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Continuous Optimization

Stackelberg equilibria in managerial delegation games

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ABSTRACT

Managerial compensation packages do not only influence managers' behavior, but also have an impact on competing firms. In a managerial delegation game investigating the latter aspect, it is shown that the inherent prisoner's dilemma situation can be resolved (without changing the normally studied setup or timing). In the first stage, owners choose an incentive function for their managers, in the second stage they choose the weights assigned to that function besides profits and in the third stage managers play a Cournot game. Solving this continuous optimization problem with the implicit function theorem shows that choosing an incentive from the set of "multiplicative incentives", i.e. any generalized affine transformation of the product of both firms' quantities, which includes e.g. relative profit, ensures that the Stackelberg outcome is among the set of equilibrium outcomes. Furthermore, it is the unique outcome if the rival owner opts for one of the well-known incentives like sales, revenue or market share. The general approach used allows demonstrating that with no other linear incentive a Stackelberg outcome results and that incentives like profit-to-cost ratio should be avoided. Selecting a multiplicative incentive is a dominant strategy of the game.

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1. Introduction

In principal–agent models, and, therefore, in the subcategory of managerial delegation models, interest is usually focused on inducing the agent to exert a high level of effort when designing the agent's compensation package (for a general overview, see e.g. van Ackere (1993), for an application to managerial incentives, see e.g. Balachandrian and Ronen (1989) and recently, Asseburg and Hofmann (2010) or Forno and Merlone (2010)). However, besides the obvious direct impact of agent's effort on the profit of the firm, the chosen remuneration for the agent also affects competing firms. This adds a strategic element to contract design, as it offers the opportunity for principals to manipulate decisions taken in rival firms through agent's incentive contracts.

The most recognized papers analyzing this aspect are the delegation models by Vickers (1985), Fershtman and Judd (1987) and Sklivas (1987). Vickers (1985) shows in a duopoly framework with quantity as the strategic variable that if managers, i.e. the agents, are given a contract to maximize profits, but with an additional incentive for sales, the profit obtained by the firm owner, i.e. the principal, is higher than the profit of the rival owner who just prescribes her manager to maximize absolute profits. Obviously then, the latter owner is induced to change her strategy (since it is dominated) and also includes incentives for sales in her manager's contract. Unfortunately, this results in lower payoffs for both owners than in a standard Cournot game, and a prisoner's dilemma situation emerges, i.e. although both owners would benefit by abstaining from the use of incentives and, hence, play a normal Cournot game, they will not. After this seminal contribution, Fershtman and Judd (1987) and Sklivas (1987) essentially show the same point, but they use revenue as an additional incentive scheme.

Since then, many papers have investigated almost any aspect of sales and revenue delegation. For instance, in an extension to the basic two stage model, Basu (1995) demonstrates that if owners additionally have the decision whether to hire a manager or not, it is possible that a Stackelberg situation arises which is due to the sequential structure of his game. Mujumdar and Pal (2007) also obtain this result in an endogenous timing model with sales delegation. In contrast to that dynamic model, we show that the Stackelberg outcome can even occur in a simultaneous decision model given an appropriate incentive scheme, and that this outcome is a subgame perfect Nash equilibrium (SPNE) of the whole game.

Jansen et al. (2007) and Ritz (2008) have proposed to include incentives for market shares as an optimal incentive scheme, since it outperforms sales and revenue and results in a less severe prisoner's dilemma in the symmetric case. Recently, in a follow up paper, Jansen et al. (2009) identified relative profit to surpass market shares in terms of attainable profits. Earlier, Salas Fumas (1992) has shown in a general symmetric setting, i.e. in a game where both owners use relative profit as an incentive scheme that a Stackelberg type solution can possibly exist. Later, Miller and Pazgal (2002) analyzed a purely symmetric game with relative profits as incentives and found multiple equilibria, which can occur in the

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present context as well. Using a more generalized setup, it turns out that relative profits belong to a large class of equally beneficial incentives, the so-called "multiplicative incentives", which is any generalized affine transformation of the product of both firms' quantities. Moreover, the analysis reveals that members of this incentive set are the best linear incentive scheme possible and, thus, set the end point in the hunt for an even better (and yet practically relevant, since easily comprehendible) incentive scheme. Intuitively, the driving force behind this class of incentives is the forced misperception of the manager, because less weight is attributed to the quantity of the rival firm in the manager's objective function. That is, the situation is analogous to a game with inhomogeneous goods. As a consequence, the manager is less susceptible to strategic manipulation attempts through the rival firm's quantity (in fact, in some situations these attempts are completely disregarded).

However, in order to solve the continuous optimization problem and to derive our results, a mathematically more involved and thorough analysis is necessary. For instance, to be able to use the implicit function theorem, we first show that in our setup the requirements for its application are met, i.e. in contrast to the common approach of simply ignoring equilibria of those subgames in stage 3 which are off the equilibrium path, they are explicitly considered here. The required uniqueness of the Nash equilibrium in stage 3 is shown by applying an approach developed by Chenault (1986) which is amended where necessary. This analysis leads to the first result of the paper: if one owner uses incentives, while the other owner just prescribes her manager to maximize profits then only the Stackelberg outcome results as an equilibrium outcome. This result was already hinted at in special cases in the literature before, but never shown in such generality. Of course, the owner who uses incentives receives the Stackelberg leader payoff.

Due to the general approach used, it is straightforward to show that adding additional elements not influencing the actually produced output is neither advantageous nor harmful for the strategic manipulation of the other firm. Solving the optimization problem, the next result shows that given an incentive function fulfills the property provided in Proposition 3, it is possible to obtain a Stackelberg outcome as a SPNE, although the rival owner uses an incentive function herself. Next, it is argued that the only linear incentives which can fulfill this property belong to the class of multiplicative incentives. This finding constitutes the main result of the paper as it shows that with no other linear incentive scheme higher payoffs are attainable.

In a symmetric setting, i.e. both owners use multiplicative incentives, multiple equilibria exist and solving the optimization problem using the Kuhn–Tucker method, the prisoner's dilemma either vanishes completely, or if existent, payoffs for the owners are still higher as compared to symmetric outcomes of other incentive functions typically considered in the literature. The next result of the paper states that if one owner uses a multiplicative incentive and her rival owner uses one of the before mentioned incentives (or any arbitrary incentive which parallelly shifts the best response function compared to the standard Cournot case) then the only equilibrium outcome is the Stackelberg outcome. That is, the prisoner's dilemma situation is resolved, although both owners choose an incentive scheme for her managers. Finally, stating a dominance result reflecting the superiority of multiplicative incentives is then straightforward.

Several empirical studies show that it is common practice to use more than one performance measure in managerial compensation contracts. For instance, Aggarwal and Samwick (1999) run regressions on a dataset including payment of roughly 8000 executives from more than 1500 firms, and they find that own as well as rival firm profits have a significantly positive effect on managers' compensation. Also related to the considerations here, is the strand of business literature which proposes to pay executives with indexed stock options, i.e. stock options, which include e.g. total industry performance rather than just the performance of the firm employing the manager (see e.g. Rappaport, 1999).

In his empirical study on executive compensation, Murphy (1999, p. 2500) observes that "[l]ess than half of the companies use a single performance measure in their incentive plan; most companies use two or more measures.[...] In other cases, the measures are multiplicative, in which the bonus paid on one performance measure might be increased or diminished depending on the realization of another measure". Another example from economic history is Hviid (2006), who investigates managerial compensation in Danish creameries at the beginning of the 20th century. 13.9% of the more than 3000 contracts in his dataset use more than one form of performance measure, and "non-linearities in one or more of the performance measures are not unusual".[1]

2. Model setup

Consider two firms $i = 1,2$ competing in quantities and producing output levels $q^1, q^2 \geqslant 0$, respectively. Throughout the paper $i,j \in \{1,2\}$, $i \neq j$. Demand in the market is characterized by the linear inverse demand function $p(Q) = \max\{a - bQ, 0\}$, where $Q = q^1 + q^2$ and $b > 0$. Assume that $q^i \leqslant \frac{a}{2b} \forall i$.[2] Production costs are given by cq^i, i.e. constant marginal costs, where $3c > a > 2c > 0$. Each firm has an owner who delegates the output decision to a manager. The game has three stages: in the first two stages owners decide upon the managers incentive contracts to maximize firms' profit, i.e. the owners' objective function, given by

$$\pi^i(q^i, q^j) = (a - bQ)q^i - cq^i.$$

In the first stage, the owners determine the form of incentives besides profit, denoted by $f^i(q^i,q^j)$. In the second stage, they choose the weights $0 \leqslant w^i < +\infty$ they wish to place on this other goal. In the third stage, managers choose their wage-maximizing output q^i. Manager i receives a lump-sum transfer and a fraction of firm i's profits $\pi^i(q^i,q^j)$ and the non-profit maximizing goal $f^i(q^i,q^j)$ which will be discussed in detail below.[3] Thus, each manager seeks to maximize her utility

$$u^i(q^i, q^j) = \pi^i(q^i, q^j) + w^i f^i(q^i, q^j),$$

where w^i is the weight owner i associates with the non-profit goal in stage 2.

For later reference, the equilibrium outcome of a linear standard, Cournot duopoly game, i.e. without delegation, where each owner maximizes her profit $\pi^i(q^i,q^j)$ by choosing a quantity q^i, is $q_C = \frac{a-c}{3b}$, and $\pi_C = \frac{(a-c)^2}{9b}$ for both firms. The best response function of firm i is given by $BR^i_C = \arg\max_{q^i} \pi^i(q^i, q^j)$, i.e. $BR^i_C = \frac{a-c-bq^j}{2b}$. In a standard Stackelberg game, the equilibrium quantity produced by the leader is $q^i_L = \frac{a-c}{2b}$ and the quantity produced by the follower in equilibrium is $q^j_F = \frac{a-c}{4b}$. Note that, although the present model does not involve sequential play in any stage, we will nonetheless use the terms "leader" and "follower" for the firm with the higher and lower profit, respectively. Profits are $\pi^i_L = \frac{(a-c)^2}{8b}$ for the leader and $\pi^j_F = \frac{(a-c)^2}{16b}$ for the follower. Finally, in a monopoly setting the output is $q_M = \frac{a-c}{2b}$ and the respective profit $\pi_M = \frac{(a-c)^2}{4b}$.

In order to be able to construct relevant examples, define a set of standard incentives $f^i(q^i,q^j)$, i.e. those incentives which have

[1] See Hviid (2006, p. 183).

[2] Note that this assumption ensures that the price is non-negative. As will be shown, this assumption is not very restrictive, since such high quantities will never be produced on the equilibrium path. For convenience, in the following the best responses are presented for the case that the produced quantity does not exceed $a/2b$.

[3] For brevity, the manager of firm i is referred to as manager i, and analogously for the owners.

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