GREENWASHING WITH DETECTION

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ABSTRACT

This paper investigates how environmental quality competition between a greenwashing firm and a genuinely eco-conscious one affects the two firms' quality choices and consumer perceptions of environmental quality. Using a differential game theoretical framework, it highlights the significance of early detection mechanisms and regulatory interventions in mitigating the adverse effects of greenwashing, thereby fostering a more conducive environment for genuine environmental stewardship. Furthermore, this study explores the potential trajectories for both firms' post-exposure, addressing the implications for consumer perceptions, market dynamics, and the overall corporate environmental responsibility landscape.

INTRODUCTION

Greenwashing is defined as "the act of misleading consumers regarding the environmental practices of a company or the environmental performance and positive communication about environmental performance" (Terrachoice). In recent years, regulatory pressures to reduce carbon emissions and competition to produce environmentally friendly products have driven the market of sustainable product development. However, in the race to achieve a high level of "greenness," firms have often resorted to misleading communications regarding the true environmental quality of the products (Boncinelli et al. (2023); Szabo and Webster (2021)). Such greenwashing is hard to detect and often goes unnoticed by consumers. Therefore, the consumers make purchasing decisions based on their perceived greening level of the product, which is not necessarily the true level. Regulatory bodies often impose penalties if such an act of greenwashing is caught. Some recent examples of greenwashing resulting in such penalties include the following:

- In 2019, paper straws introduced by McDonald's were non-recyclable. Paper straws aimed to reduce plastic pollution but came at the cost of cutting trees and not really reducing pollution (Akepa, 2021).
- In 2015, Volkswagen was accused of greenwashing when they made falsified mileage claims and purposefully distorted emission tests (Shepardson, 2016).

- There are many other such incidents of misleading claims, and big brands like Coca-Cola, Nestle, Pepsi, H&M, etc., are often associated with these claims (Laville (2022); Akepa (2021)).

Given the rising number of greenwashing cases, much research is being done in this area. The case where an actual green firm and a greenwasher compete is of sufficient interest (Wu et al., (2020)). Several papers, like Baksi et al. (2017), Lee et al. (2018), and Huang et al. (2020), focus on the competition in a greenwashing environment. Greening efforts and greenwashing are dynamic policies that will vary over time depending on the market parameters. However, there is a paucity in the literature studying this. In comparison, some studies consider multi-period models (Huang et al., (2020); Shen and Shen, (2019)). We consider a continuous time competitive differential game models, which help us answer the following important questions.

In this paper, we investigate environmental quality efforts and greenwashing efforts when two competing firms, one green and the other one a greenwasher, anticipate that greenwashing may be detected by regulators, resulting in a penalty. Our research questions are:

1. What are the equilibrium environmental and greenwashing policies of the competing firms in the two periods?
2. How do these policies and firm profits vary with the likelihood of being caught?

Our major findings are the following. First, farsighted firms consider the likelihood of detection (hazard rate) while choosing their optimal environmental qualities. Second, greenwashing diminishes consumer trust, leading to a reduced optimal environmental quality for the greenwashing firm post-detection. Third, as the likelihood of detection rises, the pre-detection equilibrium quality of the greenwasher drops while that of the genuinely eco-friendly firm increases. Our numerical analysis reveals that the perceived quality of each firm is inversely related to the hazard rate. The greenwashing firm outperforms the genuine green firm in profits until detection, after which their earnings fall due to fines. In summary, strategic considerations, consumer trust, and detection dynamics significantly impact firms in environmentally regulated markets.

There are several model parameters, and our findings are subject to the model parameter values before and after getting caught. In the subsequent sections, we first build our model and then discuss the results.

MODEL

Demand Functions and State Variables

We consider a duopoly model where two firms compete based on environmental quality. The demand function of each firm is based on this competition. Our model is a continuous time differential game model, where one firm is a genuine green firm, and another firm will greenwash. The greenwasher can get audited by a regulatory body at a random time τ, *and if greenwashing is detected,* a penalty of amount F is imposed. We assume the time of detection is a random variable following a negative exponential distribution. Thus, we have an associated hazard rate χ which is defined by:

$$\chi(t) = \lim_{dt \to 0} \frac{Pr\left\{t \leq \tau < t + dt | \tau \geq t\right\}}{dt} \tag{1}$$

This detection time splits the decision horizon into two regimes: $[0,\tau] \cup (\tau,\infty)$ where $[0,\tau]$ is the period when the greenwashing was not detected. In contrast, (τ,∞) is the period when it was detected and the penalty was imposed.

The demand functions of the green firm (firm 1) and the greenwasher (firm 2) are given by:

$$D_{1j}(t) = \alpha_1 + \beta_{1j}(G_{1j}(t) - G_{2j}(t))$$
$$D_{2j}(t) = \alpha_2 + \beta_{2j}(G_{2j}(t) - G_{1j}(t)) \tag{2}$$

where α_i is the market potential, and βij is the sensitivities to the product differentiation in terms of the environmental attributes. The decision variables for the two firms in the two periods are:

Firm 1 (green firm) environmental quality: q_{1j}, $j \in \{1,2\}$

Firm 2 (greenwasher) environmental quality and greenwashing efforts: q_{2j}, w_{2j}, $i \in \{1,2\}$.

The state variables of our model are $G_{ij}(t)$, $i,j \in \{1,2\}$. The evolution of the state variables is given by:

$$\begin{aligned} \frac{dG_{1j}}{dt} &= k_{1j}q_{1j}(t) - \delta_{1j}G_{1j}(t), \ j \in \{1,2\} \\ \frac{dG_{2j}}{dt} &= l_{2j}w_{21}(t) + (k_{2j}q_{2j}(t) - \delta_{2j}G_{2j}(t)), \ j \in \{1,2\} \end{aligned} \tag{3}$$

In the above equations, $q_{ij}(t)$ is the true green quality efforts of firm i in period j and $w_{2j}(t)$ is the greenwashing efforts of the firm 2 in period j. In addition, k_{ij} is the marginal effect of greenwashing on the perceived green quality evolution of firm i in period j, while δ_{ij} is the decay in the perceived green quality of firm i in period j.

Model assumptions:

- $w_{22} = 0$ as in this model, the firm cannot greenwash when it gets detected
- After greenwashing, there is a constant penalty of F, which the firms can estimate ex-ante
- $\delta_{22} > \delta_{21}$ implies that consumers punish the greenwashing firm as they lack trust.

Such use of the decay parameter can be found in Mukherjee and Chauhan (2021).

- In general, for the green firm, $\delta_{11} = \delta_{12}$.
- $\beta_{11} = \beta_{21}$, and $\beta_{21} = \beta_{22}$ that is, the sensitivities with respect to product differentiation do not change over the two regimes for each of the two competing firms.
- $m_{22} < m_{21}$: this implies that for the greenwashing firm 2, the unit profit margins are less in regime 2 than in regime 1. This is because, in regime 2, it has already been detected for greenwashing.
- $m_{11} < m_{12}$: For the true green firm 1, the profit margins are higher in period 2 than period 1 since in period 2, firm 2 has stopped greenwashing.

Noting that j is the index for the time period, the instantaneous profits of the firm i in period j are given by $\pi_{ij}(t) = D_{ij}(t)m_{ij}(t) - C_{ij}(t)$ where $C_{ij}(t)$ are the costs of the firm i. Thus, the instantaneous profit functions for the green firm ($\pi_{1j}(t)$) and the probable greenwasher ($\pi_{2j}(t)$) are:

$$\pi_{1j}(t) = D_{1j}(t)m_{1j} - \frac{\mu}{2}q_{1j}^2(t) \tag{4}$$

$$\pi_{2j}(t) = D_{2j}(t)m_{2j} - \frac{\mu}{2}q_{2j}^2(t) - \frac{\theta}{2}w_{2j}^2(t) - \Phi F,\ w_{22} = 0,\ \Phi = 1 \qquad j = 1, 2. \tag{5}$$

We consider an infinite horizon regime switching differential game with two regimes. The first regime is when firm 2 greenwashes, and regime 2 is where the greenwashing firm gets caught. We are interested in each firm's long-term decisions and profits. Such games are widely used in the applications of management science and economics (Dockner et al., 2000). The second regime's decision problem of the firm i is given by:

$$V_{i2}(G_{12}, G_{22}) = \underset{q_i}{Max} \int_{\tau}^{\infty} e^{-rt}\pi_{i2}(t)dt, \text{ given } G_{i2}(\tau) = \widehat{G_i} \tag{6}$$

where (6) is subject to the state equations given by (3).

In the first regime, the long-term profit of firm i is the expected profit, which is given by:

$$J_i = E[\int_0^{\tau} \pi_{i1}(t)dt + e^{-r\tau}V_{i2}(G_{12}, G_{22})] \tag{7}$$

DETERMINATION OF FEEDBACK EQUILIBRIUM STRATEGIES

We use the Hamilton - Jacobi- Bellman (HJB) equations to solve the above problems. The HJB equations (10) and (11) are linear quadratic, and such linear quadratic games have been extensively studied in the literature under different contexts. It can be shown that the value functions of such games are linear quadratic (Dockner et al., 2000). We posit that the value functions will be of the form:

$$V_{1j(}G_{1j}, G_{2j}) = X_{1j}G_{1j} + X_{2j}G_{2j} + X_{3j} \quad (8)$$

$$V_{2j}(G_{1j}, G_{2j}) = Y_{1j}G_{1j} + Y_{2j}G_{2j} + Y_{3j} \quad (9)$$

where X_{ij} and Y_{ij} are the constant coefficients. The second period's HJB equations are:

$$rV_{12}(G_{12}, G_{22}) = \max_{q_{12}}\left[D_{12}(t)m_{12}(t) - \frac{\mu_q}{2}q_{12}^2(t) + \frac{\partial V_{12}}{\partial G_{12}}\dot{G_{12}}(t) + \frac{\partial V_{12}}{\partial G_{22}}\dot{G_{22}}(t)\right] \quad (10)$$

$$rV_{22}(G_1, G_2) = \max_{p_2, q_2, g_2}\left[D_2(t)p_2(t) - \frac{\mu_q}{2}q_2^2(t) - \frac{\mu_g}{2}g_2^2(t) + \frac{\partial V_2}{\partial G_1}\dot{G_1}(t) + \frac{\partial V_2}{\partial G_2}\dot{G_2}(t)\right] \quad (11)$$

Equilibrium Analysis

Proposition 1. *The equilibrium quality decisions of the two firms in the second period are:*

$$q_{12} = \frac{k_{12}m_{12}\beta_{12}}{\mu(r+\delta_{12})}$$

$$q_{22} = \frac{k_{22}m_{22}\beta_{22}}{\mu(r+\delta_{22})} \quad (12)$$

and the value functions are given by:

$V_{12} = X_{12}G_{12} + Y_{12}G_{22} + Z_{12}$ & $V_{22} = X_{22}G_{12} + Y_{22}G_{22} + Z_{22}$; where

$$X_{12} = \frac{m_{12}\beta_{12}}{r+\delta_{12}};\ Y_{12} = -\frac{m_{12}\beta_{12}}{r+\delta_{22}}$$

The second regime's decision is the environmental quality levels of the two firms. Observing the second regime quality levels, we deduce the following Lemma.

Lemma 1. *In the second regime, a lack of consumer trust can result in lower environmental quality for the greenwashing firm.*

Proof: From equation (12), $q_{22} = \frac{k_{22}m_{22}\beta_{22}}{\mu(r+\delta_{22})}$; which implies that as δ_{22} increases, q_{22} decreases.

Intuitively, as δ_{22} (the consumers' perceived environmental quality of firm 2) decreases, firm 2 has no incentive to increase its quality since producing quality is expensive. Nevertheless, consumers will not trust that it is producing high quality. Consumer perception of the low environmental quality of firm 2 turns into a self-fulfilling expectation.

Proposition 2. *The equilibrium quality and greenwashing decisions of the two firms in the first period are:*

$$q_{11} = k_{11}\left(\frac{m_{11}\beta_{11} + \chi\frac{m_{12}\beta_{12}}{r+\delta_{12}}}{\mu(r+\delta_{11}+\chi)}\right)$$
$$q_{21} = k_{21}\left(\frac{m_{21}\beta_{21} + \chi\frac{m_{22}\beta_{22}}{r+\delta_{22}}}{\mu(r+\delta_{21}+\chi)}\right)$$
$$w_{21} = l_{21}\left(\frac{m_{21}\beta_{21} + \chi(\frac{m_{22}\beta_{22}}{r+\delta_{22}})}{\omega(r+\delta_{21}+\chi)}\right) \qquad (13)$$

and the value functions are given by:
$V_{11} = X_{11}G_{11} + Y_{11}G_{21} + Z_{11}$; and $V_{22} = X_{21}G_{11} + Y_{21}G_{21} + Z_{21}$.

Lemma 2. *The equilibrium quality effort of the greenwashing firm in the first regime is decreasing in hazard rate.*

Proof: It can be easily shown that the derivative of environmental quality of firm 2 with respect to hazard rate, i.e., $d(q_{21})/d\chi < 0$ if $m_{22} < m_{21}$, which always holds by assumption. The higher the detection rate, the lower the equilibrium quality produced by firm 2 in regime 1.

Lemma 3. *The equilibrium quality level of the green firm in the first regime is increasing in the hazard rate.*

Proof: Differentiating the equilibrium quality level of the green firm 1 in the first regime (q_{11}), with respect to the hazard rate χ, we find that $d(q_{11})/d\chi > 0$ if $m_{12} < m_{11}$, which we have assumed to be the case. The higher the detection rate, the higher the equilibrium quality produced by firm 1 in regime 1.

NUMERICAL ANALYSIS

In our analytical results, we could derive the firms' strategies. However, the expressions of the value functions, which are the instantaneous profits, are complex. This section shows the profit variation with the most important parameter χ. We consider the following parameter values:

$\alpha_i = 10$: (Market size parameter); $\beta_{ij} = 0.5$ (product quality differentiation sensitivity on demand);

$k_{ij} = 1$; $l_{ij} = 0.4$; (Other sensitivity parameters) $F = 1$, (Penalty);

$m_{11} = 1$; $m_{12} = 1.1$; $m_{21} = 1$; $m_{22} = 0.8$ (Profit margins); $r = 0.06$; $\delta_{ij} = 0.2$; $\omega = 1$; $\mu_i = 5$;

In Figures 1, 2, 3, and 4, the green curves denote the greenwashing firm's perceived quality (Figures 1 and 2) and profit (Figures 3 and 4), while the blue one denotes the same for the genuine green firm. From the figures, we observe that:

- The perceived qualities (G_{ij}) of both the firms reduce with increases in the hazard rate χ.
- The perceived environmental quality of the green firm remains lower than that of the greenwashing firm in the first period. However, once the greenwasher is caught and penalized, the perceived environmental quality of the greenwasher drops below that of the green firm.
- From figures 3 and 4, When the likelihood (χ) of getting caught is low, the greenwasher's profit (value function) is higher in the first regime but plummets significantly because of the penalty and reduced margins in the second period. The green firm's profit increases in the second period because of increased profit margins.

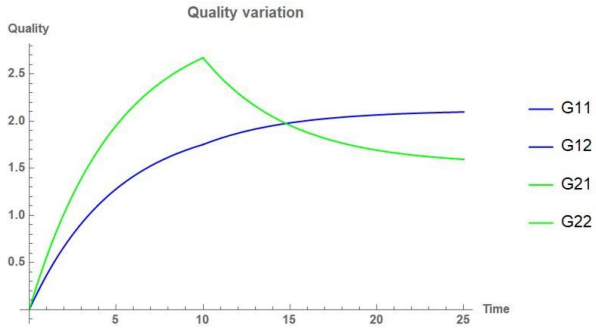

Figure 1: Quality variation ($\chi = .25$)

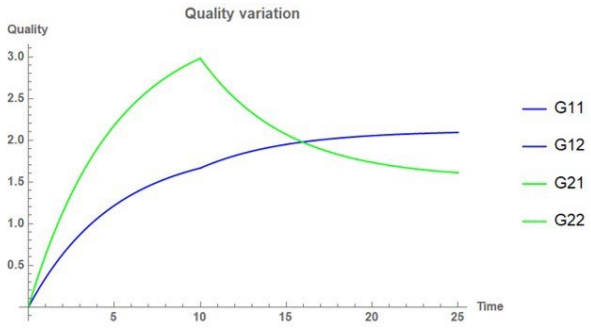

Figure 2: Quality variation ($\chi = .05$)

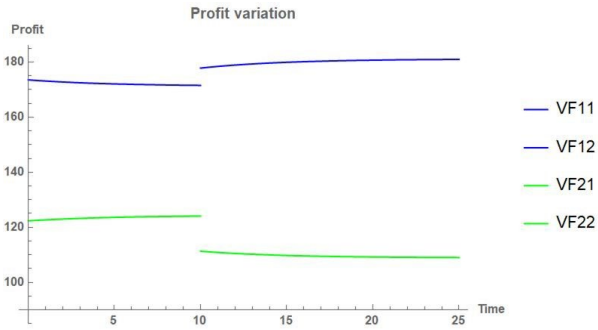

Figure 3: Profit variation ($\chi = .25$)

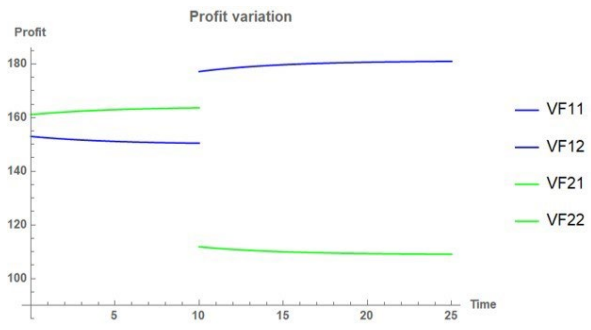

Figure 4: Profit variation ($\chi = .05$)

CONCLUDING REMARKS

In this article, we considered two firms competing on green quality: one firm is a genuine green firm, and the other is a greenwasher. The firm engaging in greenwashing may undergo random audit at time τ by a regulatory authority. If any instances of greenwashing are identified during these audits, a penalty of magnitude F will be levied on the firm, and further greenwashing is not assumed to be possible. We used a differential game model to analyze the equilibrium strategies of two firms under such a framework. Our key findings are:

- Farsighted firms incorporate uncertainties (hazard rate) in their environmental quality strategies in a regulated market.
- Lower consumer trust due to greenwashing can decrease optimal environmental quality for the greenwashing firm after detection.
- As the likelihood of detection increases, the equilibrium quality level of the greenwashing firm before detection decreases while that of the genuine green firm increases.
- From our numerical analysis, we further observe that the perceived quality of each firm is a decreasing function of the hazard rate. The profits of the greenwasher are higher than those of the genuine green firm before detection but are lower than those of the latter after getting caught and fined for greenwashing.

We have built a theoretical model that gives us inter-temporal strategic interventions. To the best of our knowledge, this is one of the first models studying duopoly and time-dependent strategies in the framework of greenwashing.

Our model generates piecewise constant strategies because of the mathematical structure of the game. A differential game model with price as a decision variable along with quality in the competitive setting would be of interest. We are considering one of the firms as a greenwasher. In the real world, competition can force greenwashing for a genuine green firm. Investigating such duopoly greenwashing is of considerable interest. Moreover, one can consider other members of a supply chain, like a retailer and supplier, and examine the resolution of conflicts of supply chain contracts when a manufacturer is caught greenwashing. This is an exciting topic for future research.

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