Using Market Structure to Regulate a Vertically Integrated Monopolist

by

Sang H. Lee and Jonathan H. Hamilton

Department of Economics
University of Florida
Gainesville FL 32611 USA

May 1998

We thank David Sappington, Sanford Berg, and an anonymous referee for many helpful comments. The second author thanks the University of Florida College of Business Administration and the Public Utility Research Center for financial support for this research.

Abstract

A natural monopolist whose cost is private information produces a good which is combined with another good that can be produced by the monopolist or by other firms. The agency that regulates the monopolist can impose any of several different market structures in the industry: integrated monopoly, vertical separation with free entry downstream, or liberalization downstream (both integrated and independent production). When several firms produce downstream, a Cournot quantity-setting game with free entry determines the market price. We derive the optimal contracts to offer the monopolist under all three market structures and examine the influence of downstream cost differences on access prices.

We then study the optimal regulatory policy where the regulator can condition the downstream market structure on the monopolist's cost report to the regulator. The optimal regulatory policy awards a monopoly to a low-cost upstream firm, but requires free entry downstream if the monopolist reports high upstream costs. Thus, the choice of market structure is an additional tool to limit rent extraction by the monopolist. Simulation analysis reveals the possibility of significant welfare gains from this additional regulatory tool.

1. Introduction

Since Baron and Myerson (1982), asymmetric information models have been a major focus of research on monopoly regulation. Work by Lewis and Sappington (1988a, 1988b, 1989, 1997) and Laffont and Tirole (1986, 1990a, 1990b, 1994) has added greatly to our understanding of incentive regulation. Recent policy initiatives attempt to restructure traditional regulated industries, particularly by reducing the degree of vertical integration. In several industries, segments of the industry that had been part of a natural monopoly are now open to free entry by competing firms. Sometimes the original monopolist has been barred from entering the competitive segment. In telecommunications, the 1984 divestiture completed the opening of inter-LATA long distance markets, but the Baby Bells were prevented from offering long-distance service. Now competition is coming to even more of the industry. In electricity, several regulatory commissions' retail wheeling proposals effectively deregulate parts of the generation sector, but incumbent monopolists retain control of distribution and remain subject to regulation.

Our goal is to analyze how the existence of potential competition affects a regulator's decision regarding market structure in a network industry and how market structure itself can be used to limit rent extraction. One branch of the existing literature considers the terms on which to permit small-scale entry in one sector. In a full information framework, Willig (1979) studies interconnection by competing suppliers and stresses the fact that strategic behavior may lead the network operator to deter socially beneficial entry. Baumol and Sidak (1994) discuss similar issues in the framework of railroad access pricing. Their efficient component pricing rule (ECPR) states that an entrant should pay the incumbent its full opportunity cost (incremental revenues minus incremental costs) for use of the network. While this prohibits uneconomic entry, it places little competitive pressure on the monopolist. Armstrong and Doyle (1995) discuss a number of limitations of the ECPR. While full information provides a useful benchmark case, incorporating information asymmetries between firms and the regulator is important. Laffont and Tirole (1994) analyze access pricing in a hidden action model of multiproduct monopoly regulation. When public funds have a social cost due to the deadweight loss of taxation, the optimal access price must exceed marginal cost, even though the regulator has complete information. Moreover, they study the impact of the regulator's incomplete information about the monopoly's cost structure on the monopoly's informational rents.

Vickers (1995) studies access pricing rules in the Baron and Myerson (B-M) (1982) model in which the regulator does not know (upstream) marginal cost. Vickers compares vertically integrated monopoly with an imperfectly competitive downstream sector with and without the monopolist producing downstream. All firms, including the monopolist, who produce downstream have constant marginal cost and a positive fixed cost. These firms engage in Cournot competition with free entry.[1] One question is whether the monopolist should be allowed in the deregulated downstream sector. Another question is whether the presence of the fringe firms who are only active downstream always enhances welfare. As long as the regulator can dictate that either the monopolist or the fringe firms be shut down, to increase expected welfare the regulator may permit second sources of production in the deregulated downstream market to

[1]Two sources of inefficiency must be evaluated for the welfare comparison of vertical integration and vertical separation: the information asymmetry, which allows the monopolist to get distributionally costly rents, and imperfect competition downstream, which leads to excess entry (duplication of the fixed costs). Vertical integration has disadvantages for reasons related to anti-competitive incentives to raise rivals' costs, but it may be advantageous to reduce duplication of fixed costs insofar as it allows greater productive efficiency. See Vickers (1995).

replace, or to produce alongside, the existing monopolist.[2]

Section 2 describes our model that combines B-M monopoly upstream with Cournot oligopoly downstream. We allow marginal production costs downstream to differ between the monopolist and fringe firms.[3] The regulator knows both downstream costs; the only private information is upstream marginal cost. While it may be difficult to observe costs of network operation, the technology of combining network access with another input may be a simple technology. We consider cases where the monopolist is more or less efficient in the downstream sector. If there are economies of scope, the monopolist would be more efficient. If the monopolist has higher labor costs (perhaps due to union contracts), the monopolist would be less efficient.

Section 3 studies optimal contracts under three different market structures: (1) vertically integrated monopoly; (2) vertical separation--the monopolist is excluded from downstream production; and (3) vertical integration with liberalization--the monopolist and the fringe can both enter downstream production (we call this simply liberalization in the remainder of the paper).[4] This last structure includes two variants, depending on whether or not the regulator controls the monopolist's downstream activity. The regulatory instrument is the offer to the monopolist of a schedule specified by the monopolist's choice of access price. If the monopolist's downstream output is contractible, vertical integration and vertical separation are special cases of liberalization. If the monopolist is more efficient than fringe firms in the downstream market,

---

[2]For recent theoretical studies on second sourcing problems, see Anton and Yao (1987), Demski, Sappington, and Spiller (1987), Auriol and Laffont (1992), and McGuire and Riordan (1995).

[3]We follow Vickers's (1995) framework, except that we allow downstream production costs to differ between the upstream monopolist and the fringe.

[4]Armstrong, Cowan, and Vickers (1994, Ch. 5) discuss a number of conceptual issues involving the choice between integration and separation or liberalization in network industries.

liberalization yields optimized expected welfare of vertical integration and thus vertical integration is optimal. Furthermore, if the monopolist is less efficient but close to fringe firms, vertical integration may still be optimal, saving fixed costs downstream. However, if the monopolist is significantly inefficient than fringe firms, liberalization yields optimized expected welfare of vertical separation and thus vertical separation is optimal.

When the monopolist's downstream output is not contractible, neither vertical integration nor vertical separation are nested in the liberalization structure. Since the regulator faces an additional constraint -- the monopolist's first order condition in the downstream Cournot game, noncontractible liberalization downstream output can not yield any higher expected welfare than liberalization with contractible downstream output. Despite this, the noncontractible form of liberalization is relevant.[5]

If the monopolist is more efficient than fringe firms in the downstream market, vertical integration dominates liberalization. Under vertical separation and liberalization, the optimal access price differs from marginal cost pricing of access due to the informational asymmetry between the regulator and the monopolist, the downstream market demand function, and fixed costs. We examine the effects of downstream cost differences on the optimal access price under liberalization. In particular, with linear demand, the more efficient the monopolist is and the less efficient the fringe is at the downstream level, the higher are the access price and the monopolist's price-cost margin. Moreover, the more efficient the monopolist is and the less efficient the fringe is at the downstream level, the fewer firms are in the downstream market and, to that extent, less duplication of fixed costs occurs.

---

[5]Under contractible liberalization, the regulator can give the monopolist an advantage by allowing it to commit to a level of output in advance of the fringe firm's choices. In practice, it may be necessary to allow everyone to compete on the same footing downstream.

In Section 4, we restrict our attention to linear inverse demand and show that differences in the level of expected social welfare under liberalization and vertical separation depend on parameter values of the demand and cost function at the downstream level, but not on the realization of the monopolist's upstream cost. Hence, if all relevant information about the inverse demand function and costs at downstream level are known, the ranking of market structures between liberalization and vertical separation in terms of expected welfare is determined at the outset, irrespective of the realization of the monopolist's upstream marginal cost.

In Section 5, we extend our analysis to design an optimal policy when both market structure and the monopolist's compensation depend on the monopolist's upstream marginal cost report. We refer to this as a hybrid regime. The relevant choices facing the regulator are: (1) vertically integrated monopoly versus vertical separation; or (2) vertically integrated monopoly versus liberalization. We focus on the former case because either vertical integration or liberalization dominates the other in the latter case. The key point is that, under the hybrid regime, the regulator considers not only vertical conduct (pricing), but also vertical structure.[6] By implementing the optimal regulatory policy that uses the choice of market structure as an additional tool to limit rent extraction by the monopolist, the regulator can increase expected social welfare significantly.[7]

---

[6]In vertically related markets, there are two major questions. The question of vertical conduct is how to regulate the terms on which the monopolist gives access to the other firms and the question regarding vertical structure is whether to allow the monopolist into the deregulated downstream sector. See Armstrong, Cowan, and Vickers (1994).

[7]Our result shows large efficiency gains for the hybrid mechanism, compared to Bower's (1993). He studies marginal benefits of certain contracting instruments in procurement model such as full commitment, self selection, multiple cost observation, and competition, and finds small differences between the mechanisms. One major difference is that he considers two-period models in which the principal (the buyer) can update the contract using information acquired in the first period.

2. The Model

A regulated industry produces a single homogeneous product. Assume there are no income effects, and denote inverse demand by $P(Q)$, which we assume to be twice differentiable. To make each unit of the good requires one unit of an input supplied by an upstream monopolist and one unit of another input provided by a downstream producer. The firms in the industry include a vertically integrated monopolist (in both the upstream and downstream sectors if the regulator permits it) and other producers who can freely enter the downstream sector (which we refer to as fringe firms).

We assume that all marginal costs are constant. Let θ denote the monopolist's upstream marginal cost (the marginal cost of network operation with respect to output). Let w and v equal the downstream marginal costs of other inputs used by the downstream monopolist and the fringe firms, respectively. Hence, if the monopolist (hereinafter, M) charges fringe firms an access fee a for the upstream input, fringe firms' marginal cost of production of the final good is $a + v$, while M's own marginal cost of production of the final good is $\theta + w$. Any firm (including the monopolist) that enters the downstream market must pay a fixed cost K. Let n denote the number of firms in the downstream market, which will be determined endogenously by a zero profit condition for the fringe firms.[8]

2.1 The Regulatory Environment

The upstream marginal cost, θ, is the monopolist's private information throughout our analysis. The regulator knows only that θ has the distribution function $F(\theta)$, with a support

[8]We ignore any integer constraints on n.

on $[\underline{\theta}, \overline{\theta}]$. We assume that $F(\theta)$ is continuous, differentiable, and strictly increasing. To keep our analysis tractable, we assume a uniform distribution for θ:

Assumption 1.

The upstream marginal cost, θ, has a distribution function: $F(\theta) = \dfrac{\theta - \underline{\theta}}{\overline{\theta} - \underline{\theta}}$. (1)

We also confine our analysis to parameter values for which it is optimal to have positive output.

Assumption 2.

For all $\theta \in [\underline{\theta}, \overline{\theta}]$, it is never optimal to have zero production in the upstream and downstream market.[9]

With asymmetric information, the regulator's problem is to maximize an expected value of social welfare which is a weighted sum of consumers' surplus and firms' profits. Social welfare equals:

$$W = S(Q) + \alpha \pi, \quad \alpha \in [0,1]^{10} \tag{2}$$

where $S(Q)$ and π denote consumers' surplus and M's profit, respectively.[11]

---

[9]For different market structures, the critical upper bound on θ differs, so we postpone stating the precise bounds until later in the paper.

[10]If $\alpha < 1$, the regulator favors consumer interests over M's interests. With this specification, a transfer of a dollar from consumers to M would result in a loss of $(1 - \alpha)$ dollars. See Baron (1989).

[11]By assuming free entry in the downstream market, the fringe firms's competitive profits are zero and are omitted. We assume that n is continuous to avoid integer problems.

2.2 The Downstream Cournot Game

Under the policy options of vertical separation or liberalization, firms in the downstream sector play a Cournot quantity competition game. Let q_1 and q_2 represent the quantities of final goods supplied by the monopolist and each competitive fringe firm, respectively. Let Q denote the aggregate quantity supplied in the downstream market. Thus, $Q = q_1 + (n-1)q_2$ under liberalization and $Q = nq_2$ under vertical separation. First, the regulator sets an access price, a, for the upstream good by offering the monopolist a menu of choices which determines the access price. If q_1 is contractible, the regulator offers a menu $\{a, q_1(a), T(a)\}$ where $T(a)$ is the transfer (positive or negative). If q_1 is not contractible, then the regulator offers a menu $\{a, T(a)\}$.

2.2.1 A Representative Fringe Firm

Once the access price is set, each identical competitive fringe firm chooses its output to solve:

$$\underset{q_2}{Max} \; [P(Q) - a - v] q_2 - K$$

where $Q = q_1 + (n-1) q_2$ and q_1 is either *M*'s downstream output choice or the output level prescribed by the regulatory contract (q_1 is zero under vertical separation). The first order condition for profit maximization and the zero profit condition are:

$$P - a - v = -P' q_2 \tag{3}$$

$$[P(Q) - a - v] q_2 = K. \tag{4}$$

To simplify notation, define $\varphi(Q) \equiv \sqrt{-P'(Q)}$ and $k \equiv \sqrt{K}$. Then conditions (3) and (4) become:

$$q_2 = \frac{k}{\varphi(Q)}, \quad a = P - v - \varphi(Q)\, k. \tag{5}$$

2.2.2 The Monopolist

When the regulator selects liberalization, if the monopolist's downstream output choice q_1 is not contractible, M solves:

$$\underset{q_1}{Max} \ [P(Q) - \theta - w] q_1 - K.$$

The first order condition is:

$$P - \theta - w = -P' q_1. \tag{6}$$

In this case, equation (5) and (6) determine the downstream equilibrium as a function of access price, a. When the menu specifies q_1, the monopolist's downstream output is tied to the access price, and equations (3) and (4) describe the downstream equilibrium as a function of q_1.

3. Optimal Contracts

We now model the contracts in two settings depending upon whether or not the monopolist's downstream output is contractible.

3.1 Liberalization with Contractible q_1

If M's downstream output q_1 is contractible, the regulatory mechanism involves three policy instruments: $\{Q(a), q_1(a), T(a)\}$.[12] Since M's profit consists of the profits from selling network access to fringe firms and from selling final product in the downstream market, plus the transfer, M's profit equals:

$$\begin{aligned}\pi^C(\theta) &= \underset{a}{Max} \ (a - \theta)(n-1)q_2 + \left[P(Q^C(a)) - \theta - w\right] q_1(a) + T^C(a) - K \\ &= \underset{a}{Max} \ (a - \theta) Q^C(a) + \left[P(Q^C(a)) - w - a\right] q_1(a) + T^C(a) - K,\end{aligned}$$

[12]The policy instruments are equivalent to $\{Q(\theta), q_1(\theta), T(\theta)\}$, where $Q(\theta)$ is M's total upstream production.

where the superscript C denotes that the market structure is liberalization with contractible q_1. Once the regulator sets an access price, Cournot competition downstream and the free entry condition determine the final good price. Then M's incentive compatibility condition is given by $\partial \pi^C(\theta) / \partial \theta = -Q^C(\theta)$. Integrating by parts with the binding individual rationality condition $\pi^C(\bar{\theta}) = 0$, M's expected profit equals:

$$E\pi^C = \int_{\underline{\theta}}^{\bar{\theta}} Q^C(\theta) \left\{ \frac{\theta - \underline{\theta}}{\bar{\theta} - \underline{\theta}} \right\} d\theta. \tag{7}$$

Hence expected welfare under liberalization equals:

$$EW^C = \int_{\underline{\theta}}^{\bar{\theta}} \Big\{ U(Q^C(\theta)) - (\theta + w) Q^C(\theta) + \left[v + \varphi(Q^C(\theta)) k - w \right] \left[q_1(\theta) - Q^C(\theta) \right]$$
$$- K\xi(q_1(\theta)) - (1 - \alpha)(\theta - \underline{\theta}) Q^C(\theta) \Big\} \left\{ \frac{1}{\bar{\theta} - \underline{\theta}} \right\} d\theta \tag{8}$$

where $\xi(q_1)$ is an indicator function that is equal to 1 if $q_1 > 0$ and 0 otherwise.[13] The only constraint the regulator must consider is $q_1 \in [0, Q]$. Then, pointwise optimization of (8) with respect to q_1 and Q, subject to $q_1 \in [0, Q]$ yields the following result:

Proposition 1

1) Vertical integration and vertical separation are special cases of liberalization in which $q_1 = Q^C$ and $q_1 = 0$, respectively.

2) If the monopolist's downstream marginal cost exceeds fringe firms' marginal cost by $\varphi(Q) k$ ($w - v > \varphi(Q^C) k$), then $q_1 = 0$ is optimal for all θ (vertical separation).

[13]If $q_1 = 0$ is the optimal case, the monopolist does not spend the fixed cost to enter downstream production.

3) If $w - v < \varphi(Q^C)\,k$, $q_1 = 0$ is optimal if $E\big[\,[\,v + \varphi(Q^C(\theta))\,k - w\,]\,Q^C(\theta)\,\big] - K < 0$, while $q_1 = Q^C$ is optimal if $E\big[\,[\,v + \varphi(Q^C(\theta))\,k - w\,]\,Q^C(\theta)\,\big] - K > 0$. If the monopolist produces a positive downstream output, $q_1 = Q^C$ is optimal (vertical integration).

(All proofs are contained in the Appendix.)

The benchmark shows that the three different regulatory regimes are different cases of a single problem in which the monopolist's downstream output is contractible. When q_1 is contractible, if we maximize (8) with respect to q_1, we typically have a corner solution, with $q_1 = Q$ or $q_1 = 0$, as long as $v + \varphi(Q)\,k - w$ does not change sign for different values of θ.

3.1.1 Vertically Integrated Monopoly

If vertical integration is optimal, pointwise optimization of (8) yields the optimal price in state θ:

$$P^I(\theta) = \theta + w + (1 - \alpha)(\theta - \underline{\theta}), \tag{9}$$

where the superscript I indicates that the market structure is vertically integrated monopoly. Equation (9) implies that the regulator sets the final good price above marginal cost $(\theta + w)$ in such a way to reduce the firm's rents when its costs are low. For $w = 0$, (9) is simply the B-M result for a monopolist with unknown cost.

3.1.2 Vertical Separation

Under the market structure of vertical separation, the number of the firms in the downstream market is $n = \varphi(Q)\,Q\,/\,k$ and the total amount of fixed costs incurred in the downstream market is $nK = \varphi(Q)\,k\,Q$.[14] The regulator sets an access price equal to:

$$a^S(\theta) = \theta - \frac{1}{2}\,\varphi(Q^S(\theta))\,kE + (1-\alpha)(\theta - \underline{\theta}) \tag{10}$$

where S denotes vertical separation and $E \equiv -QP''(Q)/P'(Q)$ is the elasticity of the slope of inverse demand.[15] The resulting final good price is:

$$P^S(\theta) = \theta + v + \varphi(Q^S(\theta))\,k\left[\,1 - \frac{1}{2}E\,\right] + (1-\alpha)(\theta - \underline{\theta}). \tag{11}$$

Note that the access price is higher with concave inverse demand ($E < 0$) than with convex inverse demand ($E > 0$) through the term $-\frac{1}{2}\,\varphi(Q^S)\,kE$. We may consider this term as a means of balancing welfare loss because, when the regulator reduces the number of units of output to limit M's rent on the upstream input, the amount by which the final good price increases rises more rapidly with convex inverse demand than with concave inverse demand.

3.2 Liberalization with Noncontractible q_1

If the monopolist's downstream output does not affect the upstream contract, the regulator can not induce the monopolist to choose an output level which does not satisfy M's first order condition for the downstream Cournot game. Hence M's optimization problem is:

$$\pi^L(\theta) = \underset{a}{Max}\;\; (a-\theta)Q^L(a) + \left[P(Q^L(a)) - w - a\right]q_1(a,\theta) + T^L(a) - K$$

where L denotes liberalization with noncontractible q_1 and $q_1(a, \theta)$ is the monopolist's equilibrium choice in the downstream Cournot game. Once the regulator sets an access price, the

---

[14]Since each identical fringe firm produces a quantity equal to q_2, for a given level of output Q^S, the number of firms in the downstream market is determined by $n = Q^S/q_2$. From (5), $q_2 = k/\varphi(Q^S)$, so the number of firms is $n = \varphi(Q^S)\,Q^S/k$.

[15]For example, $E = 0$ with a linear demand and $E = (b+1)/b$ with a constant elasticity demand, $Q = aP^{-b}$.

final good price is determined by Cournot competition and free entry. Then M's incentive compatibility condition is given by

$$\partial \pi^L(\theta)/\partial \theta = \left[v + \varphi(Q^L(\theta))k - w\right]/P'(Q^L(\theta)) - Q^L(\theta).$$ [16]

To avoid countervailing incentives for the monopolist, we confine our analysis to a parameter region in which $\partial \pi^L(\theta)/\partial\theta$ does not change sign.[17]

Assumption 3.

$$\frac{\partial \pi^L(\theta)}{\partial \theta} = \frac{v + \varphi(Q^L(\theta))k - w}{P'(Q^L(\theta))} - Q^L(\theta) < 0 \quad \text{for all } \theta \in [\underline{\theta}, \overline{\theta}].$$

In other words, we rule out pooling solutions. Note that $w - v > \varphi(Q^L)k$ is sufficient, but not necessary, for Assumption 3 to hold. We will assume that Assumption 3 holds throughout the remainder of the paper.

With the individual rationality condition $\pi^L(\overline{\theta}) = 0$, M's expected profit equals:

$$E\pi^L = \int_{\underline{\theta}}^{\overline{\theta}} \left\{ Q^L(\theta) + \frac{v + \varphi(Q^L(\theta))k - w}{-P'(Q^L(\theta))} \right\} \left\{ \frac{\theta - \underline{\theta}}{\overline{\theta} - \underline{\theta}} \right\} d\theta. \tag{12}$$

[16]From the first order condition (5) and (6), $a = P - v - \varphi(Q)k$ and $P - w - \theta = -P'(Q)q_1$. Hence we can rewrite M's profit as $\pi^L(\theta) = Max_a \ (a - \theta)Q^L(a) + \left[v + \varphi(Q^L(a))k - w\right]\left[P(Q^L(a)) - \theta - w\right]/ -P'(Q^L(a)) + T^L(a) - K$ and get the incentive compatibility condition.

[17]When countervailing incentives arise, pooling generally characterizes the equilibrium contract and agents' performance is distorted both above and below efficient levels. See Lewis and Sappington (1989). We exclude this case to illustrate the potential of endogenizing market structure more clearly.

With M's first order condition and (12), expected welfare equals:

$$EW^L = \int_{\underline{\theta}}^{\overline{\theta}} \Big\{ U(Q^L(\theta)) - (\theta + w) Q^L(\theta) + \big[v + \varphi(Q^L(\theta)) k - w \big] \big[q_1(\theta) - Q^L(\theta) \big]$$

$$- K - (1 - \alpha)(\theta - \underline{\theta}) \Big[Q^L(\theta) + \frac{v + \varphi(Q^L(\theta)) k - w}{-P'(Q^L(\theta))} \Big] \Big\} \Big\{ \frac{1}{\overline{\theta} - \underline{\theta}} \Big\} d\theta. \quad (13)$$

Lemma 1

Suppose that the monopolist's downstream output is not contractible.

1) If the monopolist is sufficiently efficient so that $w - v < \varphi(Q) k$, vertical integration dominates liberalization for all cost reports. (If $w - v > \varphi(Q) k$, the reverse effects occur.)

2) Liberalization with contractible q_1 dominates liberalization with noncontractible q_1.

When q_1 is not contractible, neither vertical integration nor vertical separation is a special case of liberalization. Vertical integration either dominates or is dominated by liberalization depending on $v + \varphi(Q) k \gtrless w$. Note that, because it uses one less instrument, liberalization with noncontractible q_1 can not yield higher expected welfare than liberalization with contractible q_1. When q_1 is not contractible, the expected welfare-maximizing regulator considers not only fixed costs associated with fringe entry but also the differences in production efficiency downstream.

The regulator sets an access price equal to:

$$a^L(\theta) = \theta + (v - w)(1 - sE) + \varphi(Q^L(\theta)) k \Big[1 - \frac{1}{2}(1 + s)E \Big]$$

$$+ (1 - \alpha)(\theta - \underline{\theta}) \Big[1 + \frac{v + \frac{1}{2}\varphi(Q^L(\theta)) k - w}{-P'(Q^L) Q^L(\theta)} E \Big], \quad (14)$$

where s denotes the ratio of M's output to Q, $s \equiv q_1 / Q$. The resulting final good price is:

$$P^L(\theta) = \theta + v + (v - w)(1 - sE) + \varphi(Q^L(\theta))\,k \left[2 - \frac{1}{2}(1 + s)E \right]$$
$$+ (1 - \alpha)(\theta - \underline{\theta}) \left[1 + \frac{v + \frac{1}{2}\varphi(Q^L(\theta))\,k - w}{-P'(Q^L)\,Q^L(\theta)} E \right]. \qquad (15)$$

We can now compare outcomes under the different institutional settings. The main issue here is to show how differences in production efficiency ($= v - w$) affects the optimal access pricing rule.

Proposition 2

Suppose that the downstream demand is linear.

1) The optimally regulated access and final good prices under liberalization and under vertical separation differ by $v + \varphi(Q)\,k - w$.

2) Under liberalization, the regulator increases both the access price and the final good price by the difference in marginal costs. Hence, if the monopolist is more efficient downstream, the monopolist's price-cost margin and market share increase. Fewer fringe firms enter and less duplication of fixed costs occurs. (If $v < w$, the reverse effects occur.)

3) If $v + \varphi(Q)\,k - w > 0$, the downstream market has fewer fringe firms under liberalization than under vertical separation. (If $v + \varphi(Q)\,k - w < 0$, the reverse effects occur.)

Note that, when the downstream market demand is linear, the optimal access price under vertical separation ($a^S(\theta)$) allows for only M's information rent, while the optimal access price under liberalization ($a^L(\theta)$) accounts for not only M's information rent but also differences in production efficiency downstream and fixed costs associated with fringe firms' entries. Hence, ranking welfare under liberalization and vertical separation depends on whether the reduction in the duplication of the fixed costs dominates the greater price-cost margin.

Proposition 3

Assume that $1 - sE > 0$.[18]

1) If the inverse demand curve is concave ($E < 0$) and the monopolist is more efficient than fringe firms, the regulator raises the access price by more than $v - w$, but reduces the monopolist's information rent relative to the case of linear demand.

2) If the inverse demand curve is convex ($E > 0$) and the monopolist is more efficient than fringe firms, the regulator raises the access price by less than $v - w$, but increases the monopolist's information rent relative to the case of linear demand.

4. Analysis of Profits and Welfare

In this section, we will restrict our attention to linear inverse demand. Suppose that the downstream market has a linear inverse demand curve: $P = A - BQ$ ($A > 0$, $B > 0$). Hence the corresponding aggregate utility from consumption will be $U(Q) = AQ - (B/2)Q^2$, ignoring an arbitrary constant.

4.1 Comparison of Welfare

Let $W^I(\theta)$, $W^S(\theta)$, and $W^L(\theta)$ denote social welfare conditional on the monopolist's upstream cost under the market structure of vertical integration, vertical separation, and liberalization, respectively. For example, social welfare under vertically integrated monopoly is

[18]For convex demand curves with constant elasticity, the condition may not hold unless the monopolist's downstream market share is small. For concave demand curves, it always holds.

given by $W^I(\theta) = U(Q^I(\theta)) - (w+\theta)Q^I(\theta) - K - (1-\alpha)\int_{\theta}^{\bar{\theta}} Q^I(\theta)\,d\theta$. The contractible q_1 liberalization policy is always either vertical integration or vertical separation, so we do not need to consider it separately. Then welfare changes as θ changes under each regulatory policy in the following manner:

Lemma 2

Suppose that the demand curve is linear.

1) The derivative of social welfare with respect to θ under liberalization is the same as that under vertical separation. Any comparisons of welfare under vertical separation and liberalization are independent of θ ($W^S(\theta) \gtrless W^L(\theta)$ if and only if $K \gtrless \frac{3(v+bk-w)^2}{2B}$).

2) If $v+bk-w>0$, social welfare decreases faster as θ increases under vertical integration than under vertical separation and liberalization. In other words,
$\frac{\partial W^I(\theta)}{\partial\theta} < \frac{\partial W^S(\theta)}{\partial\theta} = \frac{\partial W^L(\theta)}{\partial\theta} < 0$. (If $v+bk-w<0$, the reverse effects occur.)

Lemma 2 provides us with some important simple rules to choose among market structures. Since $W^S(\theta)$ and $W^L(\theta)$ decrease at the same rate as θ increases, if $W^S(\underline{\theta}) > W^L(\underline{\theta})$, liberalization can be excluded from the regulator's policy options, and if $W^S(\underline{\theta}) < W^L(\underline{\theta})$, separation can be excluded. Further, when $v+bk-w>0$, if $W^I(\underline{\theta}) < W^S(\underline{\theta})$ (or $W^I(\underline{\theta}) < W^L(\underline{\theta})$), the regulator would choose either vertical separation or liberalization rather than vertical integration because $W^I(\theta)$ decreases faster than $W^S(\theta)$ and $W^L(\theta)$ as θ increases.

4.2 Comparison of *M*'s Profit under Different Market Structures

Let us now consider *M*'s profits under each market structure. With linear inverse demand, from (9), total output in state θ under vertical integration is:

$$Q^I(\theta) = (1/B)\left[A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta\right].$$

Then *M*'s profits conditional on θ under vertical integration is as follows:

$$\pi^I(\theta) = \int_{\theta}^{\overline{\theta}} \left\{ \frac{A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta}{B} \right\} d\theta. \tag{16}$$

Similarly, *M*'s profit functions under vertical separation and liberalization are as follows:

$$\pi^S(\theta) = \int_{\theta}^{\overline{\theta}} \left\{ \frac{A - v - bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta}{B} \right\} d\theta = \pi^L(\theta). \tag{17}$$

Lemma 3

1) *M*'s profit under vertical separation is the same as that under liberalization ($\pi^S(\theta) = \pi^L(\theta)$).

2) If $v + bk - w > 0$, *M*'s profit under vertically integrated monopoly is higher than under vertical separation and liberalization for all θ ($\pi^I(\theta) > \max\{\pi^S(\theta), \pi^L(\theta)\}$ $\forall\, \theta \in [\underline{\theta}, \overline{\theta}]$). (If $v + bk - w < 0$, the reverse effects occur.)

3) If $v + bk - w > 0$, *M*'s profit under vertically integrated monopoly decreases faster as θ increases than under vertical separation or liberalization ($\frac{\partial \pi^I(\theta)}{\partial \theta} < \frac{\partial \pi^S(\theta)}{\partial \theta} = \frac{\partial \pi^L(\theta)}{\partial \theta}$). (If $v + bk - w < 0$, the reverse effects occur.)

The first result in Lemma 3 follows from the fact that price and output change in offsetting ways with linear demand. From (11) and (15), $P^L(\theta) = P^S(\theta) + v + bk - w$ (the same is also true for access prices $a^L(\theta)$ and $a^S(\theta)$). With linear demand, the difference in the output levels is independent of θ: $Q^L(\theta) - Q^S(\theta) = -(v + bk - w)/B$. If $v + bk - w > 0$, the optimal final good price (quantity) under liberalization is higher (lower) than that under vertical separation. However the integrand of *M*'s expected profit function (12) is $Q^L(\theta) + (v + bk - w)/B$ and equals the integrand of *M*'s expected profit function under vertical separation $Q^S(\theta)$. Therefore *M*'s profit is the same under both market structures. The regulator exactly offsets *M*'s higher earnings in the downstream market by adjusting the net transfer. On average, if $v + bk - w > 0$, vertical integration is the most profitable market structure for the monopolist, but its profit is more sensitive to upstream cost than with downstream production by the fringe. The regulator can exploit this feature in a particular way, which we develop in the next section.

5. A Hybrid Regime

In the previous section, assuming linear demand in the downstream market, we analyzed access price, profit, and social welfare for each regulatory policy where the regulator has *ex ante* chosen a market structure, irrespective of the monopolist's cost report. Would it be socially beneficial to allow competitors to have access to the integrated firm's network for all cost realizations? As Vickers (1995) points out, there are two underlying economic effects: the information asymmetry, which allows the monopolist to extract rents, and imperfect competition, which leads to excess entry (with duplication of fixed costs). Can the regulator gain significantly by conditioning the market structure on the realization of the cost characteristic of the firm? Consider a hybrid regime in which the regulator can allow both vertical structure and the contract payments to vary with the cost report. From Lemma 1, we know that a hybrid regime can not dominate integration or liberalization since one of these regimes dominates the other for all cost reports. Lemma 2 indicates that we can further reduce the set of policy options in hybrid regimes to ones with vertical integration and vertical separation. To simplify our analysis, we confine ourselves to a subset of the no-pooling region in parameter space with linear demand:

Assumption 4

$$v + b\,k - w > 0.$$

Assumption 4 guarantees that, as θ increases, social welfare decreases faster under vertical integration than vertical separation (Lemma 2) and that the monopolist's profit under vertical integration is higher than under vertical separation but decreases faster (Lemma 3).

5.1 Hybrid Regime with Vertically Integrated Monopoly and Vertical Separation

Suppose that, when the monopolist's upstream cost is at its lower bound, the ranking of social welfare is: $W^I(\underline{\theta}) > W^S(\underline{\theta})$. Since $W^I(\theta)$ decreases faster than $W^S(\theta)$ as θ increases, the ranking can switch so that $W^I(\overline{\theta}) < W^S(\overline{\theta})$. See Figure 1 for an illustration. In this case, the question arises whether the regulator can exploit this and blend the two market structures together depending on the cost report. Suppose that the regulator offers M a menu that changes the allowed market structure if M's reported cost is higher than a critical value $\theta^* \in [\underline{\theta}, \overline{\theta}]$. In particular, the regulator adopts monopoly if $\tilde{\theta} \in [\underline{\theta}, \theta^*]$, and vertical separation otherwise. The idea is that the regulator can use the choice of market structures as an additional tool to limit the monopolist's rent extraction and increase expected social welfare. Let

EW^H denote expected social welfare under the hybrid regime. For M's reported value of cost $\tilde{\theta} \in [\underline{\theta}, \theta^*]$, M earns the profit of the vertically integrated monopoly, $\pi^I(\theta)$. For $\tilde{\theta} \in (\theta^*, \overline{\theta}]$, since only fringe firms are allowed in the downstream market, M's profit will be $\pi^S(\theta)$ and the individual rationality condition binds with $\pi^S(\overline{\theta}) = 0$.[19] We must modify the incentive compatibility (IC) and individual rationality constraints (IR) to accommodate the structural change at θ^*:

$$\textbf{IC*} \quad \begin{cases} \dfrac{\partial \pi^I(\theta)}{\partial \theta} = -Q^I(\theta) \text{ for } \theta \in [\underline{\theta}, \theta^*] \text{ and } \pi^I(\theta^*) = \pi^S(\theta^*) \\ \text{or} \\ \dfrac{\partial \pi^S(\theta)}{\partial \theta} = -Q^S(\theta) \text{ for } \theta \in (\theta^*, \overline{\theta}] \end{cases}$$

$$\text{where } \pi^I(\theta) = \int_{\theta}^{\theta^*} Q^I(\theta)\, d\theta + \pi^S(\theta^*) \text{ for } \theta \in [\underline{\theta}, \theta^*] \text{ and}$$

$$\pi^S(\theta) = \int_{\theta}^{\overline{\theta}} Q^S(\theta)\, d\theta \text{ for } \theta \in (\theta^*, \overline{\theta}] \text{ for } \theta \in [\theta^*, \overline{\theta}].$$

Each incentive compatibility condition is continuous and differentiable on each connected interval of θ.

$$\textbf{IR*} \qquad \pi^S(\overline{\theta}) = 0$$

The condition $\pi^I(\theta^*) = \pi^S(\theta^*)$ insures that there is no incentive in the neighborhood of θ^* to misreport costs to gain from the switch in market structure. Figure 2 illustrates profit as a function of θ under such a policy. It is worth noting that, under the hybrid regime, M's

[19]If we consider an industry where fringe firms do not need units of an input provided by a monopolist for their production, the binding individual rationality condition should be $\pi^I(\theta^*) = 0$.

incentive to exaggerate its cost is dampened because M has to shut down its downstream sector for $\tilde{\theta} \in (\theta^*, \overline{\theta}]$.

5.1.1 The Regulator's Problem

With the modified individual rationality condition, let $W^I(\theta, \theta^*)$ denote welfare under vertically integrated monopoly for $\theta \in [\underline{\theta}, \theta^*]$. Since $W^S(\theta)$ remains unchanged for $\theta \in (\theta^*, \overline{\theta}]$, the regulator's objective function becomes:

$$\underset{\theta^*}{Max} \quad EW^H(\theta^*) = \int_{\underline{\theta}}^{\theta^*} W^I(\theta, \theta^*) f(\theta)\, d\theta + \int_{\theta^*}^{\overline{\theta}} W^S(\theta) f(\theta)\, d\theta \tag{18}$$

(see the appendix for details).

Since the regulator's problem is to choose a critical value θ^* optimally so that expected social welfare is maximized, maximizing expected welfare with respect to θ^* yields the first order condition:

$$\frac{\partial EW^H(\theta^*)}{\partial \theta^*} = \int_{\underline{\theta}}^{\theta^*} \frac{\partial W^I(\theta, \theta^*)}{\partial \theta^*} f(\theta)\, d\theta + W^I(\theta^*) f(\theta) - W^S(\theta^*) f(\theta) = 0. \tag{19}$$

Proposition 4

Suppose that the following condition holds: $W^I(\underline{\theta}) > W^S(\underline{\theta})$. Then the optimal market structure for the maximization of expected welfare uses a hybrid regime of vertical integration and separation if $\underline{\theta} < \theta^* = \dfrac{[2A - v - w - bk + 2(1-\alpha)\underline{\theta}](v - w + bk) - 2b^2k^2}{2(2-\alpha)(v - w + bk)} < \overline{\theta}$. In other cases, the optimal policy is either vertical separation or integrated monopoly for all cost reports.

In contrast with the cases where market structures are taken as given, Proposition 4 shows how using market structure as a contract instrument can affect the behavior of the regulated firm in the economy. Previously, the optimal access pricing rule limited the regulator's role to M's vertical conduct. Under the hybrid regime, however, the regulator can use the threat of entry by fringe firms and exclusion of the monopoly from the downstream market and thereby enhance expected welfare.

5.1.2 Example

To illustrate the magnitude of the gains from the hybrid policy, we now present some simulation results. Suppose that the inverse demand function is $P = 58 - Q$ and θ is uniformly distributed on the interval $[1, 15]$. For the parameter values, $\alpha = 0.5$, $v = 5$, $w = 10$, $K = 400 (k = 20)$, $W^I(\underline{\theta}) > W^S(\underline{\theta})$ and vertical separation dominates liberalization. Optimization of the hybrid regime yields an interior solution with $\theta^* = 9.55556$. The regulator strictly deters any entry by the fringe if $\tilde{\theta} \leq \theta^*$, and it excludes the monopolist from the deregulated sector and allows the fringe to take over the entire downstream market otherwise. Expected welfare under vertically integrated monopoly and vertical separation are 284.5 and 249.5, respectively. However, expected welfare under the hybrid regime is 308.32. The following tables indicate how the value of expected welfare varies as each parameter changes in each regulatory regime for the given example.

(1) Expected welfare with different weights on M's profit (α) (Table 1)

The larger α is, the more M's profit counts in expected social welfare and the smaller is the welfare loss from the transfer. Hence, as M's rents become less objectionable, fewer distortions will be imposed. Expected welfare under each regulatory policy increases as α increases, partly because the monopoly rents count more in welfare. As we increase α, the value of θ^* also increases, favoring the monopolist. However, the absolute expected welfare gain of the hybrid policy over the best single market structure policy is monotonically decreasing with respect to α. At α near zero, limiting rent extraction is highly valued while, at $\alpha = 1$, efficiency is highly valued.

(2) Expected welfare with different costs at the downstream level (v and w) (Table 2 and 3)

As a fringe firm's marginal cost (v) increases, expected welfare under vertical separation and the hybrid regime decreases and policy switching occurs at a larger value of θ^*. Therefore, if the fringe firms are less efficient relative to the monopolist, vertically integrated monopoly is more likely to be adopted for the optimal market structure of the industry. The same line of reasoning applies to decreases in M's marginal cost (w) at the downstream level.

(3) Expected welfare with different fixed cost (K) (Table 4)

Since we assume a fixed cost for all entrants in the downstream market, it is costly to open segments to competitors in terms of duplication of the fixed costs. As K increases, expected welfare under each regulatory policy decreases. However, the optimal switching point (θ^*) will determined by whether M's price-cost margin effect dominates the duplication of the fixed cost effect. This example is a case where M's price-cost margin effect dominates the duplication of the fixed cost effect.

5.2 How the Hybrid Regime Compares with Liberalization

We saw earlier that liberalization with contractible q_1 is dominated by either vertical integration or vertical separation (Proposition 1) and that liberalization with noncontractible q_1 is dominated by liberalization with contractible q_1 (Lemma 1). Hence, if vertical separation dominates liberalization, under some conditions, the hybrid regime dominates both vertical integration and vertical separation. Thus, it is the optimal policy among all those we have studied.

6. Conclusion

Optimal regulation under asymmetric information of a vertically integrated monopolist can include regulation of vertical structure as well as vertical conduct. In a simple combination of B-M regulation and Cournot oligopoly, if the regulator deregulates the downstream market, the optimal regulated access price and final good price are higher than when the regulator adopts vertical separation. A welfare comparison of liberalization and vertical separation depends on whether the reduction in the duplication of fixed costs dominates the greater price-cost margin.

Since the welfare comparison of liberalization and vertical separation is independent of the monopolist's upstream marginal cost, the regulator's task regarding vertical structure is to choose either sole or multiple sources of production in the deregulated market. The hybrid regime considers both the information asymmetry and imperfect competition in the downstream market. The regulator can increase expected social welfare as long as the regulator can shut down either the monopolist or (potential) fringe firms, or let both produce final goods. In contrast with the cases with fixed market structures, the hybrid example where either the monopolist or the fringe serve the entire downstream market shows how incentive issues can affect the regulated firm's competitive environment. We have shown that a low-cost monopolist is rewarded with monopoly downstream market and a high cost monopolist is excluded from or faces competition in the downstream market, even though it is the monopolist's upstream cost that affects this choice under the hybrid regime.

Our analysis presumes that free entry endogenously determines the number of firms in the downstream market. We also assume that the industry produces a single homogeneous product. In practice, however, each firm may face a capacity constraint and have a market power for its own product. If we assume that the monopolist has a few potential competitors of large-scale, then competitors would also earn oligopoly profits under quantity competition. Then the duplication of fixed costs might not be crucial in the welfare comparison of integrated monopoly and vertical separation. Endogenous incentive mechanisms for other environments remain an important topic for future research.

Table 1: Expected welfare as the weight on M's profit (α) changes:
$v = 5$, $w = 10$, $K = 400$ ($k = 20$), $\theta \in [1, 15]$, and $P = 58 - Q$.

α	θ^*	EW^H	EW^I	EW^S	Welfare gain (%)*
0.1	7.75439	250.76	197.33	204.33	22.72
0.2	8.12963	263.66	218.14	214.64	20.86
0.3	8.54902	277.51	239.61	225.61	15.81
0.4	9.02083	292.37	261.73	237.23	11.7
0.5	9.55556	308.32	284.5	249.5	8.37
0.6	10.1667	325.45	307.93	262.43	5.68
0.7	10.8718	343.88	332.01	276.01	3.57
0.8	11.6944	363.76	356.74	290.24	1.96
0.9	12.6667	385.33	382.13	305.13	0.83
1	13.8333	408.9	408.17	320.67	0.17

*The last column is calculated by $[EW^H - \max\{EW^I, EW^S\}] / \max\{EW^I, EW^S\}$.

Table 2: Expected welfare as a fringe firm's cost (v) changes:
$\alpha = 0.5$, $w = 10$, $K = 400$ ($k = 20$), $\theta \in [1, 15]$, and $P = 58 - Q$.

v	θ^*	EW^H	EW^I	EW^S	Welfare gain (%)
2	6.1111	335.3	284.5	318.5	5.27
3	7.48718	323.81	284.5	294.5	9.95
4	8.61905	315.04	284.5	271.5	10.73
5	9.55556	308.32	284.5	249.5	8.37
6	10.3333	303.17	284.5	228.5	6.56

For this example, if $v > 6$, social welfare under liberalization is greater than under vertical separation.

Table 3: Expected welfare as M's cost at the downstream level (w) changes: $\alpha = 0.5$, $v = 5$, $K = 400$ ($k = 20$), $\theta \in [1, 15]$, and $P = 58 - Q$.

w	θ^*	EW^H	EW^I	EW^S	Welfare gain (%)
9	11	335.21	321.5	249.5	4.26
10	9.55556	308.32	284.5	249.5	8.37
11	7.95238	285.75	248.5	249.5	14.52
12	6.15385	268.00	213.5	249.5	7.41

*For this example, if $w < 9$, social welfare under liberalization is greater than under vertical separation.

Table 4: Expected welfare as the fixed cost (K) changes: $\alpha = 0.5$, $v = 5$, $w = 10$, $\theta \in [1, 15]$, and $P = 58 - Q$.

k	θ^*	EW^H	EW^I	EW^S	Welfare gain (%)
15	14	460.04	459.5	369.5	0.11
16	13.1515	430.51	428.5	343.5	0.46
17	12.2778	400.26	395.5	318.5	1.20
18	11.3846	369.60	360.5	294.5	2.52
19	10.4762	338.85	323.5	271.5	4.74
20	9.55556	308.32	284.5	249.5	8.37
21	8.625	278.33	243.5	228.5	14.30
22	7.68627	249.22	200.5	208.5	19.53
23	6.74074	221.28	155.5	189.5	16.77
24	5.78947	194.85	108.5	171.5	13.61

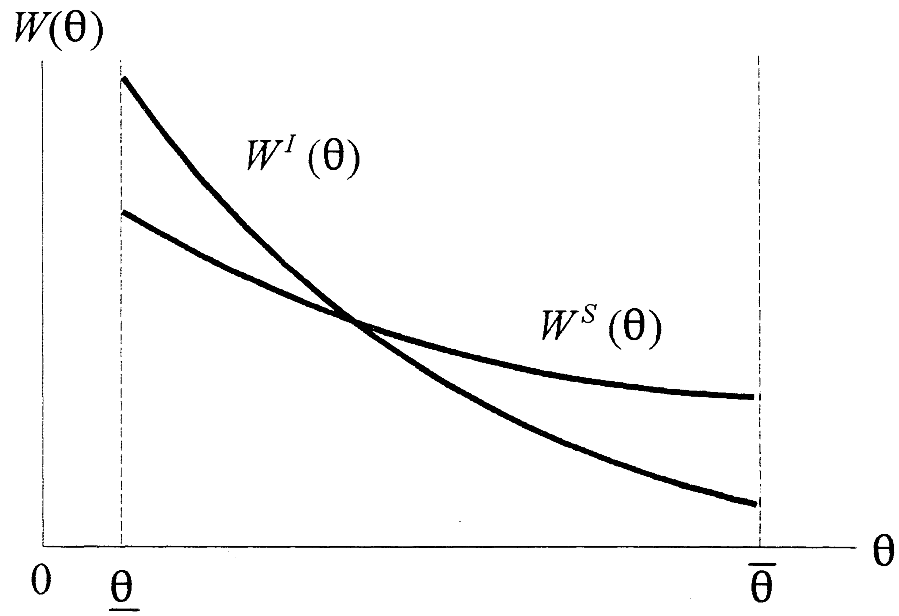

Figure 1: $\dfrac{\partial W^I(\theta)}{\partial \theta} < \dfrac{\partial W^S(\theta)}{\partial \theta} < 0$ with $W^I(\underline{\theta}) > W^S(\underline{\theta})$

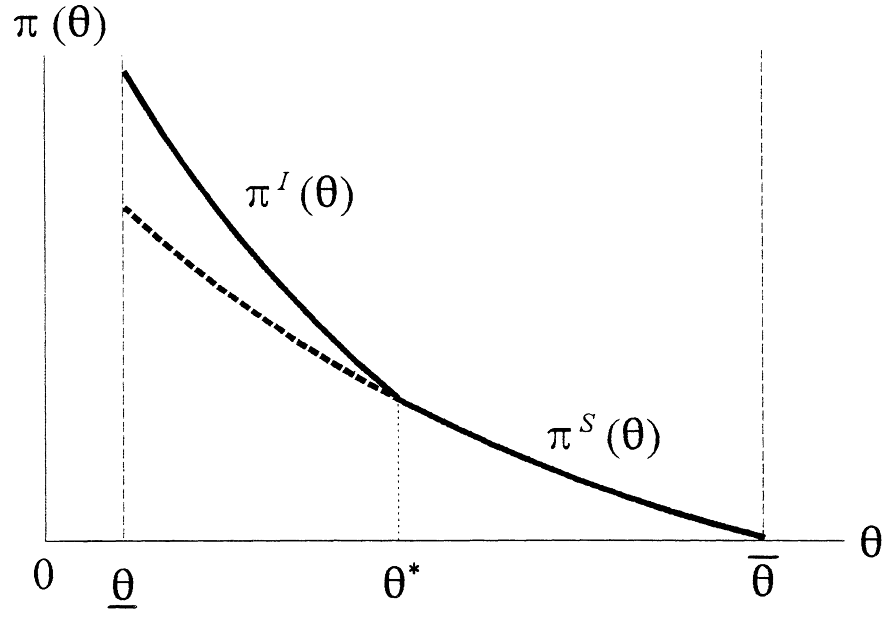

Figure 2: *M*'s incentive compatibility condition under the hybrid regime:

$$\pi^{I}(\theta) = \int_{\theta}^{\theta^*} Q^{I}(\theta)\, d\theta + \pi^{S}(\theta^*) \quad \text{for} \quad \theta \in [\underline{\theta}, \theta^*].$$

Appendix

A. Derivation of Incentive Compatibility Condition

When q_1 is contractible, the monopolist under liberalization chooses its access fee to maximize

$$\pi^C(\theta) = \underset{a}{Max} \quad (a - \theta) Q^C(a) + \left[P(Q^C(a)) - w - a\right] q_1(a) + T(a) - K.$$

By using the envelope theorem, *M*'s incentive compatibility constraint is:

$$\partial \pi^C(\theta)/\partial\theta = -Q^C(\theta).$$

With the binding individual rationality condition $\pi^C(\overline{\theta}) = 0$, integration of the monopolist's incentive compatibility constraint over $[\theta, \overline{\theta}]$ yields its profit function:

$$\pi^C(\theta) = \int_{\theta}^{\overline{\theta}} Q^C(\theta)\, d\theta.$$

When q_1 is noncontractible, the monopolist produces the equilibrium choice in the downstream Cournot game: $q_1 = \left[P(Q^L) - \theta - w\right]/-P'(Q^L)$. From (5), since $a = P(Q^L) - v - \varphi(Q^L)k$, we can rewrite the monopolist's profit as follows:

$$\pi^L(\theta) = \underset{a}{Max} \quad (a - \theta) Q^L(a) + T^L(a) - K$$
$$+ \left[v + \varphi(Q^L(a))k - w\right]\left[P(Q^L(a)) - \theta - w\right]/-P'(Q^L(a)).$$

Then, the envelope theorem yields *M*'s incentive compatibility condition as follows:

$$\partial \pi^L(\theta)/\partial\theta = -Q^L(\theta) + \left[v + \varphi(Q^L(\theta))k - w\right]/P'(Q^L(\theta)).$$

Hence, with the binding individual rationality condition $\pi^L(\overline{\theta}) = 0$, integration of the monopolist's incentive compatibility condition over $[\theta, \overline{\theta}]$ yields the monopolist's profit function:

$$\pi^L(\theta) = \int_{\theta}^{\overline{\theta}} \left\{ Q^L(\theta) + \frac{v + \varphi(Q^L(\theta))k - w}{-P'(Q^L(\theta))} \right\} d\theta.$$

B. Proofs

Proof of proposition 1

The problem of optimizing expected social welfare under contractible liberalization with respect to q_1 and Q^C is:

$$\underset{q_1, Q^C}{Max} \int_{\underline{\theta}}^{\overline{\theta}} \Big\{ U(Q^C(\theta)) - (\theta + w)Q^C(\theta) + \big[v + \varphi(Q^C(\theta))k - w\big]\big[q_1(a) - Q^C(\theta)\big]$$

$$- K\xi(q_1) - (1-\alpha)(\theta - \underline{\theta})Q^C(\theta) \Big\} \frac{1}{\overline{\theta} - \underline{\theta}} d\theta$$

$$\text{s.t.} \qquad q_1 \in [0, Q] \text{ and } \xi(q_1) = \begin{cases} 1 & \text{if } q_1 > 0 \\ 0 & \text{if } q_1 = 0. \end{cases}$$

Differentiating EW^C with respect to q_1 yields:

$$v + \varphi(Q^C)k - w \gtrless 0.$$

i) If $v + \varphi(Q^C)k - w < 0$, then $\partial EW^C / \partial q_1 < 0$ and thus $q_1 = 0$ is optimal for all θ (vertical separation).

ii) If $v + \varphi(Q^C)k - w > 0$, then $\partial EW^C / \partial q_1 > 0$. If the monopolist produces a positive downstream output, the monopolist spends K to produce downstream. Hence, $q_1 = 0$ is optimal if $E\big[[v + \varphi(Q^C(\theta))k - w]\big]Q^C(\theta) - K < 0$ while $q_1 = Q^C$ is optimal if $E\big[[v + \varphi(Q^C(\theta))k - w]\big]Q^C(\theta) - K > 0$ (vertical integration).

When vertical separation is optimal, expected social welfare equals:

$$EW^S = \int_{\underline{\theta}}^{\overline{\theta}} \Big\{ U(Q^S(\theta)) - \big[\theta + v + \varphi(Q^S(\theta))k\big]Q^S(\theta)$$

$$- (1-\alpha)(\theta - \underline{\theta})Q^S(\theta) \Big\} \Big\{ \frac{1}{\overline{\theta} - \underline{\theta}} \Big\} d\theta.$$

Optimizing EW^S with respect to $Q^S(\theta)$ yields the optimal access fee and final good price:

$$a^S(\theta) = \theta - \frac{1}{2}\varphi(Q^S)kE + (1-\alpha)(\theta - \underline{\theta}) \text{ and}$$

$$P^S(\theta) = \theta + v + \varphi(Q^S)k\left[1 - \frac{1}{2}E\right] + (1-\alpha)(\theta - \underline{\theta}).$$

Similarly, when vertical integration is optimal, expected social welfare equals:

$$EW^I = \int_{\underline{\theta}}^{\overline{\theta}} \left\{ U(Q^I(\theta)) - (\theta + w)Q^I(\theta) - K - (1-\alpha)(\theta - \underline{\theta})Q^I(\theta) \right\} \left\{ \frac{1}{\overline{\theta} - \underline{\theta}} \right\} d\theta$$

and optimizing EW^I with respect to $Q^I(\theta)$ yields:

$$P^I(\theta) = \theta + w + (1-\alpha)(\theta - \underline{\theta}).$$

Lemma 1

1) Comparing $W^I(\theta)$ and $W^L(\theta)$, $W^L(\theta)$ has the additional terms:

$$\left[v + \varphi(Q^L)k - w\right](q_1 - Q^L) \quad \text{and} \quad -(1-\alpha)\int_{\theta}^{\overline{\theta}} \frac{v + \varphi(Q^L)k - w}{-P'(Q^L)}\, d\theta.$$

Thus, take the optimal $Q^L(\theta)$ under noncontractible liberalization and substitute it for $Q^I(\theta)$ in $W^I(\theta)$. If $v + \varphi(Q(\theta))k - w > 0$ for all θ, $W^I(Q^L(\theta)) > W^L(Q^L(\theta))$ because $\left[v + \varphi(Q^L(\theta))k - w\right]\left[q_1(\theta) - Q^L(\theta)\right] < 0$ and $-(1-\alpha)\int_{\theta}^{\overline{\theta}} \frac{v + \varphi(Q^L(\theta))k - w}{-P'(Q^L(\theta))}\, d\theta < 0$ (as long as $\alpha < 1$). Also $W^I(Q^L(\theta)) < W^I(Q^I(\theta))$ since $Q^L(\theta)$ is feasible, but not optimal, under vertical integration. Thus, $W^I(\theta) > W^L(\theta)$ if $v + \varphi(Q(\theta))k - w > 0$ for all θ. Note that, even though $v < w$, $W^I(\theta) > W^L(\theta)$ as long as $v + \varphi(Q(\theta))k - w > 0$ for all θ. If $v + \varphi(Q(\theta))k - w < 0$, then $W^I(\theta) < W^L(\theta)$ by similar reasoning.

2) Contractible liberalization allows choice of q_1 by the regulator who can sustain the outcome under noncontractible liberalization. Hence, welfare must be at least as great under contractible liberalization.

Proof of Proposition 2.

1) From (10) and (11), optimal access and final good prices under vertical separation are $a^S(\theta) = \theta + (1-\alpha)(\theta - \underline{\theta})$ and $P^S(\theta) = \theta + v + \varphi(Q^S(\theta))k + (1-\alpha)(\theta - \underline{\theta})$, respectively. From (14) and (15), optimal access and final good prices under noncontractible liberalization are $a^L(\theta) = \theta + v + \varphi(Q^L(\theta))k - w + (1-\alpha)(\theta - \underline{\theta})$ and $P^L(\theta) = \theta + 2v + 2\varphi(Q^L(\theta))k - w + (1-\alpha)(\theta - \underline{\theta})$, respectively. Hence optimally regulated access and final good prices are higher or lower under liberalization by $v + \varphi(Q(\theta))k - w$.

2) Compared to the case where $v = w$, the regulator increases both the access price and the final good price by the difference in marginal costs $(v - w)$ under liberalization.

Let $C_F\ (= a^L(\theta) + v)$ and $C_M\ (= \theta + w)$ denote the overall marginal costs of the fringe firms and the monopolist, respectively. Then, C_F will rise or fall by twice the change in $v\ (\partial C_F / \partial v = 2)$ due to an increase in access price, while C_M will change exactly by a change in $w\ (\partial C_M / \partial w = 1)$. From (15), it is $\partial(P^L - \theta - w)/\partial v > 0$ and $\partial(P^L - \theta - w)/\partial w < 0$ with linear demand $(E = 0)$. The same is true for $a^L(\theta)$. If $v > w$, the monopolist's price-cost margin will be even higher than otherwise. Since the number of fringe firms in the downstream market under liberalization is determined by $n^L - 1 = (Q^L - q_1)/q_2$ and the monopolist produces the downstream output by $q_1 = [P^L(\theta) - \theta - w]/-P^L(\theta)$, the higher v is, the higher is the final good price. And, the higher the final good price is, the greater is q_1 and the smaller is the number of the fringe firms.

3) If $v + \varphi(Q)k - w > 0$, $Q^S(\theta) > Q^L(\theta)$ because $P^L(\theta) > P^S(\theta)$. The number of fringe firms in the downstream market under vertical separation is determined by $n^S = Q^S/q_2$. Then, since $Q^S > Q^L > Q^L - q_1$ and $\varphi(Q)$ is constant, $q_2^L = q_2^S = k / \varphi(Q)$ and $n^L < n^S$.

Proof of Proposition 3

1) With a concave inverse demand curve ($E<0$), if $v>w$ in equation (14), the more efficient monopolist is favored by the regulator by more than actual cost difference because $(v-w)(1-sE)>(v-w)$. However, the more efficient monopolist gains less informational rent than with linear inverse demand because $\dfrac{(v-w)E}{-P'(Q^L)Q^L}<0$. If $v<w$, the reverse effect occurs.

2) With a convex inverse demand curve ($E>0$), if $v>w$ in equation (14), the less efficient fringe firms are favored by the regulator because $(v-w)(1-sE)<(v-w)$ since $1-sE>0$. However, the more efficient monopolist gains more informational rent than with linear inverse demand because $\dfrac{(v-w)E}{-P'(Q^L)Q^L}>0$. If $v<w$, the reverse effect occurs.

Proof of Lemma 2

1) Since $U(Q)=AQ-(B/2)Q^2$ and $Q^S(\theta)=(1/B)[A-v-bk+(1-\alpha)\underline{\theta}-(2-\alpha)\theta]$, social welfare under vertical separation is

$$
\begin{aligned}
W^S(\theta) &= U(Q^S(\theta))-(\theta+v+bk)Q^S(\theta)-(1-\alpha)\int_{\theta}^{\bar{\theta}}Q^S(\theta)\,d\theta \\
&= (1/2B)[A-v-bk+(1-\alpha)\underline{\theta}-(2-\alpha)\theta]\cdot[A-v-bk-(1-\alpha)\underline{\theta}-\alpha\theta] \\
&\qquad -(1-\alpha)\int_{\theta}^{\bar{\theta}}Q^S(\theta)\,d\theta.
\end{aligned}
$$

Then:

$$\partial W^S(\theta)/\partial\theta = -(1/B)[\alpha A-\alpha v-\alpha bk-2(1-\alpha)^2\underline{\theta}+(2-\alpha)(1-2\alpha)\theta].$$

Similarly, since $Q^L(\theta)=(1/B)[A-2v-2bk+w+(1-\alpha)\underline{\theta}-(2-\alpha)\theta]$, social welfare under liberalization downstream is:

$$W^L(\theta) = U(Q^L(\theta)) - (\theta + v + bk)Q^L(\theta) + (v + bk - w)(P - w - \theta)/B - K$$
$$- (1-\alpha) \int_{\underline{\theta}}^{\overline{\theta}} \{Q^L(\theta) + (v - w + bk)/B\}\, d\theta.$$
$$= (1/2B)[A - 2v + w - 2bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]\cdot$$
$$[A - w - (1-\alpha)\underline{\theta} - \alpha\theta] - K$$
$$+ (1/B)(v + bk - w)[2v + 2bk - 2w + (1-\alpha)(\theta - \underline{\theta})]$$
$$- (1-\alpha) \int_{\underline{\theta}}^{\overline{\theta}} \{ Q^L(\theta) + (v + bk - w)/B\}\, d\theta.$$

Then, it is straightforward to show:

$$\partial W^S(\theta)/\partial\theta = -(1/B)[\alpha(A - v - bk) - 2(1-\alpha)^2\underline{\theta} + (2-\alpha)(1-2\alpha)\theta]$$
$$= \partial W^L(\theta)/\partial\theta.$$

Note that $Q^S(\theta) = Q^L(\theta) + (v + bk - w)/B$. Then, we find:

$$W^S(\theta) - W^L(\theta) = -(3/2B)(v + bk - w)^2 + K.$$

Therefore, $W^S(\theta) \gtrless W^L(\theta)$ does not depend on the monopolist's upstream marginal cost, θ.

Hence

$$W^S(\theta) \gtrless W^L(\theta) \quad \text{if and only if} \quad \frac{3(v + bk - w)^2}{2B} \lesseqgtr K.$$

2) From (9), $Q^I(\theta) = (1/B)[A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]$. Then:

$$W^I(\theta) = U(Q^I(\theta)) - (\theta + w)Q^I(\theta) - K - (1-\alpha) \int_{\underline{\theta}}^{\overline{\theta}} Q^I(\theta)\, d\theta$$
$$= (1/2B)[A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]\cdot[A - w - (1-\alpha)\underline{\theta} - \alpha\theta] - K$$
$$- \int_{\underline{\theta}}^{\overline{\theta}} Q^I(\theta)\, d\theta,$$

and $\partial W^I(\theta)/\partial\theta = -(1/B)[\alpha(A - w) - 2(1-\alpha)^2\underline{\theta} + (2-\alpha)(1-2\alpha)\theta]$.

If $v + bk - w > 0$, $\dfrac{\partial W^I(\theta)}{\partial\theta} < \dfrac{\partial W^S(\theta)}{\partial\theta} = \dfrac{\partial W^L(\theta)}{\partial\theta} < 0.$

Proof of Lemma 3

1) To prove that $\pi^S(\theta) = \pi^L(\theta)$, it is sufficient to show that

$Q^L(\theta) + (v + bk - w)/B = Q^S(\theta)$. From (13) and (19), With linear demand, since

$P^L(\theta) = \theta + 2v + 2bk - w + (1-\alpha)(\theta - \underline{\theta})$,

$Q^L(\theta) + (v - w + bk)/B = (1/B)[A - v - bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta] = Q^S(\theta)$.

2) Since $\pi^S(\theta) = \pi^L(\theta)$, it is sufficient to show that $Q^I(\theta) > Q^S(\theta)$ if $v + bk - w > 0$. From (9) and (11), $P^S(\theta) - P^I(\theta) = v + bk - w$. Hence $Q^I(\theta) > Q^S(\theta)$ if $v + bk - w > 0$. Therefore $\pi^I(\theta) > \pi^S(\theta) = \pi^L(\theta)$ for all $\theta \in [\underline{\theta}, \overline{\theta})$.

3) From (16) and (17), $\partial\pi^I(\theta)/\partial\theta = (1/B)[A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]$ and $\partial\pi^S(\theta)/\partial\theta = (1/B)[A - v - bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]$. If $v + bk - w > 0$, $\partial\pi^I(\theta)/\partial\theta < \partial\pi^S(\theta)/\partial\theta$. Since $\pi^S(\theta) = \pi^L(\theta)$, $\partial\pi^I(\theta)/\partial\theta < \partial\pi^L(\theta)/\partial\theta$ also holds.

Proof of Proposition 4

For $\tilde{\theta} \in [\underline{\theta}, \theta^*]$:

$$W^I(\theta, \theta^*) = U[Q^I(\theta)] - (\theta + w)Q^I(\theta) - K - (1-\alpha)\int_{\underline{\theta}}^{\theta^*} Q^I(\theta)\,d\theta - (1-\alpha)\pi^S(\theta^*)$$

where $\pi^S(\theta^*) = \int_{\theta^*}^{\overline{\theta}} Q^S(\theta)\,d\theta$.

Similarly, for $\tilde{\theta} \in (\theta^*, \overline{\theta}]$:

$$W^S(\theta) = U(Q^S(\theta)) - (\theta + v + bk)Q^S(\theta) - (1-\alpha)\int_{\theta}^{\overline{\theta}} Q^S(\theta)\,d\theta.$$

Pointwise optimization with respect to Q yields

$Q^I(\theta) = (1/B)[A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]$ under vertically integrated monopoly and

$Q^S(\theta) = (1/B)[A - v - bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]$ under vertical separation. Note that Q^I on the interval $\theta \in [\underline{\theta}, \theta^*]$ is the same as the one derived from (9). The regulator offsets a change in M's profit under vertically integrated monopoly by adjusting the net transfer. Then social welfare under the hybrid regime is as follows:

i) for $\tilde{\theta} \in [\underline{\theta}, \theta^*]$,

$$W^I(\theta,\theta^*) = (1/2B)[A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]\cdot[A - w - (1-\alpha)\underline{\theta} - \alpha\theta] - K$$
$$- (1-\alpha)\int_{\underline{\theta}}^{\theta^*}\left\{(1/B)[A - w + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]\right\}d\theta$$
$$-(1-\alpha)\int_{\theta^*}^{\overline{\theta}}\left\{(1/B)[A - v - bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]\right\}d\theta$$

ii) for $\tilde{\theta} \in (\theta^*, \overline{\theta}]$,

$$W^S(\theta) = (1/2B)[A - v - bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]\cdot[A - v - bk - (1-\alpha)\underline{\theta} - \alpha\theta]$$
$$-(1-\alpha)\int_{\underline{\theta}}^{\overline{\theta}}\left\{(1/B)[A - v - bk + (1-\alpha)\underline{\theta} - (2-\alpha)\theta]\right\}d\theta.$$

We then obtain:

$$\frac{\partial EW^H}{\partial\theta^*} = \int_{\underline{\theta}}^{\theta^*}\frac{\partial W^I(\theta,\theta^*)}{\partial\theta^*}\,dF(\theta) + W^I(\theta^*)f(\theta) - W^S(\theta^*)f(\theta)$$
$$= \frac{[2A - v - bk - w + 2(1-\alpha)\underline{\theta} - 2(2-\alpha)\theta^*](v + bk - w) - 2b^2k^2}{2B(\overline{\theta} - \underline{\theta})}.$$

Therefore expected social welfare under the hybrid regime is maximized when the regulator offers M a menu that contains the possibility of shutting down M's downstream sector if M's reported cost is higher than a critical value:

$$\theta^* = \frac{[2A - v - bk - w + 2(1-\alpha)\underline{\theta}](v + bk - w) - 2b^2k^2}{2(2-\alpha)(v + bk - w)}.$$

Further the assumption of $v + bk - w > 0$ guarantees the second order condition of the maximization problem: $\dfrac{\partial^2 EW^H}{\partial\theta^{*2}} = -(2-\alpha)(v + bk - w) < 0.$

References

Anton, J., and Yao, D. 1987. "Second Sourcing and Experience Curve: Price Competition in Defense Procurement," *The RAND Journal of Economics* 18: 57-76.

Armstrong, C. M., Cowan, S. G., and Vickers, J. S. 1994. *Regulatory Reform: Economic Analysis and British Experience*, Cambridge, MA: The MIT Press.

Armstrong, C. M. and Doyle, C. 1995. "Access Pricing, Entry and the Baumol-Willig Rule," Discussion Papers in Economics and Econometrics no. 9422, University of Southampton.

Auriol, E. and Laffont, J. 1992. "Regulation by Duopoly," *Journal of Economics and Management Strategy* 1: 507-533.

Baron, D. 1989. "Design of Regulatory Mechanisms and Institutions," in *Handbook of Industrial Organization, vol. II*, edited by R. Schmalensee and R. Willig, North-Holland, Amsterdam, 24: 1347-1447.

Baron, D. and Myerson, R. 1982. "Regulating a Monopolist with Unknown Costs," *Econometrica* 50:911-930.

Baumol, W. J., and Sidak, J. G. 1994. *Toward Competition in Local Telephony*, Cambridge, MA: The MIT Press.

Bower, Anthony G. 1993. "Procurement Policy and Contracting Efficiency," *International Economic Review* 34: 873-901.

Demski, J. S., Sappington, D. E. M., and Spiller, P. T. 1987. "Managing Supplier Switching," *The RAND Journal of Economics* 18: 77-97.

Laffont, J., and Tirole, J. 1986. "Using Cost Observations to Regulate Firms," *Journal of Political Economy* 94: 614-641.

Laffont, J., and Tirole, J. 1990. "The Regulation of Multiproduct Firms Part I: Theory," *Journal of Public Economics* 43: 1-36.

Laffont, J., and Tirole, J. 1990. "The Regulation of Multiproduct Firms part II: Applications to Competitive Environments and Policy Analysis," *Journal of Public Economics* 43: 37-66.

Laffont, J., and Tirole, J. 1993. *A Theory of Incentives in Procurement and Regulation*, Cambridge, MA: The MIT Press.

Laffont, J., and Tirole, J. 1994. "Access Pricing and Competition," *European Economic review* 38: 1673-1710.

Lewis, T. R. and Sappington, D. E. M. 1988 "Regulating a monopolist with unknown demand and cost functions," *The RAND Journal of Economics* 19: 438-457.

Lewis, T. R. and Sappington, D. E. M. 1988. "Regulating a Monopolist with Unknown Demand," *American Economic Review* 78: 986-998.

Lewis, T. R. and Sappington, D. E. M. 1989. "Countervailing Incentives in Agency Problems," *Journal of Economic Theory* 49: 294-313.

Lewis, T. R. and Sappington, D. E. M. 1997. "Access Pricing and with Unregulated Downstream Competition," Mimeo, University of Florida.

McGuire, T. G., and Riordan, M. H. 1995. "Incomplete Information and Optimal Market Structure: Public Purchases from Private Providers," *Journal of Public Economics* 56: 125-141.

Vickers, J. S. 1995. "Competition and Regulation in Vertically Related Markets," *Review of Economic Studies* 62: 1-17.

Willig, R. D.1979. "The Theory of Network Access Pricing," in *Issues in Public Utility Regulation*, edited by H.M. Trebing, Michigan State University Public Utilities Papers.