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Emission tax and optimal privatization in Cournot–Bertrand comparison☆

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ABSTRACT

We compare a Cournot with a Bertrand duopoly in a differentiated mixed market when both emission tax and privatization policies are used together. We find that the optimal emission tax is always lower than the marginal environmental damage, and it is always lower under Cournot than under Bertrand. We also find that the optimal privatization is always a partial privatization, and it is always higher under Cournot than under Bertrand. The socially optimal combinations of emission tax and privatization will damage the environment most, but Cournot yields lower environmental damage and social welfare than those under Bertrand. Finally, we show that the environmental damage is non-monotone in the level of privatization under both Cournot and Bertrand competitions.

1. Introduction

In environmental economics literature, policy concerns over environmental quality and oligopolistic competition have been prominent since the 1980s. Governments are usually encouraged to conduct environmental regulations by imposing environmental taxes, pollution permits, and standards on polluting private firms, which require the procedures to clean up the pollution and adopt abatement technology.[1] The possible benefits of public ownership have also motivated recent analyses on mixed markets where profit-maximizing private firms compete against a welfare-maximizing public firm.[2] Nowadays, a partial or complete privatization of a public firm has been a feature of government policy in many developing as well as developed countries.[3]

Since the last decade, analysis of environmental concerns on a mixed market has been paid attention by several researchers. Beladi and Chao (2006) proved that privatization might exert a negative effect on environment and thus environmental quality should be managed under the public domain. Bárcena-Ruiz and Garzón (2006) showed that an environmental tax is lower in a mixed oligopoly than in a private one, and thus the environmental damage is greater under nationalization. Ohori (2006); Wang et al. (2009), and Pal and Saha (2015) explored the interaction between privatization and environmental tax, and showed that the optimal environmental tax is lower than the marginal environmental damage and partial privatization is the best policy.

Recent studies on mixed markets have considered the environmental impact of differentiated products in the context of Cournot–Bertrand comparison. Wang and Wang (2009) showed that the environment is less (more) damaged, but social welfare deteriorates more (less) accompanied with privatization when the product is more (less) substitutable. Ohori (2014) showed that Cournot competition entails both lower environmental damage and lower social welfare than Bertrand competition. However, these papers did not consider the optimal degree of partial privatization in a differentiated mixed market.

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[1] The research on environmental regulation on polluting firms in an oligopolistic competition has diversified in several directions, which include Cournot oligopoly (Levin, 1985), asymmetric abatement cost (Simpson, 1995), endogenous market structure (Lee, 1999), eco-industry (David and Sinclair-Desgagne, 2005; Lee and Park, 2011), and international competition (Ohori, 2006; Xu and Lee, 2015).

[2] We have witnessed mixed markets that exist in a broad range of industries, such as oil, gas, automobile, steel, chemical, telecommunications, electricity, power plant, hospital, and so on, which emit pollutants in the production process. It has also been noted that in transition economies many state-owned industries were reliant on highly polluting technologies. Some related descriptions can be found in Wang and Wang (2009) and Pal and Saha (2015).

[3] Many empirical evidences of partial privatization can be found in recent discussions. See, for example, Gupta (2005); Fan et al. (2007); Boubakri et al. (2008), and Pal and Saha (2015).

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In this paper, we try to disentangle the privatization-environment relationship in a differentiated mixed duopoly model where partial privatization and emission tax are used together. Pal and Saha (2015) recently examined this issue under Cournot model and showed that the environmental damage is non-monotone in the level of privatization and the optimal privatization is always a partial privatization. Using their model with a quadratic cost function, we investigate and compare the effect of product differentiation to choose an optimal privatization and emission tax under both Cournot and Bertrand competitions.[4]

Comparing a Cournot with a Bertrand duopoly, we find that the optimal emission tax is always lower than the marginal environmental damage, and it is always lower under Cournot than under Bertrand, which is in contrast to Ohori (2014). We also find that the optimal privatization is always a partial privatization, and it is always higher under Cournot than under Bertrand, which supports the results by Scrimitore (2014a), who examined the Cournot–Bertrand comparisons in a mixed market without considering an emission tax. The socially optimal combinations of emission tax and privatization will damage the environment most, but Cournot yields lower environmental damage and social welfare than those under Bertrand, which is also in contrast to Ohori (2014). Irrespective of the degree of product differentiation, we show that Bertrand competition yields lower prices, higher abatements, and less profits. Finally, we show that the environmental damage is non-monotone in the level of privatization under both Cournot and Bertrand, which also support the results in Pal and Saha (2015), who examined the privatization-environment relationship under Cournot competition. Furthermore, when the public firm cares about environment, we show that the environmental damage will be lower than the pre-privatization level under both Cournot and Bertrand competitions.

The remainder of this paper is organized as follows. In Section 2, we formulate the model of a product differentiated mixed duopoly. In Section 3, we analyze two canonical models of Cournot and Bertrand competitions, and investigate the optimal decisions on emission tax and partial privatization. In Section 4, we compare the results of the two models and provide some interesting results. The final section provides the concluding remarks.

2. The model

We consider a mixed duopoly model where a (partially) public firm and an (entirely) private firm produce differentiated products. Firm 0 is a public firm that maximizes a certain objective function, which will be described later, while firm 1 is a profit-maximizing private firm. Following Dixit (1979), a representative consumer's utility function is given by

$$U(q_0, q_1) = q_0 + q_1 - \frac{1}{2}\left({q_0}^2 + 2bq_0q_1 + {q_1}^2\right), \tag{1}$$

where q_i is the output of public and private firms, and $b \in (0,1)$ measures the degree of product differentiation. A higher value of b represents a lower degree of product differentiation or higher substitutability.

The inverse demand function aof each firm is $p_i = 1 - q_i - bq_j$, $i = j = 0, 1$, $i \neq j$, where p_i is the market price of product i. Then, the consumer surplus is represented by $CS = (q_0^2 + 2bq_0q_1 + q_1^2)/2$. Note that a higher substitutability reduces consumer's willingness to pay for each product, but increases the consumer surplus. We assume that both firms have identical technologies and the production cost function takes a quadratic form, $C(q_i) = F + q_i^2$, where $F = 0$ without the loss of the generality.

The production in both public and private firms leads to pollution e_i, but each firm can prevent pollution by undertaking abatement activities. Suppose that firm i chooses pollution abatement level a_i, then the emission level of each firm is given by $e_i = q_i - a_i$, where firm i can reduce its emission a_i by investing an amount of $a_i^2/2$ in abatement activities.[5] The extent of environmental damage due to pollution by the industry is assumed to be given by $ED = \left(\sum_i e_i\right)^2/2$. The government imposes an environmental tax on the emission level for which the tax rate is t. The resulting total tax revenue is $T = t\sum_i e_i$.

The profit of firm i is given by

$$\pi_i = p_iq_1 - {q_i}^2 - te_i - \frac{a_1^2}{2}, i = 0, 1. \tag{2}$$

Then, the social welfare is the sum of consumer surplus CS, both firms' profits $\pi_o + \pi_1$, and tax revenue T, minus environmental damage ED:

$$W = CS + \pi_0 + \pi_1 + T - ED. \tag{3}$$

Regarding the objective functions of the firms, we assume that a private firm seeks profit maximization, whereas a public firm considers not only its profit but also consumer surplus. Adopting the mixed duopoly model proposed by Matsumura (1998), we assume that the objective function of a (partially) public firm is defined as the weight sum of consumer surplus and its profit[6]:

$$G = \theta\ \pi_0 + (1-\theta)(\pi_0 + CS), \tag{4}$$

where θ is interpreted as the degree of privatized ownership, $\theta \in [0,1]$. That is, the private sector owns a share θ of the public firm. Clearly, the larger the value of θ, the more private ownership. For example, when $\theta = 1$, it is a fully profit-oriented private firm and when $\theta = 0$, it is a completely consumer surplus-concerned public firm. We can interpret this objective function as a situation that semi-public firm takes its profit-maximizing decision under consumer surplus-constrained regulation in which consumer surplus in the market does not fall below a fixed level. Note that the result of price regulation is equivalent to that of the rate-of-return regulation for semi-public firm, in which the government obtains the market quantities and prices that maximize consumer surplus subject to permitting the firm to earn some fixed profit.[7]

In this paper, a two-stage game is constructed. In the first stage, the government chooses the levels of emission tax and privatization to maximize social welfare. In the second stage, both the firms choose output (price) and abatement levels simultaneously. The backward induction produces a sub-game perfect Nash equilibrium.

[4] Recently, several researches have investigated the Cournot-Bertrand comparisons in a product differentiated mixed market. See, for example, Ghosh and Mitra (2010, 2014); Matsumura and Ogawa (2012, 2014); Scrimitore (2013, 2014a, 2014b); Haraguchi and Matsumura (2014, 2015), and Nakamura (2015).

[5] For simplicity of tractability, in line with the literature (Wang and Wang, 2009; Lee and Park, 2011), we focus on end-of-pipe abatement, which is additively separable. Implicitly, we also assume that both products emit the same type of pollutants.

[6] A public firm may or may not share the same objectives as the government. Several papers have allowed divergence between the decisions on firm level (output, price, abatement, etc.) and those on government level (privatization, emission tax). Bárcena-Ruiz and Garzón (2006); Kato (2013), and Pal and Saha (2015) explored the objective function of the government in mixed markets and found that the optimal decision to privatize a public firm may differ depending on whether the government internalizes the environmental damage or ignores it. Some researchers also examined a mixed market where a public firm no longer internalizes environmental externalities in its objective function. See, for example, Beladi and Chao (2006); Saha (2009); Wang and Wang (2009); Ohori (2012), and Pal and Saha (2015). In the Appendix, we provide results of the public firm that concerned about environment, in which the objective function of the public firm is $G = \theta\pi_0 + (1-\theta)W$.

[7] The price regulation with welfare-constraint yields the well-known Ramsey prices, in which the price–cost margins are inversely proportional to the elasticity of demand. For more detailed discussions on this point, see Brennan (1991) and Lee (1998).