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# Quality improvement and goodwill accumulation in a dynamic duopoly

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## Abstract

This paper analyzes optimal advertising and quality improvement decisions by duopolist firms competing in a dynamic setting. An extended version of the Lanchester model is formulated where conformance quality and goodwill are both involved in competition for market share. Each competitor's new customer attraction rate depends on its own goodwill, while the disloyalty rate for current customers is influenced by the proportion of defective items. The search for a non-cooperative solution by qualitative as well as numerical means leads to definition of the optimal path for advertising and improvement efforts for each competitor, examined under a wide range of configurations.

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## 1. Introduction

Though Feichtinger et al. (1994) pointed out the need “to build more realistic corporate models . . . , [where] product quality should have an important place” a decade ago, Jørgensen and Zaccour (2004) still recently observed that there “seems to be [almost] no literature on differential games dealing with product quality competition”. This paper seeks to fill the gap by introducing quality and advertising goodwill into the Lanchester model, to analyze competitive equilibrium strategies.

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Initially developed to represent military combat, the Lanchester model has been widely adapted to study dynamic competition for market share in duopolistic markets (El Ouardighi, 2003). As emphasized in Erickson (1995), duopolistic market structures describe common competitive situations (e.g. Coke vs. Pepsi, Anheuser-Busch vs. Miller, Yoplait vs. Danone). Previous studies using the Lanchester model have mostly considered the manipulation of one unique decision variable, namely advertising effort, such that the model has been essentially devoted to advertising competition.

Basically, the Lanchester model relies on the assumption that customers are naturally disloyal and will drift towards the firm that makes the greatest advertising effort. Advertising effort may enable a firm to attract a rival's customers, but confers no power to reduce the rival's advertising influence over its own current customers. Clearly, this assumption contradicts a number of empirical observations showing that quality is a decisive factor for current customer retention (e.g. Garvin, 1988).

In this paper, we argue that insufficient quality may be another motivation for customer disloyalty. We propose an extended version of the Lanchester model where each competitor's accumulated advertising (i.e. goodwill) attracts customers dissatisfied by the rival's brand quality, and vice versa. Furthermore, each competitor's goodwill and brand quality may be respectively incremented through its own advertising and quality improvement efforts.

In the next section, a differential game model is designed where the market share competition depends upon the duopolist firms' goodwill accumulation and quality improvement activities. In Section 3, the search for a qualitative solution to the game leads to definition of the optimal path for the control variables, as well as their sensitivity to certain influential state variables. A two-point boundary-value problem is then formulated to conduct a numerical analysis. Section 4 contains a numerical analysis addressing the following issue: how do the initial configurations of the game influence the players' equilibrium strategy? Section 5 concludes our study.

## 2. Model formulation

With a few exceptions,<sup>1</sup> the Lanchester model applies to mature markets where two competitors are battling for market share. Two formulations are possible:

- In the first, the rate of change of each competitor's market share is determined by their respective current investments in advertising. Letting  $x(t) \in [0, 1]$  denote firm 1's market share,  $u_i(t) \geq 0$  firm  $i$ 's advertising effort level, and  $f_i(u_i(t))$  a positive attraction function, such that  $f_{iu_i} > 0$  and  $f_{iu_i u_i} \leq 0$ ,  $i = (1, 2)$ , the Lanchester model with no advertising carry-over effect is as follows:

$$\dot{x}(t) = f_1(u_1(t))(1 - x(t)) - f_2(u_2(t))x(t), \quad x(0) = x_0 \in [0, 1]. \quad (1)$$

This formulation has been used most notably by Jarrar et al. (2004), Wang and Wu (2001), Fruchter and Kalish (1997), Chintagunta and Vilcassim (1992) and Erickson (1992) to determine the optimal advertising path for each competitor.

- In the second, the market share dynamics depend on the firms' respective accumulated advertising efforts. Letting  $g_i(G_i(t))$  be a positive function of firm  $i$ 's goodwill  $G_i(t)$ ,  $i = (1, 2)$ , with  $g_{iG_i} > 0$  and  $g_{iG_i G_i} \leq 0$ , the Lanchester model with a positive goodwill retention rate is:

$$\dot{x}(t) = g_1(G_1(t))(1 - x(t)) - g_2(G_2(t))x(t), \quad x(0) = x_0 \in [0, 1]. \quad (2)$$

<sup>1</sup> For a review, cf. Jørgensen and Zaccour (2004).

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