DESIGNING CARRIER OF LAST RESORT OBLIGATIONS

By

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ABSTRACT

Public utilities are generally subject to a carrier of last resort (COLR) obligation which requires that they stand by with capacity in place to serve consumers on demand. When the competitive fringe of suppliers is "relatively reliable", imposing a COLR constraint [asymmetrically] on the incumbent firm tends to lower the optimal price for output in the industry. Moreover, when the fringe is allowed to choose its reliability strategically, the optimal price is further reduced. A principal finding is that the competitive fringe has incentives to "over-capitalize" ("under-capitalize") in the provision of reliability when the COLR obligation is zero (one-hundred) percent. The need for a COLR may thus prove to be a self-fulfilling prophecy in equilibrium. These findings may explain competitive fringe strategy in the telecommunications industry.

I. Introduction.

The advent of competition in regulated industries, such as telephone, electric power and natural gas, has caused economists to study the effects of *asymmetric regulation* on social welfare.[1] This research has examined the effect of constraining the [regulated] incumbent firm to honor historical public utility obligations, while allowing competitive entry. These historical obligations generally take the form of broadly averaged service rates, extensive tariff review processes in formal regulatory proceedings and carrier of last resort (COLR) obligations. It is the COLR obligation that is the focus of the formal analysis here.

The COLR obligation dates back the Railway Act of 1920 which prohibited railroads from abandoning certain routes absent the issuance of a *certificate of convenience and necessity* from the Interstate Commerce Commission (ICC). The ICC was generally reluctant to issue such certificates if consumers were harmed by such abandonment, even when the continuation of service proved financially burdensome to the railroads.[2]

In the case of traditional public utility services, the COLR obligation essentially charges the incumbent firm with responsibility for standing by with facilities in place to serve consumers on demand, including customers of competitors. The historical origins of this obligation are significant because it is the asymmetry of this obligation that is the source of the market distortion. A public utility with a franchised right to serve a certificated geographic area maintains a responsibility to serve all

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[1]See for example Haring (1984) and Weisman (1989A).

[2]See Goldberg (1979) p. 150 and notes 18-20 and Keeler (1983) pp. 38-39.

consumers on demand. Yet, at least historically, there was a corresponding obligation on the part of consumers to be served by this public utility. As Victor Goldberg (1976) has argued, this form of *administrative contract* relied upon a form of reciprocity (symmetrical entitlements) which balanced the utilities' obligation to serve with the consumers' obligation to be served.[3] This balance evolved over time as a fundamental tenet of the regulatory compact. Regulators have been reluctant to relieve the incumbent of its COLR obligation in the face of competitive entry over concern that consumers could be deprived of access to essential services.[4]

Alfred Kahn (1971) first recognized that a non-discriminatory COLR obligation might well handicap the incumbent firm. The context was MCI's entry into the long distance telephone market in competition with AT&T. The exact citation is revealing.

> It is this problem that is the most troublesome aspect of the MCI case and others like it. If such ventures are economically feasible only on the assumption that when they break down or become congested subscribers may shift over to the Bell System for the duration of the emergency, they are indeed supplying an only partial service. If the common carrier is obliged to stand ready to serve and must carry the burden of excess capacity required to meet that obligation, it would seem that the average total costs would necessarily be higher than those of a private shipper or cream-skimming competitor who has no such obligation: the latter can construct capacity merely sufficient for operation at 100 percent load factors, with the expectation that it or its customers can turn to the common carriers in case of need.[5]

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[3] See Goldberg (1976, 1979) and Weisman (1989A).

[4] For a case study of this phenomenon, see Weisman (1989C).

[5] See Kahn (1971, p. 238).

Weisman (1989B, p. 353) makes a similar observation with regard to more recent competitive entry in carrier access markets.[6] An interesting question for analysis concerns whether an entrant will choose to strategically exploit the incumbent's COLR obligation by under-investing or over-investing in reliability.[7]

The COLR issue *per se* has received little attention in the formal economic literature. Weisman (1988) discusses the distortions caused by the utilities' COLR obligation and recommends *Default Capacity Tariffs* as a possible solution. Under this proposal, the subscriber purchases service under a two-part tariff. The first part of the tariff is a capacity charge that varies directly with the level of capacity purchased. The utility is responsible for capital outlays no greater than the collective demand for capacity across the universe of subscribers. The second part of the tariff is a usage charge. The subscriber's total usage is limited by the level of capacity purchased. Panzar and Sibley (1978) find that self-rationing, two-part tariffs of this type possess desirable efficiency properties.[8]

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[6]An alternative viewpoint is offered by a recent competitive entrant in the carrier access market. See Metropolitan Fiber Systems (1989, pp. 67-70). The carrier access market in the telephone industry refers generically to the local access component of both the originating and terminating ends of long distance calls. Entrants in this market also supply digital, point-to-point dedicated circuits within a local calling area. These competitors are sometimes referred to as competitive access providers (CAPs).

[7]It is a noteworthy contrast that early entrants in the long distance telephone market supplied relatively unreliable service, whereas recent entrants in the carrier access and local distribution market supply what is purported to be a relatively superior grade of service.

[8]See also Spulber (1990).

As a matter of positive economics, however, regulators have been reluctant to force consumers to bear the risk of self-rationing demand. Consequently, the set of instruments presumed available in the literature may be politically unacceptable in practice. Here, we intentionally restrict the set of viable policy instruments to correspond with current regulatory practice. This modeling convention facilitates a clear understanding of fringe competitor strategies while offering practical guidance on the design of efficient regulatory policies.

The primary objectives of this paper are to characterize the optimal COLR obligation and pricing rules in an environment where the incumbent firm faces a competitive fringe. We find that when the competitive fringe is "relatively reliable", imposing a COLR constraint [asymmetrically] on the incumbent firm tends to lower the optimal price. Moreover, when the fringe is allowed to choose its reliability strategically, the optimal price is further reduced. A principal finding is that the competitive fringe has incentives to "over-capitalize" ("under-capitalize") in the provision of reliability when the COLR obligation is zero (one-hundred) percent.[9] It follows that concerns about fringe reliability may be validated as self-fulfilling prophecies in equilibrium.

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[9]In general, we cannot discern whether the fringe is (over) under-supplying reliability merely by observing its reliability relative to the incumbent. The determination of the efficient level of reliability naturally turns on whether the fringe invests in reliability up to the point where the marginal benefits of increased reliability are equated with corresponding marginal costs. The inferior quality of service which plagued MCI in its start-up phase was, at least in part, due to regulatory and technological constraints which precluded efficient interconnection with the Bell System's local distribution network. MCI now makes claim of network reliability superior to that of AT&T.

With a low COLR requirement, the regulator responds to increased unreliability on the part of the fringe by lowering price so as to retain a larger amount of output with the (reliable) incumbent. The competitive fringe can thus increase price by increasing reliability, *ceteris paribus*. With a high COLR requirement, an increase in reliability will reduce "default output" since the fringe serves a larger share of traffic diverted from the incumbent. The effective price elasticity for the incumbent therefore increases with fringe reliability which implies that the optimal price decreases with fringe reliability.

The analysis proceeds as follows. The elements of the formal model are developed in Section II. The benchmark results are presented in Section III. In Section IV, we present our principal findings. The conclusions are drawn in Section V.

II. Elements of the Model.

The regulator wishes to maximize a weighted average of consumer surplus across two distinct markets. These markets might represent the local service and long distance (or carrier access) markets in the telephone industry. Let $\beta \in [0,1]$ and $1-\beta$ denote the regulator's weight on consumer surplus in markets 1 and 2, respectively. These weights enable us to simulate a regulator's interest in certain social policy objectives (i.e., universally available telephone service) that transcend pure efficiency considerations.

There are three "players" in the game to be analyzed, the regulator, the incumbent [regulated] firm and the fringe competitor. The incumbent is a franchised monopolist in market 1 in the sense that competition is strictly prohibited. In market 2, the incumbent faces an exogenous fringe competitor. The term "exogenous fringe" means that the regulator can exert only indirect control over the fringe by setting prices or quantities, but retains no other instruments to control the fringe directly. This set-up again reflects the institutional structure of the telecommunications industry, wherein both technological advance and externalities in the design of regulatory policies frequently limit the ability of a regulator to directly control the degree of competitive entry.[10]

The incumbent's profits in market 1 are denoted by $\pi^1 = [p_1 - v - k]q_1$, where $p_1 = p_1(q_1)$ is the market price, $p_1(q_1)$ is the inverse demand function and q_1 is market (and firm) output. Variable and capital costs per unit of output are denoted by v and k, respectively.

The incumbent's profits in market 2 are denoted by $\pi^2 = \Big[[p_2 - v - k][1-e] + \gamma e[\phi(p_2 - v) - k]\Big]q_2$, where $p_2 = p_2(q_2)$ is the market price, $p_2(q_2)$ is the inverse demand function and q_2 is market output. Let $e(p_2) \in [0,1]$ denote the fringe share of market output with $e'(p_2) > 0$. The incumbent's COLR obligation is denoted by $\gamma \in [0,1]$ so that γe represents the share of fringe output that is backed-up by the incumbent as the COLR. Let $\phi \in [0,1]$ denote the probability that the fringe (network) operation will fail. The variable cost per unit of output for the fringe is denoted by $\tilde{v}$; whereas fringe fixed

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[10] An example may prove instructive. The Federal Communications Commission (FCC) regulates the electromagnetic spectrum in the United States. In the *Above 890 Decision* (1959), the FCC authorized the construction of private microwave networks in frequencies above 890 megacycles. This decision effectively sanctioned competition in both interstate and intrastate telecommunications markets, but the ratemaking authority for intrastate telecommunications is reserved to the state public service commissions (PSCs). The PSCs could thus indirectly affect the degree of competitive entry through telephone company rate structures, but were otherwise powerless to affect the degree of entry directly. See Weisman (1989B, pp. 341-350).

(capital) costs are denoted by $F(\phi)$, with $F'(\phi) < 0$, $F''(\phi) > 0$, $F(0) = \infty$ and $F(1) = 0$. Consumer welfare is given by $W^c(q_1,q_2) = \beta S^1(q_1) + (1-\beta)S^2(q_2)$, where $S^i(q_i)$ denotes consumer surplus in market i, i = 1,2 and

$$(0)\ S^i(q_i) = \int_0^{q_i} p_i(z_i)dz_i - p_i(q_i)q_i.$$

Finally, we define the own price elasticity of demand in market i by $\varepsilon_i = -(\partial q_i/\partial p_i)(p_i/q_i)$, i = 1,2, and the competitive fringe elasticity by $\varepsilon_c = e'(p_2)(p_2/e)$. We assume throughout the analysis that the fringe output is increasing in p_2, which implies that $\varepsilon_c > \varepsilon_2$.

Lemma 1. If the output of the competitive fringe is strictly increasing in p_2, then $\varepsilon_c > \varepsilon_2$.

Proof: Let the fringe output be given by

$$(1)\ \tilde{q}_2 = e(p_2)q_2.$$

$$(2)\ d\tilde{q}_2/dp_2 = e'(p_2)q_2 + e(dq_2/dp_2).$$

Dividing (2) through by e and q_2 and multiplying through by p_2 yields

$$(3)\ d\tilde{q}_2/dp_2 = e'(p_2)(p_2/e) + (dq_2/dp_2)(p_2/q_2),\ \text{so}$$

$$(3')\ d\tilde{q}_2/dp_2 = \varepsilon_c - \varepsilon_2 > 0$$

when $\varepsilon_c > \varepsilon_2$. ■

The regulator's problem [RP-1] is to

$$(4)\quad \underset{\{q_1,q_2,\phi\}}{\text{Maximize}}\quad W^c(q_1,q_2) = \beta\left[\int_0^{q_1} p_1(z_1)dz_1 - p_1q_1\right] + [1-\beta][1-\phi]\left[\int_0^{q_2} p_2(z_2)dz_2 - p_2q_2\right]$$

$$+\ [1-\beta][\phi]\left[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2q_2^*\right].$$

subject to:

$$(5)\quad \pi^1 + \pi^2 \geq 0,$$

$$(6)\quad \phi \in \underset{\phi'}{\text{argmax}}\left[[1-\phi'][e(p_2)][p_2(q_2)-\tilde{v}][q_2] - F(\phi')\right],$$

$$(7)\quad \phi \in [0,1],$$

$$(8)\quad \gamma \in [0,1];\ \text{and}$$

$$(9)\quad q_i \geq 0,\ i = 1,2,$$

where $q_2^* = q_2[1 - (1-\gamma)e]$.

In [RP-1], equation (5) is the individual rationality (IR) or participation constraint for the incumbent. (6) defines the fringe's profit-maximizing choice of reliability. (7) defines the feasible bounds for the fringe choice of reliability. (8) defines the feasibility bounds for the incumbent's COLR obligation which is treated exogenously in this problem. (9) rules out negative output quantities. Note that q_2^* represents market 2 output when the fringe operation fails since $(1-\gamma)e$ is the share of fringe output not backed-up by the incumbent as the COLR. Figure 1 illustrates consumer surplus in market 2.

III. Benchmark Solutions.

We begin by establishing the benchmark "first-best" case. The regulator's problem [RP-2] is identical to [RP-1] with the exception that the incentive compatibility constraint (6) representing the fringe choice of reliability is omitted and the COLR obligation (γ) is treated as an endogenous parameter. In this problem, the regulator has perfect commitment ability to specify q_1, q_2, γ and ϕ. The Lagrangian for [RP-2] is given by

$$(10)\quad \mathcal{L} = \beta\left[\int_0^{q_1} p_1(z_1)dz_1 - p_1q_1\right] + [1-\beta][1-\phi]\left[\int_0^{q_2} p_2(z_2)dz_2 - p_2q_2\right]$$
$$+ [1-\beta][\phi]\left[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2q_2^*\right] + \lambda\Big[q_1(p_1-v-k) + q_2(p_2-v-k)(1-e)$$
$$+ \gamma e q_2[\phi(p_2-v)-k]\Big] + \delta[1-\phi] + \xi[1-\gamma],$$

where λ, δ and ξ are the Lagrange multipliers associated with (5), (7) and (8), respectively.

In the first proposition, we show how the regulator will optimally set the incumbent's COLR obligation (γ) and the unreliability of the competitive fringe (ϕ).

Proposition 1. At the solution to [RP-2], $\phi = 1$ iff $\gamma = 1$ and $\phi = 0$ iff $\gamma = 0$.

Proof: Necessary first-order conditions for ϕ and γ include

$$(11)\quad \phi\text{: } [1-\beta][S(q_2^*)-S(q_2)] + \lambda q_2\gamma e(p_2-v) - \delta \le 0\ ;\ \phi[\mathcal{L}_\phi] = 0,$$

and

$$(12)\quad \gamma\text{: } [1-\beta][\phi][p_2(q_2^*)-p_2(q_2)][eq_2] + \lambda e q_2[\phi(p_2-v)-k] - \xi \le 0;\ \gamma[\mathcal{L}_\gamma] = 0.$$

From (11),

(i) When $\gamma = 1$, $S^2(q_2^*) = S^2(q_2)$, $\delta > 0$ and $\phi = 1$.

(ii) When $\gamma = 0$, $S^2(q_2^*) < S^2(q_2)$, $\mathcal{L}_\phi < 0$ and $\phi = 0$.

From (12),

(iii) When $\phi = 0$, $p_2(q_2^*) = p_2(q_2)$, $\mathcal{L}_\gamma < 0$ and $\gamma = 0$.

(iv) When $\phi = 1$, $p_2(q_2^*) > p_2(q_2)$, $\xi > 0$ and $\gamma = 1$. ∎

If one-hundred percent back-up is in place ($\gamma = 1$), the incumbent serves as COLR for all of the fringe output, and it is optimal for the regulator to choose a perfectly unreliable fringe. If $\phi < 1$, inefficient duplication of facilities would result. Conversely, if the fringe network is perfectly reliable ($\phi = 0$), then it is optimal to relieve the incumbent of its COLR obligation and set $\gamma = 0$, since any value of $\gamma > 0$ results in the deployment of capital that will never be utilized.

Now consider optimal pricing rules for q_1 and q_2 assuming $q_i > 0$, $i = 1,2$.

(13) $(p_1-v-k)/p_1 = [\lambda - \beta]/\lambda\varepsilon_1$,

and

(14) $$[1-\beta]\Big[1 + \phi\Big[[\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau + (\gamma-1)e\Big]\Big] + \lambda\Big[[p_2-v-k][(1-e)\varepsilon_2+ e\varepsilon_c]/p_2 + \gamma e[\phi(p_2-v)-k][\varepsilon_2-\varepsilon_c]/p_2 - (1-e) - \gamma\phi e\Big] = 0,$$

where $\tau = [p_2(q_2^*) - p_2(q_2)]/p_2(q_2)$. Equation (14) implicitly defines the optimal pricing rule for market 2. Observe now that when there is no competitive fringe ($e = 0$), (14) reduces to

(15) $(p_2-v-k)/p_2 = [\lambda -(1-\beta)]/\lambda\varepsilon_2$.

Dividing (15) into (13) and assuming the regulator weights consumer surplus equally in the two markets so that $\beta = 1/2$, we obtain

$$(16) \quad \frac{(p_1-v-k)/p_1}{(p_2-v-k)/p_2} = \frac{\varepsilon_2}{\varepsilon_1},$$

which is the standard Ramsey pricing rule. If we now set $\gamma = \phi = 0$, so that we have a perfectly reliable fringe with no COLR obligation, the optimal pricing rule in (14) reduces to

(17) $(p_2^e-v-k)/p_2^e = [\lambda(1-e)-(1-\beta)]/\lambda[(1-e)\varepsilon_2+e\varepsilon_c]$.

Since $\varepsilon_c > \varepsilon_2$, the optimal price is lower with a competitive fringe than in the standard Ramsey pricing rule, or $p_2^e < p_2$. The presence of a competitive fringe tends to lower the optimal price in market 2. Stated differently, the price for market 1 must now carry a heavier burden of satisfying the incumbent's revenue requirement, or participation constraint.[11] This occurs because the fringe raises the effective price elasticity in market 2.

Let p_2^c define the optimal price when the incumbent maintains a COLR obligation ($\gamma > 0$). In the next proposition, we characterize the relationship between p_2^c and p_2^e, where the subscripts refer to COLR and competitive entry, respectively.

Proposition 2. If $\gamma \geq \max[1/2, (2\varepsilon_2-\varepsilon_c)/(\varepsilon_2-\varepsilon_c)]$, there exists a $\tilde{\phi}$ such that $p_2^c < p_2^e \; \forall\phi < \tilde{\phi}$ and $p_2^c > p_2^e \; \forall\phi > \tilde{\phi}$.

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[11]This type of argument was a familiar refrain on the part of AT&T when fringe competitors (e.g., MCI and U.S. Sprint) first appeared in the long distance telephone market. See Wenders (1987) chapters 8 and 9.

Proof: The optimal pricing rule in (14) can be written as

$$(18)\quad (p_2^c-v-k)/p_2^c = \Big[\lambda[(1-e)+\phi\gamma e]/\lambda-[1-\beta]\Big[1+\phi[[\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau+(\gamma-1)e]]\Big]/\lambda$$

$$-\gamma e[\phi(p_2-v)-k]/p_2\Big]/[(1-e)\varepsilon_2 + e\varepsilon_c].$$

(i) For $\phi = 0$ (18) reduces to

$$(19)\quad (p_2^c-v-k)/p_2^c = \Big[[\lambda(1-e) -(1-\beta)]/\lambda +\gamma ek(\varepsilon_2- \varepsilon_c)/p_2\Big]/[(1-e)\varepsilon_2 + e\varepsilon_c] <$$

$$[\lambda(1-e) -(1-\beta)]/\lambda[(1-e)\varepsilon_2 + e\varepsilon_c] = (p_2^e-v-k)/p_2^e.$$

(ii) For $\phi = 1$, (18) reduces to

$$(20)\quad (p_2^c-v-k)/p_2^c = \Big[\lambda[(1-e)+\gamma e]-[1-\beta][1+[\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau+(\gamma-1)e]\Big]/\lambda\hat{\varepsilon}$$

$$< [\lambda(1-e) -(1-\beta)]/\lambda[(1-e)\varepsilon_2 + e\varepsilon_c] = (p_2^e-v-k)/p_2^e,$$

where $\hat{\varepsilon} = [(1-e)\varepsilon_2 + e\varepsilon_c+ \gamma e(\varepsilon_2-\varepsilon_c)]$, provided that

$$(21)\quad \lambda\gamma e > [1-\beta][1+[\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau + (\gamma-1)e],$$

or

$$(22)\quad e > [\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau,$$

since $\lambda \geq \max[\beta,(1-\beta)]$. Now recognize that

$$(23)\quad e > 2\varepsilon_2\tau > [\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau, \text{ if}$$

$$(24)\quad \varepsilon_2 > (\varepsilon_2-\varepsilon_c)(\gamma-1) >(\varepsilon_2-\varepsilon_c)(\gamma-1)e.$$

Solving for γ in (24) yields

$$(25)\quad \gamma > (2\varepsilon_2-\varepsilon_c)/(\varepsilon_2-\varepsilon_c),$$

which is one of the conditions of the proposition. Observe from (23) that

(26) $\varepsilon_2\tau = [q_2 - q_2[1+(\gamma-1)e]]/q_2 = 1 - [1+(\gamma-1)e] = (1-\gamma)e.$

Hence, upon substitution of (26) into (23)

(27) $e > 2(1-\gamma)e.$

Canceling terms and solving for γ in (27) yields

(28) $\gamma > 1/2,$

which is another condition of the proposition. Equations (25) and (28) jointly require that $\gamma \geq \max[1/2,\ (2\varepsilon_2-\varepsilon_c)/(\varepsilon_2-\varepsilon_c)]$, which is the statement in the proposition. Since the optimal pricing rule is assumed to be differentiable for $\phi \in [0,1]$, it is also continuous for $\phi \in [0,1]$ and the Intermediate Value Theorem applies. Hence, there exists a $\tilde{\phi} \in [0,1]$ such that $p_2^c = p_2^e$ for $\phi = \tilde{\phi}$. The result follows. ∎

For low values of ϕ, the firm realizes a net loss on its "default operations" since it incurs capital costs but little or no offsetting revenues. Hence, it is optimal to set $p_2^c < p_2^e$ to minimize the fringe output for which the incumbent serves as the [unremunerative] COLR. For high values of ϕ, it is as if there is no fringe at all (Note: for $\phi = 1$, there is essentially no fringe) provided γ is sufficiently large to serve the default output and it is optimal to set $p_2^c > p_2^e$.

The next proposition characterizes the optimal price in market 2 when the fringe is unreliable ($\phi > 0$) and there is no COLR obligation ($\gamma = 0$).

Proposition 3. $p_2^c < p_2^e$ at $\gamma = 0\ \forall\phi > 0$.

Proof: With $\gamma = 0$, the optimal price term in (14) can be written as

$$(29)\quad (p_2^c-v-k)/p_2^c \;=\; \left[\lambda[(1-e)]/\lambda-[1-\beta]\left[1+\phi[[\varepsilon_2+(\varepsilon_c-\varepsilon_2)e]\tau-e]\right]\right]/\lambda[(1-e)\varepsilon_2+e\varepsilon_c]$$

$$< [\lambda(1-e)\ -(1-\beta)]/\lambda[(1-e)\varepsilon_2 + e\varepsilon_c] = (p_2^e-v-k)/p_2^e$$

$\forall\phi > 0$, provided that

$$(30)\ [\varepsilon_2 + (\varepsilon_c-\varepsilon_2)e]\tau > e,$$

$$(31)\ [(1-e)\varepsilon_2 + e\varepsilon_c]\tau > e.$$

Let $\varepsilon_c = z\varepsilon_2$, where $z > 1$ since $\varepsilon_c > \varepsilon_2$. Substitution into (31) yields

$$(32)\ [(1-e)\varepsilon_2 + ze\varepsilon_2]\tau > e.$$

Consolidating terms yields

$$(33)\ [1+e(z-1)]\varepsilon_2\tau > e.$$

Observe that $\varepsilon_2\tau = (1-\gamma)e$. Substitution into (33) yields

$$(34)\ [1+e(z-1)][(1-\gamma)e] > e.$$

Imposing the $\gamma = 0$ condition of the proposition yields

$$(35)\ [1+e(z-1)]e > e,$$

$$(36)\ 1+e(z-1) > 1$$

$$(37)\ e(z-1) > 0,$$

which is satisfied $\forall e > 0$ since $z > 1$. ∎

If $\phi > 0$, there is a non-zero probability that demand lost to the fringe will not be served since $\gamma = 0$. Hence, there is an expected loss of consumer surplus on output supplied by the competitive fringe. The regulator desires to minimize this expected loss in consumer surplus, so he sets a relatively low price in order to retain a larger share of total output with the incumbent.

In fact, the higher the probability of fringe failure, the lower the optimal price set by the regulator. This result is summarized in proposition 4.

Corollary to Proposition 3. $p_2^c < p_2^e$ at $\gamma = 1$ and $\phi = 0$.

Proof: The proof is similar in technique to that for Proposition 3 and is therefore omitted. ■

With a one-hundred percent COLR obligation and a zero probability of fringe failure, the optimal price is lowered to reduce unremunerative capital costs. The lower price ensures that a larger share of output remains with the incumbent since $e'(p_2) > 0$.

We now examine the general comparative statics for [RP-2], treating ϕ and γ as exogenous parameters. Let $\bar{H}$ denote the bordered Hessian for [RP-2] and $|\bar{H}|$ its corresponding determinant. Necessary second-order conditions which are assumed to hold require that $|\bar{H}| > 0$ at a maximum. We begin by identifying the sign pattern for $\bar{H}$ and its corresponding parameter vector for the limiting values of ϕ and γ.

Total differentiation of the necessary first-order conditions for [RP-2] with respect to ϕ yields the following sign pattern for $\bar{H}$ and the corresponding parameter vector.

$$(38)\quad \bar{H}\Big|_{\gamma=1} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 0 \\ + \\ - \end{bmatrix}.$$

$$(39) \quad \bar{H}\Big|_{\gamma=0} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 0 \\ - \\ 0 \end{bmatrix}.$$

Application of Cramer's rule yields standard comparative static results which we formalize in the following proposition.

Proposition 4. At the solution to [RP-2],

(i) If $\gamma = 1$, $dp_1/d\phi < 0$ and $dp_2/d\phi > 0$ for ε_1 "small".

(ii) If $\gamma = 0$, $dp_1/d\phi > 0$ and $dp_2/d\phi < 0$.

An increase in the rate of fringe failure with $\gamma = 1$ implies an increase in default output revenues with which to offset COLR capital costs. Since $\lambda > 0$ at the solution to [RP-2], the increase in revenues allows p_1 to fall. Hence, the more unreliable the competitive fringe, the lower the price in market 1.

At $\gamma = 1$, p_2 decreases with the price elasticity of demand in market 2 for ε_1 sufficiently small. The more reliable the fringe, the higher the effective price elasticity for the incumbent since a smaller share of output diverted to the fringe returns to the incumbent in the form of "default output".

With no COLR obligation ($\gamma = 0$), an increase in the unreliability of the fringe will cause the regulator to reduce the price for p_2 in order to retain a greater amount of output with the incumbent (see Proposition 3). To ensure the incumbent firm remains viable, with a binding IR constraint ($\lambda > 0$), a reduction in p_2 requires an increase in p_1.

Total differentiation of the necessary first-order conditions for [RP-2] with respect to γ yields the following sign pattern for $\bar{H}$ and the corresponding parameter vector.

$$(40)\ \bar{H}\big|_{\phi=1} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 0 \\ + \\ - \end{bmatrix}.$$

$$(41)\ \bar{H}\big|_{\phi=0} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 0 \\ - \\ + \end{bmatrix}.$$

Application of Cramer's rule again yields a set of standard comparative static results which we formalize in the following proposition.

Proposition 5. At the solution to [RP-2],

(i) At $\phi = 1$, $dp_1/d\gamma < 0$.

(ii) At $\phi = 0$, $dp_1/d\gamma > 0$.

With a one-hundred percent default rate ($\phi = 1$), deploying capital costs to serve as the COLR is financially remunerative for the firm since p_2 is optimally set above marginal cost and p_1 falls. The effect on p_2 is ambiguous. An increase in p_2 results in output moving to the fringe (independent of whether it is ultimately served) which may prove to be financially unremunerative for the incumbent. This occurs because raising p_2 may divert more traffic to the fringe than the incumbent can serve on a default basis for any given level of γ.

With a perfectly reliable fringe ($\phi = 0$), raising γ increases the level of financially unremunerative capital costs which are financed by raising p_1. The effect on p_2 is again ambiguous. Even though costs rise with an increase in γ, the presence of the fringe renders it uncertain as to whether p_2 will be increased to finance these additional capital costs.

IV. Principal Findings.

We now examine the properties of the general model [RP-1]. In this modeling framework, the competitive fringe chooses its optimal level of reliability. The regulator is the Stackelberg leader, choosing q_1, q_2 and γ. The competitive fringe is the Stackelberg follower, choosing ϕ. Recognize that the timing in [RP-1] is such that the regulator is able to affect the fringe reliability choice (ϕ) only indirectly, as it is assumed that the regulator has [perfect] knowledge of the fringe reaction function. In subsequent analysis, [RP-3], we reverse the timing and allow the fringe to be the Stackelberg leader.

We begin with analysis of the reliability choice of the fringe which appears as an incentive compatibility constraint (6) in [RP-1]. This constraint is expressed as follows.

$$(42)\quad \phi \in \underset{\phi'}{\operatorname{argmax}}\left[[1-\phi'][e(p_2)][p_2(q_2)-\tilde{v}][q_2] - F(\phi')\right].$$

For an interior solution, (42) requires

$$(43)\quad -eq_2(p_2 - \tilde{v}) - F'(\phi) = 0.$$

If $0 < (p_2 - \tilde{v}) < \infty$, we obtain an interior solution for ϕ since $F(0) = \infty$. Sufficient second-order conditions (concavity) for a unique maximum (ϕ^*) requires that

$$(44)\quad -F''(\phi) < 0,$$

which is satisfied since $F''(\phi) > 0$. (43) can be viewed as the competitive fringe reaction function for ϕ conditioned on the regulator's choice of p_2

or q_2. Hence, for the regulator's choice of p_2 or q_2, the reaction function yields a unique ϕ^*.

Differentiating the reaction function in (43) implicitly with respect to p_2, we obtain

(45) $-e'q_2(p_2 - \tilde{v}) - e(\partial q_2/\partial p_2)(p_2 - \tilde{v}) - eq_2 - F''(\phi)(d\phi/dp_2) = 0.$

Rearranging terms and appealing to the definition of ε_2 and ε_c, we obtain

(46) $-\varepsilon_c(p_2 - \tilde{v})/p_2 + \varepsilon_2(p_2 - \tilde{v})/p_2 - 1 - F''(\phi)/eq_2(d\phi/dp_2) = 0.$

Rearranging terms and solving for $d\phi/dp_2$ yields

(47) $d\phi^*/dp_2 = [eq_2/F''(\phi)]\Big[[(p_2 - \tilde{v})(\varepsilon_2 - \varepsilon_c)]/p_2 - 1\Big] < 0,$

The inequality in (47) holds because $\varepsilon_c > \varepsilon_2$. Hence, the higher the price (p_2) set by the regulator, the more reliable the competitive fringe operation. When p_2 rises, the fringe can serve a larger share of traffic at a higher price. It thus has incentives to increase reliability with a higher p_2. Note also that $d\phi^*/dq_2 > 0$ since $p_2 = p_2(q_2)$ and $\partial p_2/\partial q_2 < 0$.

The Lagrangian for [RP-1] is given by

$$(48)\ \mathcal{L} = \beta\left[\int_0^{q_1} p_1(z_1)dz_1 - p_1q_1\right] + [1-\beta][1-\phi]\left[\int_0^{q_2} p_2(z_2)dz_2 - p_2q_2\right]$$

$$+ [1-\beta][\phi]\left[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2q_2^*\right] + \lambda\Big[q_1(p_1-v-k) + q_2(p_2-v-k)(1-e)$$

$$+ \gamma eq_2[\phi(p_2-v)-k]\Big] + \rho[-eq_2(p_2-\tilde{v})-F'(\phi)] + \delta[1-\phi] + \xi[1-\gamma].$$

Necessary first-order conditions for q_2, assuming an interior solution and rearranging terms yields

$$(49)\ [1-\beta]\Big[1 + \varepsilon_2(\partial\phi/\partial q_2)[S(q_2^*) - S(q_2)] + \phi[\varepsilon_2 + (\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau + (\gamma-1)e\Big] +$$

$$\lambda\Big[[p_2-v-k][(1-e)\varepsilon_2 + e\varepsilon_c]/p_2 + \gamma e[\phi(p_2-v)-k][\varepsilon_2-\varepsilon_c]/p_2 - (1-e) - \phi\gamma e +$$

$$\gamma\varepsilon_2 q_2 e(\partial\phi/\partial q_2)(p_2-v)/p_2\Big] + \rho\Big[e(p_2-\tilde{v})(\varepsilon_2-\varepsilon_c)/p_2 + e - F''(\phi)(\partial\phi/\partial q_2)\varepsilon_2/p_2\Big]$$

$$= 0.$$

Equation (49) implicitly defines the optimal pricing rule for p_2 in [RP-1]. Denote this optimal price by $\tilde{p}_2^c$. We define the following terms

$$(50)\ b_1 = \gamma\varepsilon_2 q_2 e(p_2-v)/p_2 > 0, \text{ and}$$

$$(51)\ b_2 = \rho\Big[e(p_2-\tilde{v})(\varepsilon_2-\varepsilon_c)/p_2 + e - F''(\phi)(\partial\phi/\partial q_2)\varepsilon_2/p_2\Big] > 0.$$

In the next proposition, we characterize the relationship between $\tilde{p}_2^c$ and p_2^c. Since the regulator cannot specify ϕ directly in [RP-1], he indirectly influences ϕ through his choice of $\tilde{p}_2^c$.

Proposition 6. At the solution to [RP-1], $\tilde{p}_2^c < p_2^c$ when $\gamma = 1$.

Proof: With $\gamma = 1$, $S^2(q_2^*) = S^2(q_2)$. The optimal pricing rule in (49) can thus be written as

$$(52)\ (\tilde{p}_2^c - v - k)/\tilde{p}_2^c = \Big[\lambda[(1-e) + \phi\gamma e - b_1 - (b_2/\lambda)] - [1-\beta]\Big[1 + \phi(\gamma-1)e +$$

$$\phi[\varepsilon_2 + (\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau\Big] - \gamma e\lambda[\phi(p_2-v) - k][\varepsilon_2-\varepsilon_c]/p_2\Big]/\lambda[(1-e)\varepsilon_2 + e\varepsilon_c]$$

$$< \Big[\lambda[(1-e)+\phi\gamma e]/\lambda - [1-\beta]\Big[1+\phi[[\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau + (\gamma-1)e]\Big]\Big]/\lambda$$

$$-\gamma e[\phi(p_2-v)-k]/p_2\Big]/[(1-e)\varepsilon_2 + e\varepsilon_c] = (p_2^c - v - k)/p_2^c,$$

since $b_1 > 0$ and $b_2 > 0$. ■

With 100 percent back-up ($\gamma = 1$), the regulator wants an entirely unreliable fringe ($\phi = 1$) in order to avoid inefficient duplication of facilities [unremunerative capital costs]. Yet in [RP-1], the regulator cannot control ϕ directly, only indirectly through p_2. From the competitive fringe reaction function, $d\phi/dq_2 > 0$. Hence, in order to induce the fringe to choose a lower level of reliability (higher ϕ), the regulator lowers p_2 relative to [RP-1]. It follows that $\tilde{p}_2^c < p_2^c$.

The optimal price is lower when the fringe chooses its own level of reliability in order to maximize profits under a one-hundred percent COLR obligation. The effect of this lower price is not only to ensure that a larger share of traffic remains with the incumbent since $e'(p_2) > 0$, but also to induce more default output since $d\phi/dp_2 < 0$.

In [RP-1], we assumed that the regulator is the Stackelberg leader and the competitive fringe is the Stackelberg follower. In [RP-3], we reverse the timing to explore the implications of allowing the competitive fringe to lead with its choice of reliability (ϕ).[12]

In [RP-3], the regulator's problem is to

$$(53)\quad \underset{\{q_1,q_2,\phi\}}{\text{Maximize}} \quad \Big[[1-\phi'][e(p_2)][p_2(q_2)-\tilde{v}][q_2] - F(\phi')\Big]$$

subject to:

[12]The timing sequence in [RP-3] is modeled after the FCC's practice of allowing incumbent firm's to respond to new service offerings of competitors. The set of rules that the FCC enforces with regard to the incumbent's ability to respond is referred to formally as the *Competitive Necessity Test.*

$$(54)\quad q_1, q_2 \in \underset{q_1', q_2'}{\operatorname{argmax}}\ \beta \left[\int_0^{q_1'} p_1(z_1)dz_1 - p_1 q_1' \right] + [1-\beta][1-\phi] \left[\int_0^{q_2'} p_2(z_2)dz_2 - p_2 q_2' \right]$$

$$+ [1-\beta][\phi] \left[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2 q_2^* \right],$$

(55) subject to: $\pi^1 + \pi^2 \geq 0$,

(56) $\phi \in [0,1]$,

(57) $\gamma = \bar{\gamma}$; and

(58) $q_i \geq 0,\ i = 1,2$,

where $q_2^* = q_2[1 - (1-\gamma)e]$.

With the exception of the timing reversal, the structure of [RP-3] is quite similar to [RP-1]. One exception is equation (57) which specifies a constant COLR obligation for the incumbent firm. As a practical matter, the COLR obligation is not a topic for standard tariff review. In fact, in a number of state jurisdictions, the COLR obligation is a provision of state statute and thus not amenable to review and modification by public utility regulators. Given that one of our primary objectives here is to explain competitive fringe strategy in response to existing regulatory institutions, this modeling convention appears within reason.

We begin our analysis of [RP-3] by examining the objective function of the competitive fringe. Let π^f denote the profit function of the competitive fringe, where

$$(59)\quad \pi^f = \Big[[1-\phi'][e(p_2)][p_2(q_2) - \tilde{v}][q_2] - F(\phi') \Big].$$

Differentiating (59) with respect to ϕ, assuming an interior solution, we obtain

$$(60) \quad \partial\pi^f/d\phi = -e[p_2(q_2) - \tilde{v}] - F'(\phi) = 0.$$

The first term to right of the equals sign in (60) can be interpreted as the marginal benefit of increased unreliability; the second term to the right of the equals sign can be interpreted as the marginal cost of increased unreliability. Observe now that if

$$(61) \quad -e[p_2(q_2) - \tilde{v}] - F'(\phi) > (<)\ 0,$$

at the solution to [RP-3], "over-capitalization" ("under-capitalization") in the provision of reliability occurs relative to the benchmark case. To see this, recall that $F''(\phi) > 0$. Hence, if (61) is strictly positive (negative), ϕ is too low (too high) in comparison with the benchmark case. Because a higher degree of reliability is associated with a larger capital expenditure, $F'(\phi) < 0$, it is instructive to refer to this as an "over-capitalization" ("under-capitalization") distortion.

In the next proposition, we characterize sufficient conditions for the "over-capitalization" ("under-capitalization") distortion.

Proposition 7. The competitive fringe "over-capitalizes" in the provision of reliability at the solution to [RP-3] if $\gamma = 0$ and "under-capitalizes" if $\gamma = 1$ and ε_1 is "small".

Proof: Differentiating (59) with respect to ϕ, assuming an interior solution, and rearranging terms, we obtain

$$(62) \quad -e[p_2(q_2) - \tilde{v}] - F'(\phi) = -\ [1-\phi'][e'(\partial p_2/\partial q_2)(\partial q_2/\partial\phi)][p_2 - \tilde{v}]q_2$$

$$- [1-\phi'][e][(\partial p_2/\partial q_2)(\partial q_2/\partial\phi)]q_2 - [1-\phi'][e][p_2 - \tilde{v}][\partial p_2/\partial q_2].$$

By Proposition 4 part (ii), $\partial q_2/\partial\phi > 0$ at $\gamma = 0$. Hence for $\gamma = 0$, the expression to the left of the equals sign in the first line of (62) is strictly positive when

$$(63)\ -[1-\phi'][e][(\partial p_2/\partial q_2)(\partial q_2/\partial\phi)]q_2-[1-\phi'][e][p_2 - \tilde{v}][\partial p_2/\partial q_2] > 0.$$

After canceling terms and rearranging, we obtain

$$(64)\ -(\partial p_2/\partial q_2)q_2 - [p_2 - \tilde{v}] > 0, \text{ or}$$

$$(65)\ 1 - \varepsilon_2[p_2 - \tilde{v}]/p_2 > 0,$$

which is satisfied for $\varepsilon_2 < 1$ (inelastic demand). The second part of the proof follows from Proposition 4 part (i). ■

When $\gamma = 0$, an increase in reliability allows p_2 to rise as the regulator is less concerned about retaining output with the incumbent since there is a reduced probability of a fringe failure. The fringe views this increase in price as a *de facto* subsidy to investment in reliability which leads to the "over-capitalization" distortion.

When $\gamma = 1$, an increase in reliability decreases the [expected] level of "default output" for the incumbent since the probability of a fringe failure is reduced.[13] The effective price elasticity for the incumbent in market 2 increases with fringe reliability. The optimal price in market 2

[13]It is conceivable that the fringe may increase reliability so as to strand the incumbent's plant and thereby "raise its rivals' costs" along the lines suggested by Salop and Scheffman (1983). This is advantageous for the fringe, however, only when the incumbent finances the revenue deficiency by raising the price in market 2. Yet, raising the price in market 2 will not only divert more traffic to the fringe, but it will also induce the fringe to increase reliability resulting in an even larger revenue deficiency for the incumbent.

is thus reduced to reflect this higher price elasticity.[14] The fringe views this decrease in price as a "tax" on investment in reliability which leads to the "under-capitalization" distortion.

Proposition 7 thus supports Professor Kahn's (1971) original hypothesis that fringe competitors may tend to under-invest in reliability. He argues that consumers may be reluctant to patronize the competitive fringe unless the incumbent serves as the COLR due to concerns about service reliability.[15] We find that when there is a one-hundred percent COLR obligation, the fringe has incentives to under-invest in reliability. Conversely, for COLR obligations close to zero, the fringe has incentives to over-invest in reliability. These findings suggest that consumer concerns about fringe reliability may be validated as self-fulfilling prophecies in equilibrium!

The implications of Proposition 7 for competitor strategy in the telecommunications industry raise interesting questions for further research. For example, MCI and U.S. Sprint now compete with AT&T amid claims of superior reliability. It would be interesting to examine whether these competitors have "over-capitalized" in the provision of reliability, and whether such "over-capitalization" can be explained by a relaxation of AT&T's COLR obligation.

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[14]The price elasticity of demand for basic local telephone service is very small, on the order of 0.10 or less in absolute value. See Taylor (1993). This corresponds to the condition in the Proposition that ε_1 be "small".

[15]This suggests that $e = e(p_2,\phi,\gamma)$, with $e_1 > 0$, $e_2 < 0$ and $e_3 > 0$, where the subscripts denote partial derivatives. Kahn suggests that concerns about service reliability are alleviated when the incumbent serves as the COLR for the entire market, so $e_2(p_2,\phi,1) = 0$. This is supported by the case study in Weisman (1989C). Hence, when $\gamma = 1$, the fringe share function can reasonably be expressed solely as a function of p_2, which is the formulation here. Incorporating the more general formulation of the fringe share function into the analysis is a topic for future research.

Similar developments are unfolding in the carrier access market where entrants are deploying fiber optic networks with reliability standards [arguably] superior to those of common carriers.[16] Absent demand and cost information, it is not possible to determine whether these activities represent "over-capitalization" in the provision of reliability. Yet, our findings do suggest how the incumbent's COLR obligation will affect the fringe competitors' incentives in this regard.

V. Conclusion.

The advent of competition for public utility-like services poses complex problems for regulators who must ultimately balance equity and efficiency considerations in crafting public policy. Frequently, this dichotomy results in *asymmetric regulation* wherein the incumbent bears responsibility for certain historical obligations not likewise borne by its competitors. Here, we have focused on one such obligation, the responsibility of the incumbent to serve as the non-discriminatory COLR.

In general, we find that in the presence of a "relatively reliable" fringe competitor ($\phi < \tilde{\phi}$), the optimal price (p_2^c) is lower when the incumbent is required to serve as the COLR. Moreover, when the fringe is allowed to choose its level of reliability strategically while the incumbent must maintain a one-hundred percent COLR obligation ($\gamma = 1$), the optimal price ($\tilde{p}_2^c$) is lower yet, $\tilde{p}_2^c < p_2^c$.

Our principal finding shows that the competitive fringe has incentives to "over-capitalize" ("under-capitalize") in the provision of reliability

[16] See Weisman (1989B,1989C) and Metropolitan Fiber Systems (1989).

when the COLR obligation is zero (one-hundred) percent. The need for a COLR may thus prove to be a self-fulfilling prophecy in equilibrium. These findings may explain competitive fringe strategies in the telecommunications industry.

As competition intensifies for public utility-like services, regulators may be forced to consider a richer set of policy instruments to address the distortions inherent in a non-discriminatory COLR obligation. The insightful work of Panzar and Sibley (1978) offers some interesting possibilities in this regard. Here, working within the confines of existing regulatory institutions, we provide some guidance in the design of welfare-enhancing public policies under asymmetric regulation.

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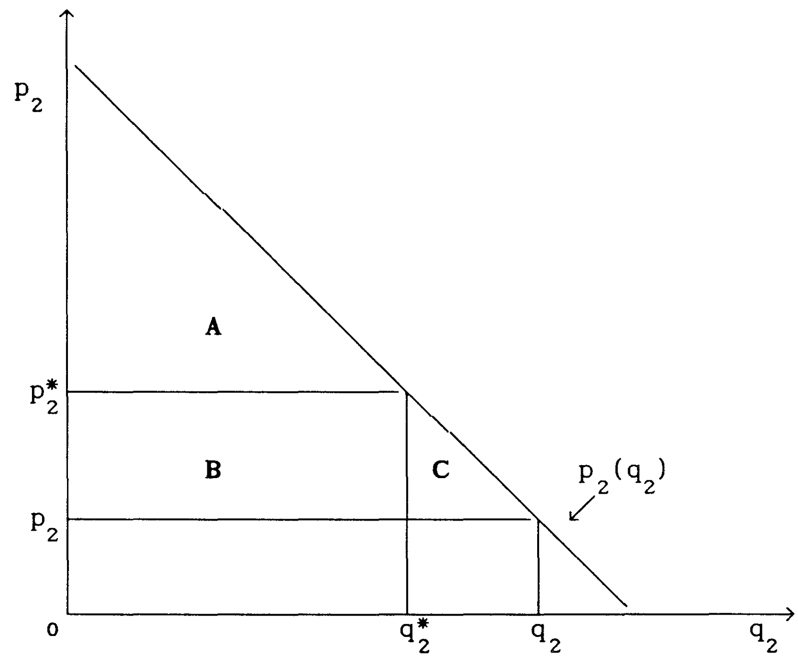
Figure 1

Consumer Surplus in Market 2



$S^2(q_2) = A + B + C$ with probability $1-\phi$

$S^2(q_2^*) = A + B$ with probability ϕ

where $q_2^* = q_2[1-(1-\gamma)e]$.