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Abstract

We explore the characteristics of a Kantian equilibrium and their impact on corporate environmentalism. We focus on oligopolistic firms' investments in environmental technology and compare the level of investment under Kantian behavior with that under Nashian behavior and the social optimum. We demonstrate that firms invest more under Kantian behavior than under Nashian behavior if they are concerned about other firms' environmental damage and that investment at the Kantian equilibrium can be greater than that at the socially optimal level. That is, overcompliance may happen at a Kantian equilibrium.

JEL Classification: C72, D43, Q52

Keywords: Corporate environmentalism; Kantian equilibrium; Oligopoly; Overcompliance

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1 Introduction

Concern about the global environment has rapidly increased over the past few decades. Reflecting this fact, a burgeoning economic literature studies the aspects of economic activities relating to environmentally friendly behavior (Copeland and Taylor, 2003; Grafton et al., 2017). A branch of this literature focuses on corporate environmentalism (Lyon and Maxwell, 2004; Jinji, 2013; Yanase, 2014; Calveras and Ganuza, 2016).

Although existing studies consider firms' behavior noncooperatively using the concept of the Nash equilibrium, a more attractive approach is to model implicit cooperation, which seems appropriate because the environment is a common infrastructure such as international public goods. Kantian behavior is one of the implicit cooperative rules. The concept of the Kantian equilibrium was formulated by Roemer (2010, 2015). Long (2016) proposes a generalization and examines several formulations of the concept of Kant–Nash behavior.[1] However, as far as we know, no theoretical studies analyze corporate environmentalism using the concept of the Kantian equilibrium.

This paper presents a model in which firms' objective includes an element of social responsibility, and they behave in a Kantian way when it comes to making decisions that directly influence the environment. To describe the strategic relationship between an environmental technology and a production activity, we consider an oligopolistic model. In addition to their choice of output levels, firms also select among a spectrum of technologies with respect to environmental friendliness. The cleaner is the technology, the higher is the unit cost of production and the lower is the emission per unit of output. We compare the level of firms' investments in the environmental technology at a cooperative Kantian equilibrium with those that would arise in a noncooperative Nash equilibrium. In addition, we examine whether Kantian investment is efficient from the welfare viewpoint. Through these investigations, we clarify the role of Kantian behavior.

[1] Alger and Weibull (2013, 2016) model the behavior of agents that are partially motivated by Kantian ethics.

We demonstrate that firms invest more at a Kantian equilibrium than at a Nash equilibrium. Further, although Kantian behavior improves economic welfare in most cases, it can be excessive from the welfare point of view. In other words, overcompliance may happen. This result implies that policies promoting environmental friendliness may mitigate economic welfare. This overcompliance can occur only in an oligopoly. If firms operate under perfect competition, there will be no overcompliance when each firm is concerned about other firms' pollution.

2 Model

Let us consider two goods: good x and a numeraire good y. Good x is produced by m oligopolistic firms, while good y is produced by perfectly competitive firms. The economy has an endowment of M units of labor. Each unit of labor can produce one unit of the numeraire good.

The production process for good x can be environmentally damaging. Let $a_i \in [0, 1]$ denote the environmental friendliness of the production process chosen by firm i. The per-unit cost of producing q_i units of good x by firm i depends on a_i. We denote the unit cost by $c(a_i)$, where $c'(a_i) > 0$ and $c''(a_i) > 0$, indicating that more environmentally friendly production processes are costlier to the firm. We suppose that a_i is a technological choice that must be made by firm i before output q_i is produced. Given the choice $a_i \in [0, 1]$, if firm i produces q_i units of good x, its emission level is $(1 - a_i)q_i$. Based on the empirical evidence on conventional air pollution reported by Muller and Mendelsohn (2009, 2012), we suppose that the total environmental damage that arises from the production of good x is linear in emissions:

$$D = \sum_{i=1}^{m} \gamma(1 - a_i)q_i, \tag{1}$$

where $\gamma > 0$ is the damage parameter. Further, we make the following assumptions:

Assumption 1. $c'(0) < \gamma < c'(1)$.

Assumption 2. $u'(0) > c(a_i) + \gamma(1 - a_i) \quad \forall a_i \in [0, 1]$.

Assumption 1, taken together with the convexity of $c(a_i)$, implies that the socially efficient technology choice is in the interior of the interval $[0, 1]$. Assumption 2 states that the marginal utility of the first unit of consumption is higher than the costs arising from one unit of output.

For simplicity, we assume that the consumer's utility function is linear in y and D and nonlinear in x. Assume the consumer's utility function is quasi-linear:

$$U(X, Y) = u(X) + Y - D, \tag{2}$$

where X and Y are the respective quantities of goods x and y that the representative individual consumes and $u(X)$ is the subutility obtained by consuming x, which is increasing and strictly concave. Here, let us assume that $u(X)$ is quadratic, which leads to linear inverse demand: $P(X) = A - X$. In the equilibrium, $X = \sum_{i=1}^{m} q_i$.

Firms are concerned about the environment. In addition to their profits, they have a distaste for their contribution to environmental damage, $\gamma(1 - a_i)q_i$. We describe this distaste as

$$\theta_i \gamma(1 - a_i)q_i, \tag{3}$$

where $\theta_i \in [0, 1]$. We refer to θ_i as firm i's degree of direct environmental concern. In addition, each firm i feels partly responsible for the damage that other firms inflict on the environment. We capture this by the term

$$\rho_i \sum_{j \neq i} \gamma(1 - a_j)q_j, \tag{4}$$

where $\rho_i \in [0, 1]$. We refer to ρ_i as firm i's degree of indirect environmental concern.

The profit of firm i is given by

$$\pi_i = P(X)q_i - c_i(a_i)q_i, \tag{5}$$

where $X = q_i + \sum_{j \neq i} q_j \equiv q_i + Q_{-i}$. From (3), (4), and (5), the objective function of firm i is then

$$\begin{aligned} G_i(q_i, q_j; a_i, a_j) &= \pi_i - \theta_i \gamma (1 - a_i) q_i - \rho_i \sum_{j \neq i} \gamma (1 - a_j) q_j \\ &= \left[P(q_i + Q_{-i}) - c(a_i) \right] q_i - \theta_i \gamma (1 - a_i) q_i - \rho_i \sum_{j \neq i} \gamma (1 - a_j) q_j. \end{aligned} \quad (6)$$

We consider the following two-stage game. In the first stage, each firm chooses its technology parameter, a_i. In the second stage, given the technology parameters and other firm's output, each firm chooses its output level, q_i. For simplicity, we consider the case of a duopoly (i.e., $m = 2$).

3 Nashian Behavior

We solve the game via backward induction. Before considering Kantian behavior, we consider Nashian behavior in both stages as a benchmark.

In the second stage, given the predetermined (a_i, a_j), firm i chooses q_i to maximize its payoff, while taking q_j as given. Partially differentiating (6) with respect to q_i, the first-order condition (FOC) for firm i's output is

$$\frac{\partial G_i}{\partial q_i} = P + q_i P'(X) - \omega_i(a_i) = 0,$$

where $\omega_i(a_i) \equiv c(a_i) + \theta_i \gamma (1 - a_i)$. We may regard $\omega_i(a_i)$ as the per-unit cost of production. Then, we can solve for the equilibrium Cournot outputs q_i for all i, as functions of the stage-one choice. The FOC becomes

$$2q_i + q_j = A - \omega_i.$$

We have

$$q_i = \frac{A - 2\omega_i + \omega_j}{3} \equiv q_i^N(\omega_1, \omega_2). \quad (7)$$

Substituting the second-stage Nash equilibrium outputs into (6), we have

$$G_i(a_1,a_2) = \left[A - q_i^N(\omega_1(a_1),\omega_2(a_2)) - q_j^N(\omega_1(a_1),\omega_2(a_2)) - \omega_i(a_i)\right] q_i^N(\omega_1(a_1),\omega_2(a_2)) \\ - \rho_i\gamma(1-a_j)q_j^N(\omega_1(a_1),\omega_2(a_2)). \quad (8)$$

Turning to the first stage, firm i must determine a_i given a_j. Firm i maximizes (8) with respect to a_i, taking a_j as given, subject to $a_i \geq 0$ and $1 - a_i \geq 0$. Let λ_i and ϕ_i be the Lagrange multipliers associated with these inequality constraints. The Lagrangian is

$$L = G_i(a_1,a_2) + \lambda_i a_i + \phi_i(1-a_i). \quad (9)$$

From (9), firm i's FOC with respect to a_i, taking a_j as given, yields

$$-\left[q_i^N + \left(q_i^N + \rho_i\gamma(1-a_j)\right)\frac{\partial q_j^N(\omega_1,\omega_2)}{\partial\omega_i}\right](c'(a_i) - \theta_i\gamma) + \lambda_i - \phi_i = 0. \quad (10)$$

The square brackets in the first term are positive. Thus, (10) implies that

$$c'(a_i^N) = \theta_i\gamma, \quad (11)$$

where a_i^N is the Nash equilibrium investment level.

4 Kantian Behavior

Now, we focus on Kantian behavior. Based on the difference in activities, we assume that firms adopt Nashian behavior to determine their output levels and Kantian behavior to choose the cleanliness of their production process. Thus, we achieve a Kantian equilibrium in the first stage.

In this setting, a Kantian equilibrium is defined in the following way.

Definition (Kantian equilibrium). *A profile of activity levels (a_1^K, a_2^K) is called a Kantian equilibrium if any expansion or contraction of that profile by a factor $\kappa \geq 0$, where $\kappa \neq 1$, will make each player worse off.*[2] *That is, for all $i = 1, 2$,*

$$G_i(a_1^K, a_2^K) \geq G_i(\kappa a_1^K, \kappa a_2^K). \quad (12)$$

[2] Strictly speaking, this definition applies if $a_i \in [0,\infty)$. In the case where a_i is restricted to be in some finite interval $[0,\overline{a}]$, we must slightly modify the definition; see Roemer (2010).

Equality holds at $\kappa = 1$.

Condition (12) means that to determine whether its current choice a_i^K of the cleanliness of its technology is appropriate, each firm i asks itself the following question: what kind of payoff would I receive if I were to deviate from my current choice a_i^K by a factor $\kappa \geq 0$, assuming that all other agents would deviate from their current choice in the same way? If each firm finds that its payoff under this counterfactual scenario would be worse than at (a_1^K, a_2^K), then (a_1^K, a_2^K) is a Kantian equilibrium. In other words, we say the choice (a_1^K, a_2^K) is a Kantian equilibrium if

$$\begin{aligned} G_i(\kappa a_1^K, \kappa a_2^K) = \big[A - q_1^N(\omega_1(\kappa a_1^K), \omega_2(\kappa a_2^K)) - q_2^N(\omega_1(\kappa a_1^K), \omega_2(\kappa a_2^K)) - \omega_i(\kappa a_i^K)\big] \\ \cdot q_i^N(\omega_1(\kappa a_1^K), \omega_2(\kappa a_2^K)) - \rho_i\gamma(1 - \kappa a_j^K) q_j^N(\omega_1(\kappa a_1^K), \omega_2(\kappa a_2^K)) \quad (13) \end{aligned}$$

achieves its maximum at $\kappa = 1$ for each firm.

Differentiating (13) with respect to κ and substituting

$$\begin{aligned} \frac{dq_i^N}{d\kappa} &= -\left(\frac{2}{3}\right)(c'(a_i) - \theta_i\gamma)\, a_i + \left(\frac{1}{3}\right)(c'(a_j) - \theta_j\gamma)\, a_j, \\ \text{and} \quad \frac{d\omega_i}{d\kappa} &= \frac{d\omega_i}{d(\kappa a_i)} \frac{\partial(\kappa a_i)}{\partial \kappa} = (c'(a_i) - \theta_i\gamma)\, a_i \end{aligned}$$

evaluated at $\kappa = 1$, we have firm i's FOC as

$$\begin{aligned} &- q_i^N(a_1, a_2)\left[\left(\frac{4}{3}\right)(c'(a_i) - \theta_i\gamma)\, a_i - \left(\frac{2}{3}\right)(c'(a_j) - \theta_j\gamma)\, a_j\right] \\ &+ \rho_i\gamma\left\{q_j^N(a_1, a_2)a_j - (1 - a_j)\left[\left(\frac{1}{3}\right)(c'(a_i) - \theta_i\gamma)\, a_i - \left(\frac{2}{3}\right)(c'(a_j) - \theta_j\gamma)\, a_j\right]\right\} = 0. \quad (14) \end{aligned}$$

We obtain the Kantian equilibrium from the FOCs (14) of both firms as long as the second-order conditions (SOCs) are satisfied.

In what follows, we focus on the symmetric Kantian equilibrium, namely $a_1^K = a_2^K = a^K$, which holds if firms' degrees of direct and indirect environmental concern are common: $\theta_1 = \theta_2 = \theta$ and $\rho_1 = \rho_2 = \rho$. Assuming an interior solution such that $0 < a^K < 1$, (14) becomes

$$-q^N(a^K,a^K)\left(\frac{2}{3}\right)\left(c'(a^K)-\theta\gamma\right) + \rho\gamma\left\{q^N(a^K,a^K)+(1-a^K)\left(\frac{1}{3}\right)\left(c'(a^K)-\theta\gamma\right)\right\}=0. \quad (15)$$

Further, we must check the SOC, namely that G_i is locally concave in κ at $\kappa = 1 : \frac{d^2G_i}{d\kappa^2} < 0$. To satisfy the SOC, the following expression should be negative:

$$-\left(\frac{2}{3}\right)\left(c'(\kappa a^K)-\theta\gamma\right)\frac{dq^N}{d\kappa}-\left(\frac{2}{3}\right)c''(\kappa a^K)a^Kq^N + \rho\gamma\frac{dq^N}{d\kappa}+\rho\gamma(1-\kappa a^K)\left(\frac{1}{3}\right)c''(\kappa a^K)a^K-\rho\gamma\left(\frac{1}{3}\right)\left(c'(\kappa a^K)-\theta\gamma\right)a^K. \quad (16)$$

Under the symmetric equilibrium,

$$\frac{dq^N}{d\kappa}=-\frac{1}{3}\frac{d\omega(\kappa a^K)}{d\kappa}=-\frac{1}{3}(c'(\kappa a^K)-\theta\gamma)a^K.$$

After substitution, we find that (16) is rewritten as

$$\left(\frac{2}{9}\right)(c'(a^K)-\theta\gamma)^2-\left(\frac{2}{3}\right)c''(a^K)q^N-\rho\gamma\left(\frac{2}{3}\right)\left(c'(a^K)-\theta\gamma\right)+\rho\gamma(1-a^K)\left(\frac{1}{3}\right)c''(a^K). \quad (17)$$

(17) is negative at $\rho = 0$ and hence also at ρ near zero.

From (15), we obtain the condition satisfying the symmetric Kantian equilibrium:

$$c'(a^K)=\theta\gamma+\frac{3\rho\gamma q^N(a^K,a^K)}{2q^N(a^K,a^K)-\rho\gamma(1-a^K)}. \quad (18)$$

If firms are unconcerned about other firms' environmental damage (i.e., $\rho = 0$), condition (18) is coincident with condition (11). By contrast, if firms are concerned about other firms' environmental damage (i.e., $\rho > 0$), these conditions are different.

Proposition 1. *If $\rho = 0$, then the Kantian equilibrium value a^K is equal to the Nash equilibrium a^N. A small increase in ρ will increase a^K, making it larger than a^N.*

Proof. Define the function $F(a,\rho)$ by

$$F(a,\rho)\equiv -q^N(a,a)\left(\frac{2}{3}\right)(c'(a)-\theta\gamma)+\rho\gamma q^N(a,a)+\rho\gamma(1-a)\left(\frac{1}{3}\right)(c'(a)-\theta\gamma),$$

where

$$q^N(a,a) = \frac{A - 2\omega(a) + \omega(a)}{3} = \frac{A - \omega(a)}{3}.$$

Then,

$$\frac{\partial F}{\partial a} = \frac{1}{9}(c'(a) - \theta\gamma)^2 - \left(\frac{2}{3}\right)\left(\frac{A - \omega(a)}{3}\right)c''(a) \\ - \rho\gamma\left(\frac{2}{3}\right)(c'(a) - \theta\gamma) + \rho\gamma(1-a)\left(\frac{1}{3}\right)c''(a),$$

which is negative under the SOC (17), and

$$\frac{\partial F}{\partial \rho} = \gamma q^N(a,a) + \gamma(1-a)\left(\frac{1}{3}\right)(c'(a) - \theta\gamma),$$

which is positive at $\rho = 0$ (and $a^K = a^N$). Then,

$$\frac{da^K}{d\rho} = -\frac{\frac{\partial F}{\partial \rho}}{\frac{\partial F}{\partial a}} > 0.$$

This conclude the proof that a small increase in ρ leads to an increase in a^K. □

Figure 1 is useful for understanding this result. We place the investment in the environmental technology (hereafter, environmental investment), a, on the horizontal axis and the marginal benefit and cost from the environmental investment on the vertical axis. As stated in Section 2, the marginal cost from the environmental investment is increasing. Under Nashian behavior, firms face a marginal benefit from the environmental investment, $\theta\gamma$. This effect is brought about by the oligopolistic competition, and thus this term also appears in the Kantian equilibrium. In addition, the Kantian equilibrium has an extra term from the coordination of actions. Let us define

$$f(a;\rho) \equiv \frac{3\rho\gamma q^N(a,a)}{2q^N(a,a) - \rho\gamma(1-a)} \tag{19}$$

as the coordination effect of the Kantian equilibrium. Note that $f(a;\rho)$ is decreasing in a, $f(a;0) = 0$, and $f(a;\rho) > 0$ for $\rho \neq 0$. As long as an indirect environmental concern exists, the investment level under Kantian behavior is greater than that under Nashian behavior. If

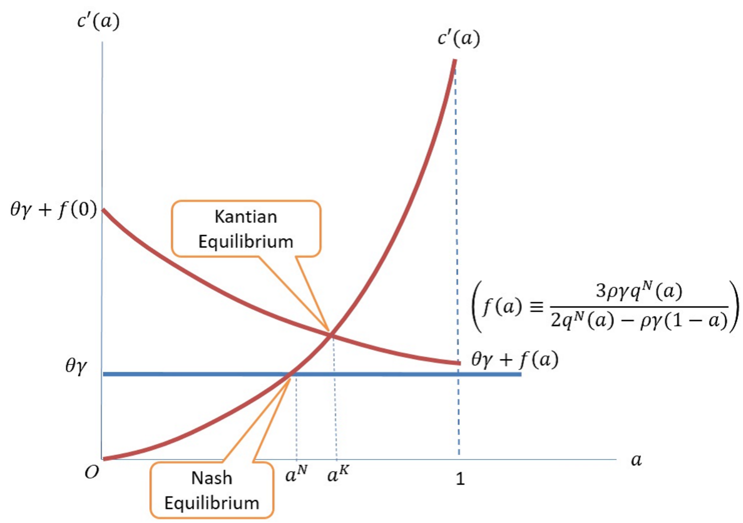

Figure 1: Nash equilibrium and Kantian equilibrium

no indirect concern exists, then the coordination effect disappears and the investment level under Kantian behavior is the same as that under Nashian behavior.

The intuition behind this lemma is as follows: since the damage cost is linear in output, if each firm is only concerned about the damage that its own output inflicts on the economy (i.e., $\rho = 0$), then there is no need for firms to coordinate their choice of a_i. Therefore, in this case, the coordination implicit in the concept of the Kantian equilibrium is redundant.

5 Social Efficiency

In this section, we examine whether the Kantian equilibrium is efficient from the welfare viewpoint.

5.1 Social optimum

First, we derive the social planner's solution. The planner maximizes the welfare of the representative individual:

$$W \equiv u(X) + \left[M - \sum_{i=1}^{m} c(a_i)q_i\right] - D. \tag{20}$$

The FOCs of the social planner's problem are

$$\frac{\partial W}{\partial q_i} = u'(X) - \{c(a_i) + \gamma(1 - a_i)\} = 0 \tag{21}$$

$$\frac{\partial W}{\partial a_i} = \gamma - c'(a_i) = 0. \tag{22}$$

The necessary condition (22) yields the optimal level of the environmental friendliness of the production process, a^*:

$$c'(a^*) = \gamma \quad \Leftrightarrow \quad a_i^* = c'^{-1}(\gamma) \equiv a^*. \tag{23}$$

Substituting (23) into the necessary condition (21)

$$u'(X) = [c(a^*) + \gamma(1 - a^*)] \tag{24}$$

yields the optimal output level.

5.2 Comparison

We now examine the social efficiency in corporate environmentalism by comparing the environmental investment levels, a^N and a^K, with the socially optimal level, a^*.

From Proposition 1, we already know that $a^N < a^K$. Furthermore, from (11) and (23), it is straightforward to see that a^N is less than a^* if $\theta < 1$. As stated in Section 4, the marginal benefit from the environmental investment under Nashian behavior is $\theta\gamma$. This is less than the socially optimal level γ under oligopolistic competition, and thus the same relationship holds in the investment levels.

We then consider the relationship between a^K and a^*. There are two possibilities: (i) $a^K < a^*$, that is, the Kantian equilibrium investment level is insufficient compared with the social optimum (see Figure 2); (ii) $a^* < a^K$, that is, the Kantian equilibrium investment level is excessive from the welfare point of view. In this case, overcompliance happens (see Figure 3).

In the following, we specify the cost function as $c(a) = \beta a + \frac{\mu}{2}a^2$, and then $c'(a) = \beta + \mu a$.

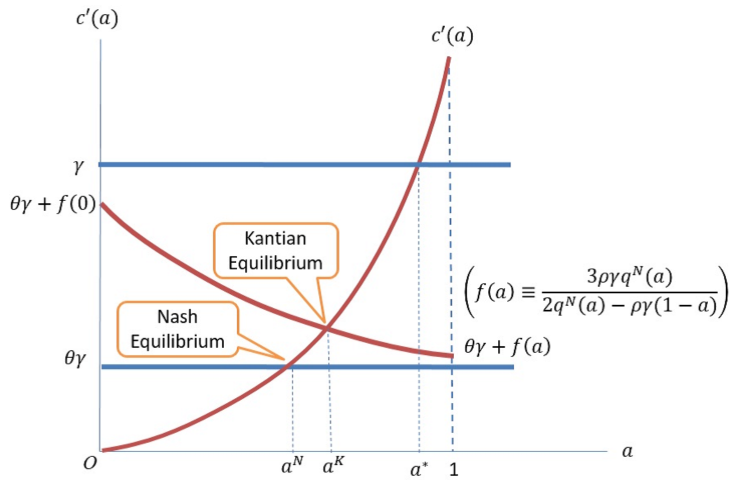

Figure 2: Insufficient investment at the Kantian equilibrium

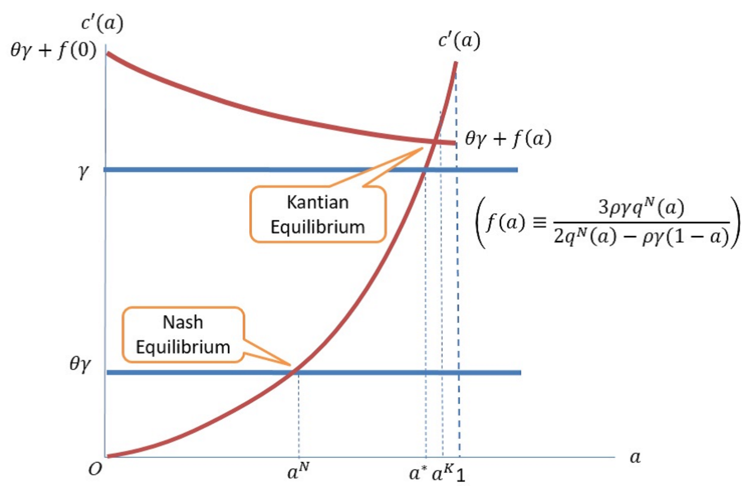

Figure 3: Excessive investment at the Kantian equilibrium

Table 1: Simulation results

Case	A	β	γ	μ	θ	ρ	a^N	a^K	a^*
(i)	1	0.15	0.4	0.3	0.5	0	0.166	0.166	0.833
(ii)	1	0.15	0.4	0.3	0.5	0.2	0.166	0.593	0.833
(iii)	1	0.15	0.4	0.3	0.7	0.2	0.433	0.844	0.833
(iv)	1	0.15	0.4	0.3	0.5	0.35	0.166	0.889	0.833

The Kantian equilibrium a^K satisfies

$$-q^N\left(\frac{2}{3}\right)\left(\beta+\mu a^K-\theta\gamma\right)+\rho\gamma\left\{q^N+(1-a^K)\left(\frac{1}{3}\right)\left(\beta+\mu a^K-\theta\gamma\right)\right\}=0, \tag{25}$$

where q^N is the stage-two Nash equilibrium output choice shown in Section 3,

$$\begin{aligned} q^N &= \frac{A-\omega(a^K)}{3}=\frac{A-c(a^K)-\theta\gamma(1-a^K)}{3} \\ &= \frac{A-\beta a^K-\frac{\mu}{2}(a^K)^2-\theta\gamma(1-a^K)}{3}. \end{aligned} \tag{26}$$

Substituting eq. (26) into (25), we have a cubic equation to determine a^K. We thus conduct numerical simulations to find that the above two cases happen.

Table 1 illustrates the environmental investment levels at the Nash equilibrium, Kantian equilibrium, and social optimum under the given parameter values. We use the following common parameters: $A=1$, $\beta=0.15$, $\gamma=0.4$, and $\mu=0.3$. First, under $\rho=0$ (Case (i)), the second term in eq. (18) is zero. In this case, as shown in Proposition 1, the Kantian equilibrium is equivalent to the Nash equilibrium. Second, under $\rho=0.2$ (Case (ii)), the environmental investment at the Kantian equilibrium is lower than the social optimum. In other words, Kantian behavior leads to insufficient investment from the welfare point of view. Third, under $\theta=0.7$ (Case (iii)), the Kantian equilibrium is above the socially optimal level of technology. Kantian behavior thus leads to over-investment from the welfare point of view. Fourth, under $\rho = 0.35$ (Case (iv)), the Kantian equilibrium is also above the socially optimal level of technology. That is, overcompliance happens. We summarize this result as the following proposition.

Proposition 2. *Under the given parameters, the Kantian investment can exceed the social optimal level.*

Finally, let us find the conditions under which there exists a Kantian equilibrium a^K that overshoots the social optimal a^*. From (18), (19), and (23), we have the following condition:

Proposition 3. *If $\rho \geqslant \underline{\rho}$, the Kantian investment level is excessive from the social optimum, where*

$$\underline{\rho} \equiv \frac{(1-\theta)\left\{2\mu A - (\gamma-\beta)(\gamma+\beta) - 2\theta\gamma(\mu-\gamma+\beta)\right\}}{3\left\{2\mu A - (\gamma-\beta)(\gamma+\beta) + 2(1-\theta\gamma)(\mu-\gamma+\beta)\right\}}. \tag{27}$$

Proof. The curve $\theta\gamma + f(a;\rho)$ lies above the curve $c'(a)$ if

$$\theta\gamma + f(a^*;\rho) > \gamma \tag{28}$$

(see Figure 3). Under $c(a) = \beta a + \frac{\mu}{2}$, the socially optimal level is $a^* = \frac{\gamma-\beta}{\mu}$. Substituting the social optimal level, (18), (19), and (23) into (28), we obtain the condition with the threshold value (27). □

As firms are more concerned about other firms' environmental damage, the possibilities of overshooting Kantian behavior rises. This property corresponds to the simulation result (Case (iv)).

6 Summary

We focus on corporate environmentalism under Kantian behavior. In particular, we consider oligopolistic firms' environmental investments and examine how Kantian investment is different from Nashian behavior and the social optimum. We demonstrate that Kantian investment is greater than Nashian investment as long as firms are concerned about other firms' investments. Furthermore, we point out the possibility that Kantian investment exceeds the socially optimal level. That is, overcompliance may occur at the Kantian equilibrium.

In this paper, we simply point out the possibility of overcompliance. However, future research should undertake a more rigid analysis of the conditions. In addition, firms' asymmetries should be considered. Including these factors would make our analysis richer and more persuasive.

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