Review of Industrial Organization **22:** 183–206, 2003.

Incentives for Anticompetitive Behavior by Public Enterprises ⋆

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Abstract. We examine the competitive behavior of a public enterprise that does not seek solely to maximize its profit. We find that despite a reduced focus on profit, a public enterprise may have stronger incentives to pursue anticompetitive activities than does a private, profit-maximizing firm. These activities include setting prices below marginal cost, raising the operating costs of existing rivals, erecting entry barriers to preclude the operation of new competitors, and circumventing regulations designed to foster competition.

Key words: Anticompetitive behavior, public enterprises.

JEL Classifications: L44, H10, K21.

I. Introduction

Most formal analyses of competition among firms assume that each firm seeks to maximize its profit. This is a reasonable approximation in many settings. But government (public) enterprises do not typically seek to maximize profit, and public enterprises compete directly with private, profit-maximizing enterprises in many important markets. For example, government postal firms often offer overnight mail and package shipping services in direct competition with private delivery companies. Public hospitals and educational institutions also compete directly with private suppliers of similar services in many countries. Production by public enterprises can be particularly widespread in developing countries. During the 1980s, for example, public enterprises accounted for approximately 14 percent of gross domestic product (GDP) in African nations, and for approximately 11 percent of GDP in developing countries as a whole (World Bank, 1995, p. 30).[1]

⋆ We thank Gary Grizzle, Thomas Hazlett, John Mayo, John McKeever, Hal Singer, Gregory Vistnes, seminar participants at the American Enterprise Institute, the Editor, and an anonymous referee for helpful comments.

[1] These statistics are consistent with Short's (1984, p. 118) earlier findings that, on average, public enterprises accounted for 8.6 percent of GDP and 27.0 percent of capital formation in the late 1970s. The corresponding percentages for Africa were 17.5 and 32.4, respectively.

Because public enterprises may pursue objectives other than profit maximization,[2] their behavior may differ systematically from the behavior of profit-maximizing firms. The purpose of this research is to begin to explore some of these systematic differences. In particular, we ask whether a public enterprise that pursues both profit and additional objectives will act less aggressively toward its competitors than will its profit-maximizing counterparts. The answer, of course, depends upon the nature of the other objectives the public enterprise pursues. Although we allow for the possibility that the public enterprise might pursue a variety of objectives, we focus our formal analysis on the setting where the public enterprise seeks both profit and expanded scale of operations, perhaps because the managers of the enterprise benefit personally from expanded scale (Niskanen, 1975) and because limited oversight from capital markets provides the managers with expanded freedom to pursue their personal objectives (Geddes, 1994).

One might suspect that a reduced concern with profit could render the public enterprise a less aggressive competitor. We find, to the contrary, that a reduced focus on profit can provide a public enterprise with stronger incentives than profit-maximizing firms to pursue activities that disadvantage competitors. We also find that the less concerned is the public enterprise with profit, the stronger its incentives may be to undertake activities that disadvantage competitors. These activities include setting prices below cost, misstating costs and choosing inefficient technologies in order to circumvent restrictions on below-cost pricing, raising the operating costs of existing rivals, and erecting entry barriers to preclude the operation of new competitors.

Our analysis differs from many other analyses in the literature because we focus on the strategic actions that public enterprises might undertake to disadvantage competitors and to evade regulations designed to foster competition.[3] Although others have shown that profit-maximizing firms may pursue some of these actions, we demonstrate that public enterprises may have the incentive to pursue these actions even more aggressively.[4] Since these actions can reduce welfare, our findings complement those of other researchers who have shown that the operation of a public enterprise can be detrimental even when the public enterprise seeks to maximize social welfare (Cremer et al., 1991; De Fraja and Delbono, 1989).[5] Our analysis

[2] The United States Postal Service, for example, is required by statute to consider the fairness, equity, and simplicity of its rate structure as well as the relationships among prices, production costs, and the value of the service provided (39 U.S.C. § 3622).

[3] In this respect, our analysis is similar to Lott's (1990, 1999) seminal work. We describe some of the differences between our analysis and Lott's work immediately below.

[4] Salop (1979), Salop and Scheffman (1983, 1987), Brock (1983), Salop et al. (1984), Krattenmaker and Salop (1986), Ordover and Saloner (1989), and Economides (1998), among others, analyze the incentives for profit-maximizing firms to raise their rivals' operating costs.

[5] The welfare loss in Cremer et al.'s (1991) model arises because the presence of a public enterprise induces private firms to offer less product variety to consumers. The loss in De Fraja and Delbono's (1989) model occurs because the public enterprise produces a disproportionate share of industry output, thereby raising total production costs.

also extends Lott's (1990) observation that public enterprises may set prices below marginal production costs and thereby harm competition and reduce welfare.[6] We extend Lott's analysis by modeling formally a range of possible objectives for the public enterprise and by specifying precise conditions under which a public enterprise will price below marginal cost.

We do not provide a comprehensive assessment of the benefits and costs of public enterprises. In particular, we do not explain why the operation of public enterprises may be preferred to operation by private, profit-maximizing firms in some settings.[7] We also abstract from any innate cost differences between public and private enterprises,[8] and we examine formally only a subset of the many possible objectives that a public enterprise might pursue. Therefore, our research is not designed to deliver broad prescriptions regarding the most appropriate policies toward public enterprises. Our analysis does suggest, however, that the incentives that public enterprises have to engage in various forms of anticompetitive behavior deserve careful consideration in any comprehensive assessment of the benefits and costs of public enterprises.[9]

Our formal analysis begins in Section II, where we examine the equilibrium prices a public enterprise will set when it faces no explicit pricing restrictions. The analysis identifies sufficient conditions for a public enterprise to set prices below marginal production costs. In Section III, we investigate some of the methods that a public enterprise might employ to relax a binding prohibition against below-cost pricing. We show that a public enterprise may have stronger incentives than a profit-maximizing firm to manipulate accounting data in order to understate marginal costs and to over-invest in capital in order to reduce marginal production costs.

Section IV examines the incentives a public enterprise may have to raise the operating costs of existing rivals or to erect barriers to keep potential rivals from entering the market. We identify conditions under which a public enterprise will have stronger incentives to undertake these activities than will a private, profit-maximizing firm. Conclusions and directions for future research are discussed in Section V. The proofs of all formal results are provided in Appendix A.

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[6] Lott (1999) reiterates this observation and provides some supporting empirical evidence.

[7] See Baumol (1984), Ruys (1988), Cremer et al. (1989), Delbono and Rossini (1992), Delbono and Denicolo (1993), MacAvoy and McIsaac (1995), Hansmann (1996), Cremer et al. (1997), Hart et al. (1997), and Shleifer (1998), among others, for some analyses of this issue.

[8] Boardman and Vining (1989) provide a review of the empirical literature that addresses this issue. Also see Newbery (1999).

[9] Our focus throughout is on public enterprises. However, to the extent that private, nonprofit firms share similar objectives with public enterprises or to the extent that a separation of ownership and control leads a private for-profit firm to pursue objectives other than pure profit maximization, some of our conclusions may pertain to private enterprises. Philipson and Posner (2001) argue that a nonprofit firm may act particularly aggressively toward its competitors, since driving competitors from the market can provide the nonprofit firm with expanded freedom to pursue its varied objectives. See Hansmann (1996), Rose-Ackerman (1996), and Weisbrod (1997), for example, for additional analyses of nonprofit organizations.

II. Public Enterprise Pricing

We first examine how the equilibrium prices that a public enterprise sets vary with its objectives. As noted above, a public enterprise may not seek solely to maximize the profit it generates. The profit that a public enterprise is permitted to earn is often explicitly limited, and public enterprises are commonly instructed to pursue goals that are distinct from, if not fundamentally incompatible with, profit maximization.[10] As these goals can be many and varied, it is difficult to specify a single objective function that reflects all relevant goals of all public enterprises. However, some progress toward specifying the likely objectives of public enterprises can be made by considering the objectives of the various parties that may influence the activities of a public enterprise. As Stigler (1971), Peltzman (1971), and Becker (1983), among others, have noted, parties affected by the actions of a public entity may have strong incentives to influence these actions. The resulting influence may induce the public entity to act in the interest of the affected parties.

Taxpayers may influence the policies of a public enterprise, perhaps by lobbying elected or appointed representatives. Taxpayers as a whole may encourage the public enterprise to maximize the profit it generates. Consumers of the goods and services produced by the public enterprise and its private counterparts may also be able to gain some influence over the activities of the public enterprise in some settings. As a group, these consumers may encourage the public enterprise to maximize the consumers' surplus generated in the industry. Conceivably, competitors themselves might secure some influence over the activities of the public enterprise in some settings (via lobbying government officials, for example). Private competitors would likely employ any such influence to encourage the public enterprise to enhance the profit earned by its competitors.

The managers of a public enterprise may secure particular influence over its activities. This influence may stem in part from the fact that public enterprises typically are immune from takeover threats and are generally less subject to the discipline of capital markets than are private enterprises (Geddes, 1994, 2002; Oster, 1995).[11] The reduced discipline of capital markets can afford managers of a public enterprise considerable discretion to pursue their own objectives. Managers of public enterprises may have considerable interest in expanding the scale or scope of their activities (Niskanen, 1971, 1975), in part because a manager's abilities are often inferred from the size of the operations that he or she oversees. Furthermore, for the reasons identified by Niskanen (1975), the government officials that monitor most closely and direct the activities of public enterprises often share this preference for relatively large output levels. Expanded output can also promote expanded

[10] Universal service – providing high-quality service that is affordable to all citizens – is one such common goal. See Posner (1971), for example.

[11] Therefore, even though the managers of private, profit-maximizing firms may have goals and interests similar to those of managers in public enterprises, the discipline of capital markets will limit the freedom of private managers to pursue private interests that do not maximize shareholder value.

employment, which can be a goal of public enterprises and elected officials alike (Geddes, 2002).[12]

To capture these varied interests formally,[13] the following notation is helpful. Suppose the public enterprise supplies $n \geq 1$ products. Let $p_i \geq 0$ denote the price of the ith product, and $p \equiv (p_1, \ldots, p_n)$ the vector of prices for all n products. Also let $Q_i(\cdot)$ denote the demand for the public enterprise's ith product and $Q \equiv (Q_1(\cdot), \ldots, Q_n(\cdot))$ the vector of demands for the public enterprise's n products. $C(Q)$ will denote the public enterprise's cost of producing output Q.

For simplicity, suppose the public enterprise faces the same, single profit-maximizing competitor in each market in which it operates. The prices charged by this competitor are denoted $\tilde{p} \equiv (\tilde{p}_1, \ldots, \tilde{p}_n)$, and the corresponding vector of the competitor's outputs is denoted $\tilde{Q} \equiv (\tilde{Q}_1(\cdot), \ldots, \tilde{Q}_n(\cdot))$. The competitor's cost of producing output $\tilde{Q}$ is $\tilde{C}(\tilde{Q})$. The surplus enjoyed by customers of the public enterprise when prices p and $\tilde{p}$ are set is denoted $S(p, \tilde{p})$. The corresponding surplus of the competitor's customers is denoted $\tilde{S}(\tilde{p}, p)$.

Finally, let α^T, α^M, α^C, $\tilde{\alpha}^\pi$, and $\tilde{\alpha}^C$ denote the weight the public enterprise places on the interests of taxpayers, the enterprise's managers, its customers, the competitor, and the competitor's customers when it formulates its policies. Presuming that the public enterprise acts to maximize a weighted average of these varied interests, its objective function can be written as:

$$\begin{aligned}\alpha^T[p \cdot Q(p, \tilde{p}) \; - \; & C(Q(\cdot))] + \alpha^M p \cdot Q(\cdot) + \alpha^C S(p, \tilde{p}) \\ & + \; \tilde{\alpha}^\Pi[\tilde{p} \cdot \tilde{Q}(\tilde{p}, p) - \tilde{C}(\tilde{Q}(\cdot))] + \tilde{\alpha}^C \tilde{S}(\tilde{p}, p). \qquad (1)\end{aligned}$$

The first term in expression (1) reflects taxpayers' concern with the profit of the public enterprise. The second term captures the managers' preference for expanded scale and scope, which is proxied by the revenue generated by the public enterprise. Revenue often provides a reasonable measure of the scale and scope of a firm's operations, in part because revenue constitutes a natural metric for aggregating the outputs of multiple products.[14] The third term reflects the consumers' surplus

[12] In summarizing the relevant empirical evidence, Blais and Dion (1991) conclude that bureaucrats may seek to expand the scale of their operations (by securing larger budgets) in order to realize the power and prestige that often accompany expanded operations. Rees (1984) assumes that managers in a public enterprise seek to maximize an increasing, concave function of output, subject to capital constraints and workers' preferences for high wages and expanded employment. Lindsay (1976) suggests that managers of public enterprises may seek to maximize those dimensions of output that are most highly valued by and most readily monitored by Congress, subject to specified budget constraints. For simplicity, we abstract from multiple performance dimensions, although this possibility merits attention in future research.

[13] These interests do not exhaust the set of interests that might conceivably be reflected in the objective of a public enterprise. To mention just one of the many additional possibilities, a public enterprise might be concerned with the welfare of its input suppliers. Such concern may further enhance the incentive of the public enterprise to expand its scale and scope if increased output requires that additional inputs be purchased.

[14] As Baumol (1959, pp. 32, 45) points out, "In ordinary business parlance the term 'sales' refers not to the number of physical units ... but, rather, to the *total revenue* obtained by the firm from the

that accrues to the customers of the public enterprise. The fourth and fifth terms, respectively, reflect the profits of the competitor and the surplus enjoyed by its customers.

Now consider the prices a public enterprise will set when it seeks to maximize the objective function in expression (1). Observation 1 characterizes the public enterprise's prices at a Nash equilibrium, where the public enterprise and its competitor set prices simultaneously.[15] For simplicity, Observation 1 (and all ensuing formal conclusions) analyze the case of independent demands (so that $\partial Q_i(\cdot)/\partial p_j = \partial Q_i(\cdot)/\partial \tilde{p}_j = \partial \tilde{Q}_i(\cdot)/\partial \tilde{p}_j = \partial \tilde{Q}_i(\cdot)/\partial p_j = 0$ for all $j \neq i$) and separable production costs (so $C(Q) = \sum_{i=1}^{n} C_i(Q_i(\cdot))$ and $\tilde{C}(\tilde{Q}) = \sum_{i=1}^{n} \tilde{C}_i(\tilde{Q}_i(\cdot))$, where $C_i(\cdot)$ and $\tilde{C}_i(\cdot)$, respectively, denote the total cost of producing the ith product for the public enterprise and for the competitor). It is also assumed throughout that the relevant objective functions of the public enterprise are concave.[16] Observation 1 refers to $\epsilon_i = \left|\frac{\partial Q_i}{\partial p_i}\frac{p_i}{Q_i}\right|$ and $\tilde{\epsilon}_{ii} \equiv \frac{\partial \tilde{Q}_i}{\partial p_i} \cdot \frac{p_i}{\tilde{Q}_i}$, which are the own-price elasticity of demand for the public enterprise's ith product and the cross-price elasticity of demand for the competitor's ith product with respect to the price of the public enterprise's ith product, respectively.

OBSERVATION 1. *When it acts to maximize expression* (1)*, the equilibrium prices set by the public enterprise are characterized by:*

$$\frac{p_i - w^T \dfrac{\partial C_i(\cdot)}{\partial Q_i}}{p_i} = \frac{1 - w^C}{\epsilon_i} + \tilde{w}^{\Pi}\left[\frac{\tilde{p}_i - \dfrac{\partial \tilde{C}_i(\cdot)}{\partial \tilde{Q}_i}}{\tilde{p}_i}\right]\frac{\tilde{p}_i \tilde{Q}_i(\cdot)}{p_i Q_i(\cdot)}\frac{\tilde{\epsilon}_{ii}}{\epsilon_i} + \tilde{w}^C \frac{\partial \tilde{S}(\cdot)}{\partial p_i}\frac{Q_i(\cdot)}{\epsilon_i}, \tag{2}$$

where

$$w^T \equiv \frac{\alpha^T}{\alpha^T + \alpha^M},\ w^C \equiv \frac{\alpha^C}{\alpha^T + \alpha^M},\ \tilde{w}^{\Pi} \equiv \frac{\tilde{\alpha}^{\Pi}}{\alpha^T + \alpha^M},$$

purchases of its customers". Furthermore, "In the near universal multi-product firm any measure of overall physical volume must involve index number problems, and the adoption of a value measure is doubtless to be expected".

[15] We assume the existence of a Nash equilibrium in which both firms serve customers. Thus, we presume sufficient product differentiation and sufficient similarity of cost structures.

[16] This assumption allows us to focus on the necessary conditions for solutions to the public enterprise's problems. Concavity in prices is facilitated by two assumptions that, unless otherwise noted, are maintained throughout: (1) Demand is a concave function of price ($Q_i''(p_i) \leq 0$, where primes denote derivatives); and (2) either marginal production costs increase with output ($C_i''(Q_i) \geq 0$) or they decline with output less rapidly than price declines with output along the inverse demand curve ($C_i''(Q_i(\cdot))Q_i'(p_i) < 1$).

and

$$\tilde{w}^C \equiv \frac{\tilde{\alpha}^C}{\alpha^T + \alpha^M}.$$

Equation (2) illustrates how the various interests of a public enterprise affect its equilibrium prices. If the public enterprise were concerned solely with the profit it generated for taxpayers (so $w^T = 1$ and $w^C = \tilde{w}^C = \tilde{w}^\Pi = 0$), for example, it would follow the standard rule for maximizing profit, and mark up the price of each product above its marginal cost by an amount that is inversely proportional to the price elasticity of demand for the product (i.e., $\frac{[p_i - \partial C_i(\cdot)/\partial Q_i]}{p_i} = \frac{1}{\epsilon_i}$).

Alternatively, if the public enterprise were concerned primarily with the welfare of its customers (so $w^C > 1$), it might set prices below marginal cost (as the first term to the right of the equality in Equation (2) suggests). In contrast, sufficient concern with the welfare of its competitor (so $\tilde{w}^\Pi$ is large) could induce the public enterprise to set prices well above marginal cost (as the second term to the right of the equality in Equation (2) reveals). High prices for the public enterprise's products can increase demand for the products of the competitor (and more so the higher is the cross-price elasticity of demand, $\tilde{\epsilon}_{ii}$) and thereby increase the competitor's profit, provided the competitor's prices exceed relevant marginal production costs (so $\tilde{p}_i > \partial \tilde{C}_i(\cdot)/\partial \tilde{Q}_i$). The public enterprise may also set prices well above marginal cost if it values highly the surplus enjoyed by the customers of its competitor (i.e., if $\tilde{\alpha}^C$ is large) and if this surplus increases rapidly as the prices set by the public enterprise increase (as reflected in the last term in Equation (2)).

A primary focus of this research is on how a public enterprise's concern with goals other than profit-maximization might affect its behavior in competitive environments. It is intuitively obvious (and evident from the second term to the right of the equality in Equation (2)) that a concern with the profit earned by competitors can induce a public enterprise to act in an accommodative fashion toward rival producers. It is also apparent (in part from the first term to the right of the equality in Equation (2)) that a public enterprise that aggressively pursues the interests of its customers may act as a particularly fierce competitor. The same low prices that benefit customers (including prices below marginal production costs) can severely disadvantage competitors.

To abstract from these obvious effects,[17] we focus the remainder of this research on the setting where the public enterprise's concern with the profit it generates for taxpayers is diluted only by the concern of its managers for expanded scale

[17] Some might also find unrealistic the assumption that a public enterprise typically acts in the best interests of its competitors. This view would seem to be supported, for example, by the fact that in 2001, the European Commission (EC) found that Deutsche Post AG had used profits from its state-granted monopoly in letter mail services to subsidize below-cost pricing of its competitive parcel delivery services. The EC ordered Deutsche Post to divest its parcel delivery business and to interact with the new owner of the business only on an arms' length basis. (Case COMP/35.141, Deutsche Post AG, 2001 O.J. (L125) 27 at para. 36.)

and scope. Thus, our focus is on how limited oversight by investors who seek the maximum achievable profit may affect the interaction between a public enterprise and its competitors. Formally, we will assume from this point on that $\alpha^C = \tilde{\alpha}^C = \tilde{\alpha}^\Pi = 0$, so that the public enterprise seeks to maximize

$$w\left[\sum_{i=1}^{n} p_i Q_i(\cdot)\right] + [1-w]\left[\sum_{i=1}^{n} p_i Q_i(\cdot) - C(Q(\cdot))\right], \tag{3}$$

where $w \in [0, 1]$ is the weight the public enterprise places on its managers' objective of revenue maximization and $1 - w$ is the corresponding weight on the taxpayers' objective of profit maximization. Notice that w and $1 - w$ in expression (3) correspond, respectively, to α^M and α^T in expression (1) when $\alpha^C = \tilde{\alpha}^C = \tilde{\alpha}^\Pi = 0$ and when the sum of α^M and α^T is normalized to unity. The ensuing discussion will refer to a public enterprise that seeks to maximize expression (3) as a managerially-oriented public enterprise (MPE).

Before proceeding, it is important to note that the key qualitative conclusions drawn below hold more generally. They hold, for example, if the public enterprise seeks to maximize a weighted average of output and profit, or if it seeks to maximize revenue (or output) subject to the constraint that its profit exceed some specified level. The key assumption is that the public enterprise values revenue or output as well as profit.[18]

One might suspect that an MPE's reduced focus on profit would lead it to act less aggressively toward its competitors. However, there is a countervailing effect that often outweighs this tendency, as the ensuing discussion reveals. The countervailing effect arises because the extra value that the MPE places on expanded scale and scope causes the MPE to be less concerned with the cost of output expansion than a profit-maximizing firm. Consequently, even though the MPE values the profit that its anticompetitive activities can generate less highly than does a private profit- maximizing firm, the public enterprise finds it optimal to pursue anticompetitive activities particularly aggressively. In essence, the public enterprise's increased concern with expanded scale and scope outweighs its reduced concern with profit in determining its interactions with competitors. This fact is readily observed by rewriting the MPE's objective function in expression (3) as:

$$\sum_{i=1}^{n} p_i Q_i(p) - [1-w]C(Q(\cdot)). \tag{4}$$

[18] This is not to say that all of the qualitative conclusions drawn below necessarily hold whenever a public enterprise is not concerned solely with profit maximization. Suppose, for example, that a public enterprise seeks to maximize the sum of aggregate consumers' surplus and profit in the industry (as in De Fraja and Delbono (1989), Delbono and Rossini (1992), and Delbono and Denicolo (1993), for instance). Then, even though the public enterprise will typically expand output beyond profit-maximizing levels, it will not generally set prices below marginal production costs. Although the objective of welfare maximization merits further consideration, the objective abstracts from a range of management and control issues within public firms.

Expression (4) reveals that because of its increased concern with revenue, an MPE prefers an extra dollar of revenue to a dollar reduction in cost. Consequently, an MPE will act as if its production costs were subsidized.

The failure of an MPE to internalize fully all relevant production costs parallels the failure of a regulated firm to internalize all of the costs it incurs in diversifying into unregulated markets. When the profit-maximizing firm is able to shift costs from unregulated to regulated markets under cost- based regulation, regulated customers effectively subsidize the firm's expansion into unregulated markets.[19] Consequently, a profit-maximizing regulated firm may have excessive incentive to operate in unregulated markets, just as an MPE may have excessive incentive to expand the scale and scope of its operations. An MPE's failure to internalize all relevant costs of output expansion causes it to alter its pricing decisions in predictable ways, as indicated in Corollary 1.

COROLLARY 1. *The equilibrium prices set by an MPE are characterized by the following modified inverse-elasticity rule:*

$$\frac{p_i - [1 - w]\frac{\partial C_i(\cdot)}{\partial Q_i}}{p_i} = \frac{1}{\epsilon_i}. \tag{5}$$

Expression (5) can be viewed as a modified inverse-elasticity rule (Ramsey, 1927; Baumol and Bradford, 1970). In order to maximize a weighted average of revenue and profit, the MPE implements proportional mark-ups of price over modified marginal cost ($[1 - w]\partial C_i(\cdot)/\partial Q_i$) that vary inversely with the price elasticity of demand. Prices are set further above modified cost the more inelastic is the demand for the product. This pricing rule is the same rule that a profit-maximizing firm follows, except that marginal costs are scaled down by the factor $1 - w$ to reflect the public enterprise's reduced focus on profit. The greater is its focus on revenue rather than profit (that is, the larger is w), the more the public enterprise discounts marginal costs in the modified inverse-elasticity rule.[20]

Expression (5) implies that the less profit-oriented is the public enterprise, the lower is the price it will set for each of its products (that is, $dp_i/dw < 0$ for all $i = 1, \ldots, n$). The magnitudes of the price reductions that the public enterprise

[19] See, for example, Brennan (1990), Brennan and Palmer (1994), Braeutigam and Panzar (1989), and Weisman (1993).

[20] If the public enterprise seeks to maximize revenue subject to the constraint that profit exceed a specified level, $\bar{\pi}$, its preferred prices are characterized by a modified inverse-elasticity rule analogous to expression (5). The only difference is that the term $1 - w$ in expression (5) is replaced by the term $\tilde{\lambda} \equiv \lambda/[1 - \lambda]$, where λ is the Lagrange multiplier associated with the constraint that profit exceed $\bar{\pi}$. It is readily shown that $\tilde{\lambda}$ increases as $\bar{\pi}$ decreases, and that $\tilde{\lambda} \epsilon (0, 1)$ when $\bar{\pi} \in (\pi^r, \pi^m)$, where π^r (respectively, π^m) is the level of profit the firm generates when it sets prices so as to maximize revenue (respectively, profit). Therefore, a lower value of $\tilde{\lambda}$ reflects an increased focus on revenue relative to profit when the public enterprise seeks to maximize revenue subject to a binding profit constraint, just as a lower value of $1 - w$ does when the firm seeks to maximize a weighted average of revenue and profit.

implements as it becomes less profit-oriented generally vary with the shapes of the relevant demand and cost curves. It can be shown, though, that when the MPE faces constant elasticity demand functions, a reduced focus on profit will lead the MPE to increase the extent to which it implements relatively high proportional mark-ups of price above cost on products with inelastic demand. (Formally, if $Q_i(p_i) = \alpha_i p_i^{-\epsilon_i}$ where $\epsilon_i > 1$ for all $i = 1, \ldots, n$, then $d[m_i - m_j]/dw > 0$ for $\epsilon_i < \epsilon_j$, where $m_k \equiv [p_k - \partial C_k(.)/\partial Q_k]/p_k$, for $k = i, j$.).[21] This pricing pattern reflects the fact that as the public enterprise becomes more concerned with revenue relative to profit, it becomes less averse to the higher costs that arise from increased output. Consequently, the public enterprise favors more highly the expanded output and revenue that result when the prices of products with more elastic demand are reduced.[22] As Corollary 2 reveals, the preference of the public enterprise for expanded scale and scope can induce it to set prices below marginal production costs.

COROLLARY 2. *Suppose the MPE faces constant elasticity demand functions* ($Q_i(p_i) = \alpha p_i^{-\epsilon_i}$). *Then in a Nash equilibrium, the MPE will set price below marginal cost on those products for which the price elasticity of demand exceeds* $1/w$.

Corollary 2 reflects the fact that even though profit declines as price is reduced below marginal cost, revenue can increase. Therefore, if the public enterprise's relative valuation of revenue is sufficiently pronounced and/or if demand is sufficiently elastic, the public enterprise may choose to set prices below marginal production costs. To illustrate, if the public enterprise faces constant-elasticity demand functions and values profit and revenue equally, then it will set prices below marginal cost on all products for which the price elasticity of demand exceeds 2.

Corollary 2 supports Lott's (1990, 1999) observation that a public enterprise, unlike a profit- maximizing firm, might prefer to set the price of a product below its marginal cost of production on an ongoing basis, even if the low price does not drive competitors from the market. Thus, a promise by a public enterprise to continually set prices below marginal production costs may be credible, even though a corresponding promise or threat by a firm that is known to maximize its

[21] See Sappington and Sidak (2001) for a formal proof of this conclusion. This conclusion also holds if the public enterprise faces linear demands and constant marginal production costs. Simulations reveal that the conclusion also holds in other plausible settings, but we have not been able to prove that the conclusion always holds.

[22] In practice, a public enterprise often faces the most elastic demand on those products for which competition from alternative suppliers is most pronounced. Consequently, a reduced focus on profit may lead the public enterprise to allocate price reductions disproportionately toward those products for which it faces the most intense competition. Of course, the price elasticity of demand that a firm faces typically depends upon the market price elasticity of demand and the nature and extent of industry competition. These interactions merit explicit analysis in a more comprehensive examination of the pricing policies of public enterprises.

profit may not be credible.[23] Consequently, public enterprises may be better able than profit-maximizing firms to drive more efficient competitors from the market.

III. Avoiding Restrictions on Below-Cost Pricing

The analysis to this point has focused on the prices that a public enterprise will set when its pricing flexibility is unrestricted. In practice, a public enterprise may face restrictions on feasible prices. For example, a public enterprise may be prohibited from pricing below marginal cost, as private, profit-maximizing firms typically are.[24] The purpose of this section is two-fold. First, we illustrate how a managerially-oriented public enterprise might attempt to relax a binding prohibition against below-cost pricing. Second, and more importantly, we show that a MPE may have stronger incentives than a profit-maximizing firm to devote resources to relaxing this prohibition.

1. Manipulating Accounting Data

One obvious way in which a firm might attempt to relax a binding constraint against pricing below marginal cost is to manipulate accounting data so as to understate its actual marginal cost.[25] Such understatement might be achieved by classifying as overhead (fixed) production costs some or all of the costs that truly vary as output varies. For example, the firm might count some of the personnel hired to supply the product in question as central management. An alternate way for the firm to understate its true marginal cost is to record as variable costs incurred in the provision of a different product costs that are truly incurred in producing the product whose price the firm would like to set below marginal cost. For example, the firm might claim that materials and supplies employed to produce the product in question were employed to produce a different product.

Intentional understatement of marginal production costs is likely to entail personal risk. Laws against fraud can carry severe financial penalties, and career prospects can be dimmed for managers who are suspected of knowingly reporting false information. We capture these and other costs of understating marginal

[23] Kreps and Wilson (1982) and Milgrom and Roberts (1982a, b), among others, show that a profit-maximizing firm may set below-cost prices to convince imperfectly-informed potential competitors that the firm does not simply seek to maximize profit or that its costs are lower than they truly are. See Tirole (1988, chapter 9) for a review of the relevant literature.

[24] In American law, the doctrine of sovereign immunity may shield public enterprises of the federal or state governments from application of the antitrust laws. In addition, public enterprises of state or municipal governments may be exempt from the antitrust laws under the state action immunity doctrine. See Areeda and Hovenkamp (1999, ¶ 2.12). If neither immunity applies, the public enterprise may be subject to general antitrust constraints, including those on below-cost pricing.

[25] See Sidak and Spulber (1996, pp. 105–126). For parallel observations regarding the incentives of profit-maximizing firms to overstate the costs of its regulated operations and understate the costs of its unregulated operations, see the references in footnote #19.

production costs in the function $D(u)$, which denotes the firm's expected disutility or cost of understating marginal cost by u dollars. This disutility is assumed to increase at an increasing rate with the degree of understatement.[26] So as not to bias our analysis against the public enterprise, we analyze the case in which the MPE views the costs of manipulating accounting data exactly as a profit-maximizing firm does. In particular, the MPE bears the full costs ($D(\cdot)$)of the manipulation, and does not discount these costs by the factor $1 - w$, as it implicitly discounts production costs.

The public enterprise's formal problem in this setting with possible cost understatement, labeled $[P - u]$, is:

$$\underset{p,u}{\text{Maximize}} \quad w[pQ(p)] + [1 - w][pQ(p) - C(Q(p))] - D(u) \tag{6}$$

$$\text{subject to :} \quad p \geq C'(Q(p)) - u. \tag{7}$$

Expression (3.1) reflects the MPE's desire to maximize a weighted average of revenue and profit less the disutility associated with understating marginal cost.[27] Expression (7) captures the prohibition against pricing below measured marginal cost, which is true marginal cost ($C'(\cdot)$) less any understatement (u) of marginal cost. For simplicity, we assume that the public enterprise produces only one product and we abstract from the influence of competitors' prices on the demand for the MPE's product. However, the conclusion reported in Observation 2 holds more generally.[28]

OBSERVATION 2. *In the setting with possible cost understatement, the MPE will understate its marginal cost of production in order to relax a binding prohibition against pricing below cost. The less profit-oriented is the MPE, the more it will understate its marginal cost (that is,* $u > 0$ *and* $\frac{du}{dw} > 0$ *when constraint* (7) *binds at the solution to* $[P - u]$*).*[29]

[26] Formally, $D'(u) > 0$ and $D''(u) > 0$ for all $u > 0$. It is also convenient to assume that the costs of understatement initially increase slowly but eventually increase very rapidly with u, that is, $\text{limit}_{u \to 0} D'(u) = 0$ and $\text{limit}_{u \to \infty} D'(u) = \infty$. This simple representation of the firm's costs of understating its production costs admits many possible interpretations. For example, the firm might be averse to the financial penalty it expects to incur from understating costs. The financial penalty (F) might increase linearly with the magnitude of understatement (so $F(u) = \alpha u$). Furthermore, the probability of detection (φ) might increase at an increasing rate with the magnitude of the understatement (so $\varphi'(u) > 0$ and $\varphi''(u) > 0$). In this setting, the expected financial penalty from understating marginal cost by amount u is $\alpha u \varphi(u)$, which increases at an increasing rate with u.

[27] Recall from expression (4) that expression (6) can be rewritten as $pQ(p) - [1 - w]C(Q(p)) - D(u)$.

[28] The presumed concavity of $[P - u]$ is ensured if, for example, demand is linear and marginal cost increases with output at an increasing rate or if demand is concave and marginal cost is constant.

[29] A corresponding conclusion is readily shown to hold in the case where the public enterprise seeks to maximize revenue subject to the requirement that it generate at least $\bar{\pi}$ in profit. In this

Observation 2 reveals that when they face the same risks from understating costs, a public enterprise may understate its marginal cost more than will a profit-maximizing firm.[30] The public enterprise may be willing to bear the higher costs that accompany more pronounced understatement when it values more highly the expanded output and revenue that result from the lower price that the understatement facilitates.

2. Strategic Choice of Technology

There are alternative strategies a public enterprise might pursue to relax a binding prohibition against pricing below cost. For example, instead of misstating its true marginal cost, the firm might choose to operate with an inefficient technology that secures a relatively low marginal cost at the expense of a particularly high overhead (fixed) cost of production. In practice, a firm might do so by installing general-purpose equipment on a large scale and thereby reduce the need for project-specific equipment. Alternatively, the firm might retain a large on-site staff with broad legal, engineering, computing, and/or marketing expertise that can substitute for specific expertise on individual products.

It is straightforward to demonstrate that in such a setting where the strategic choice of technology is possible, an MPE will install more than the cost-minimizing level of capital in order to secure an abnormally low level of marginal cost in order to relax a binding prohibition on pricing below cost.[31] Furthermore, the less profit-oriented is the MPE, the more it will over-invest in capital. This is because the more highly the public enterprise values revenue relative to profit, the more it benefits from the expanded output and revenue that a lower price provides, and thus the greater the technological inefficiency it will endure to secure a lower price. It is readily shown that the MPE will install an inefficiently large level of capital in order to reduce its marginal cost even if it faces the same market cost of capital that private enterprises face. If the MPE's capital purchases are subsidized (as they often are in practice, since public enterprises are commonly afforded privileged access to government funds),[32] then inefficient over-capitalization will become even more pronounced (see Sappington and Sidak (2001) for details).

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case, $u > 0$ and $-du/d\bar{\pi} > 0$, so that as the firm's profit constraint becomes less binding, the firm understates its marginal cost more extensively. The case on which we focus in the text is slightly less cumbersome to analyze because it permits an exogenous parameter (w) rather than an endogenous Lagrange multiplier to reflect the extent of the public enterprise's focus on revenue.

[30] Notice that in the simple setting of problem $[P - u]$, a profit-maximizing firm will set price above marginal cost and will not understate marginal cost. In a dynamic setting with entry barriers, though, a profit-maximizing firm might choose to price below marginal cost and understate marginal cost.

[31] This finding parallels the observation of Baseman (1981) and Brennan (1990) that a regulated firm may adopt an inefficient operating technology in order to realize a lower incremental cost of operating in unregulated markets. Crew and Crocker (1991) provide related insights.

[32] See MacAvoy and McIsaac (1995) and Sidak and Spulber (1996, p. 2), for example.

IV. Raising the Costs of Actual and Potential Rivals

It is well known that private enterprises may find it profitable to raise their rivals' operating costs in order to achieve a competitive advantage in the marketplace. (Recall footnote #4.) Activities that can raise rivals' costs include securing monopoly control over essential inputs and lobbying for regulations that burden rivals disproportionately. The purpose of this section is to demonstrate that public enterprises may have even stronger incentives than their profit-maximizing counterparts to engage in such activities and/or activities that serve to exclude rivals from the marketplace altogether.

1. Raising the Costs of Existing Rivals

To demonstrate formally the expanded incentive that a public enterprise may have to raise the costs of existing rivals, consider the following simple setting. Suppose the public enterprise is an MPE that seeks to maximize a weighted average of revenue and profit. Also suppose the public enterprise is one of two firms producing differentiated products. The two firms establish prices for their products simultaneously after learning the amount (r) by which the public enterprise has raised its rival's constant marginal cost of production ($\tilde{c}$). For simplicity, the public enterprise is assumed to incur a separable cost, $L(r)$, that increases at an increasing rate with its cost-raising activity (that is, $L'(r) > 0$ and $L''(r) > 0$ for all $r > 0$). To illustrate, this cost might constitute expected penalties for anticompetitive behavior or the costs of lobbying for regulations that restrict its rival's access to key inputs (for example, transmission or delivery media).[33] The public enterprise's production cost is c per unit.[34]

The higher is the price that one firm sets for its product, the greater is the demand for the other firm's product. This is why the public enterprise may act to raise its rival's marginal cost of production, even though doing so is personally costly. As the rival's marginal cost increases, the price it charges for its product increases, thereby increasing the demand for the public enterprise's product. For analytic simplicity, we consider a setting in which demand curves are linear in prices. The public enterprise's demand curve is:

$$Q(p, \tilde{p}) = a - b_0 p + b_1 \tilde{p}; \tag{8}$$

and the rival's demand curve is:

$$\tilde{Q}(\tilde{p}, p) = \tilde{a} - \tilde{b}_0 \tilde{p} + \tilde{b}_1 p, \tag{9}$$

[33] In cases where an MPE supplies an essential input (e.g., network access) to downstream competitors, the MPE's cost-raising activities might include artificially raising competitors' costs of securing the critical input. See Weisman (1995), Economides (1998), Reiffen (1998), Sibley and Weisman (1998), Mandy (2000), and Mandy and Sappington (2001), for example, for analyses of such activities by profit- maximizing firms.

[34] For expositional simplicity, we abstract from fixed costs of production.

where $p \geq 0$ is the price the public enterprise sets for its product, $\tilde{p} \geq 0$ is the price of the rival's product, and a, $\tilde{a}$, b_0, $\tilde{b}_0$, b_1, and $\tilde{b}_1$, and $\tilde{b}_1$ are all strictly positive constants. Each firm's demand is assumed to be more responsive to changes in its own price than to changes in its competitor's price (that is, $b_0 > b_1$ and $\tilde{b}_0 > \tilde{b}_1$). In addition, demand for the public enterprise's product is substantial in the sense that the intercept of the public enterprise's demand curve exceeds the public enterprise's marginal cost of production (c) for any non-negative price ($\tilde{p}$) the rival might set.

The public enterprise's formal problem in this duopoly setting, labeled $[P-d]$, is the following:

$$\underset{p,r\geq 0}{\text{Maximize}} \quad w[pQ(p,\tilde{p})] + [1-w][(p-c)Q(p,\tilde{p})] - L(r) \tag{10}$$

subject to: (8); (9);

$$p = \underset{\hat{p}}{\text{argmax}} \quad \{w[\hat{p}Q(\hat{p},\tilde{p})] + [1-w][(\hat{p}-c)Q(\hat{p},\tilde{p})]\}; \tag{11}$$

and

$$\tilde{p} = \underset{\hat{p}}{\text{argmax}} \quad \{[\hat{p} - (\tilde{c}+r)]\tilde{Q}(\hat{p},p)\}. \tag{12}$$

Expression (10) reflects the MPE's desire to maximize a weighted average of revenue and profit, less the cost of raising its rival's production cost. Notice that the MPE is assumed to bear the full costs ($L(\cdots)$) of r, and does not discount these cost by $1-w$, as it implicitly discounts production costs.[35] Expressions (11) and (12) reflect the fact that the MPE and its rival choose prices simultaneously to maximize their objectives, after observing the extent of the MPE's cost-raising activities, r. The key features of the solution to $[P-d]$ are recorded in Observation 3.

OBSERVATION 3. *In the duopoly setting, the MPE will raise its rival's cost, and will do so to a greater extent the less profit-oriented it is* (*that is,* $r > 0$ *and* $\frac{dr}{dw} > 0$ *and at the solution to* $[P-d]$).

The public enterprise analyzed here will raise its rival's cost more extensively than will a profit-maximizing firm *ceteris paribus* because the public enterprise is more eager than its profit-maximizing counterpart to expand revenue and output. An increase in the rival's production cost induces the rival to increase its price,

[35] It is apparent that if $L(.)$ is sufficiently large for all r, no firm will act to raise its rival's cost. We abstract from this possibility by assuming $L(0) = 0$ and $L'(r)|_{r=0} = 0$. We also avoid the situation in which the public enterprise raises its rival's cost so much that the rival exits the market. We do so by assuming $L'(r)$ and $L''(r)$ are sufficiently large for all $r > 0$. Sufficient conditions are $L'(r^*) > \tilde{b}_0 b_1[a - b_0(1-w)c + b_1\tilde{p}]/A$ and $L''(r^*) > 2b_0(\tilde{b}_0)^2(b_1)^2/A$, where r^* is the optimal r for the public enterprise at the solution to $[P-d]$, and where $A \equiv 4b_0\tilde{b}_0 - b_1\tilde{b}_1$.

which results in greater equilibrium output for the MPE. The increased output for the MPE increases both its revenue and its cost. But since the MPE effectively discounts the extra costs of expanded output, it perceives greater net gain than does a profit-maximizing firm from the expanded output that results from raising its rival's costs. The higher relative valuation of increased operational scale leads the MPE to raise its rival's costs more aggressively than does a profit-maximizing firm.[36]

The finding that public enterprises can have expanded *incentive* to raise their rivals' costs takes on particular significance when it is recognized that public enterprises may also have expanded *ability* to raise their rivals' costs relative to the corresponding ability of private enterprises. A public enterprise's special position as a government entity can afford it power to set industry rules that raise rivals' costs directly.[37] To illustrate, the United States Postal Service claims to have considerable discretion in defining the letter services that it is entitled to provide as a monopoly.[38] By defining letter services broadly, the Postal Service can raise the operating costs of rival producers of non-letter services by limiting the economies of scale and scope that rivals can secure.[39] The Postal Service is also able to deny competing suppliers of non- letter services access to the mail boxes in which the Postal Service places letters.[40] Limited access to customers' mail boxes can raise operating costs by necessitating multiple delivery attempts or by otherwise increasing the time required to deliver packages, as well as by increasing potential losses from theft of packages left in non-secure places.

[36] This same qualitative conclusion holds when an MPE and a fringe of competitive firms produce a homogeneous product. See Sappington and Sidak (2001) for details.

[37] Public enterprises that provide service in many domestic political jurisdictions and that employ a large number of eligible voters may also be particularly effective at persuading elected officials to enact rules and regulations to raise rivals' costs.

[38] Sidak and Spulber (1996, pp. 18–19, 26–31).

[39] A public enterprise can have particularly pronounced incentive to exclude rivals when its production technology exhibits cost complementarities. To illustrate this point, suppose that a public enterprise produces two products, A and B, and that product B is also supplied by competitors. Further suppose that the public enterprise's marginal cost of producing product B declines as its output of product A increases. In this setting, if the public enterprise successfully precludes competition on product A and thereby increases its output of product A, the public enterprise reduces its marginal cost of delivering product B. Thus, the public enterprise may reap private gains in both market A and B when it excludes competition in market A in this setting. This fact may lead the public enterprise to be particularly aggressive in excluding rivals from market A, especially if the rivals can serve market A more efficiently than the public enterprise or if the rivals would realize even greater cost complementarities than the public enterprise in serving markets A and B.

[40] This is the case even though the mail boxes are the private property of the mail recipients. See Sidak and Spulber (1996, pp. 33–34).

2. Excluding Potential Competitors

Rather than simply raise the operating costs of its existing rivals, a public enterprise might undertake activities designed to preclude the operation of potential rivals. For example, a public enterprise might attempt to define very broadly the boundaries of its monopoly operations (as the United States Postal Service might do, for example, by offering an expansive definition of a letter). Alternatively, a public enterprise might attempt to impose rules that reduce the perceived quality of competitors' services to the point where the competitors cannot operate profitably.[41] And, like their private counterparts, public enterprises might lobby key policy makers to erect impenetrable entry barriers, including outright prohibitions on entry (allegedly in order to preserve universal service, for example). It is readily shown that an MPE typically will undertake more exclusionary activity than will a profit-maximizing firm, even when the exclusionary activity is no less costly for the MPE. It can also be shown that the MPE's exclusionary activity will increase as the MPE becomes less profit-oriented, provided competition would reduce the MPE's output[42] (see Sappington and Sidak (2001) for details).

V. Conclusions

We have shown how the diverse goals that a public enterprise faces may lead it to act more aggressively toward its rivals than a private enterprise. A reduced focus on profit can lead a public enterprise to price products below cost. It can also increase the public enterprise's incentive to raise the costs of existing rivals, to erect entry barriers that serve to preclude entry by potential rivals, and to understate costs and adopt inefficient production technologies in order to circumvent regulations designed to foster competition. Each of these activities can preclude the operation of more efficient competitors, and thereby reduce social welfare.

[41] Some might argue that a policy adopted by the United States Postal Service was designed to reduce the quality of its competitors' services. Under the policy, the Postal Service refused to deliver letters to mailboxes that customers rented from firms like Mail Boxes Etc. unless the addresses on the letters included the designation PMB (for private mail box). (See Brick, 1999.) This designation would make it clear to senders that the offices of the letter recipient were not at the specified address (of the Mail Boxes Etc. outlet, for example). To the extent that letter recipients valued the ability to have the specified address identified as their own (perhaps because the address reflected a prestigious business location), their demand for private mail box services may have been diminished by the policy.

[42] One important setting in which a public enterprise will sell more output when competition is precluded than when it is admitted is when potential competitors have lower costs than the public enterprise and pricing below marginal cost is prohibited. In this setting, if the firms engage in price competition and produce a homogenous product with constant marginal cost, the public enterprise will be driven from the market when more efficient suppliers are authorized to produce. Consequently, a public enterprise may have particularly strong incentives in this setting to act aggressively to exclude rivals.

We have analyzed selected anticompetitive activities that a public enterprise might undertake, and we have focused attention on a particular class of objectives for the public enterprise. We have not undertaken a comprehensive benefit-cost analysis of public enterprises, nor have we analyzed in complete detail all of the objectives that a public enterprise might pursue in practice. Therefore, our analysis alone cannot provide broad prescriptions regarding the most appropriate policies toward public enterprises. However, the fact that public enterprises may have both greater incentive and ability than private enterprises to pursue anticompetitive actions suggests that the costs of public enterprises need to be weighed carefully against any benefits that such firms may provide.

A comprehensive benefit-cost analysis of public enterprises would need to consider other possible objectives of the enterprises, including welfare maximization, income redistribution, and the promotion of national security. The analysis would also need to consider market failures that a public enterprise might help to correct (e.g., inadequate supply of public goods), and contrast the internal operations of public and private enterprises. The analysis should also endow the public enterprise with a richer set of policy instruments, including an expanded choice of markets in which it might participate, the possibility of bundling or tying products, non-linear and discriminatory prices, products of varying quality, and different intensities of product and process innovation.

A comprehensive assessment of the merits of public enterprises would also need to account for the fact that public enterprises, like their private counterparts, often face important regulatory restrictions. The optimal design of regulatory policy for public enterprises has received little attention in the literature, and deserves careful study. It is important to determine, for example, whether the benefits that price-cap regulation can provide when applied to profit-maximizing firms persist when price-cap regulation is applied to public enterprises. It is conceivable, for example, that a public enterprise might have greater incentive than its private counterpart to set prices strategically in order to relax a binding price-cap constraint (Sappington and Sibley, 1992; Law, 1997), or to employ the expanded freedoms of price-cap regulation to price below marginal cost (Armstrong and Vickers, 1993).

The optimal design of antitrust law as applied to public enterprises also merits careful study. Because public enterprises may have stronger incentives to engage in anticompetitive practices and circumvent antitrust laws than their private counterparts, particular vigilance in monitoring the market activities of public enterprises may be prudent. Public enterprises might also be subjected to more stringent antitrust laws and harsher penalties for violating these laws. The optimal design of such laws and policies would necessarily address the question of the proper scope of sovereign immunity for the proprietary actions of governments.

Harsh financial penalties for violating antitrust laws may not deter a public enterprise from engaging in anticompetitive activities if the enterprise is not concerned primarily with the profit it generates and/or if it can readily pass the fines it incurs on to taxpayers. Particularly under such circumstances and where it is diffi-

cult to monitor closely the activities of a public enterprise, it may be appropriate to consider limiting the services a public enterprise is authorized to provide to those services that will not be provided adequately by private operators.

In short, the incentives for anticompetitive behavior by public enterprises invite further theoretical and empirical research on a wide range of issues.[43] That research will have the opportunity to inform an emerging body of public policy having great practical significance in many nations.

Appendix A

PROOF OF OBSERVATION 1

Setting the partial derivative of expression (1) with respect to p_i equal to zero provides:

$$\alpha^T \left[p_i \frac{\partial Q_i(\cdot)}{\partial p_i} + Q_i(\cdot) - \frac{\partial C(\cdot)}{\partial Q_i} \frac{\partial Q_i(\cdot)}{\partial p_i} \right] + \alpha^M \left[p_i \frac{\partial Q_i(\cdot)}{\partial p_i} + Q_i(\cdot) \right]$$
$$+\alpha^C [-Q_i(\cdot)] + \tilde{\alpha}^C \left[\frac{\partial \tilde{S}(\cdot)}{\partial p_i} \right] + \tilde{\alpha}^\Pi \left[\tilde{p}_i - \frac{\partial \tilde{C}(\cdot)}{\partial \tilde{Q}_i} \right] \frac{\partial \tilde{Q}_i(\cdot)}{\partial p_i} = 0. \quad \text{(A.1)}$$

Equation (A.1) can be rewritten as:

$$\left[[\alpha^T + \alpha^M] p_i - \alpha^T \frac{\partial C(\cdot)}{\partial Q_i} \right] \frac{\partial Q_i}{\partial p_i}$$
$$= [\alpha^M + \alpha^T - \alpha^C] Q_i(\cdot) - \tilde{\alpha}^\Pi \left[\tilde{p}_i - \frac{\partial \tilde{C}(\cdot)}{\partial \tilde{Q}_i} \right] \frac{\partial \tilde{Q}_i(\cdot)}{\partial p_i} - \tilde{\alpha}^C \left[\frac{\partial \tilde{S}(\cdot)}{\partial p_i} \right]. \quad \text{(A.2)}$$

Dividing all terms in Equation (A.2) by $[\alpha^T + \alpha^M] p_i \frac{\partial Q_i}{\partial p_i}$ and rearranging the resulting expressions provides Equation (2). ■

PROOF OF COROLLARY 2

Since $Q_i'(p_i) = -\alpha_i \epsilon_i p_i^{-(\epsilon_i+1)}$ in the present setting, it follows from Equation (A.2) that the public enterprise's preferred price for product i is given by:

$$-\alpha_i \epsilon_i p_i^{-\epsilon_i} + \alpha_i p_i^{-\epsilon_i} + [1 - w] \frac{\partial C_i(\cdot)}{\partial Q_i} \alpha_i \epsilon_i p_i^{-(\epsilon_i+1)} = 0. \quad \text{(A.3)}$$

Rearranging the terms in (A.3) and simplifying provides:

$$p_i = [1 - w] \frac{\epsilon_i}{\epsilon_i - 1} \frac{\partial C_i(\cdot)}{\partial Q_i}. \quad \text{(A.4)}$$

[43] Lott's (1999) empirical analysis of predation by public enterprises provides useful insights and helpful guidance for future empirical work, as Sappington and Sidak (2000) explain.

Subtracting $\frac{\partial C_i(\cdot)}{\partial Q_i}$ from both sides of the equality in (A.4) provides:

$$p_i - \frac{\partial C_i(\cdot)}{\partial Q_i} = \left[(1-w)\frac{\epsilon_i}{\epsilon - 1} - 1\right]\frac{\partial C_i(\cdot)}{\partial Q_i} < 0 \text{ if and only if } \epsilon_i > \frac{1}{w}. \quad \text{(A.5)}$$

■

PROOF OF OBSERVATION 2

Let $\lambda^u \geq 0$ denote the Lagrange multiplier associated with constraint (7). Then the Lagrangean function associated with problem $[P - u]$ is:

$$L^u \equiv pQ(p) + [1-w]C(Q(p)) - D(u) + \lambda^u[p - C'(Q(p)) + u]. \quad \text{(A.6)}$$

The necessary conditions for a solution to $[P - u]$ are:

$$L^u_p \equiv [p - (1-w)C'(Q(p))]Q'(p) + Q(p) + \lambda^u[1 - C''(\cdot)Q'(p)] = 0; \text{(A.7)}$$

$$L^u_u = -D'(u) + \lambda^u \leq 0; \quad u[-D'(u) + \lambda^u] = 0; \quad \text{(A.8)}$$

$$L_{\lambda^u} = p - C'(Q(p)) + u \geq 0; \quad \lambda^u[p - C'(\cdot) + u] = 0. \quad \text{(A.9)}$$

Since $\lambda^u > 0$ and $\text{limit}_{u\to 0} D'(u) = 0$ by assumption, $u > 0$ from (A.8).

Let H^u denote the matrix of second order partial derivates

$$\begin{bmatrix} L^u_{pp} & L^u_{pu} & L^u_{p\lambda^u} \\ L^u_{up} & L^u_{uu} & L^u_{u\lambda^u} \\ L^u_{\lambda^u p} & L^u_{\lambda^u u} & L^u_{\lambda^u\lambda^u} \end{bmatrix}.$$

It follows from (A.7)–(A.9) that $|H^u| = D''(u)(L_{p\lambda^u u})^2 - L^u_{pp} > 0$. Cramer's rule implies:

$$\frac{du}{dw} \overset{s}{=} \begin{vmatrix} L^u_{pp} & L^u_{pw} & L^u_{p\lambda^u} \\ 0 & 0 & 1 \\ L^u_{p\lambda^u} & 0 & 0 \end{vmatrix} = -L_{p\lambda^u}L_{pw}. \quad \text{(A.10)}$$

From (A.7), $L^u_{pw} = C'(Q(\cdot))Q'(p) < 0$ and $L^u_{p\lambda^u} = 1 - C''(\cdot)Q'(p) > 0$. Therefore, from (A10), $\frac{du}{dw} > 0$. ■

PROOF OF OBSERVATION 3

From (8)–(10), the objective of the MPE is to:

$$\text{Maximize}_p[p - (1-w)c][a - b_0 p + b_1 \tilde{p}]. \quad \text{(A.11)}$$

Setting the partial derivative of (A.11) with respect to p equal to zero and solving for p provides:

$$p = \frac{1}{2b_0}[a + b_0[1 - w]c + b_1\tilde{p}]. \tag{A.12}$$

The corresponding analysis for the rival provides:

$$\tilde{p} = \frac{1}{2\tilde{b}_0}[\tilde{a} + \tilde{b}_0[\tilde{c} + r] + \tilde{b}_1 p]. \tag{A.13}$$

Solving (A.12) and (A.13) simultaneously provides:

$$p = \frac{1}{A}[2a\tilde{b}_0 + b_1\tilde{a} + 2b_0\tilde{b}_0[1 - w]c + \tilde{b}_0 b_1[\tilde{c} + r]] \tag{A.14}$$

and

$$\tilde{p} = \frac{1}{A}[2\tilde{a}b_0 + \tilde{b}_1 a + 2b_0\tilde{b}_0[\tilde{c} + r] + b_0\tilde{b}_1[1 - w]c], \tag{A.15}$$

where $A \equiv 4b_0\tilde{b}_0 - b_1\tilde{b}_1 > 0$.

$[P - d]$ can now be rewritten as:

$$\text{Maximize}_{r\geq 0} U \equiv [p - (1 - w)c][a - b_0 p + b_1\tilde{p}] - L(r) \tag{A.16}$$

subject to (A.14) and (A.15).

Differentiating (A.16) with respect to r provides:

$$U_r = \{[a - b_0 p + b_1\tilde{p}] - b_0[p - (1 - w)c]\}\frac{dp}{dr} + [p - (1 - w)c]b_1\frac{d\tilde{p}}{dr} - L'(r). \tag{A.17}$$

From (A.14) and (A.15)

$$\frac{dp}{dr} = \frac{\tilde{b}_0 b_1}{A} \quad \text{and} \quad \frac{d\tilde{p}}{dr} = \frac{2b_0\tilde{b}_0}{A}. \tag{A.18}$$

Substituting (A.18) into (A.17), simplifying, and rearranging terms provides:

$$U_r = \frac{\tilde{b}_0 b_1}{A}[a - b_0[1 - w]c + b_1\tilde{p}] - L'(r). \tag{A.19}$$

Since $L'(0) = 0$ and $a > b_0 c$ by assumption, (A.19) implies $U_r|_{r=0} > 0$, which ensures $r > 0$.

Under the maintained assumptions, $U_{rr} < 0$. Furthermore, from (A.18) and (A.19):

$$U_{rw} = \frac{\tilde{b}_0 b_1}{A}\left[b_0 c - \frac{1}{A} b_1 b_0 \tilde{b}_1 c\right] = \frac{2 b_0 \tilde{b}_0 b_1 c}{A^2}[2 b_0 \tilde{b}_0 - b_1 \tilde{b}_1] > 0. \qquad \text{(A.20)}$$

The inequality in (A.20) holds because $b_0 > b_1$ and $\tilde{b}_0 > \tilde{b}_1$. Therefore, $\frac{dr}{dw} = -\frac{U_{rw}}{U_{rr}} > 0$. ■

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