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29 June 2021

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Abstract

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; socially concerned firm

JEL classification: C72; D21; Q58

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1. Introduction

The 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 behaviour 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 behaviour. For example, some economic models include partially cooperating firms (Cyert and DeGroot, 1973; Bischi et al, 2010; Matsumoto et al, 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; Lambertini and Tampieri, 2012; Cracau, 2015; Kopel, 2015; Garcfa et al, 2019). Each socially concerned firm's aim is to maximize the sum of its own profit and a proportion of consumer surplus.

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 2, we describe the model

used. Section 3 presents the main result of this study. Finally, Section 4 concludes the paper.

2. The model

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 $i(i = \mathrm{P},\mathrm{C},\mathrm{S})$ is represented as q_i. The inverse demand function is linear: $P = a - Q$, where P represents the market price, $Q = q_{\mathrm{P}} + q_{\mathrm{C}} + q_{\mathrm{S}}$ is the aggregate demand, and a is a constant. The total amount of pollution generated by the firms is given by $E = e\left(q_{\mathrm{P}} + q_{\mathrm{C}} + q_{\mathrm{S}}\right)$, where $e \in (0,\infty)$ denotes the pollution abatement technology.

Firm *i*'s profit is given by

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

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 $m\left(\bar{E} - eQ\right)$, whereas if $eQ > \bar{E}$, then the firms will be penalized by $m\left(eQ - \bar{E}\right)$.

Firm C's objective function is given by

$$V_{\mathrm{C}} = \pi_{\mathrm{C}} + \beta\left(\pi_{\mathrm{P}} + \pi_{\mathrm{S}}\right), \tag{2}$$

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

Firm S's objective function is given by

$$W_{\mathrm{S}} = \pi_{\mathrm{S}} + \theta CS, \tag{3}$$

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.

3. Main result

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

$$R_{\mathrm{P}}(q_{\mathrm{C}}, q_{\mathrm{S}}) = \frac{a - c_{\mathrm{P}} - em - q_{\mathrm{C}} - q_{\mathrm{S}}}{2}. \tag{4}$$

$$R_{\mathrm{C}}(q_{\mathrm{P}}, q_{\mathrm{S}}) = \frac{a - c_{\mathrm{C}} - (1+2\beta)em - (1+\beta)q_{\mathrm{P}} - (1+\beta)q_{\mathrm{S}}}{2}, \tag{5}$$

$$R_{\mathrm{S}}(q_{\mathrm{P}}, q_{\mathrm{C}}) = \frac{a - c_{\mathrm{S}} - em - (1-\theta)q_{\mathrm{P}} - (1-\theta)q_{\mathrm{C}}}{2-\theta}. \tag{6}$$

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

$$q_{\mathrm{P}}^{*} = \frac{(1-\theta+\beta\theta)a - (3-\beta-\theta+\beta\theta)c_{\mathrm{P}} + c_{\mathrm{C}} + (1-\beta)c_{\mathrm{S}} - (1-2\beta-\theta+\beta\theta)em}{4-2\beta-\theta+\beta\theta},$$

$$q_{\mathrm{C}}^{*} = \frac{(1-2\beta-\theta)a + (1+\beta)c_{\mathrm{P}} - (3-\theta)c_{\mathrm{C}} + (1+\beta)c_{\mathrm{S}} + (1-4\beta+\theta+2\beta\theta)em}{4-2\beta-\theta+\beta\theta},$$

$$q_{\mathrm{S}}^{*} = \frac{(1+2\theta-\beta\theta)a + (1-\beta-\theta+\beta\theta)c_{\mathrm{P}} + (1-\theta)c_{\mathrm{C}} - (3-\beta)c_{\mathrm{S}} - (1-2\beta+2\theta-\beta\theta)em}{4-2\beta-\theta+\beta\theta}.$$

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

$$e\left(q_{\mathrm{P}}^{*} + q_{\mathrm{C}}^{*} + q_{\mathrm{S}}^{*}\right) = \frac{e\left[(3-2\beta)a - (1-\beta)c_{\mathrm{P}} - c_{\mathrm{C}} - (1-\beta)c_{\mathrm{S}} - 3em\right]}{4-2\beta-\theta+\beta\theta}. \tag{7}$$

Equation (7) is a function of the policy parameter m. Therefore, we can represent $e\left(q_{\mathrm{P}}^{*} + q_{\mathrm{C}}^{*} + q_{\mathrm{S}}^{*}\right)$ 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.

4. 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.

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