but not eliminate, positivity of the process improvement weight. Veldman et al. (2013) also studied the effects of process improvement incentives on firm profits. They found that the use of process improvement incentives always results in a prisoner's dilemma for the high-cost producer. However, whether or not a prisoner's dilemma occurs for the low-cost producer depends on the difference between both firms' cost structures: in case this difference is large, the use of process improvement incentives increases profits for the low-cost producer (compared to the case where a manager is rewarded for profit only).

The current paper extends the work by Overvest and Veldman (2008) and Veldman et al. (2013) in two ways. First, whereas these authors based their models on Cournot competition, the demand function in the current paper is an extended Bertrand model with product quality added as a strategic variable. Second, whereas these authors only considered incentives for process improvement, in the current paper the use and effects of incentives for product quality is included as well. Since in practice managerial remuneration is often based on more than one (strategic) variable, this paper will thus be better able to explain the use and workings of these compound incentive contracts.

### 1.3. Research question and approach

The main question in this paper is as follows: *Are managers rewarded for process improvement and product quality in equilibrium? What are the effects of considering upfront incentives for process improvement and product quality on optimal product quality, prices and profits?* We study this problem by modeling a duopoly consisting of two owner-manager pairs. The relevant decisions are made in three stages. In the first stage, the firm owners will either instruct their manager to maximize firm profits, or provide him /her with incentives for process improvement and product quality. Such incentives can both influence the decisions of the manager to whom the incentives are given, as well as serve as a signal towards the competitor, allowing him to act as a Stackelberg leader. In the second stage, the managers will choose the appropriate process improvement and product quality levels. In the third stage, pricing decisions will be made after which the market clears and managers are paid accordingly. Considering that the two firm owners can reward their managers for production economics decisions or not, a $2 \times 2$ matrix of cases can be made. In the next section we present each of these cases.

## 2. The model

This section covers three models. In Section 2.2 two firm owners instruct their managers to maximize firm profits (note that since the managers maximize the firm's goal function, this model is referred to as the 'owner-led model'. In Section 2.3 one of the firm owners deviates from pure profit maximization by also providing incentives for product quality and process improvement. In Section 2.4 both firm owners use product quality and process improvement incentives. In order to be better able to analyze the outcomes, we find and present a way to normalize and rewrite the goal functions and the model outcomes. This is done in Section 2.5. The effects of incentives on firm profitability are discussed in Section 2.6. We start this section with the basic setup of the model. For a general overview of the timeline of the game, see Fig. 1.

### 2.1. Basic setup

There are two firms $i$ and $j$ in the market: $i, j = 1,2; i \neq j$ (note: in the remainder of this paper we will suppress any additional information on these subscripts, unless it is warranted in order to avoid confusion). Following Balasubramanian and Bhardwaj (2004) both firms face the following demand function:

$$q_i = 1 - \beta(p_i - p_j) + \gamma(k_i - k_j),$$

where $q$ is the quantity supplied to and purchased by customers, $p$ is the product price and $k$ is product quality. As state quality is defined in many different forms in operations management literature. We view product quality as a combination of design quality (i.e. product characteristics such as performance, reliability and durability) and conformance quality (i.e. whether the product meets the product specifications). The key point here is that the product quality as perceived by the customers makes the firm's demand function shift upwards and the rival firm's demand function shift downwards. In this paper we assume that the objectively measured product quality equals the product quality as perceived by the firm's customers. The parameters $\beta \in (0,1]$ and $\gamma \in (0,1]$ indicate the volatility with which market quantities change with respect to price and quality differences, respectively. Both firms incur a marginal cost $(c - x_i)$, where $c$ is a constant and $x_i$ is the chosen process improvement level. The process improvement variable may be interpreted here as 'learning before doing', since the firm decides on the optimal investment before the actual production run (e.g. Carrillo and Gaimon, 2002; Fine and Porteus, 1989). The firms bear a convex product quality investment cost, $hk_i^2$. Process improvement cost is also convex and expressed as $mx_i^2$. The quadratic expression of product quality and process

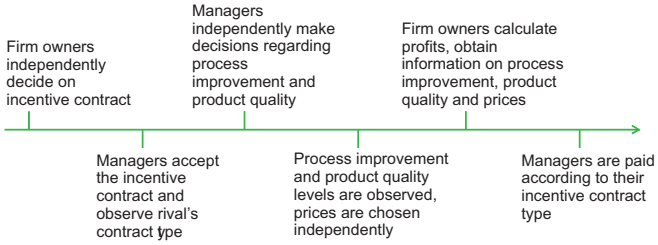


**Fig. 1.** General timeline of the game.