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Corporate Environmentalism: How Do Kantian Equilibrium and Nash Equilibrium Differ?

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Abstract

To explore the characteristics of Kantian equilibrium, we focus on investments in environmental technology under oligopoly and compare Nash equilibrium and Kantian equilibrium investments with the socially optimal investment. We demonstrate that the Kantian equilibrium investment is more than the Nash equilibrium investment if firms are concerned about the environmental damage by other firms and that the Kantian investment can be insufficient, socially optimum, and excessive from the welfare viewpoint depending on the degree of such concerns. These results imply that firms' concern for environmental damage is crucial for the welfare evaluation of the Kantian equilibrium under oligopoly.

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1 Introduction

The Kantian equilibrium, formulated by Roemer (2010), is an equilibrium concept which describes implicit cooperation among individuals. It is derived by the Kantian optimization, with expectations based on Kant's categorical imperative: one should take actions one would like to see universalized. Kantian optimizers expect other players to choose common strategies that would be best for them (Roemer, 2019).[1] Applying Kantian optimization to matters necessary for cooperation is relevant, such as environment-related activities.

This study focuses on corporate environmentalism, which corresponds to firms' voluntary actions to protect the environment.[2] Existing research on corporate environmentalism (e.g., Jinji, 2013; Yanase, 2013) applies the Nash equilibrium to examine the environmental actions of firms. However, we consider applying the Kantian equilibrium is relevant because the environment is like infrastructure, which firms should protect cooperatively. To the best of our knowledge, no theoretical study has analyzed corporate environmentalism using the Kantian equilibrium. By incorporating the Kantian equilibrium into the analysis of corporate environmentalism, we can propose a more appropriate analysis and find new aspects of the Kantian equilibrium.

We present a corporate environmentalism model to explore the characteristics of Kantian equilibrium. We consider an oligopoly to describe the strategic relationship between environmental technology and production activities. Firms producing environmentally damaging goods care about their environmental responsibilities and choose technology levels for environmental friendliness (hereafter, environmental investment) and output levels. The higher the investment, the higher the unit cost of production, and the lower is the emissions per unit of output. We compare the level of firms' environmental investments at a cooperative Kantian equilibrium with those that would arise in a non-cooperative Nash equilibrium. Furthermore, we examine whether these investment levels are insufficient or excessive from a welfare perspective.

We demonstrate that the Kantian equilibrium investment is more than the Nash equilibrium investment if firms are concerned about the environmental damage by other firms. We also demonstrate that the Kantian investment can be insufficient, socially optimum, and excessive from the welfare viewpoint depending on the degree of such concerns. These results imply that firms' concern for environmental damage is crucial for the welfare evaluation of the Kantian equilibrium under oligopoly.

2 Setup and Benchmark

2.1 Model

We consider two goods, good x and numeraire good y. n oligopolistic firms supply good x, while perfectly competitive firms supply good y. The economy has an endowment of M unit of labor. Each unit of labor produces 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 determined by firm i before producing output q_i. Given the choice $a_i \in [0,1]$, if firm i produces q_i units of good x, then its emission level is $(1-a_i)q_i$. Based on empirical evidence on conventional air pollution reported by Muller and Mendelsohn (2009, 2012), we assume that the total environmental damage which arises from the production of good x is linear in emissions:

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

where $\gamma > 0$ is the damage parameter. In the following analysis, we assume that $c'(0) < \gamma < c'(1)$, and $u'(0) > c(a_i) + \gamma(1-a_i)$, for any $a_i \in [0,1]$.

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

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

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 a linear inverse demand $P(X) = \alpha - X$. In the equilibrium, $X = \sum_{i=1}^{n} q_i$.

Firms are concerned about the environment. In addition to their profits, they have a distaste for their contribution to environmental damage, $\gamma(1 - a_i)q_i$. This distaste is described as follows:

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

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

The profit of firm i is given by

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

where $X = q_i + \sum_{j \neq i} q_j$. Define Q_{-i} and A_{-i} as sets of outputs and environmental investments of firm j, q_j and a_j, respectively, for $j = 1, \dots, n$; $j \neq i$. Then from (3), (4), and (5), the objective function of firm i is:

$$\begin{aligned} G_i(q_i, Q_{-i}; a_i, A_{-i}) &= \pi_i - \theta_i \gamma(1 - a_i)q_i - \rho_i \sum_{j \neq i} \gamma(1 - a_j)q_j \\ &= \{P(X) - c(a_i)\} q_i - \theta_i \gamma(1 - a_i)q_i - \rho_i \sum_{j \neq i} \gamma(1 - a_j)q_j. \end{aligned} \tag{6}$$

2.2 Benchmark: Social optimum

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

$$W \equiv u(X) + M - \sum_{i=1}^{n} c(a_i)q_i - D. \tag{7}$$

Let a^* be the social optimal level of environmental investment. Partially differentiating (1) with respect to q_i and a_i, the first-order condition(FOC)s of the social planner's problem are

$$\frac{\partial W}{\partial q_i} = u'(X) - \{c(a_i) + \gamma(1 - a_i)\} = 0 \tag{8}$$

$$\frac{\partial W}{\partial a_i} = \gamma - c'(a_i) = 0. \tag{9}$$

In particular, (9) shows that a^* satisfies the following condition:

$$c'(a^*) = \gamma. \tag{10}$$

3 Equilibria

To explore Nash and Kantian equilibria, we consider a two-stage game.[3] In the first stage, each firm chooses its level of environmental investment a_i. In the second stage, each firm chooses its output level q_i.

3.1 Nash equilibrium

First, we find the Nash equilibrium. In this part, we consider the case where firms choose their action à la Cournot in both stages.

In the second stage, given the predetermined (a_i, A_{-i}), firm i chooses q_i to maximize its payoff while taking Q_{-i} as given. Partially differentiating objective function (6) with respect to q_i, the first-order condition for firm i's output is:

$$\frac{\partial G_i}{\partial q_i} = P + q_i P'(X) - \omega_i(a_i) = 0, \tag{11}$$

where $\omega_i(a_i) \equiv c(a_i) + \theta_i\gamma(1-a_i)$, which is regarded as the per-unit cost of production. From (11), we can solve for the equilibrium Cournot outputs q_i for all i as functions of the stage-one choice. We have

$$q_i = \frac{\alpha - n\omega_i(a_i) + \sum_{j\neq i}\omega_j(a_j)}{n+1} \equiv q_i^N(\omega_i, \Omega_{-i}), \tag{12}$$

where superscript N stands for the Nash equilibrium, and Ω_{-i} is a set of ω_j except ω_i, $j = 1,\dots,n$; $j \neq i$. By substituting (12) into (6), we obtain the first-stage objective function $G_i(a_i, A_{-i})$:

$$G_i(a_i, A_{-i}) = \left[A - q_i^N(\omega_i(a_i), \Omega_{-i}(A_{-i})) - q_j^N(\omega_j(a_j), \Omega_{-j}(A_{-j})) - \omega_i(a_i)\right] q_i^N(\omega_i(a_i), \Omega_{-i}(A_{-i}))$$
$$- \rho_i\gamma(1-a_j)q_j^N(\omega_j(a_j), \Omega_{-j}(A_{-j})). \tag{13}$$

In the first stage, firm i maximizes $G_i(a_i, A_{-i})$ with respect to a_i, taking A_{-i} 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 the inequality constraints. Taking A_{-i} as a given, firm i's FOC with respect to a_i is

$$-\left[q_i^N + \left\{q_i^N + \rho_i\sum_{j\neq i}\gamma(1-a_j)\right\}\frac{\partial q_j^N(\omega_i,\omega_j)}{\partial\omega_i}\right](c'(a_i) - \theta_i\gamma) + \lambda_i - \phi_i = 0. \tag{14}$$

The square brackets in the first term are positive. Thus, denoting a_i^N as the Nash equilibrium investment level, we obtain the condition that a^N satisfies:

$$c'(a_i^N) = \theta_i\gamma. \tag{15}$$

3.2 Kantian equilibrium

Next, we focus on Kantian equilibrium. Based on the types of activities, we assume that firms adopt Nashian behavior to determine their output levels in the second stage, whereas Kantian behavior to choose a level of environmental investment in the first stage.

A profile of activity levels $(a_1^K, \dots, a_n^K)$ is called a Kantian equilibrium if any expansion or contraction of that profile by a factor of $\kappa \geq 0$, where $\kappa \neq 1$, will make each player worse off.[4] Since firms follows Kantian optimization only in the first stage,

$$G_i(a_1^K, \dots, a_n^K) \geq G_i(\kappa a_1^K, \dots, \kappa a_n^K) \tag{16}$$

holds for all $i = 1, \ldots, n$. Equality holds at $\kappa = 1$. That is, we say the choice $(a_1^K, \ldots, a_n^K)$ is a Kantian equilibrium if

$$G_i(\kappa a_i^K, \kappa A_{-i}^K) = \{\alpha - q_i^N(\omega_i(\kappa a_i^K), \Omega(\kappa A_{-i}^K)) - q_j^N(\omega_i(\kappa a_i^K), \Omega(\kappa a_j^K)) - \omega_i(\kappa a_i^K)\} \cdot q_i^N(\omega_i(\kappa a_i^K), \Omega(\kappa A_{-1}^K)) - \rho_i \sum_{j \neq i} \gamma(1 - \kappa a_j^K) q_j^N(\omega_i(\kappa a_i^K), \Omega(\kappa A_{-i}^K)) \quad \text{(C.1)}$$

reaches its maximum at $\kappa = 1$ for each firm $i = 1, \ldots, n$.

In the following, we consider the symmetric Kantian equilibrium, namely, $a_1^K = \cdots = a_n^K = a^K$, which holds if firms' degrees of direct and indirect environmental concern are common: $\theta_1 = \cdots = \theta_n = \theta$ and $\rho_1 = \cdots = \rho_n = \rho$. Under symmetry, firm i's FOC will be

$$- q^N(a^K) \left(\frac{2}{n+1} \right) (c'(a^K) - \theta\gamma) + \rho\gamma \left\{ q^N(a^K) + (1 - a^K) \left(\frac{1}{n+1} \right) \left(c'(a^K) - \theta\gamma \right) \right\} = 0. \quad (17)$$

Here, we focus on the situation where the second-order condition(SOC)s are satisfied; that is, G_i is locally concave in κ at $\kappa = 1$: $\frac{d^2 G_i}{d\kappa^2} < 0$.[5] From (17), we obtain the condition satisfying the symmetric Kantian equilibrium:

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

4 Results and Discussion

Comparing (18) with (15), we obtain the following result.[6]

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

Proposition 1 states that, if firms are unconcerned about the environmental damage by other firms (i.e., $\rho = 0$), condition (18) is coincident with the Nash equilibrium condition (15). In contrast, if firms are concerned about environmental damage by other firms (i.e., $\rho > 0$), these conditions are different. That is, the Kantian equilibrium is different from the Nash equilibrium.

Figure 1 explains the result graphically. In Figure 1, we take 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 of environmental investment is increasing. In the Nash equilibrium, firms face a marginal benefit from environmental investment $\theta\gamma$. This effect is brought about by oligopolistic competition, and thus, this term also appears in the Kantian equilibrium. The Kantian equilibrium includes an extra term from the coordination of actions. Let us define

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

as the coordination effect of the Kantian equilibrium. It should be noted 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 in the Kantian equilibrium is greater than that in the Nash equilibrium.[7]

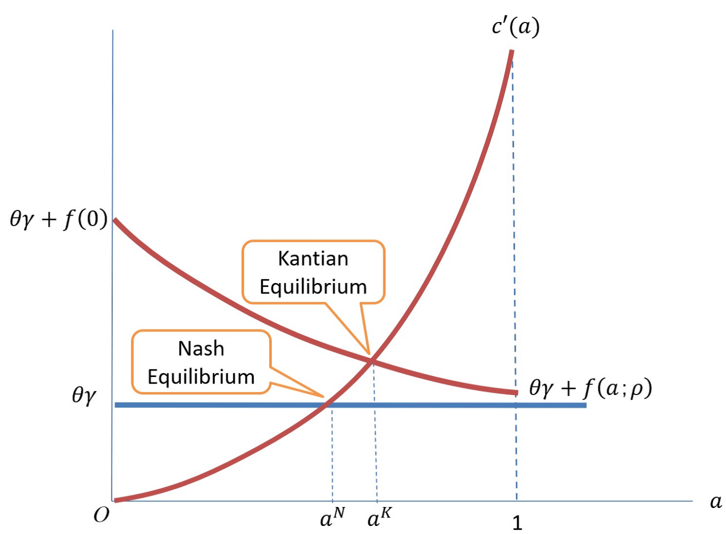

Figure 1: Nash equilibrium and Kantian equilibrium

We then compare the environmental investment levels a^N and a^K with the socially optimal level a^*.

It is straightforward to see that a^N is less than a^* because $\theta \in [0,1]$. In other words, the Nash equilibrium investment levels are always insufficient from a welfare viewpoint.

We then compare the Kantian equilibrium investment a^K to the socially optimal level a^*. There are three possibilities: (i) $a^K < a^*$, that is, the Kantian equilibrium investment is insufficient (Figure 2), (ii) $a^K = a^*$, that is, the Kantian equilibrium investment is socially optimum, and (iii) $a^* < a^K$, that is, the Kantian equilibrium investment is excessive. (Figure 3).

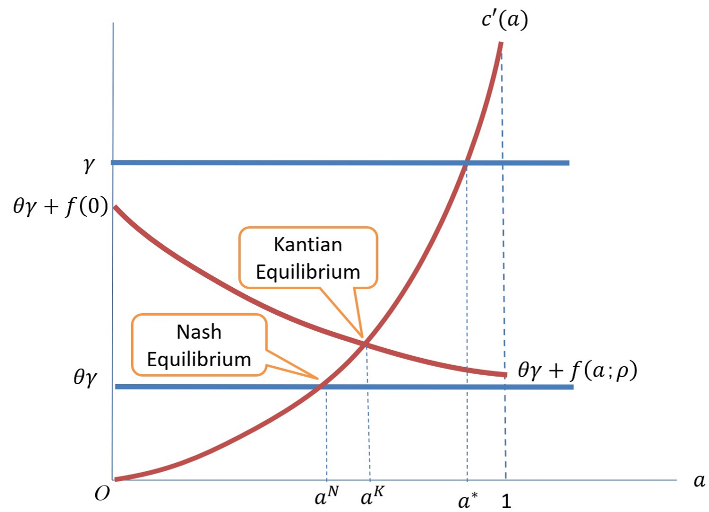

Figure 2: Insufficient investment at the Kantian equilibrium

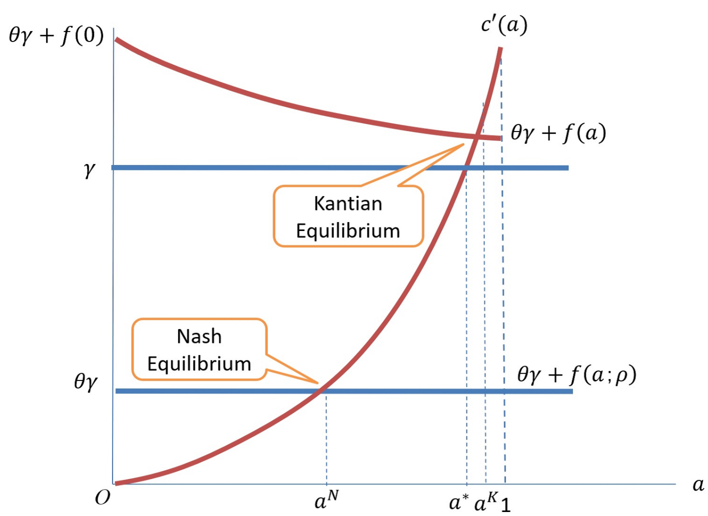

Figure 3: Excessive investment at the Kantian equilibrium

From (10), (18), and (19), we obtain the following propositon.

Proposition 2. *The Kantian investment level is insufficient if $\rho < \bar{\rho}$, socially optimal if $\rho = \bar{\rho}$, and excessive from the social optimum if $\bar{\rho} < \rho$, where*

$$\bar{\rho} \equiv \frac{2(\alpha - \omega(a^*))(1-\theta)}{\alpha - \omega(a^*) + (n+1)\gamma(1-\theta)(1-a^*)} \tag{20}$$

The Kantian equilibrium can be insufficient, socially optimum, and excessive, while the Nash equilibrium cannot.[8] It is worthwhile to show that the Kantian equilibrium can be socially optimum or even excessive under oligopoly. The result depends on the firms' concerns about environmental damage by other firms, Propositions 1 and 2 imply that firms' concerns about environmental damage are crucial for the welfare evaluation of the Kantian equilibrium under oligopoly.

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Notes

[1]Roemer (2015, 2019) offers the detailed explanation of Kantian optimization. Long (2016) proposes a generalization and examines several formulations of the concept of Kant–Nash behavior.

[2]For a survey on corporate environmentalism, see Lyon and Maxwell (2004).

[3]We obtain the same solutions even if we consider a game where each firm simultaneously decide the technology parameter a_i and the output q_i.

[4]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).

[5]The SOCs are satisfied as long as ρ is extremely large. See Appendix.

[6]Proofs of upcoming propositions are upon request to the author.

[7]If we consider the Kant-Nash equilibrium (Long, 2016), which is the equilibrum in the stituation where there are both Cournot maximizers and Kantian maximizers, the Kant-Nash investment levels should be between a^N and a^K.

[8]We conduct numerical simulations to check whether all cases are possible. See Appendix.

Appendix A. On the Second-Order conditions for the Kantian Maximization

To satisfy the SOCs, the following expression should be negative:

$$-\left(\frac{2}{n+1}\right)\left(c'(\kappa a^K)-\theta\gamma\right)\frac{dq^N}{d\kappa}-\left(\frac{2}{n+1}\right)c''(\kappa a^K)a^K q^N \\ +\rho\gamma\frac{dq^N}{d\kappa}+\rho\gamma(1-\kappa a^K)\left(\frac{1}{n+1}\right)c''(\kappa a^K)a^K-\rho\gamma\left(\frac{1}{n+1}\right)\left(c'(\kappa a^K)-\theta\gamma\right)a^K. \quad \text{(A.1)}$$

Under the symmetric equilibrium, we have

$$\frac{dq^N}{d\kappa}=-\frac{1}{n+1}\frac{d\omega(\kappa a^K)}{d\kappa}=-\frac{1}{n+1}(c'(\kappa a^K)-\theta\gamma)a^K. \quad \text{(A.2)}$$

After substituting (A.2), we find that (A.1) can be rewritten as:

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

Because $a, \theta, \rho \in [0,1]$, (A.3) is negative at $\rho = 0$; hence, this relationship also holds unless ρ is extremely large.

Appendix B. Proof of Proposition 1

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

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

Under the symmetric equilibrium,

$$q^N(a) = \frac{A - 2\omega(a) + (n+1)\omega(a)}{n+1} = \frac{A-\omega(a)}{n+1}. \quad \text{(B.2)}$$

Then, substituting (B.2) into (B.1), and partially differentiating it yields

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

that is negative under the SOC (A.3) and

$$\frac{\partial F}{\partial \rho} = \gamma q^N(a) + \gamma(1-a)\left(\frac{1}{n+1}\right)(c'(a)-\theta\gamma)\,, \quad \text{(B.4)}$$

that is positive at $\rho = 0$ (and $a^K = a^N$). Thus, from (B.3) and (B.4),

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

This concludes the proof that a small increase in ρ leads to an increase in a^K. ■

Appendix C. Proof of Proposition 2

At the socially optimal level $a = a^*$, if the curve $\theta\gamma + f(a^*; \rho)$ lies below curve $c'(a^*) = \gamma$, the investment level is insufficient (see Figure 2) , if $\theta\gamma + f(a^*; \rho)$ intersects γ, the investment level is socially optimum, and if the curve $\theta\gamma + f(a^*; \rho)$ lies above curve $c'(a^*)$ (see Figure 3).

Let us cosider the case where the investment level is excessive.

$$\theta\gamma + f(a^*; \rho) > \gamma \tag{C.1}$$

holds. Substituting (19) into (C.1) and rearranging, we obtain

$$\rho > \frac{2(\alpha - \omega(a^*))(1-\theta)}{\alpha - \omega(a^*) + (n+1)\gamma(1-\theta)(1-a^*)} \equiv \bar{\rho}. \tag{C.2}$$

We can prove the insufficiency and optimality of the Kantian equilibrium investment, considering reverse inequality and equality. ■

Appendix D. Numerical Simulation

In the following, we consider $n = 2$, that is, a duopoly, and specify the cost function as $c(a) = \beta a + \frac{\mu}{2}a^2$, and then $c'(a) = \beta + \mu a$. The Kantian equilibrium a^K satisfies

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

where q^N is the stage-two Nash equilibrium output choice under the above specification:

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

Substituting (D.2) into (D.1), we obtain a cubic equation to determine a^K. Thus, we conducted numerical simulations to determine if the above two cases happen.

Table 1 illustrates Nash equilibrium, Kantian equilibrium, and social optimum investment levels for the given parameter values. We use the following common parameters: $\alpha = 1$,

Table 1: Simulation results

Case	ρ	a^N	a^K	a^*
(i)	0	0.166	0.166	0.833
(ii)	0.2	0.166	0.593	0.833
(iii)	0.318	0.166	0.833	0.833
(iv)	0.35	0.166	0.889	0.833

$\beta = 0.15$, $\gamma = 0.4$, $\theta = 0.5$, and $\mu = 0.3$. First, under $\rho = 0$ (Case (i)), the second term in (D.1) is zero. In this case, as Proposition 1 shows, the Kantian equilibrium is equivalent to the Nash equilibrium. Second, under $\rho = 0.2$ (Case (ii)), environmental investment at the Kantian investment is lower than the social optimum. In other words, Kantian equilibrium is insufficient from the welfare point of view. Third, under $\rho = 0.318$ (Case (iii))[9], environmental investment at the Kantian equilibrium is coincident to the social optimum. In other words, Kantian equilibrium is efficient from the welfare point of view. Finally, under $\rho = 0.35$ (Case (iv)), Kantian investment is above the socially optimal level. The Kantian equilibrium is thus excessive from the welfare point of view.