國立政治大學經濟學系

碩士論文

廠商 ESG 績效、經理人報酬與競爭策略之分析

ESG Performance, Managerial Compensation, and Competition in Differentiated Product Market

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摘要

本論文研究 ESG 與市場競爭的策略的三個議題。首先，本文分析 ESG 與廠商的其他競爭策略（數量，廣告及研發）的影響。其次，本文分析將 ESG 納入管理薪酬結合所造成的影響。最後，本文分析懲罰機制造成的影響。結果顯示：（1）ESG 對廠商其他競爭策略（數量，廣告及研發）影響的效果會因為價格彈性和產品差異化程度減少而增加，但不會因為市場規模或生產效率的改變而有變化。而且當大企業增加 ESG 活動或小企業減少 ESG 活動時，市場集中度會增加。此外，我們發現當廠商規模較大、生產更有效率、彈性較低或產品差異化程度較高時，將從事更多的 ESG 活動。（2）包含 ESG 的薪酬可以增加或減少均衡產出，取決於廠商薪酬中的 ESG 成份是否足夠高於對手。（3）我們發現固定懲罰會增加管理者對 ESG 活動的努力誘因，但對均衡產出的影響將取決於懲罰的相對大小。而且我們發現對產出的影響會隨著 ESG 績效的不確定性水平增加而降低。此外，我們發現在均衡時，管理者對 ESG 付出的努力和產出在比例懲罰下更高。

JEL 分類代號：D21, D43, L13, M12, M37, M52, O30

關鍵詞：ESG、研發、廣告、產品差異化、經理人薪酬

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Abstract

This paper studies three issues of ESG and market competition strategies. First, this paper analyzes the impact of ESG and firms' other competitive strategies (output, advertising, and R&D). Second, this paper analyzes the impact of incorporating ESG into managerial compensation. Finally, this paper analyzes the impact of the penalty schemes. The results show that: (1) The own ESG effects decrease the own price elasticity and the degree of product differentiation, but not related to market size or production efficiency. We also find that when large firms increase the ESG activities or small firms decrease ESG activities, the degree of concentration will increase. In addition, we find that the firm with larger sizes, the firm with more efficient, the firm with a lower elasticity, and the firm with a higher degree of production differentiation will engage in more ESG activities. (2) We find that the inclusion of ESG-related compensation can increase or decrease the equilibrium output, depending on whether the firm's ESG component in compensation is sufficiently higher than opponents'. (3) We find that fixed penalties will increase managers' effort incentive on ESG activities, but the effect on equilibrium outputs will depend on the relative sizes of penalties. And, we find that the effects on outputs will decrease with the level of uncertainty in ESG performance. Moreover, we find that the equilibrium efforts and outputs are higher with the proportional penalties.

JEL Classification: D21, D43, L13, M12, M37, M52, O30

Keywords: ESG, R&D, Advertising, Product Differentiation, ESG-based Compensation

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Contents

DOI:10.6814/NCCU202101246

List of Figures

DOI:10.6814/NCCU202101246

1. Introduction

UN Global Compact first proposed the concept of ESG in 2004, which is regarded as an indicator for evaluating the operation of a company. ESG is an abbreviation consisting of three words: Environmental, Social, and Corporate Governance, which means a set of quantifiable metrics for companies to achieve sustainable performance. ESG uses quantifiable data to define and measure the health and stability of an enterprise, and it can also be used as an important reference for investors to judge investment targets.

When the financial crisis broke out in 2008, the concept of ESG gained attention. Lins, Servaes, and Tamayo (2017) found that high-scoring US non-financial companies in the financial results for this period better than other companies. That is, companies with higher ESG scores are less affected by the financial crisis. The reason is that companies' long-term investment in social assets and the trust of investors drive the company's performance to maintain a certain level.

With the increasing complexity of factors affecting corporate evaluation, in addition to capital investment performance, many intangible assets that will affect corporate operating performance and image, so the concept of sustainable management and the contribution of social culture will also be included. Use ESG indicators to measure the operational performance and strategic direction of the company, and provide investors and the general public with a set of references for measuring the company's performance. And by measuring corporate effectiveness in a more precise way, business operations can be more mature. For example, in terms of environmental protection, setting quantifiable sustainable management goals, such as reducing carbon emissions or achieving carbon neutrality by tracking carbon equivalent, energy intensity, and water consumption.

As we know if a company has better ESG performance, the more effective it is to reduce corporate risks, increase returns, and be able to respond and manage flexibly in the face of

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corporate crises to ensure better investment performance. Therefore, this article will use the economic model to discuss what changes will be made to the firm's behavior when sustainability is added to the firm's strategy.

In section 3.1, we will analyze how ESG activities affect the firm's three competitive strategies, which are output, R&D, and advertisement, and their values in equilibrium by treating ESG as an exogenous variable. And we find that ESG activities are complementary to all three competitive strategies and the profits. Moreover, we find that the own ESG effects decrease the own price elasticity and the degree of product differentiation, but not related to market size or production efficiency. According to the analysis of market concentration, we find that in duopoly competition, when large firms increase the ESG activities, the degree of concentration will increase, while small firms increase ESG activities, the degree of concentration will decrease.

In section 3.2, we will analyze the full equilibrium by treating ESG as an endogenous variable. We find that the firm with larger sizes of potential customers will engage in more ESG activities, which will further reduce the smaller competitors' ESG activities. And more efficient firms will increase their ESG activities. Moreover, we find that the firm with a higher elasticity will use fewer ESG activities and the firm with a higher degree of production differentiation will use more ESG activities.

In section 4, we will study the impact of tying managerial compensation on the firm's ESG performance. In section 4.1, we analyze the difference between equilibrium with ESG related compensation and equilibrium without ESG related compensation. We find that the inclusion of ESG-related compensation can increase or decrease the equilibrium output, depending on whether the firm's ESG component in compensation is sufficiently higher than opponents'. Even when the two firms have the same ESG component, the adoption of ESG-related compensation can increase the equilibrium output if the degree of product differentiation is sufficiently high, or if the rival's slope to be high enough. About the analysis

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of market concentration, we find that when large firms adopt the ESG-based compensation, the degree of concentration will increase, while small firms adopt the ESG-based compensation, the degree of concentration will decrease. In section 4.2, we analyze the owner's strategy which is to decide the equilibrium share of the ESG component. We find that the equilibrium share of the ESG component in managerial compensation will increase with market scale and production efficiency.

In section 5, we examine the effects of penalty schemes. In section 5.1, we study how the existence of a fixed penalty improves ESG performance. We find that fixed penalties will increase managers' effort incentive on ESG activities, but the effect on equilibrium outputs will depend on the relative sizes of penalties. Moreover, we consider an uncertain relationship between effort and ESG activities, and we find that the effects on outputs will decrease with the level of uncertainty in ESG performance. In section 5.2, we study how the existence of proportional penalty improves the ESG performance and compare it to the fixed penalty case. We find that the equilibrium efforts and outputs are higher with the proportional penalties.

This current paper will contribute in several aspects. We will analyze how ESG activities affect the firm's three competitive strategies, which are output, R&D, and advertisement, and their values in equilibrium. And we find the effect will depend on each firm's relative sizes of the ESG component, the degree of product differentiation, and the degree of elasticity. Moreover, we analyze the impact of ESG on market concentration. Additionally, we will discuss adding ESG to the manager's compensation to analyze the impact on firms' strategies such as output, R&D, and advertisement. We also the impact of ESG on market concentration. And we will also analyze the owner's optimal share of the ESG component in managerial compensation. Moreover, we will use the penalty mechanism to analyze the impact of ESG on the firm's strategy, and we will compare the impact of using fixed penalty and using proportional penalty in the model.

DOI:10.6814/NCCU202101246

The organization of this paper is divided into the following sections. In section 3, we will describe the assumptions of the model, and we will analyze how ESG activities affect the firm's competitive strategies and market concentration. In section 4, we will study the impact of tying managerial compensation on the firm's ESG performance. In section 4.1, we analyze the difference between equilibrium with ESG related compensation and equilibrium without ESG related compensation. In section 4.2, we analyze the owner's strategy which is to decide the equilibrium share of the ESG component. In section 5, we examine the effects of penalty schemes, including fixed penalty and proportional penalty.

2. Related Literature

Here we present the related literature for our models. There are mainly two groups of literature addressing (i) the impacts of ESG on market competition (ii) the impact of ESG based managerial compensation.

2.1 Impacts of ESG on competition

The existing literature regards corporate social responsibility (CSR) as a product differentiation strategy (Navarro 1988, Bagnoli and Watts 2003, Siegel and Vitaliano 2007). Ho and Huang (2017) addressed the problem between the effectiveness of donations and altruistic preferences. Albuquerque et al. (2019) proposed a model of monopolistic competition, in which the company makes a binary choice on whether to engage in CSR. CSR is an investment to increase product differentiation. It is predicted that CSR decreases systematic risk and increases firm value, and firms with high product differentiation have a greater effect.

Unlike the monopolistic competition setups (where demands are rationed according to exogenously given price elasticity and hence it is assumed that market interaction does not

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exist), we will analyze the actual competition among firms and their CSR strategies. We analyze the impacts on other competitive strategies such as R&D or advertising and the impacts on market concentration. These are not mentioned in the existing literature.

Our model setups reflect the evidence presented by the existing literature. First, some references are supporting that sustainability activities will increase demand and consumer recognition. Luo and Bhattacharya (2006, 2009) believe that corporate social responsibility improves customer loyalty, resulting in companies having more pricing power. The direct evidence in this regard is that firms can sell at higher prices or sell more products with corporate social responsibility characteristics (see e.g., Creyer and Ross 1997, Auger et al. 2003, Pelsmacker et al. 2005, Elfenbein and McManus 2010, Elfenbein et al. 2012, Ailawadi et al. 2014, Hilger et al. 2019). Positive CRS is positively correlated with the company and product reviews (Biehal and Sheinin, 2007, Brown and Dacin, 1997, Sen and Bhattacharya, 2001). Compared with positive CRS associations, negative CRS associations are more influential and have greater detrimental effects. Baron (2001) suggests that part of firm value due to corporate donations is supported by the threat of boycotts. Casadesus-Masanell et al. (2009) concluded that green products can be sold at high prices. For example, customers of Patagonia, an outdoor sportswear brand, are willing to pay high prices for organic cotton clothing. Jones (1995) and Baron (2011) concluded that active participation in CSR activities led to an improvement in the company's reputation and brand recognition, which in turn benefited from the reduction in transactional and agency costs. Servaes and Tamayo (2013) provided evidence that when customers are highly familiar with firm activities, there is a positive correlation between CSR and firm value. Lin et al. (2021) analyzed 164 listed companies in the global automotive industry between 2011 and 2018. And they find that green innovation strategy has a positive impact on brand value. Moreover, firms with high R&D intensity and high marketing capability investment can further enhance the impact of green innovation strategy (GIS) on brand value.

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Second, some literature studies the relationship between CSR or ESG and firm values. (i) For the positive relationship, Klassen and McLaughlin (1996) proposed a theoretical model that combines environmental management with improved financial performance through market gains and cost savings. Russo and Fouts (1997) found that the positive correlation between environmental performance and economic performance increases with the growth of the industry. Margolis et al. (2009) reviewed 251 studies published up to 2007. These studies show that the effect of CSR on corporate performance is small but positive and significant. Edmans (2011) shows that firms with high employee satisfaction have higher valuations. Several studies tried to identify and evaluate these effects and show that CSR activities can create opportunities for firms: to lower the costs of capital (El Ghoul et al. 2011); to reduce the residual risk (Sharfman and Fernando, 2008); or to anticipate best practices (Eccles et al. 2012). Fatmi et al. (2015) attribute the higher firm valuation to a firm's commitment to social responsibility, which can increase the firm's survival probability, improve the firm's medium and long-run cash flow, and reduce its capital cost. (ii) For the insignificant or negative relationship, Beurden and Gossling (2008) analyzed the literature of previous decades and provided evidence of insignificant or adverse market reaction to CSR practices. Renneboog et al. (2008) found that socially responsible investment has no significant impact, and believes that existing studies imply but do not indicate that socially responsible investments (SRI) investors are willing to accept suboptimal financial performance to pursue social or ethical objectives. Ioannou and Serafeim (2012) and Orlitzky (2013) concluded that there is no conclusively positive correlation.

Third, while the focus of this current paper is to study the impacts of ESG on market competition, some articles have studied the opposite direction, that is, how firm or industry characteristics affect the reporting of ESG indicators. Tamimi and Sebastianelli (2017) use the Bloomberg ESG scores to explore the transparency status of S&P 500 companies, considering

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the influence of the industry sector, firm size, and governance practices. Deng and Cheng (2019) study the relationship between ESG indices and the stock market performance, and further examine the heterogeneous impact of ESG indices on the stock market performance, considering different ownership backgrounds and industrial backgrounds.

This current paper will contribute in several aspects. We will analyze how ESG activities affect the firm’s three competitive strategies, which are output, R&D, and advertisement, and their values in equilibrium. The existing literature on ESG research does not address the impact of R&D or advertisement. We find the effect will depend on each firm’s relative sizes of the ESG component, the degree of product differentiation, and the degree of elasticity. Moreover, we analyze the impact of ESG on market concentration.

2.2 ESG based CEO compensations

On the impacts on ESG performance, the existing literature also found conflicting evidence. Some of the existing literature found that ESG-based compensation has a positive impact on firms. Banker et al. (2000), Said et al. (2003), and HassabElnaby et al. (2005) conclude that these metrics refocus managerial actions on a long-term strategy that could improve both the firms' financial. Ittner et al. (2003) showed that the more extensive use of non-financial measures leads to higher returns in the stock market. Russo and Harrison (2005), Flammer et al. (2016), and Velte (2016) documented positive impacts of sustainability standards in compensation contracts on the firm’s social and environmental performance. Mahoney and Thorn (2006) show that the percentage of bonus payment on total CEO compensation and the percentage of stock options on total CEO compensation has a significantly positive effect on a firm's CSR strength. Berrone and Gomez-Mejia (2009) found that CSR-linked compensation has a positive impact on the environmental performance of companies, especially firms in high-polluting industries. Hong et al. (2016) conclude that “providing executives with direct incentives for CSR is an effective tool to increase firm social performance”. Winschel and Stawinoga (2019) conclude that sustainability-oriented CEO compensation has a positive influence on the combined economic, environmental, and social performance of an enterprise.

However, there are some of the existing literature show that ESG-based compensation has a negative impact on firms. Coombs and Gilley (2005) confirm the negative relationship between executive salaries and stakeholder management. They suggest that stakeholder management reduces the rewards of CEOs to increase levels of financial performance. Beck et al. (2018) find a significant relationship between CSR engagement and financial performance across three reporting jurisdictions: Australia, Hong Kong, and the United Kingdom. D'apolito et al. (2019) analyzed the financial and non-financial impacts of the use of sustainability standards in banks' executive compensation plans by covering all the globally and systemically important European banks from 2013 to 2017 as a sample. They show that the implementation of sustainable criteria in the banks' remuneration contracts was found to negatively impact economic performance, to negatively impact the riskiness profile, and to positively impact sustainability performance. It is found that the implementation of sustainability standards in banks’ compensation contracts has a negative relationship between economic performance, has a negative relationship between risk status, and has a positive relationship between sustainability performance.

This current paper will contribute in several aspects. First, we will discuss adding ESG to the manager's compensation and use the duopoly competition model to analyze the impact on firms' strategies such as output, R&D, and advertisement. At the same time, we also analyze the impact of adding ESG to the manager’s compensation on HHI which is an index to measure the market concentration. And we will also analyze the owner’s optimal share of the ESG component in managerial compensation. Second, we will use the penalty mechanism to analyze the impact of ESG on the firm's strategy. At the same time, we will compare the impact of using fixed penalty and using proportional penalty in the model. It is

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a trend for firms to consider ESG in their strategies, but there is currently no specific study on compensation and penalty.

3. The Effects of ESG Performance

To investigate the effects of firms' sustainability activities on their competitive strategies, we consider a duopoly market with differentiated products.

The reason for assuming differentiated product competition is because strategies such as sustainable performance or R&D might enhance brand recognition, which will increase the firm's demand. Some references are supporting that sustainability activities will increase demand and consumer recognition, such as Luo and Bhattacharya (2006, 2009), Jones (1995), Baron (2011), and Lin et al. (2021).

However, if we assume a model of homogeneous competition, consumers will have no difference in brand recognition for the products produced by the two firms. Specifically, we follow Dixit (1979) and Singh and Vives (1984) by assuming the following demand function for firm *i*, *i=1,2*:

$$P_i = \alpha_i - \beta_i q_i - \gamma_i q_j,$$

where *Pi* denotes product *i*'s price and q_i indicates product *i*'s output. $\beta_i > \frac{3}{2}$ indicates product *i*'s own price effect and $\gamma_i > 0$ indicates product *j*'s cross-price effect on the product *i*. We assume that the own price effect is greater than the cross-price effect: $\beta_i > \gamma_i$.

We consider three competitive strategies: output (q_i), R&D (denoted as r_i), and advertisements (denoted as A_i). The R&D investment can result in cost-saving process innovation. For example, Bernstein (1988) evaluated Canadian industries and found that intra-industry and inter-industry spillovers reduced the marginal cost of production.

DOI:10.6814/NCCU202101246

Bromiley, Washburn (2011) use empirical analysis to support that R&D can reduce costs. To simplify the analysis, we assume a linear product cost $c_i q_i$, and r_i can reduce the marginal cost to $(c_i - r_i)$. Next, the advertisement can change consumers' brand recognition toward brand *i*. For example, Ansari and Joloudar (2011) found that TV advertisements can effectively enhance customers' attention and interest. The effect of advertisement is captured by an upward shift of the demand function. That is, firm *i*'s advertisement A_i can increase the demand to $(\alpha_i + A_i)$. Both the costs of r_i and A_i are assumed to be quadratic, i.e., $\frac{{r_i}^2}{2}$ and $\frac{{A_i}^2}{2}$.

The ESG activities can increase brand recognition and increase corporate government and employee welfare. To simplify the analysis, we assume that the sustainability activities can increase brand recognition and their demand. Supporting evidence that sustainability activities will increase demand and consumer recognition can be found in Luo and Bhattacharya (2006, 2009), Jones (1995), Baron (2011), and Lin et al. (2021). That is, let s_i indicate firm *i*'s sustainability activities and s_i can also increase brand *i*'s market demand to $(\alpha_i + s_i)$. The cost of s_i is also quadratic i.e., $\frac{{s_i}^2}{2}$. Notice that both ESG activities and advertisement can increase firms' market demand. We will later demonstrate whether the two strategies are complementary or substitutive. As described earlier, the increasing evidence shows that more and more companies include the ESG performance in their managerial compensations. The effects of the two strategies need to be discussed separately.

To sum up, firm *i*'s profit function after considering the effects from R&D, advertising, and sustainability activities are given by

$$\pi_i = (\alpha_i + A_i + s_i - \beta_i q_i - \gamma_i q_j) q_i - (c_i - r_i) q_i - \frac{{r_i}^2}{2} - \frac{{A_i}^2}{2} - \frac{{s_i}^2}{2}. \qquad (P1)$$

DOI:10.6814/NCCU202101246

To clarify the effects of ESG performance, we proceed with the analysis in two steps. We first characterize the market equilibrium, by treating s_i as a parameter or exogenous variable. Given a nonnegative value of s_i, we can have a clear picture of how s_i affects the firm's three competitive strategies and their values in equilibrium. Next, we characterize the full equilibrium by solving the equilibrium values of s_i.

3.1 Treating s_i as Exogenous

By treating s_i as an exogenous variable, we can clarify the effects of s_i on other competitive strategies. We first calculate the first order conditions (FOC) for q_i, r_i, and A_i as follows.

$$\frac{\partial \pi_i}{\partial q_i} = \left(\alpha_i + A_i + s_i - 2\beta_i q_i - \gamma_i q_j\right) - c_i + r_i = 0, \quad (1)$$

$$\frac{\partial \pi_i}{\partial r_i} = q_i - r_i = 0, \quad (2)$$

$$\frac{\partial \pi_i}{\partial A_i} = q_i - A_i = 0. \quad (3)$$

From equations (2) and (3), we have $r_i = A_i = q_i$. In our model, both R&D and advertisement have the same marginal effect on revenue, and due to the quadratic cost function, they have the same marginal cost. Substituting these values into equation (1) gives for *i=1,2*,

$$\alpha_i + s_i - (2\beta_i - 2)q_i - \gamma_i q_j = c_i. \quad (4)$$

Then, we use Cramer's rule on equation (4) to solve the equilibrium output:

$$\begin{bmatrix} 2\beta_1 - 2 & \gamma_1 \\ \gamma_2 & 2\beta_2 - 2 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} \alpha_1 + s_1 - c_1 \\ \alpha_2 + s_2 - c_2 \end{bmatrix}.$$

DOI:10.6814/NCCU202101246

So, the equilibrium q_i, r_i ,and A_i are

$$q_i^* = r_i^* = A_i^* = \frac{(2\beta_j - 2)(\alpha_i + s_i - c_i) - \gamma_i(\alpha_j + s_j - c_j)}{4(\beta_i - 1)(\beta_j - 1) - \gamma_i\gamma_j}, \qquad (5)$$

provided that $4(\beta_i - 1)(\beta_j - 1) > \gamma_i\gamma_{j.}$

The effects of ESG performance are captured by the following partial differentiation on the equilibrium. That is,

$$\frac{\partial q_i^*}{\partial s_i} = \frac{\partial r_i^*}{\partial s_i} = \frac{\partial A_i^*}{\partial s_i} = \frac{2\beta_j - 2}{4(\beta_i - 1)(\beta_j - 1) - \gamma_i\gamma_j} > 0, \qquad (6)$$

$$\frac{\partial q_i^*}{\partial s_j} = \frac{\partial r_i^*}{\partial s_j} = \frac{\partial A_i^*}{\partial s_j} = \frac{-\gamma_i}{4\beta_i\beta_j - \gamma_i\gamma_j} < 0. \qquad (7)$$

Equation (6) shows that the effects of own ESG performance are all positive, indicating that ESG activities are complementary to all three competitive strategies. Equation (7) describes that the effects of cross ESG performance are all negative. This is because the two firms are compositing with outputs, and the two outputs are strategic substitutes. So, given the positive own ESG effects, the cross ESG effects are negative.

It is interesting to notice that these ESG effects are only related to elasticity (β_i) and the degree of product differentiation (γ_i), but not related to market size (α_i) or production efficiency (c_i). In particular, from equation (6), we can calculate how these effects are sensitive to elasticity and the degree of product differentiation. Here since the effects on q_i^*, r_i^* *and* A_i^* are the same, we only present the cross differentiations of q_i^* below.

DOI:10.6814/NCCU202101246

$$\frac{\partial^2 q_i{}^*}{\partial s_i \partial \beta_i} = \frac{-8(\beta_j - 1)^2}{[4(\beta_i - 1)(\beta_j - 1) - \gamma_i\gamma_j]^2} < 0, \tag{8}$$

$$\frac{\partial^2 q_i{}^*}{\partial s_i \partial \beta_j} = \frac{-2\gamma_i\gamma_j}{[4(\beta_i - 1)(\beta_j - 1) - \gamma_i\gamma_j]^2} < 0. \tag{9}$$

$$\frac{\partial^2 q_i{}^*}{\partial s_i \partial \gamma_i} > 0, \quad and \quad \frac{\partial^2 q_i{}^*}{\partial s_i \partial \gamma_j} > 0. \tag{10}$$

Equation (8) shows that the own ESG effect will decrease with the own price elasticity. The intuition is: when the elasticity is higher, increasing output has a higher impact on profit, so the marginal effect of own ESG activities on demand is smaller, and hence the effect on the equilibrium outputs and other strategies are smaller.

Moreover, equation (10) shows that the own ESG effect will decrease with the degree of product differentiation. Notice that as γ_i increases, the two products become more homogenous (the degree of product differentiation is smaller), then more ESG can increase the brand recognition, thus increase the firm's demand more.

Similar arguments apply to the cross ESG effects but in different directions. It can be verified that $\frac{\partial^2 q_i{}^*}{\partial s_j \partial \beta_i} > 0$, $\frac{\partial^2 q_i{}^*}{\partial s_j \partial \beta_j} > 0$, $\frac{\partial^2 q_i{}^*}{\partial s_j \partial \gamma_i} < 0$, and $\frac{\partial^2 q_i{}^*}{\partial s_j \partial \gamma_j} < 0$.

Since the equilibrium profit is $(\beta_i - \frac{3}{2})(q_i{}^*)^2$. The above results apply to the equilibrium profits. Proposition 1 summarizes our findings.

Proposition 1: *(i) The effects of own ESG performance are all positive, indicating that ESG activities are complementary to all three competitive strategies and the profits. (ii) The own ESG effects decrease the own price elasticity (β_i) and the degree of product differentiation (γ_i), but not related to market size (α_i) or production efficiency (c_i).*

DOI:10.6814/NCCU202101246

Next, the Herfindahl–Hirschman Index (HHI) is an industry index to measure the degree of concentration in the market. In our case, HHI is defined as:

$$HHI = \left(\frac{{q_1}^*}{{q_1}^* + {q_2}^*}\right)^2 + \left(\frac{{q_2}^*}{{q_1}^* + {q_2}^*}\right)^2.$$

To simplify, let $k = \frac{{q_2}^*}{{q_1}^*}$, so HHI can be written as $\left(\frac{1}{1+k}\right)^2 + \left(\frac{k}{1+k}\right)^2$, which is also equal to $1 - 2\frac{k}{(1+k)^2}$. Hence, the effect of ESG performance on the degree of market competition is captured by the following partial differentiation.

First,

$$\frac{\partial(HHI)}{\partial k} = \frac{\partial[1 - 2\frac{k}{(1+k)^2}]}{\partial k} = \frac{2(k-1)}{(1+k)^3}.$$

That is, the effect of increasing k on the degree of concentration will depend on the relative sizes of ${q_1}^*$ and ${q_2}^*$. If $k > 1$, then increasing *k* will increase the degree of concentration; if $k < 1$, then increasing *k* will decrease the degree of concentration.

The intuition is as follows. When $k > 1$ $(i.e., {q_2}^* > {q_1}^*)$, then increasing *k* will increase the difference between the two equilibrium outputs, thus increasing the degree of concentration. On the other hand, when $k < 1$ $(i.e., {q_2}^* < {q_1}^*)$, then increasing *k* will reduce the difference between the two equilibrium outputs, thus decreasing the degree of concentration.

Next, we can calculate the marginal effects of s_1 and s_2 on *k*. That is,

$$\frac{\partial k}{\partial s_1} = \frac{\frac{\partial {q_2}^*}{\partial s_1}({q_1}^*) - \frac{\partial {q_1}^*}{\partial s_1}({q_2}^*)}{({q_1}^*)^2} < 0,$$

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$$\frac{\partial k}{\partial s_2} = \frac{\frac{\partial q_2{}^*}{\partial s_2}(q_1{}^*) - \frac{\partial q_1{}^*}{\partial s_2}(q_2{}^*)}{(q_1{}^*)^2} > 0.$$

According to equations (6) and (7), we know that $\frac{\partial k}{\partial s_1} < 0$, and $\frac{\partial k}{\partial s_2} > 0$.

Thus, the overall effects on HHI are:

$$\frac{\partial(HHI)}{\partial k}\frac{\partial k}{\partial s_1} \quad and \quad \frac{\partial(HHI)}{\partial k}\frac{\partial k}{\partial s_2}.$$

First, the effect of increasing s_2 is the same as the effect of increasing *k*, as $\frac{\partial k}{\partial s_2} > 0$. Second, the effect of increasing s_1 is contrary to the effect of increasing *k*, as $\frac{\partial k}{\partial s_1} < 0$. Specifically, when $k > 1$ $(i.e., q_2{}^* > q_1{}^*)$, then increasing s_1 will reduce the relative sizes of $q_2{}^*$ and $q_1{}^*$ (decreasing *k*), so the effect is to decrease the degree of market concentration; when $k < 1$ $(i.e., q_2{}^* < q_1{}^*)$, then increasing s_1 will also increase the relative sizes of $q_2{}^*$ and $q_1{}^*$ (decreasing *k*), so the effect is to increase the degree of market concentration. Proposition 2 summarizes our findings.

Proposition 2: *(i) When* $q_2{}^* > q_1{}^*$, *then increasing* s_2 *will increase the degree of concentration; when* $q_2{}^* < q_1{}^*$, *then increasing* s_2 *will reduce the degree of concentration. (ii) The effect of increasing* s_1 *on market concentration is contrary to the effect of increasing* s_2.

Corollary 1 is an immediate result of Proposition 2.

Corollary 1: *When large firms increase the ESG activities, the degree of concentration will increase, while small firms increase ESG activities, the degree of concentration will decrease.*

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3.2 Full Equilibrium (s_i endogenous)

When s_i is determined in the equilibrium, the equilibrium values of the three competitive strategies become too complicated to identify the effects of firms' ESG performance. Our analyses in the previous section help us at least clarify these effects. The full characterization of the equilibrium in this section is needed to understand the determinants of the ESG activities.

In addition to equation (1)~(3), we add the FOC for s_i:

$$\frac{\partial \pi_i}{\partial s_i} = q_i - s_i = 0. \tag{11}$$

This suggests that s_i and s_j are strategic substitutes. Next, from equations (2), (3) and (11), we have $r_i = A_i = s_i = q_i$. As described earlier, this is because in our setup, the marginal revenues of r_i, A_i, and s_i are the same and due to the quadratic cost function, they have the same marginal cost. Substituting these values into equation (1) gives for *i=1,2*,

$$\alpha_i - (2\beta_i - 3)q_i - \gamma_i q_j = c_i. \tag{12}$$

Then, we use Cramer's Rule to solve the equilibrium output:

$$\begin{bmatrix} 2\beta_1 - 3 & \gamma_1 \\ \gamma_2 & 2\beta_2 - 3 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} \alpha_1 - c_1 \\ \alpha_2 - c_2 \end{bmatrix}.$$

So, the equilibrium q_i, r_i, A_i and s_i are:

$$q_i^* = r_i^* = A_i^* = s_i^* = \frac{(2\beta_j - 3)(\alpha_i - c_i) - \gamma_i(\alpha_j - c_j)}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j}. \tag{13}$$

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Note that by assumption, $(2\beta_i - 3)(2\beta_j - 3) > \gamma_i\gamma_j$. The equilibrium profit is: $(\beta_i - \frac{3}{2})(q_i{}^*)^2$. Equation (13) shows that ESG activities are determined by market size, production efficiency as well as elasticity, and the degree of product differentiation. First, it is obvious that

$$\frac{\partial s_i{}^*}{\partial a_i} > 0 \quad and \quad \frac{\partial s_i{}^*}{\partial a_j} < 0.$$

Firm *i*'s ESG activities will increase with its own market size and decrease with the rival firm's market size. This suggests that larger firms, with larger sizes of potential customers, will engage in more ESG activities. This also forms a pressure on the rival firm, since due to strategic substitution, the smaller firm will further reduce its ESG activities. Similarly, it is also obvious from equation (13) that $\frac{\partial s_i{}^*}{\partial c_i} < 0$ and $\frac{\partial s_i{}^*}{\partial c_j} > 0$. This suggests that more efficient firms will increase their ESG activities.

Next, to clarify the effects of elasticity, we can rewrite the equilibrium as:

$$s_i{}^* = \frac{(\alpha_i - c_i) - \frac{\gamma_i(\alpha_j - c_j)}{(2\beta_j - 3)}}{(2\beta_i - 3) - \frac{\gamma_i\gamma_j}{(2\beta_j - 3)}}.$$

It is obvious that $\frac{\partial s_i{}^*}{\partial \beta_i} < 0$ and $\frac{\partial s_i{}^*}{\partial \beta_j} > 0$. This suggests that the firm with a higher elasticity will use price reduction to push up market demand, and use fewer ESG activities.

Finally, we can also rewrite equation (13) as

$$s_i{}^* = \frac{\frac{(2\beta_j - 3)(\alpha_i - c_i)}{\gamma_i} - (\alpha_j - c_j)}{\frac{(2\beta_i - 3)(2\beta_j - 3)}{\gamma_i} - \gamma_j}.$$

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It is obvious that $\frac{\partial s_i{}^*}{\partial \gamma_i} < 0$ and $\frac{\partial s_i{}^*}{\partial \gamma_j} > 0$. This suggests that the firm with a higher degree of production differentiation (smaller γ_i) will use more ESG activities to boost up its market demand. Proposition 3 summarizes our findings.

Proposition 3: *(i) The firm with larger sizes of potential customers will engage in more ESG activities, which will further reduce the smaller competitors' ESG activities. (ii) More efficient firms will increase their ESG activities. (iii) The firm with a higher elasticity will use price reduction to push up market demand, and use fewer ESG activities. (iv) The firm with a higher degree of production differentiation will use more ESG activities to boost up their market demand.*

In the next section, we examine the effects of tying managerial compensation with firms' ESG performance. In the first model (Section 4), a proportion of managerial compensation is based on ESG performance. In the second model (Section 5), the manager will receive a penalty if the ESG performance falls below a predetermined level. We are concerned whether these schemes can help increase the ESC activities, and how the other competitive strategies are affected by such schemes.

4. ESG-Based Managerial Compensation

To simplify the analysis, we assume that a predetermined proportion θ_i of manager *i*'s compensation is based on firm *i*'s ESG performance. The assumptions for the differentiated product market and cost functions remain the same as Section 3. Also, we consider three competitive strategies: output, R&D, and advertising. Let M_i indicate manager *i*'s compensation, and we consider the following form:

$$M_i = (1 - \theta_i)\pi_i + \theta_i s_i, \qquad \text{(P2)}$$

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where π_i is firm i's profit as defined as (P1) in Section 3.

We assume the following sequence of actions. First, each owner or shareholders' board decides the level of θ_i to maximize $(\pi_i - M_i)$. Second, the two managers compete in the market using their outputs, R&D, advertising, and ESG strategies. We will solve the subgame perfect equilibrium for this game by backward induction.

First, the maximization problem faced by manager i is:

$$\max_{q_i, r_i, A_i, s_i} M_i = (1-\theta_i)\left[\left(\alpha_i + A_i + s_i - \beta_i q_i - \gamma_i q_j\right)q_i - (c_i - r_i)q_i - \frac{{r_i}^2}{2} - \frac{{A_i}^2}{2} - \frac{{s_i}^2}{2}\right] + \theta_i s_i.$$

Notice that the ESG activities are now endogenously solved in the equilibrium. We can calculate the FOCs for q_i, r_i, A_i and s_i as follows.

$$\frac{\partial M_i}{\partial q_i} = (1-\theta_i)\left[\left(\alpha_i + A_i + s_i - 2\beta_i q_i - \gamma_i q_j\right) - c_i + r_i\right] = 0, \quad (14)$$

$$\frac{\partial M_i}{\partial r_i} = q_i - r_i = 0, \quad (15)$$

$$\frac{\partial M_i}{\partial A_i} = q_i - A_i = 0, \quad (16)$$

$$\frac{\partial M_i}{\partial s_i} = (1-\theta_i)(q_i - s_i) + \theta_i = 0. \quad (17)$$

The FOCs (14)~(16) are the same as equations (1)~(3), so we have $r_i = A_i = q_i$. The best replies of s_i are affected by q_i and θ_i:

$$s_i = q_i + \frac{\theta_i}{1-\theta_i}.$$

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Compared to the case without the ESG related compensation (equation (11)), the best reply of s_i is lifted up by a nonnegative term $\frac{\theta_i}{1-\theta_i}$, which increases with θ_i. Substitute these best replies to equation (14) and we have:

$$\alpha_i - (2\beta_i - 3)q_i - \gamma_i q_j = c_i - \frac{\theta_i}{1-\theta_i}. \quad (18)$$

Then we use Cramer's Rule to solve the equilibrium output:

$$\begin{bmatrix} 2\beta_1 - 3 & \gamma_1 \\ \gamma_2 & 2\beta_2 - 3 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} \alpha_1 - c_1 + \dfrac{\theta_1}{1-\theta_1} \\ \alpha_2 - c_2 + \dfrac{\theta_2}{1-\theta_2} \end{bmatrix}$$

So the equilibrium q_i, r_i, A_i are:

$$q_i{}^c = r_i{}^c = A_i{}^c = \frac{(2\beta_j - 3)\left(\alpha_i - c_i + \dfrac{\theta_i}{1-\theta_i}\right) - \gamma_i(\alpha_j - c_j + \dfrac{\theta_j}{1-\theta_j})}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j}. \quad (19)$$

The superscript "c" indicates the case with ESG-related compensation. According to equation (17), the equilibrium $s_i{}^c$ is:

$$s_i{}^c = q_i{}^c + \frac{\theta_i}{1-\theta_i}. \quad (20)$$

4.1 Equilibrium Comparison (with vs without θ_i)

Compared to the equilibrium without ESG related compensation (equation (13)), the difference of $(q_i{}^c - q_i{}^*)$ is:

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$$\frac{(2\beta_j - 3)\frac{\theta_i}{1-\theta_i} - \gamma_i \frac{\theta_j}{1-\theta_j}}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j}. \qquad (21)$$

This indicates that the effect of ESG related compensation will depend on the relative sizes of θ_i and θ_j. Notice that $\frac{\theta_i}{1-\theta_i}$ increases with θ_i. Equation (21) indicates that if θ_i is sufficiently higher than θ_j such that

$$\frac{\frac{\theta_i}{1-\theta_i}}{\frac{\theta_j}{1-\theta_j}} > \frac{\gamma_i}{(2\beta_j - 3)},$$

then the effects of ESG compensation are positive. Moreover, in the symmetric case where $\theta_i = \theta_j$, the condition for a positive effect is that the degree of production differentiation is sufficiently high, i.e.,

$$\gamma_i < (2\beta_j - 3), \text{ or } \beta_j > \frac{\gamma_i + 3}{2}.$$

The intuition is as follows. First, the ESG-related compensation gives the manager an incentive to increase ESG activities, as demonstrated by equation (17). When both firms are using ESG compensation, the opponent's choice of θ_j has a negative impact on each firm's strategies through market interaction. Hence when θ_i is sufficiently higher than θ_j, then the positive effect will dominate and lead to an increase in the equilibrium. Second, even in the symmetric case, the incentive to increase s_i alone can have a positive effect if the degree of product differentiation (or substitution) is sufficiently high (low). In this case, the negative effect from the rival's increase in s_j will be smaller than the positive effect. Alternatively, this requires the rival's slope (or elasticity) to be high (low) enough, so that the negative effect

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from market interaction will be relatively small. Figures 1 and 2 depict the cases where the overall effects are positive and negative, respectively.

As for the impact on s_i, the difference of $({s_i}^c - {s_i}^*)$ is:

$$({q_i}^c - {q_i}^*) + \frac{\theta_i}{1 - \theta_i}.$$

This indicates that if the equilibrium output is increased, then ${s_i}^c > {s_i}^*$. However, even when the opponent's θ_j is sufficiently higher than θ_i so that ${q_i}^c < {q_i}^*$, this implies that it is still possible that ${s_i}^c > {s_i}^*$ if θ_i is high enough. Proposition 4 summarizes our findings.

Proposition 4: *(i) The adoption of ESG-related compensation can increase or decrease the equilibrium output, depending on whether a firm's ESG component in compensation is sufficiently higher than the opponents'. (ii) Even when the two firms have the same ESG component, the adoption of ESG-related compensation can increase the equilibrium output if the degree of product differentiation (or substitution) is sufficiently high (low), or if the rival's slope (or elasticity) to be high (low) enough.*

Figure 1 demonstrates the case where $(\frac{\theta_i}{1-\theta_i} / \frac{\theta_j}{1-\theta_j}) > \frac{\gamma_i}{(2\beta_j - 3)}$. E_1 indicates the equilibrium without the ESG related compensation. The best replies of q_i are given by equation (12):

$$\alpha_i - (2\beta_i - 3)q_i - \gamma_i q_j = c_i.$$

E_2 indicates the equilibrium with the ESG related compensation. The best replies of q_i are given by equation (18):

$$\alpha_i - (2\beta_i - 3)q_i - \gamma_i q_j = c_i - \frac{\theta_i}{1 - \theta_i}.$$

DOI:10.6814/NCCU202101246

The ESG-related compensation will shift out the best reply function by $\frac{\theta_i}{1-\theta_i}$. When $\left(\frac{\theta_i}{1-\theta_i} / \frac{\theta_j}{1-\theta_j}\right) > \frac{\gamma_i}{(2\beta_j-3)}$, both firms' outputs will increase, as indicated by E_2.

However, this is not the only result. Our analysis shows that if the degree of product differentiation is not sufficiently high, or if the rival's elasticity of demand is not sufficiently high (such that $\gamma_i \nless (2\beta_j - 3)$, or $\beta_j \ngtr \frac{\gamma_i+3}{2}$), then the firm's equilibrium output may decrease, as depicted by Figure 2.

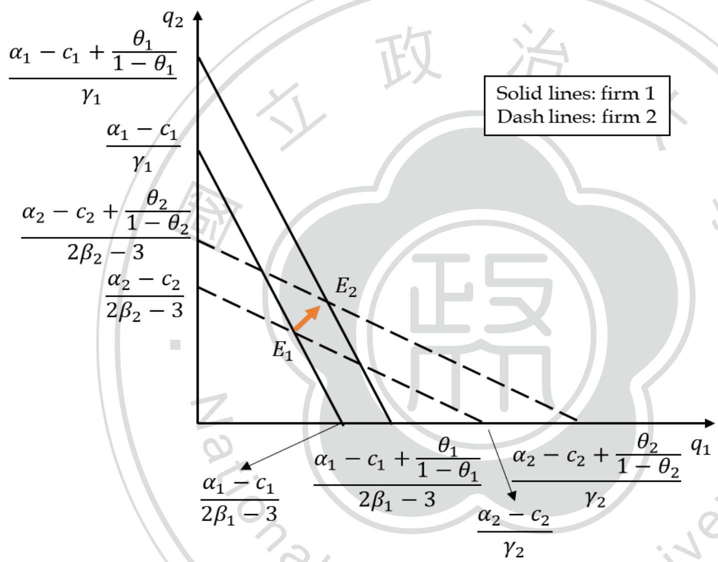

Figure 1 The ESG compensations increases the equilibrium outputs.

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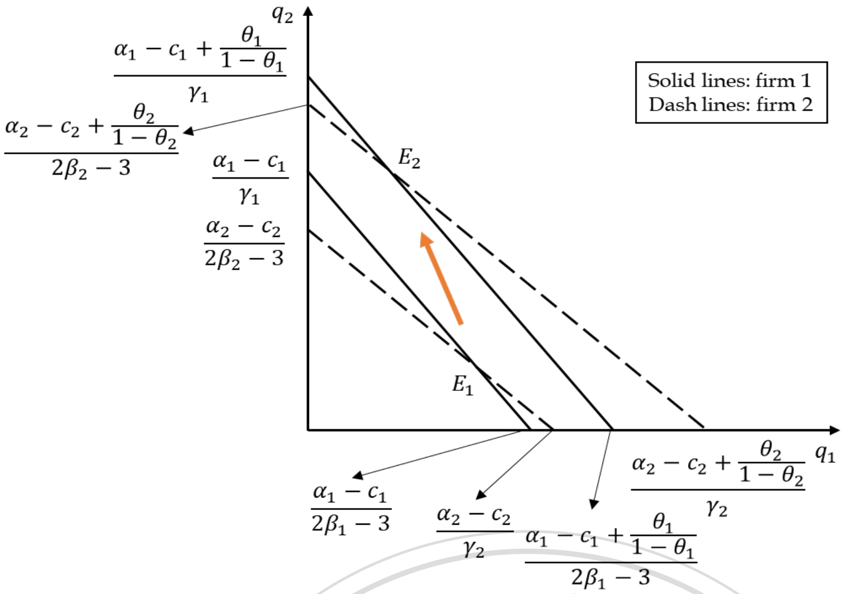

Figure 2 The ESG compensations may decrease the equilibrium output.

Finally, we examine how ESG based compensation affects the market concentration. Recall the definition of HHI from Section 3 and $k = \frac{q_2}{q_1}$. The marginal effect of changing k is:

$$\frac{\partial(HHI)}{\partial k} = \frac{2(k-1)}{(1+k)^3}.$$

We now need to calculate $\frac{\partial k}{\partial \theta_1}$ and $\frac{\partial k}{\partial \theta_2}$. Recall the equilibrium output $q_i{}^c$ from equation (19), so we have

$$\frac{\partial q_i{}^c}{\partial \theta_i} = \frac{\frac{2\beta_j - 3}{(1-\theta_i)^2}}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j} > 0,$$

$$\frac{\partial q_i{}^c}{\partial \theta_j} = \frac{\frac{-\gamma_i}{(1-\theta_j)^2}}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j} < 0.$$

Hence we have:

$$\frac{\partial k}{\partial \theta_1} = \frac{\frac{\partial q_2{}^c}{\partial \theta_1}(q_1{}^c) - \frac{\partial q_1{}^c}{\partial \theta_1}(q_2{}^c)}{(q_1{}^c)^2} < 0,$$

$$\frac{\partial k}{\partial \theta_2} = \frac{\frac{\partial q_2{}^c}{\partial \theta_2}(q_1{}^c) - \frac{\partial q_1{}^c}{\partial \theta_2}(q_2{}^c)}{(q_1{}^c)^2} > 0.$$

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Thus, the overall effects on HHI are:

$$\frac{\partial(HHI)}{\partial k}\frac{\partial k}{\partial \theta_1} \quad and \quad \frac{\partial(HHI)}{\partial k}\frac{\partial k}{\partial \theta_2}.$$

Our results show that the effects of ESG-related compensation have the same directions as s_i. Proposition 5 summarizes our findings.

Proposition 5: *(i) When* ${q_2}^c > {q_1}^c$*, then increasing* θ_2 *will increase the degree of concentration; when* ${q_2}^c < {q_1}^c$*, then increasing* θ_2 *will reduce the degree of concentration. (ii) The effect of increasing* θ_1 *on market concentration is contrary to the effect of increasing* θ_2.

Corollary 2 is an immediate result of Proposition 5.

Corollary 2: If *Large firms adopt the ESG-based compensation, the degree of concentration will increase. On the contrary, if small firms use the ESG compensation, the degree of concentration will decrease.*

4.2 Equilibrium θ_i

Given the equilibrium ${q_i}^c$, ${r_i}^c$, ${A_i}^c$, and ${s_i}^c$, we now solve the equilibrium θ_i to maximize $(\pi_i - M_i)$. Since $M_i = (1-\theta_i)\pi_i + \theta_i s_i$, the board's objective becomes:

$$\max_{\theta_i}(\pi_i - M_i) = \theta_i\{(\beta_i - 1)({q_i}^c)^2 - \frac{1}{2}\left({q_i}^c + \frac{\theta_i}{1-\theta_i}\right)^2 - {q_i}^c - \frac{\theta_i}{1-\theta_i}\}.$$

DOI:10.6814/NCCU202101246

Notice that the equilibrium profit π_i is: $(\beta_i - 1)({q_i}^c)^2 - \frac{1}{2}\left({q_i}^c + \frac{\theta_i}{1-\theta_i}\right)^2$. We consider the case with a positive managerial incentive, and hence we ignore the first θ_i in the maximization problem. The FOC is:

$$\frac{\partial(\pi_i - M_i)}{\partial\theta_i} = \frac{\partial\left\{(\beta_i - 1){q_i}^{c2} - \frac{1}{2}\left({q_i}^c + \frac{\theta_i}{1-\theta_i}\right)^2 - {q_i}^c - \frac{\theta_i}{1-\theta_i}\right\}.}{\partial\theta_i} = 0.$$

To have a clear presentation, we refer to the Appendix for the detailed calculation of θ_i. In Appendix, we let $X_i = \frac{1}{1-\theta_i}$, and $X_j = \frac{1}{1-\theta_j}$. Hence $\frac{\partial X_i}{\partial\theta_i} = \left(\frac{1}{1-\theta_i}\right)^2 = {X_i}^2$. Hence we can rewrite ${q_i}^c$ in equation (19) as:

$${q_i}^c = AX_i - BX_j + C,$$

where $A = \frac{(2\beta_j - 3)}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j}$, $B = \frac{\gamma_i}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j}$, and $C = \frac{(2\beta_j - 3)(\alpha_i - c_i - 1) - \gamma_i(\alpha_j - c_j - 1)}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j}$. Notice that A, B, and C are all related to demand elasticities and the degree of product differentiation. In addition, C is increasing in α_i and c_j, and decreasing in c_i and a_j.

From the FOC, we can first show that

$$X_i = \frac{[A(2\beta_i - 3) - 1](BX_j - C)}{(2\beta_i - 3)A^2 - 2A - 1}.$$

The best replies of X_i are positively related to X_j. In other words, both θ_i and θ_j are strategic complements.

Next, we can focus on the symmetric equilibrium where $X_i = X_j$. Substitute this assumption in equation (A1), we have the symmetric equilibrium where

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$$X_i = \frac{[A(2\beta_i - 3) - 1]C}{A + 1 - [A(2\beta_i - 3) - 1](A - B)}.$$

Hence

$$\theta_i{}^c = \theta_j{}^c = 1 - \frac{A + 1 - [A(2\beta_i - 3) - 1](A - B)}{[A(2\beta_i - 3) - 1]C}.$$

$\theta_i{}^c$ increases with C. Thus the equilibrium increases with α_i and c_j and decreases with c_i and a_j. Proposition 6 summarizes our findings.

Proposition 6: *The equilibrium share of the ESG component in managerial compensation will increase with market scale and production efficiency.*

A firm with a higher market scale or more efficient production technology tends to adopt a higher share of the ESG component in the managerial compensation.

5. Penalty Schemes

In Section 4 we have addressed the effects of ESG-based compensations on firms' competitive strategies and their ESG performance. We have shown that, through market interactions, the effects will depend on each firm's relative sizes of the ESG component, the degree of product differentiation, and the degree of elasticity.

In this section, we turn to the other direction and examine the effects of penalty schemes. Given a predetermined level of ESG threshold ($\underline{S}$), we will examine two penalty schemes if the firm's ESG performance falls below this threshold. The first is to penalize the firm with a fine F_i, and the second considers a penalty which is a proportion φ of the firm's profit.

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5.1 Fixed Penalty

To focus on the effect of a penalty, we consider a simplified model by dropping the R&D and advertising strategies. To study how the existence of a penalty can change the effort to improve the ESG performance, we consider an uncertain relationship between effort and ESG performance. Specifically, let e_i indicate manager *i*'s effort on ESG activities. The actual ESG performance s_i is equal to $e_i + \epsilon$, where $\epsilon \sim U[-\varepsilon,\ \varepsilon]$. If s_i falls below a threshold $\underline{S}$, then the manager will receive a fine F_i and let $\rho(e_i)$ indicate this probability.

Figure 3 illustrates the probability of being penalized. For example, when $e_i = \underline{S}$, the ESG performance ranges from $\underline{S} - \varepsilon$ to $\underline{S} + \varepsilon$. So, there is a chance $\frac{\underline{S}-(\underline{S}-\varepsilon)}{2\varepsilon} = \frac{1}{2}$ that the manager will receive the fine. If $e_i \leq \underline{S} - \varepsilon$, then $\rho(e_i) = 1$. On the contrary, if $e_i \geq \underline{S} + \varepsilon$ then $\rho(e_i) = 0$. For the intermediate level, $\rho(e_i) = \frac{\underline{S}-(e_i-\varepsilon)}{2\varepsilon}$. That is,

$$\rho(e_i) = \begin{cases} 1 & \text{if } e_i \leq \underline{S} - \varepsilon \\ \frac{\underline{S}-(e_i-\varepsilon)}{2\varepsilon} & \text{if } \underline{S} - \varepsilon \leq e_i \leq \underline{S} + \varepsilon \\ 0 & \text{if } \underline{S} + \varepsilon \leq e_i \end{cases} \tag{22}$$

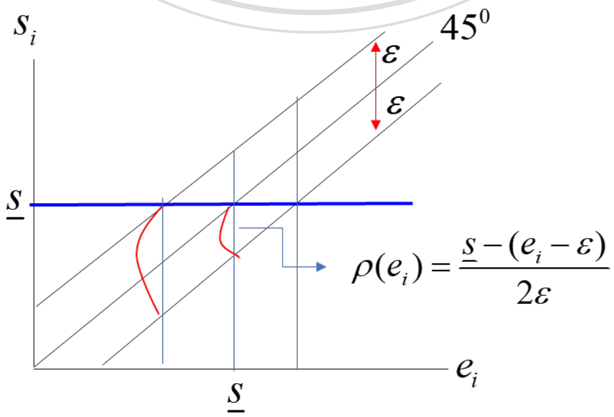

Figure 3. The probability of being penalized.

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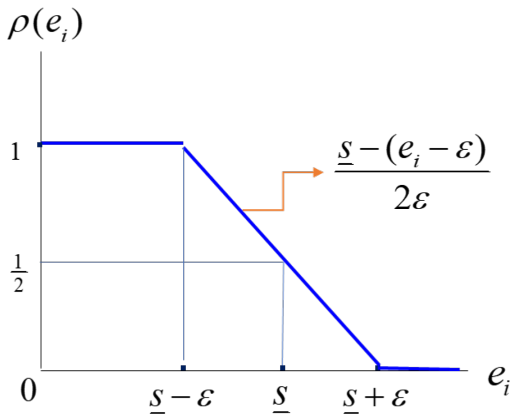

Figure 4. The probability of being penalized (II).

Figure 4 depicts the probability of penalization as a function of effort. From the definition of $\rho(e_i)$, we have

$$\frac{\partial \rho(e_i)}{\partial e_i} = -\frac{1}{2\varepsilon}.$$

That is, more effort can reduce the probability of being penalized if $\underline{S} - \varepsilon \leq e_i \leq \underline{S} + \varepsilon$. To investigate the effect of the penalty, we assume that the equilibrium effort will belong to this interval.

The maximization problem faced by manager *i* is:

$$\max_{q_i, e_i} \pi_i = \left(\alpha_i - \beta_i q_i - \gamma_i q_j + E(s_i)\right) q_i - c_i q_i - \frac{{e_i}^2}{2} - \rho(e_i) F_i.$$

Here, since $s_i = e_i + \epsilon$, with $\epsilon \sim U[-\varepsilon,\ \varepsilon]$, the expectation $E(s_i) = e_i$. We can calculate the FOCs for q_i, and e_i as follows.

$$\frac{\partial \pi_i}{\partial q_i} = \alpha_i - 2\beta_i q_i - \gamma_i q_j + e_i - c_i = 0, \quad (23)$$

$$\frac{\partial \pi_i}{\partial e_i} = q_i - e_i + \frac{F_i}{2\varepsilon} = 0. \quad (24)$$

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Equation (24) shows that the best replies of e_i are affected by $q_i, F_i,$ and ε:

$$e_i = q_i + \frac{F_i}{2\varepsilon}. \qquad (25)$$

Substitute the best replies of e_i to equation (23) and we have:

$$(2\beta_i - 1)q_i + \gamma_i q_j = \alpha_i + \frac{F_i}{2\varepsilon} - c_i.$$

Then we use Cramer's Rule to solve the equilibrium output.

$$\begin{bmatrix} 2\beta_1 - 1 & \gamma_1 \\ \gamma_2 & 2\beta_2 - 1 \end{bmatrix}\begin{bmatrix} q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} \alpha_1 + \frac{F_1}{2\varepsilon} - c_1 \\ \alpha_2 + \frac{F_2}{2\varepsilon} - c_2 \end{bmatrix}.$$

Firm *i*'s equilibrium output is

$$q_i^{\,f} = \frac{(2\beta_j - 1)\left(\alpha_i + \frac{F_i}{2\varepsilon} - c_i\right) - \gamma_i(\alpha_j + \frac{F_j}{2\varepsilon} - c_j)}{(2\beta_i - 1)(2\beta_j - 1) - \gamma_i\gamma_j}.$$

The superscript "*f*" indicates the case with a fixed penalty. It can be easily verified that

$$\frac{\partial q_i^{\,f}}{\partial F_i} = \frac{2\beta_j - 1}{2\varepsilon\left[(2\beta_i - 1)(2\beta_j - 1) - \gamma_i\gamma_j\right]} > 0,$$
$$\frac{\partial q_i^{\,f}}{\partial F_j} = \frac{-\gamma_i}{2\varepsilon\left[(2\beta_i - 1)(2\beta_j - 1) - \gamma_i\gamma_j\right]} < 0.$$

The existence of a fixed penalty will increase manager *i*'s incentive for the effort by $\frac{F_i}{2\varepsilon}$. This increase in effort can increase the expected ESG performance and customers' brand

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recognition and the demand for the product *i*. However, when both firms use fixed penalty to boost managers' efforts, the changes in equilibrium will also depend on the degrees of elasticities and product differentiation.

Compared to the equilibrium without this penalty (equation (13) with $(2\beta_i - 3)$ replaced by $(2\beta_i - 1)$), the extra term is:

$$\frac{(2\beta_j - 1)\frac{F_i}{2\varepsilon} - \gamma_i \frac{F_j}{2\varepsilon}.}{(2\beta_i - 1)(2\beta_j - 1) - \gamma_i\gamma_j}.$$

If $F_i = F_j = 0$, then this term becomes zero and the equilibrium will be the same. Also, this term is increasing in F_i and decreasing in F_j, indicating that the increase in equilibrium output will increase with F_i and decrease with F_j. Even with the symmetric case $F_i = F_j$, this increase in output will not be cancelled. Moreover, the size of ε measures the uncertainty of ESG performance. The higher level of uncertainty, the smaller the increase in equilibrium outputs. Proposition 7 summarizes our findings.

Proposition 7: *(i) Fixed penalties will increase managers' effort incentive, but the effect on equilibrium outputs will depend on the relative sizes of penalties. (ii) The effects on outputs will decrease with the level of uncertainty in ESG performance.*

5.2 Proportional penalty

In this subsection, we consider a proportional penalty if the firm's ESG performance falls below a threshold ($\underline{S}$). The proportional penalty is a proportion φ of the firm's profit. To be able to compare the two penalty schemes, we leave all other assumptions unchanged. That is, to investigate the effect of penalty, we assume that the equilibrium effort will belong to $[\underline{S} - \varepsilon, \underline{S} + \varepsilon]$.

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The maximization problem faced by manager *i* is:

$$\max_{q_i,e_i} \tilde{\pi}_i = \big(\alpha_i - \beta_i q_i - \gamma_i q_j + E(s_i)\big)q_i - c_i q_i - \frac{{e_i}^2}{2}$$
$$- \rho(e_i)\varphi\{\big(\alpha_i - \beta_i q_i - \gamma_i q_j + E(s_i)\big)q_i - c_i q_i\}.$$

$\rho(e_i)$ is the probability of receiving a penalty, which is a proportion φ of firm i's profit. We can calculate the FOCs for q_i, and e_i as follows.

$$\frac{\partial\, \pi_i}{\partial q_i} = \{\alpha_i - 2\beta_i q_i - \gamma_i q_j + e_i - c_i\}[1 - \rho(e_i)\varphi] = 0, \quad (26)$$
$$\frac{\partial\, \pi_i}{\partial e_i} = q_i(1 - \rho(e_i)\varphi) - e_i + \frac{\varphi}{2\varepsilon}\{\big(\alpha_i - \beta_i q_i - \gamma_i q_j + E(s_i)\big)q_i - c_i q_i\} = 0. \quad (27)$$

Equations (26) and (27) can be rewritten as：

$$\alpha_i - 2\beta_i q_i - \gamma_i q_j + e_i - c_i = 0,$$
$$e_i = (1 - \rho(e_i)\varphi)q_i + \frac{\varphi}{2\varepsilon}\{\big(\alpha_i - \beta_i q_i - \gamma_i q_j + e_i - c_i\big)q_i\}. \quad (28)$$

In other words, the FOC on q_i is the same as in the fixed penalty case. Next, we compare equation (28) with the FOC on e_i with the fixed penalty (i.e., equation (25)).

$$e_i = q_i + \frac{F_i}{2\varepsilon}.$$

Notice that if $\rho(e_i)\varphi$ is sufficiently small and $\frac{F_i}{\varphi} < \{\big(\alpha_i - \beta_i q_i - \gamma_i q_j + e_i - c_i\big)q_i\}$, then the effort with the proportional penalty in (28) is higher than the effort with a fixed penalty.

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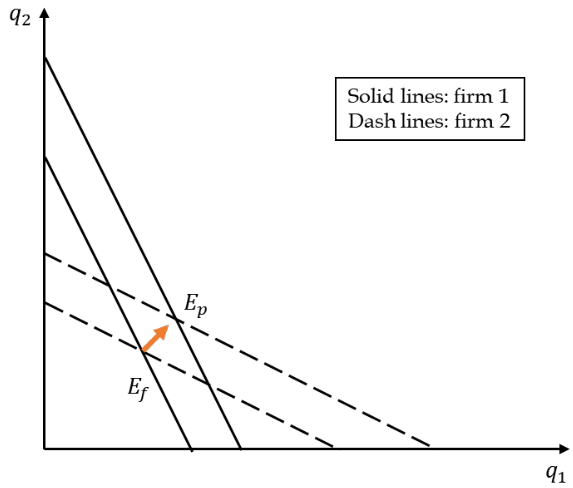

Figure 5. Fixed v.s. proportional penalties.

Since the FOCs on q_i are the same as for both cases, we can conclude that the equilibrium outputs with proportional penalties are higher than those with fixed penalties. The explicit solutions of q_i and e_i are complicated. We use Figure 5 to illustrate our point. In Figure 5, E_f and E_p indicate the equilibria with fixed and proportional penalties, respectively. Since the FOCs on q_i are the same as for both cases, the two cases are different in the only causes the difference in the intercepts of the best replies functions. With proportional penalties, the effort levels are higher, so the best replies will shift out and hence the equilibrium outputs are higher with proportional penalties. Proposition 8 summarizes our findings.

***Proposition** 8: If $\rho(e_i)\varphi$ and $\frac{F_i}{\varphi}$ are sufficiently small, then the equilibrium efforts and outputs are higher with the proportional penalties.*

6. Conclusions

We summarize the conclusions of this current paper. First, we incorporate ESG activities into the firms' competitive strategies and analyze the impact on the other three competitive

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strategies, which are output, R&D, and advertisement. We treat ESG as an exogenous variable, and we find that ESG activities are complementary to all three competitive strategies and the profits.

Moreover, we find that the own ESG effects decrease the own price elasticity and the degree of product differentiation, but not related to market size or production efficiency. Because when the elasticity is higher, increasing output has a higher impact on profit, the marginal effect of own ESG activities on demand is smaller, and the effect on the equilibrium outputs and other strategies are smaller. And when the degree of product differentiation is smaller, the two products become more homogenous, than more ESG can increase the brand recognition, thus increase the firm’s demand more.

About the market concentration, we find that when large firms increase the ESG activities, the degree of concentration will increase, while small firms increase ESG activities, the degree of concentration will decrease. Because if a large firm increases ESG activities, the size difference with the other firm will increase, and the degree of market concentration will increase. If a small firm increases ESG activities, the size difference with the other firm will decrease, and the degree of market concentration will decrease.

Then we analyze the full equilibrium by treating ESG as an endogenous variable. We find that the firm with larger sizes of potential customers will engage in more ESG activities, which will further reduce the smaller competitors’ ESG activities. And more efficient firms will increase their ESG activities. Moreover, we find that the firm with a higher elasticity will use price reduction to push up market demand, and use fewer ESG activities. The firm with a higher degree of production differentiation will use more ESG activities to boost up its market demand.

Second, we study the effects of tying managerial compensation on the firm's ESG performance and the equilibrium of this model. We analyze the difference between

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equilibrium with ESG related compensation and equilibrium without ESG related compensation.

We find that the inclusion of ESG-related compensation can increase or decrease the equilibrium output, depending on whether the firm's ESG component in compensation is sufficiently higher than opponents'. The reasons are as follows. The ESG-related compensation gives the manager an incentive to increase ESG activities. When both firms are using ESG compensation, the opponent's choice of the predetermined proportion of ESG-related compensation has a negative impact on each firm's strategies through market interaction. Hence when our predetermined proportion of ESG-related compensation is significantly higher than the opponent's predetermined proportion of ESG-related compensation, then the positive effect will dominate and lead to an increase in the equilibrium.

Even when the two firms have the same ESG component, the adoption of ESG-related compensation can increase the equilibrium output if the degree of product differentiation is sufficiently high, or if the rival's slope to be high enough. Because even in the symmetric case, the incentive to increase ESG activities alone can have a positive effect if the degree of product differentiation is sufficiently high. In this case, the negative effect from the rival's increase in their ESG activities will be smaller than the positive effect. Alternatively, this requires the rival's elasticity to be low enough, so that the negative effect from market interaction will be relatively small.

About the analysis of market concentration, we find that when large firms adopt the ESG-based compensation, the degree of concentration will increase, while small firms adopt the ESG-based compensation, the degree of concentration will decrease. The effects of ESG-related compensation have the same directions as the ESG activities.

We analyze the owner's strategy which is to decide the equilibrium share of the ESG component. We find that the equilibrium share of the ESG component in managerial

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compensation will increase with market scale and production efficiency. A firm with a higher market scale or more efficient production technology tends to adopt a higher share of the ESG component in the managerial compensation.

Third, we examine the effects of penalty schemes. About the analysis of how the existence of a fixed penalty improves ESG performance, we find that fixed penalties will increase managers' effort incentive on ESG activities. This increase in effort can increase the expected ESG performance and customers' brand recognition and the demand for the product. But the effect on equilibrium outputs will depend on the relative sizes of penalties. Moreover, the higher level of uncertainty, the smaller the increase in equilibrium outputs. About the analysis of how the existence of proportional penalty improves the ESG performance and compare it to the fixed penalty case. We find that the equilibrium efforts and outputs are higher with the proportional penalties.

Appendix: Equilibrium θ_i

To simplify the analysis, recall the definition of $q_i{}^c$ from equation (19).

$$q_i{}^c = \frac{(2\beta_j - 3)\left(\alpha_i - c_i + \frac{1}{1-\theta_i} - 1\right) - \gamma_i(\alpha_j - c_j + \frac{1}{1-\theta_j} - 1)}{(2\beta_i - 3)(2\beta_j - 3) - \gamma_i\gamma_j}.$$

We can redefine the following variables. First, let $X_i = \frac{1}{1-\theta_i}$, and $X_j = \frac{1}{1-\theta_j}$. Hence

$$\frac{\partial X_i}{\partial \theta_i} = \left(\frac{1}{1-\theta_i}\right)^2 = X_i{}^2.$$

Then we can rewrite $q_i{}^c$ in equation (19) as:

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$$q_i{}^c = AX_i - BX_j + C,$$

where $A = \frac{(2\beta_j-3)}{(2\beta_i-3)(2\beta_j-3)-\gamma_i\gamma_j}$, $B = \frac{\gamma_i}{(2\beta_i-3)(2\beta_j-3)-\gamma_i\gamma_j}$, and $C = \frac{(2\beta_j-3)(\alpha_i-c_i-1)-\gamma_i(\alpha_j-c_j-1)}{(2\beta_i-3)(2\beta_j-3)-\gamma_i\gamma_j}$.

Firm i's maximization problem is:

$$\max_{\theta_i}(\pi_i - M_i) = \theta_i\{(\beta_i - 1)(q_i{}^c)^2 - \frac{1}{2}\left(q_i{}^c + \frac{\theta_i}{1-\theta_i}\right)^2 - q_i{}^c - \frac{\theta_i}{1-\theta_i}\}.$$

The FOC of maximization is given by equation (22), where

$$\frac{\partial(\pi_i - M_i)}{\partial\theta_i} = \frac{\partial\left\{(\beta_i - 1)q_i{}^{c2} - \frac{1}{2}\left(q_i{}^c + \frac{\theta_i}{1-\theta_i}\right)^2 - q_i{}^c - \frac{\theta_i}{1-\theta_i}\right\}}{\partial\theta_i}$$

$$= (\beta_i - 1)\cdot 2q_i{}^c \cdot \frac{\partial q_i{}^c}{\partial X_i}\frac{\partial X_i}{\partial\theta_i} - \left(q_i + \frac{\theta_i}{1-\theta_i}\right)\cdot\frac{\partial\left(q_i + \frac{\theta_i}{1-\theta_i}\right)}{\partial\theta_i} - \frac{\partial q_i{}^c}{\partial X_i}\frac{\partial X_i}{\partial\theta_i} - \frac{\partial\left(\frac{\theta_i}{1-\theta_i}\right)}{\partial\theta_i} \quad (22)$$

Recall that $X_i = \frac{1}{1-\theta_i}$, and $\frac{\partial X_i}{\partial\theta_i} = X_i{}^2$. Thus, the FOC in equation (22) becomes

$$[2q_i(\beta_i - 1) - 1]\cdot A\cdot X_i{}^2 - (q_i + X_i - 1)\left(A\cdot X_i{}^2 + X_i{}^2\right) - X_i{}^2$$

$$= X_i{}^2\{A[2q_i{}^c(\beta_i - 1) - 1] - (A+1)(q_i + X_i - 1) - 1\}$$

$$= X_i{}^2\{A(2\beta_i q_i{}^c - 2q_i - 1 - q_i - X_i + 1) - q_i - X_i\}$$

$$= X_i{}^2\{[A(2\beta_i - 3) - 1]q_i{}^c - (A+1)X_i\} = 0$$

We focus on the following case:

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$$[A(2\beta_i - 3) - 1]q_i{}^c - (A+1)X_i$$
$$= [A(2\beta_i - 3) - 1]\big(AX_i - BX_j + C\big) - (A+1)X_i = 0. \qquad \text{(A1)}$$

From (A1), we can find that

$$X_i = \frac{[A(2\beta_i - 3) - 1]\big(BX_j - C\big)}{(2\beta_i - 3)A^2 - 2A - 1}.$$

The best replies of X_i are positively related to X_j. In other words, both θ_i and θ_j are strategic complements.

Next, we can focus on the symmetric equilibrium where $X_i = X_j$. Substitute this assumption in equation (A1), we have the symmetric equilibrium where

$$X_i = \frac{[A(2\beta_i - 3) - 1]C}{A + 1 - [A(2\beta_i - 3) - 1](A - B)}$$

Hence

$$\theta_i{}^c = \theta_j{}^c = 1 - \frac{A + 1 - [A(2\beta_i - 3) - 1](A - B)}{[A(2\beta_i - 3) - 1]C}. \quad \blacksquare$$

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Table of Notations

P_i	Product *i*'s price
q_i	Product *i*'s output
β_i	Product *i*'s own price effect
γ_i	Product *j*'s cross-price effect on product *i*
α_i	Market size
c_i	Marginal cost
r_i	R&D investment
A_i	Advertisements
s_i	Firm *i*'s sustainability activities
π_i	Firm *i*'s profit
θ_i	Predetermined proportion of manager *i*'s compensation
M_i	Manager *i*'s compensation
$\underline{S}$	Predetermined level of ESG threshold
F_i	Fixed penalty
φ	A proportion of the firm's profit as the proportional penalty
e_i	Manager *i*'s effort on ESG activities
$\rho(e_i)$	Probability of being penalized

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