The Environmental Effect of Ambient Charges in Mixed Triopoly with Diverse Firm Objectives

Kazuhiro OHNISHI
Institute for Economic Sciences, Japan
ohnishi@e.people.or.jp

Article's history:

Received 10th of September, 2021; *Received in revised form* 28th of September, 2021; *Accepted* 4th of October, 2021; *Published* 15th of October, 2021.

Suggested citation:

Ohnishi, K. 2021. The Environmental Effect of Ambient Charges in Mixed Triopoly with Diverse Firm Objectives, *Journal of Applied Economic Sciences*, Volume XVI, Fall, 3(73): 247– 250.

Abstract:

Most models of economic theory assume that firms maximize profits. However, in the real world, not all firms adopt profit maximizing behavior. Therefore, this paper examines a quantity-setting mixed triopoly model comprising a profit-maximizing firm, a partially cooperating firm and a socially concerned firm to reassess the environmental effect of an increase in ambient charges. The paper demonstrates that an increase in the ambient charge can reduce pollutant emissions.

Keywords: ambient charge; Cournot triopoly; partially cooperating firm; pollution; profit-maximizing firm; socially concerned firm.

JEL Classification: C72; D21; Q58

Introduction

The theoretical analysis by Ganguli and Raju (2012) considers two Bertrand duopoly games to reassess the effect of an increase in ambient charges as a policy measure for reducing industrial non-point source pollution. In the first game, the regulator first announces the ambient charge and then two firms non-cooperatively and simultaneously choose their prices. In this game, the pollution abatement technologies are assumed to be fixed. In the second game, knowing that the ambient charge has been announced by the regulator, two firms non-cooperatively and simultaneously choose their pollution abatement technologies in the first stage and prices in the second stage. Ganguli and Raju demonstrate that in each game an increase in the ambient charge leads to more pollution. In addition, Sato (2017) examines the effect of an increase in ambient charges in a static Cournot duopoly model and shows that an increase in the ambient charge leads to less pollution as opposed to Bertrand duopoly competition.

Most models of economic theory assume that firms maximize profits. Therefore, the behavior of profit-maximizing firms has been most frequently encountered in the literature on economic theory. However, in the real world, not all firms adopt profit maximizing behavior. For example, some economic models include partially cooperating firms (Cyert and DeGroot 1973, Bischi *et al*. 2010, Matsumoto, Merlone and Szidarovszky, 2010, Cracau 2015). Each partially cooperating firm's aim is to maximize the sum of its own profit and certain proportions of the profits of the other firms.

In addition, economic market models that incorporate socially concerned firms are sometimes analyzed by economists (Goering 2007, Kopel and Brand 2012, 2013; Lambertini and Tampieri 2012, Kopel, Lamantia and Szidarovszky 2014, Xu 2014, Cracau 2015, Kopel 2015, Fanti and Buccella 2018, García, Leal and Lee 2019, Han 2019). Each socially concerned firm's aim is to maximize the weighted sum of its own profit and consumer surplus.

In this paper, we examine a quantity-setting mixed triopoly model comprising a profit-maximizing firm, a partially cooperating firm and a socially concerned firm to reassess the environmental effect of an increase in ambient charges.

The remainder of this paper is structured as follows. In section 1, we describe the model used, section 2 presents the main result of this study, and the final section concludes the paper.

1. The Model: Quantity-Setting Mixed Triopoly

We consider three firms: a profit-maximizing firm (firm P), a partially cooperating firm (firm C) and a socially concerned firm (firm S). There is no possibility of entry or exit. In the remainder of this paper, subscripts P, C and S represent firm P, firm C and firm S, respectively.

The production quantity of firm *i* (*i* = P, C, S) is represented as q_i. The inverse demand function is linear: $P = a - Q$, where P represents the market price, $Q = q_P + q_C + q_S$ is the aggregate demand, and a is a constant. The total amount of pollution generated by the firms is given by $E = e(q_P + q_C + q_S)$, where $e \in (0, \infty)$ denotes the pollution abatement technology.

Firm *i*' s profit is given by:

$$\pi_i = (a - Q)q_i - c_i q_i - m(eQ - \bar{E}), \tag{1}$$

where $c_i \in (0, \infty)$ represents firm *i*'s marginal cost of production and $\bar{E}$ is the environmental standard. If $eQ < \bar{E}$, then the regulator of the government will give the firms a subsidy of $m(\bar{E} - eQ)$, whereas if $eQ > \bar{E}$, then the firms will be penalized by $m(eQ - \bar{E})$.

Firm C's objective function is given by:

$$V_C = \pi_C + \beta(\pi_P + \pi_S), \tag{2}$$

where $\beta \in [0, 1]$ denotes the level of cooperation.

Firm S's objective function is given by:

$$W_S = \pi_S + \theta CS, \tag{3}$$

where $CS = \frac{1}{2}Q^2$ represents consumer surplus and $\theta \in [0, 1]$ is the level of social concern.

We assume that all outputs obtained in Cournot-Nash equilibrium are non-negative. In the next section, we present the result of the mixed triopoly model.

2. Main Results of the Applied Model

From (1), (2) and (3), we can derive the following reaction functions:

$$R_P(q_C, q_S) = \frac{a - c_P - em - q_C - q_S}{2}. \tag{4}$$

$$R_C(q_P, q_S) = \frac{a - c_C - (1+2\beta)em - (1+\beta)q_P - (1+\beta)q_S}{2}, \tag{5}$$

$$R_S(q_P, q_C) = \frac{a - c_S - em - (1-\theta)q_P - (1-\theta)q_C}{2-\theta}. \tag{6}$$

Solving these reaction functions simultaneously, we have the following equilibrium quantities:

$$q_P^* = \frac{(1-\theta+\beta\theta)a - (3-\beta-\theta+\beta\theta)c_P + c_C + (1-\beta)c_S - (1-2\beta-\theta+\beta\theta)em}{4-2\beta-\theta+\beta\theta},$$

$$q_C^* = \frac{(1-2\beta-\theta)a + (1+\beta)c_P - (3-\theta)c_C + (1+\beta)c_S + (1-4\beta+\theta+2\beta\theta)em}{4-2\beta-\theta+\beta\theta},$$

$$q_S^* = \frac{(1+2\theta-\beta\theta)a + (1-\beta-\theta+\beta\theta)c_P + (1-\theta)c_C - (3-\beta)c_S - (1-2\beta+2\theta-\beta\theta)em}{4-2\beta-\theta+\beta\theta}.$$

When e is given, the industrial emission quantity can be calculated as follows:

$$e(q_P^* + q_C^* + q_S^*) = \frac{e[(3-2\beta)a - (1-\beta)c_P - c_C - (1-\beta)c_S - 3em]}{4-2\beta-\theta+\beta\theta}. \tag{7}$$

Equation (7) is a function of the policy parameter m. Therefore, we can represent $e(q_P^* + q_C^* + q_S^*)$ as a function $E(m)$. If $E(m)$ is differentiated by m, then:

$$E'(m) = -\frac{3e^2}{4 - 2\beta - \theta + \beta\theta}. \tag{8}$$

We can now present the following proposition.

Proposition 1: In the quantity-setting mixed triopoly model, $E'(m) < 0$.

We find that the result of this proposition is the same as that obtained from profit-maximizing Cournot duopoly competition.

Conclusion

We have examined a quantity-setting mixed triopoly model comprising a profit-maximizing firm, a partially cooperating firm and a socially concerned firm, and have demonstrated that an increase in the ambient charge can always lead to less pollution. We have found that the result of this study is the same as that obtained from profit-maximizing Cournot duopoly competition.

References

[1] Bischi, G. I., Chiarella, C., Kopel, M., and Szidarovszky, F. 2010. *Nonlinear Oligopolies: Stability and Bifurcations.* Heidelberg, Germany: Springer-Verlag Berlin Heidelberg. DOI: https://doi.org/10.1007/978-3-642-02106-0

[2] Cracau, D. 2015. *The Effect of Strategic Firm Objectives on Competition.* In K. Ohnishi (Ed) Firms' Strategic Decisions: Theoretical and Empirical Findings, Volume 1, pp. 170-181. Sharjah, UAE: Bentham Science Publishers. Available at: https://www.eurekaselect.com/130048/chapter/the-effect-of-strategic-firm-objectives-on-competitio

[3] Cyert, R. M., and DeGroot, M. H. 1973. An analysis of cooperation and learning in a duopoly context. *American Economic Review,* 63(1): 24-37.

[4] Fanti, L., and Buccella, D. 2018. Profitability of corporate social responsibility in network industries. *International Review of Economics,* 65(3): 271-289. DOI: https://doi.org/10.1007/s12232-018-0297-8

[5] Ganguli, S., Raju, S. 2012. Perverse environmental effects of ambient charges in a Bertrand duopoly. *Journal of Environmental Economics and Policy,* 1(3): 289-296. DOI: https://doi.org/10.1080/21606544.2012.714972

[6] García, A., Leal, M., and Lee, S.-H. 2019. Endogenous timing with a socially responsible firm. *Korean Economic Review,* 35(2): 345-370. DOI: https://doi.org/10.22841/kerdoi.2019.35.2.003

[7] Goering, G. E. 2007. The strategic use of managerial incentives in a non-profit firm mixed duopoly. *Managerial and Decision Economics,* 28(2): 83-91. DOI: https://doi.org/10.1002/mde.1307

[8] Han, L. 2019. Partial ownership for a public firm and corporate social responsibility. *Theoretical Economics Letters,* 9: 2447-2455. DOI: https://doi.org/10.4236/tel.2019.97155

[9] Kopel, M. 2015. Price and quantity contracts in a mixed duopoly with a socially concerned firm. *Managerial and Decision Economics,* 36(8): 559-566. DOI: https://doi.org/10.1002/mde.2707

[10] Kopel, M., and Brand, B. 2012. Socially responsible firms and endogenous choice of strategic incentives. *Economic Modelling,* 29(3): 982-989. DOI: https://doi.org/10.15266/KEREA.2018.27.1.001

[11] Kopel, M., and Brand, B. 2013. Why do socially concerned firms provide low-powered incentives to their managers? SSRN Electric Journal. Available at: https://ssrn.com/abstract=2269192

[12] Kopel, M., Lamantia, F., and Szidarovszky, F. 2014. Evolutionary competition in a mixed market with socially concerned firms. Journal of *Economic Dynamic & Control,* 48: 394-409. DOI: https://doi.org/10.1016/j.jedc.2014.06.001

[13] Lambertini, L., and Tampieri, A. 2012. Corporate social responsibility and firms' ability to collude. In: Boubaker, S., Nguyen, D. K. (Eds.), *Board Directors and Corporate Social Responsibility*, pp: 167-178. London: Palgrave Macmillan.

[14] Matsumoto, A., Merlone, U., and Szidarovszky, F. 2010. Dynamic oligopoly with partial cooperation and antitrust threshold. *Journal of Economic Behavior & Organization,* 73(2): 259-272. DOI: https://doi.org/10.1016/j.jebo.2009.08.014

[15] Sato, H. 2017. Pollution from Cournot duopoly industry and the effect of ambient charges. *Journal of Environmental Economics and Policy,* 6(3): 305-308. DOI: https://doi.org/10.1080/21606544.2017.1296381

[16] Xu, Y. 2014. CSR impact on hospital duopoly with price and quality competition. *Journal of Applied Mathematics,* 2014: 152060. DOI: https://doi.org/10.1155/2014/152060