Journal of Regulatory Economics; 9:41–60 (1996)

Evaluating the Performance of Non-Bayesian Regulatory Mechanisms[1]

THOMAS P. LYON
Indiana University
School of Business, Bloomington, IN 47405

Abstract
This paper compares the performance of two prominent non-Bayesian regulatory mechanisms: Sappington and Sibley's (1988) Incremental Surplus Subsidy (ISS) and Hagerman's (1990) refinement of the Vogelsang-Finsinger (1979) mechanism. The two mechanisms are shown to induce identical, non-zero levels of "abuse"—unproductive expenses that benefit the firm—though neither induces pure waste. ISS pareto-dominates the Hagerman mechanism when lump-sum transfers to the firm are non-distortionary, but the Hagerman mechanism generates greater welfare and consumer surplus when the distortionary effects of transfers are large. For a wide range of intermediate parameter values, the quantitative difference in performance between the two mechanisms is surprisingly modest.

1. Introduction

Regulating a monopoly is made difficult by the regulator's lack of information about the firm's cost and demand functions. If the regulator knows the firm's cost function up to a parametric form, it can in principle design an optimal (Bayesian) mechanism along agency-theoretic lines.[2] Even if the regulator does not know the form of the firm's cost function, however, non-Bayesian ("anonymous") mechanisms can be employed. These mechanisms consist of simple price-adjustment rules that can be applied by regulators who can observe accounting data but lack probability estimates about parameters of the firm's cost function. Recently, several authors[3] have shown it is possible to design non-Bayesian mechanisms that guide the firm to an eventual state of productive and allocative efficiency when cost and demand functions are static.[4] Practical interest in these and other forms of "incentive

1 This paper has benefited from the comments of Keith Crocker, Steve Hackett, John Mayo, David Sibley, Ted Stefos, Lester Taylor, two anonymous referees, and seminar participants at the 1992 American Economic Association meetings, the Tenth Annual Eastern Conference of the Rutgers University Center for Research in Regulated Industries, the Pennsylvania State University, GTE Laboratories, and the Management Science Group, Department of Veterans Affairs, Bedford, Massachusetts.

2 Baron (1989) provides an excellent overview of the mechanism design literature.

3 Important examples include the papers by Vogelsang and Finsinger (1979), Loeb and Magat (1979), Sappington and Sibley (1988), and Hagerman (1990). In addition, Bawa and Sibley (1980) show that the stochastic nature of regulatory review under rate-of-return regulation can induce efficient behavior in the long run if demand and cost functions are static.

4 Blackmon (1992) shows that moral hazard (or "abuse," as he calls it) may remain a problem. Abuse is

regulation" has been spreading throughout the regulated industries, including the telecommunications, energy, and health care sectors.[5]

Given the variety of non-Bayesian mechanisms that have been proposed in the literature, there has been a surprising lack of comparative analysis of alternative mechanisms. This paper takes a first step toward filling this void. I examine two prominent non-Bayesian mechanisms: Sappington and Sibley's (1988) Incremental Surplus Subsidy scheme and Hagerman's (1990) refinement of the Vogelsang-Finsinger (1979) mechanism. (I refer to these papers below by the abbreviations ISS and H, respectively.) The two mechanisms improve upon the performance of rate-of-return regulation by altering the frequency of rate review and expanding the regulator's power to include the use of taxes or subsidies. By holding rate reviews every period, the regulator can eliminate the firm's incentives to pad costs just before a rate review. In addition, the regulator can use taxes or subsidies to tie profits to increases in output, thereby inducing the firm to cut prices and produce efficiently. Both mechanisms converge to productive and allocative efficiency in a static environment without moral hazard problems.

The main contribution of this paper lies in its assessment of the *relative* performance of the mechanisms when moral hazard problems are present and making transfers to the firm is costly. I show that the two mechanisms are equally vulnerable to "abuse," (non-productive expenses that benefit the firm) though both are immune to "pure waste" (non-productive expenses that provide no direct utility to the firm). I also show that ISS is more sensitive than H to changes in the cost of financing. The combination of a high level of abuse (which raises the need for transfers to the firm) and high financing costs is particularly damaging to ISS. By focusing on the case of a single-product firm facing a linear demand curve, I can solve explicitly for the price paths under the two mechanisms and make precise quantitative comparisons of their performance. I show that ISS Pareto-dominates H when transfer payments to the firm can be raised in a non-distortionary manner, but H generates greater consumer surplus and total welfare when the distortionary effects of transfers are sizable. Thus, if the demand for access to the regulated firm's system is highly inelastic (as is likely to be the case for utility services[6]), then access fees can be used to finance the firm with the loss of relatively few low-demand customers from the system; in this case, ISS should produce greater welfare than H. On the other hand, when a large portion of the firm's financing comes from cross-subsidies (as exemplified by the cross-subsidy from long-distance to local telephone service[7]), transfers to the firm are highly distortionary and H should produce greater welfare than ISS.

The following section briefly summarizes the two mechanisms analyzed here. Section 3 then examines the level of productive efficiency induced by the mechanisms, focusing on their potential for abuse. Section 4 compares their allocative efficiency, highlighting the effects of fixed costs, abuse, and costly financing on mechanism performance. Section 5 concludes.

---

discussed further is section 3 below.

5 For a survey, see Lyon (1994).

6 Cain and MacDonald (1991) provide a recent estimate for telephone service.

7 For an interesting discussion, see Kaserman and Mayo (1994a).

2. Two Non-Bayesian Mechanisms

The literature on non-Bayesian mechanisms has emerged from the pioneering work of Loeb and Magat (1979) and Vogelsang and Finsinger (1979).[8] In each of these papers, if costs and demand are static the firm converges to productive efficiency (assuming that the only divergence from efficiency is purely wasteful expenditures designed to manipulate the regulatory process) and to either marginal-cost prices (L-M) or Ramsey prices (V-F). However, the avenues through which these anonymous mechanisms achieve their results differ. Loeb and Magat propose a one-time subsidy to the firm which gives it the entire social surplus. Vogelsang and Finsinger, in contrast, propose a price adjustment mechanism that "ratchets" down the prices of a multi-product monopolist over time: at each rate review, a Laspeyre's index of the firm's new prices, with weights equal to the previous period's quantities, can be no greater than the previous period's realized expenditures.

Each of these schemes has shortcomings. L-M has severe distributional consequences, and is also difficult to implement.[9] V-F gives the firm incentives for strategic waste in early periods; in fact, waste may be so severe that the V-F mechanism generates lower total surplus than unregulated monopoly.[10] However, as described below, each of the mechanisms has been refined in a way that eliminates its worst defects.

2.1. The Incremental Surplus Subsidy (Sappington and Sibley)

Under the Loeb and Magat (1979) mechanism, the regulator promises to write a check to the firm in the amount of the total consumer surplus generated by any price changes the firm makes; as a result the firm moves to marginal-cost pricing. Sappington and Sibley (1988) propose a refinement of this mechanism: while the earlier authors allowed the firm to keep any surplus increases forever, Sappington and Sibley tax them away from the firm after one period. Sappington and Sibley refer to their scheme as the Incremental Surplus Subsidy (ISS) scheme, since under it the firm's profits in each period are equal to the net increase in total surplus over the previous period. This is accomplished by giving the firm a subsidy each period equal to $\psi_t - R_{t-1}$, where

$$\psi_t = \int_{p_t}^{p_{t-1}} q(p)dp$$

$$R_t = p_t q(p_t) - C(q(p_t)) - W_t \,.$$

The firm's demand and cost functions are $q(p)$ and $C(q)$, while p_t and W_t are price and waste in period t. The component ψ_t transfers to the firm the increase in consumer surplus generated by a change in the firm's prices, while R_{t-1} takes away the earnings obtained by the firm in the previous period.[11]

8 Bawa and Sibley's (1980) analysis of rate-of-return regulation may also be seen as a non-Bayesian mechanism. It is difficult to compare to the other mechanisms examined here, however, since regulatory lag is stochastic in their model, and they do not allow the use of taxes and subsidies.

9 See Sharkey (1979).

10 See Sappington (1980).

11 Note that by requiring the regulator to calculate ψ_t, this scheme utilizes more information about the firm's

Under ISS, the firm never has incentives to incur purely wasteful expenditures, since these reduce the incremental increase in total surplus; thus, $W_t = 0$ for all t. In addition, the firm prices at marginal cost in all periods after the mechanism is instituted. When there is no possibility of moral hazard, the scheme is first-best except that it requires an initial (possibly distortionary) lump-sum payment to the firm to induce it to move to marginal-cost pricing.[12]

2.2 Price Adjustment with a "Service Market" (Hagerman)

Under the V-F mechanism, when rate review occurs, the regulator approves any rate proposal that is consistent with the following rule:

$$(p_t - p_{t+1})q(p_t) \geq R_t\,, \tag{1}$$

where earnings are $R_t \equiv p_t q(p_t) - C(q(p_t)) - W_t$. Repeated application of this scheme guides the firm to efficient pricing and production, but may induce wasteful cost padding by the firm.

Hagerman (1990) provides a refinement of the V-F mechanism that uses lump-sum transfers to eliminate the firm's incentives for strategic waste. The key to his scheme is the introduction of a "service market" whose quantity is defined equal to unity and whose price in each period is included in the price adjustment constraint (1). Hagerman shows that in a static environment strategic waste is eliminated, even if transfers from the regulator to the firm are constrained to be non-positive.[13]

While the mechanism eventually converges to Ramsey pricing (if service payments are constrained to be non-negative) or marginal-cost pricing (if service payments are unconstrained[14]), the firm has an incentive to delay convergence. The pattern of prices in a two-period model is illustrated in figure 1. Prior to the imposition of the mechanism there is a pre-reform price p_0. If the firm were to lower price to unit cost c in periods 1 and 2, it would make profits of zero in both periods. On the other hand, if it lowers price only to p_1 in the first period, and then to c in the second period, it makes first-period profits (net of the service payment) of $\pi_1 = (C + D) - C = D$, and zero profits in the second period. Thus, delay of convergence is profitable as the firm gradually lowers price and increases quantity.

It is interesting to compare this scheme with that proposed by Sappington and Sibley. ISS "bribes" the firm to reduce prices by allowing it to keep the increment in total surplus for one period; in terms of figure 1, the firm receives a subsidy of $B + D + E$ for one period, and in return immediately lowers price to marginal cost. Hagerman, on the other hand, gives the

---

demand function than does the Hagerman mechanism. However, ISS has been refined by Sibley (1989) to address the case where the regulator has no information about the firm's demand function. The refinement is implemented by having the firm offer optional two-part tariffs.

12 Sappington and Sibley point out that if the regulator knows the firm's discount factor, then the net payment to the firm can be made arbitrarily small. This refinement is not pursued in the present paper, however, since the Hagerman mechanism does not assume the regulator knows the firm's discount factor.

13 The logic behind the elimination of waste expenditures is simple. Suppose that in some period t the firm incurs waste expenditures W_t to reduce its period t earnings and relax the price adjustment constraint in period t+1. It can achieve exactly the same relaxation of the constraint by increasing the "service payment" in period t+1 by W_t, thereby deferring the reduction in earnings by one period. Thus, waste is never optimal.

14 Service payments are assumed unconstrained throughout this paper, to facilitate comparison with ISS.

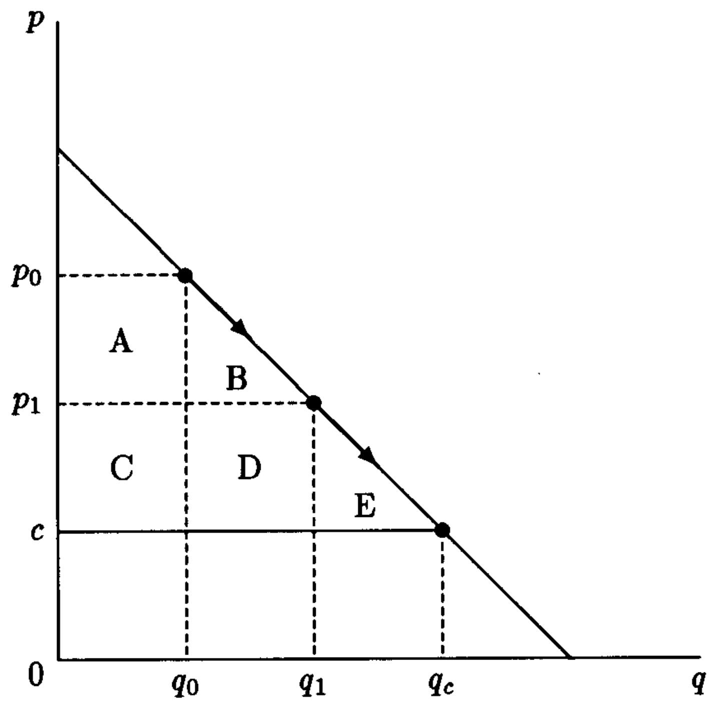

Figure 1. Illustrative Cost and Price Path for Hagerman Mechanism

firm a weaker immediate incentive to lower prices (the firm only collects area *D* in the first period), but does not require a lump-sum transfer to the firm; price does not move as quickly to marginal cost, but consumers are spared the large "bribe" in the initial period.

3. Productive Efficiency of the Mechanisms

As mentioned above, neither mechanism induces purely wasteful expenditures on the part of the firm. However, Blackmon (1992) has shown that the ISS mechanism is vulnerable to moral hazard problems. He focuses on the possibility that the firm might undertake expenditures on "abuse" which, like waste, is unproductive, but unlike waste provides direct benefits to the firm. Let A_t be expenditures on abuse, which provide benefits $B(A_t)$ for the firm, and let β be the firm's discount factor. It is assumed that $B(A_t) < A_t$, $0 \leq B' \leq 1$, and $B'' \leq 0$. Waste, then, is the extreme case of abuse where $B(A) = 0$ for all A. Blackmon shows that the level of abuse under ISS is the solution to $B'(A_t) = 1 - \beta$, and thus is constant over time.

Hagerman does not consider the possibility of abuse. The following proposition identifies the level of abuse that occurs under the Hagerman mechanism.

Proposition 1. When the service payment under the Hagerman mechanism is unconstrained in sign, the level of abuse in each period, A_t, is the solution to $B'(A_t) = 1 - \beta$, as it is under ISS.

Proof: See Appendix 2. Q.E.D.

Thus, abuse constitutes an additional fixed cost that is invariant with time and that is the same under either mechanism. Clearly, the level of abuse falls when the firm discounts the future more heavily (i.e., β decreases): expenditures on abuse must be incurred today, but will not be reimbursed until tomorrow. In addition, the more rapidly the marginal benefits of abuse diminish, the lower is the level of abuse. Given Proposition 1, in the following section expenditures on abuse will be treated simply as an increase in the firm's fixed costs.

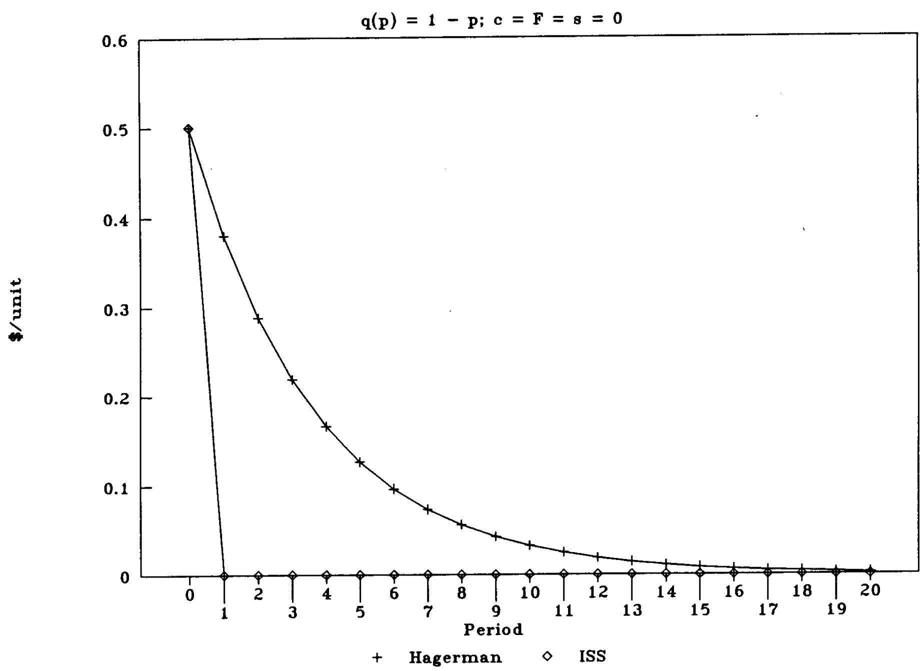

Figure 2. Price Paths for H and ISS

4. Allocative Efficiency of the Mechanisms

In order to fairly compare the two mechanisms, I make the following assumptions throughout this section: (a) regulatory reform is imposed upon the unsuspecting firm in period 1 after an initial period with pre-reform price p_0, (b) the firm's costs are $C(q) = cq + F$, where the fixed cost F includes both abuse and normal production costs, (c) the firm's demand is $q(p) = a - bp$, (d) the regulator can make transfers to and from the firm, and (e) there is a non-negative "shadow cost" of financing, denoted by s, so that each dollar transferred to the firm has costs $\$(1 + s)$.[15]

Representative price paths under each of the mechanisms are shown in figure 2. The price

15 The sources of this cost, and estimates of its magnitude, are presented in section 4.3 below.

path under ISS is simple: price moves to marginal cost immediately after the initial period. The price path under the Hagerman mechanism is more complex; Appendix 1 shows that when service payments are not constrained to be non-negative, price under H declines geometrically to marginal cost.[16] By leaving service payments unconstrained, assumption (d) above ensures that comparisons between ISS and H are not simply picking up the difference between marginal-cost prices and Ramsey prices.

Section 4.1 presents some basic analytical expressions for discounted profits and consumer surplus under second-best pricing and under the two mechanisms considered here. Section 4.2 analyzes the performance of the two mechanisms when transfers to the firm are costless, presenting both analytical results and some illustrative numerical calculations. Section 4.3 assesses mechanism performance when transfers to the firm are costly; in this case, analytical results are unavailable, so a variety of numerical results are presented to show the range of possible outcomes.

4.1. Basic Welfare Measures

The performance measures on which I focus are profits, consumer surplus, and their sum, which I refer to as "welfare." With linear demand $q(p) = a - bp$ and total costs $C(q) = F + cq$, the static monopoly price is $p^M = (a + bc)/2b$, and monopoly profits are $\pi^M = (a - bc)^2/4b - F$. Marginal-cost pricing yields per-period welfare of $\omega^* \equiv (a - bc)^2/2b$, while monopoly pricing yields per-period welfare of $\omega^M = 3\omega^*/4$.

The Second Best with Full Information Consistent with the mechanisms analyzed here, I assume the firm uses linear pricing, and the regulator can make lump -sum transfers to the firm. When $s = 0$, marginal-cost pricing is optimal, so $p_t = c$ for all t, and the firm's fixed cost is covered by a transfer from the regulator. When $s > 0$, marginal-cost pricing is no longer optimal. Instead, Ramsey pricing is used to determine the optimal markup over marginal cost. The second-best price is given by

$$\frac{p_{SB} - c}{p_{SB}} = \frac{s}{1 + s}\frac{1}{\varepsilon},$$

where $\varepsilon = -q'(p)p/q(p)$ is the elasticity of demand.[17] Note that this rule implies that the firm's profits are zero; if revenues exceed costs at p_{SB}, then the regulator collects any excess revenues through lump-sum transfer, while if costs exceed revenues the regulator gives the firm just enough money to break even. With linear demand, the second-best price is

$$p_{SB} = \frac{as/(1+s) + bc}{b(1 + 2s)/(1 + s)}.$$

The resulting net present value of welfare (and consumer surplus) under this pricing rule is

16 While it would be interesting to derive the price path under H for constant elasticity demand as well as linear demand, the dynamic price equations in Appendix 1 cannot be solved in closed form for this case.

17 See Laffont and Tirole (1993, 131-134) for a derivation and discussion. As discussed in section 4.3 below, financing costs may derive from various different sources.

$$W_{SB} = \frac{1}{1-\beta}\left[\frac{(a-bc)^2}{2b}\left(\frac{1+s}{1+2s}\right)^2 + (1+s)\left(\frac{(a-bc)^2}{b}\frac{s(1+s)}{(1+2s)^2} - F\right)\right]. \tag{2}$$

Incremental Surplus Subsidy The net present value (NPV) of outcomes under ISS is easy to compute. In period 1, the firm is granted a subsidy of $(b/2)\,(p_0 - c)^2 + F$, which induces it to price at marginal cost from period 1 onwards. Thus, the NPV of the firm's earnings is simply

$$\Pi_{ISS} = \frac{b}{2}\,(p_0 - c)^2. \tag{3}$$

The cost to consumer/taxpayers of the subsidy is $(1+s)\,[(b/2)\,(p_0 - c)^2 + F]$. Assuming consumer benefits are received at the beginning of each period, the NPV of consumer surplus is

$$CS_{ISS} = \frac{\omega^*}{(1-\beta)} - (1+s)\left[\frac{b}{2}\,(p_0 - c)^2 + \frac{F}{1-\beta}\right] \tag{4}$$

and the NPV of welfare is

$$W_{ISS} = \frac{\omega^*}{1-\beta} - s\,\frac{b}{2}\,(p_0 - c)^2 - (1+s)\,\frac{F}{1-\beta}\,. \tag{5}$$

Hagerman Because of the H mechanism's geometric series of prices, welfare calculations are somewhat more complicated for it than for ISS. For this mechanism,

$$\Pi_H = b(p_0 - c)^2\,\frac{\lambda^2}{1-\lambda^2\beta}\left[\frac{1}{\lambda} - 1\right] \tag{6}$$

$$CS_H = \frac{\omega^*}{1-\beta} + s(p_0 - c)\,(a - bc)\,\frac{\lambda}{1-\lambda\beta} + \left[\frac{1}{2} - \frac{1+s}{\lambda}\right] b(p_0 - c)^2\,\frac{\lambda^2}{1-\lambda^2\beta} - (1+s)\,\frac{F}{1-\beta} \tag{7}$$

$$W_H = \frac{\omega^*}{1-\beta} + s(p_0 - c)\,(a - bc)\,\frac{\lambda}{1-\lambda\beta} + \left[\frac{s}{\lambda} - \frac{1}{2}\right] b(p_0 - c)^2\,\frac{\lambda^2}{1-\lambda^2\beta} - (1+s)\,\frac{F}{1-\beta}\,, \tag{8}$$

where $\lambda \equiv (1/\beta)\,[1 - \sqrt{1-\beta}\,]$. (See Appendix 1 for a derivation of λ.)

While a general comparison of (3)–(5) with (6)–(8) is difficult, it is possible to establish several results for the case of $s = 0$, as shown in the following section.

4.2. Allocative Efficiency with Costless Transfers

This section presents three propositions comparing the performance of the two mechanisms when transfers to the firm are non-distortionary. Numerical calculations are then presented showing the effect of changes in the discount factor β and the level of fixed costs

F on mechanism performance.

Proposition 2. Suppose the shadow cost of transfers is zero, and $\beta \in (0,1)$. Then (a) $\Pi_{ISS} > \Pi_H$, (b) $W_{ISS} > W_H$, and (c) $CS_{ISS} > (<) \; CS_H$ if $\beta > (<) \; .5$.

Proof: See Appendix 2.

Proposition 2 shows that if $\beta > .5$, the performance of the ISS mechanism Pareto-dominates that of the H mechanism if subsidy funds can be raised in a non-distortionary manner. Both the firm and its consumers can be made better off by using ISS rather than H. The relative advantage of ISS varies systematically with several parameters of the regulatory environment, as shown in Proposition 3.

Proposition 3. Suppose the shadow cost of transfers is zero. Then $\Pi_{ISS} - \Pi_H$ and $W_{ISS} - W_H$ are (a) increasing in the initial price p_0, (b) increasing in the absolute value of the slope of the demand curve b, and (c) decreasing in the firm's marginal cost c. If $\beta > .5$, then (a)–(c) hold for consumer surplus as well.

Proof: See Appendix 2. Q.E.D.

Proposition 3 shows that the relative value of ISS increases when the pre-reform price p_0 is high, when the demand curve is steep, and when marginal cost is low. A larger price-cost margin increases the rents of the firm prior to reform, and increases the value of effective regulation. In addition, the effect of b can be seen in figure 1. Under the Hagerman mechanism, the firm delays convergence of price to marginal cost by gradually lowering price and expanding output. The larger is b, the flatter is the *inverse* demand curve, and the longer the firm can continue to expand output. Thus, large b makes the Hagerman mechanism relatively less effective. Since elasticity $\varepsilon = -q'(p)p/q(p) = bp/(a - bp)$ is increasing in b, it might also be said that H is less efficient for elastic demand.

With one additional mild assumption, the relative efficiency of ISS and H can be bounded, as shown in Proposition 4.

Proposition 4. Suppose the shadow cost of transfers is zero, and that the firm would be viable as an unregulated monopoly, i.e., $(p^M - c)q(p^M) - F \geq 0$. Then $W_H / W_{ISS} \geq .875$.

Proof: See Appendix 2. Q.E.D.

Proposition 4 shows that when $s = 0$ and fixed costs are not "too high," H produces at least 87.5% of the welfare generated by ISS, for any values of a, b, c, and p_0. Equation (16) in the proof can also be used to calculate the minimum welfare of H relative to ISS for any given discount factor. Thus, for $\beta = 0.8$, H generates at least 92.3% of W_{ISS} while for $\beta = 0.9$, it generates at least 94.0% of W_{ISS}. Additional quantitative measures of the advantage of ISS over H are provided in the following two tables.

Table 1 presents a set of "benchmark" results assuming the initial price is at the unregulated monopoly level, there is no shadow cost of funds, and the firm has no fixed costs, i.e., $p_0 = p^M = (a + bc)/2b$ and $s = F = 0$. Note that when the pre-reform price is the monopoly price, welfare results do not depend upon the parameters a, b, or c. The focus in table 1 is on changes in the discount factor (and the associated discount rate, denoted by

Table 1. Numerical Results for $p_0 = p^M(c)$ and $s = F = 0$

		Fraction of First-Best Welfare Achieved		Consumer Surplus Share of First-Best Welfare	
β	r	ISS	H	ISS	H
.95	5.3%	1.00	.977	.988	.967
.90	11.1%	1.00	.970	.975	.951
.85	17.6%	1.00	.965	.962	.938
.80	25.0%	1.00	.961	.950	.927
.75	33.3%	1.00	.958	.937	.917
.70	42.9%	1.00	.956	.925	.907
.65	53.8%	1.00	.954	.912	.899
.60	66.7%	1.00	.951	.900	.890
.55	81.8%	1.00	.950	.888	.882
.50	100.0%	1.00	.948	.875	.875
.45	122.2%	1.00	.947	.862	.868
.40	150.0%	1.00	.946	.850	.861
.35	185.7%	1.00	.944	.838	.854
.30	233.0%	1.00	.943	.825	.848
.25	300.0%	1.00	.942	.812	.842

$r = (1 - \beta)/\beta$). Note that choosing the appropriate discount rate is not straightforward, since the length of a period might be anywhere from a month to several years. Regulators have incentives to make the periods brief to encourage faster convergence, but shorter periods (and therefore higher discount factors) also encourage more abuse, as shown in Proposition 1. Since the issue of determining the optimal length of a period is beyond the scope of this paper, table 1 reports results for a wide range of discount factors.

In examining the table, one quickly sees that for $\beta > 0.5$ ISS generates greater welfare and consumer surplus than H, as shown by Proposition 2. Nevertheless, although the time pattern of prices (and thus of surplus) under the two mechanisms is completely different, they generate net present values that are surprisingly similar. ISS achieves first-best levels of total surplus, but with no fixed costs H performs better than the minimal level computed in Proposition 4, with total surplus levels greater than 96% of the first-best level for discount rates of 25% or less. Consumer surplus levels differ even less, no more than 2.3% for $r \leq 25\%$. As shown in Proposition 2, H generates greater consumer surplus than ISS for $\beta < 0.5$ (such as might be the case if the interval between periods were on the order of five years), though the difference is relatively small.

When $s = 0$, the mechanisms are only moderately sensitive to changes in the parameters a, b, c, p_0, and F. From Proposition 3, increasing c or reducing p_0 below the monopoly level will improve the relative performance of H, and indeed, as c rises or p_0 falls, the welfare performance of the two mechanisms gradually converges. However, as table 1 shows, these differences are not large to begin with. Nor do changes in a or b produce striking changes in welfare. Fixed costs are worth examining, however, since even when $p_0 = p^M(c)$ they affect the performance of H. They are also of interest because they reflect the firm's expenditures on abuse. Changes in F, as a percentage of monopoly earnings

.20	400.0%	1.00	.941	.800	.835
.15	566.7%	1.00	.941	.788	.830
.10	900.0%	1.00	.940	.776	.824

Table 2. Numerical Results for $p_0 = p^M(c)$, $\beta = 0.9$, and $s = 0$

Fixed Costs as Share of Monopoly Earnings	Fraction of First-Best Welfare Achieved		Consumer Surplus Share of First-Best Welfare	
F	ISS	H	ISS	H
0%	1.000	.970	.975	.951
10%	1.000	.968	.974	.948
20%	1.000	.967	.972	.946
30%	1.000	.965	.971	.942
40%	1.000	.962	.969	.939

$E^M \equiv [p^M(c) - c]q(p^M(c))$, are reported in table 2. Fixed costs are presented in this fashion since for any scalar α, if $p_0 = p^M(c)$ and $F = \alpha E^M$, then the relative performance of the mechanisms is unaffected by a,b, or c. As the table shows, changes in F have a modest effect on mechanism performance. This effect is more pronounced for consumer surplus, which, for H and ISS respectively, may fall to as low as 90.2% or 95% of the first-best level of welfare. Note that even though the two mechanisms induce the same level of abuse, such expenditures have less impact on the efficiency of ISS because fixed costs under ISS are assumed to be covered by non-distortionary lump-sum transfers.

The results of this section show clearly that ISS Pareto-dominates H when transfers to the firm are costless. The difference in relative performance need not be great, however; even in the worst-case scenario, H generates at least 87.5% as much total surplus as ISS. Furthermore, numerical results indicate that the difference in performance across the mechanisms may be surprisingly small given the very different price paths they generate.

4.3. Allocative Efficiency when Transfers are Costly

The above results provide a much clearer comparison of the two mechanisms than has been previously available. Nevertheless, they are built upon a suspect assumption: that lump-sum transfers to the firm are non-distortionary. This section relaxes the assumption of non-distortionary financing. The general impact of distortionary transfers on the two mechanisms studied here is clear. The effects of a positive shadow cost will fall more heavily on the ISS mechanism, since it relies upon a subsidy to induce the firm to price at marginal cost. The performance of the H mechanism, in contrast, may actually be improved when the shadow cost of transfers is recognized, since H often generates lump-sum payments to the regulator that can be used to offset other revenue requirements. The relative size of these effects is difficult to assess analytically, so this section presents numerical results comparing the two mechanisms under a variety of different circumstances. First, however, a reasonable range of estimates for the shadow cost of transfers is established.

The Distortionary Effects of Lump-Sum Transfers Lump-sum transfers play a critical role in both of the mechanisms considered here. Such transfers are generally thought to promote efficiency, since they do not directly distort the prices and consumption of individual goods and services. In regulated industries, however, transfers to the firm generally cannot be accomplished costlessly: a \$1 transfer to the firm typically creates an associated deadweight loss *s*. As Laffont and Tirole (1993, 37) point out, the deadweight loss from transfers may arise from a number of different sources. For a public enterprise, *s* represents the distortionary effects of raising revenues through the tax system. For a private enterprise that must cover its own revenue requirements via one-part prices, *s* is the shadow cost of the firm's budget constraint. For a private firm that is financed in part through cross-subsidies, as local exchange carriers are subsidized by long-distance service, *s* represents the distortions caused by further regulatory "taxation" in the subsidizing market. Finally, for a private firm that covers its costs using two-part tariffs, *s* represents the deadweight loss when low-demand customers are driven off the system by increases in the non-usage sensitive portion of the tariff.

For the case of funds raised through broad-based taxation, Ballard, Shoven, and Whalley (1985, 128) used a computable general equilbrium model to estimate the shadow cost of public funds, which they found to be "in the range of 17 to 56 cents per dollar of extra revenue." Laffont and Tirole (1993, 38) suggest "a reasonable mean estimate for the United States economy seems to be [*s*] = 0.3."

Of more immediate impact in United States telecommunications is the cross-subsidy from long-distance to local service, which Kaserman and Mayo (1994a, 131) estimate may approach \$20 billion annually for the United States as a whole. This form of "taxation by regulation"[18] has been estimated to generate deadweight losses of \$1.5 to \$10 billion annually.[19] A simple back-of-the envelope calculation for this case yields a rough estimate of *s*. Consider the change in total surplus when "tax" revenues from long-distance service are increased. Let p be the firm's price *net* of tax, t be the per-unit tax, $Q(p+t)$ be demand and W be the sum of profit and consumer surplus. Then $T = tQ(p+t)$ is total tax revenues. Some algebraic manipulation shows that

$$\frac{dW}{dT} = \frac{\frac{(p-c)\varepsilon}{p} - 1}{\frac{t\varepsilon}{p} + 1},$$

where c is marginal cost and ε is price elasticity. In the case of long-distance telephone service, a rough estimate is that $c = t = \$0.12$,[20] $\varepsilon = -0.6$,[21] and $p + t = \$0.24$,[22] so $p = \$0.12$. Then $dW/dT = -1.43$ and $s = .43$.[23] (when $c/p = 1$).

If the number of customers is fixed and totally inelastic, then financing can be accomplished without distortion through the use of access fees, and marginal-cost pricing remains optimal.[24] If access fees reduce the number of customers, however, then such fees create

18 Posner (1971) is the seminal article for this perspective on regulation.

19 See Kaserman and Mayo (1994a, 127) for further discussion.

20 Kaserman and Mayo (1994a, 127).

21 See Griffin (1982).

22 Kaserman and Mayo (1994b, 99).

23 This is consistent with Griffin's (1982) estimate of welfare losses in the range of $s = .4$ (when $c/p = 2$) to $s = 1$.

another set of distortions. A number of authors have estimated access elasticities to be quite small. For example, Cain and MacDonald (1991) estimate this value at between -.048 and -.271 for local telephone service. The associated deadweight loss is difficult to compute precisely, since it is contingent on the distribution of customer types from low to high demand; a rough estimate is possible, however. Taylor (1994, 151,161) notes that with semi-logarithmic demand, consumer surplus is simply $S = q/\alpha$, where q is quantity demanded; he also cites an estimate of $\alpha = -2.79$. Since the customers likely to be driven off the system are those with the least usage, suppose $q = 30$ phone calls per month. Such customers then receive consumer surplus of \$10.75/month. The externalities provided by one user to other customers on the system were estimated by Perl (1983) to be \$4/month in 1983, or roughly \$6/month today. Thus, suppose that each customer driven off the system generates a welfare loss of about \$17/month. Now let a be the monthly access fee, $N(a)$ be the number of customers, $A = aN(a)$ be total access revenues, and η be the elasticity of access. Then $dN/dA = \eta/[a(1+\eta)]$. Taking from Cain and MacDonald (1991) values of $a = \$7.5$ and $\eta = -0.05$, one finds $dN/dA = .007$. Multiplying this by \$17 generates a marginal welfare loss of $s = .12$ from a marginal increase in A.[25]

The above estimates, while suggestive rather than definitive, indicate that financing lump-sum transfers to a regulated firm is not costless, and that reasonable estimates of s may range anywhere from .05 to .56.

50%	1.000	.960	.967	.935
60%	1.000	.957	.964	.930
70%	1.000	.954	.962	.925
80%	1.000	.950	.958	.918
90%	1.000	.945	.955	.911
100%	1.000	.940	.950	.902

Table 3. Numerical Results for $p_0 = p^M(c)$, $\beta = 0.9$, and $F = 0$

	Fraction of Second-Best Welfare Achieved		Consumer Surplus Share of Second-Best Welfare	
s	ISS	H	ISS	H
0.00	1.000	.970	.975	.951
0.06	.995	.977	.970	.958

Performance Comparisons Table 3 examines the effects of alternative shadow costs of transfers when the firm has no fixed costs. Again, I assume $p_0 = p^M(c)$, so that the results are invariant for all a, b, and c. Note that with $s > 0$, the appropriate welfare benchmark is no longer marginal-cost pricing, but Ramsey pricing using the shadow cost of transfers.

Table 3 shows that the welfare superiority of ISS quickly evaporates when transfers are distortionary. For low levels of the shadow cost s, ISS continues to outperform H. However,

24 This is the assumption in Sibley (1989).

25 This estimate is somewhat higher than Griffin's estimate of $s = .05$ for revenues raised in the local market.

0.12	.986	.978	.961	.959
0.18	.972	.976	.948	.957
0.24	.957	.971	.933	.953
0.30	.940	.964	.916	.946
0.36	.922	.956	.898	.938
0.42	.903	.947	.880	.930
0.48	.884	.937	.862	.920
0.54	.865	.927	.843	.910

Table 4. Numerical Results for $p_0 = p^M(c)$, $\beta = 0.9$, F = 100% of monopoly earnings

	Fraction of Second-Best Welfare Achieved		Consumer Surplus Share of Second-Best Welfare	
s	ISS	H	ISS	H

for $s \in [.18,.54]$ the Hagerman mechanism consistently outperforms ISS. The reason is not hard to see. As the cost of transfers rises, the subsidy to the firm under ISS becomes increasingly costly to society; at the same time, the service payments that H collects from the firm become increasingly valuable as means of reducing transfers to the firm. Thus, it is not surprising that the relative performance of H improves when $s > 0$. What is striking in table 3 is that H outperforms ISS for most of the plausible range of estimates for s.

Given the sharp results in table 3, one would like to understand better the performance of the mechanisms when the firm's fixed costs are non-zero. Table 4 revises table 3 for the case where fixed costs are equal to monopoly earnings, so $F = E^M$.

A comparison of tables 4 and 3 shows dramatically the enhanced importance of the shadow cost of transfers when the firm's fixed production costs are high or abuse is severe. Again, ISS outperforms H for $s \le .12$, but for all higher values of s, H dominates ISS. The change from table 3, however, is that the potential deterioration of performance is now much more severe. If $s = .54$, ISS generates for consumers only 52% of the second-best level of welfare. In this case, the Hagerman mechanism produces consumer surplus that is over 40% greater than that of ISS. For the more probable case where $s = 0.3$, ISS still produces consumer surplus of only 78% of the second-best welfare level, and total welfare of only 84% of the second-best level. The Hagerman mechanism does somewhat better, generating

0.00	1.000	.940	.950	.902
0.06	.990	.950	.937	.910
0.12	.968	.951	.912	.909
0.18	.935	.943	.877	.899
0.24	.893	.928	.833	.882
0.30	.843	.907	.782	.860
0.36	.787	.880	.723	.832
0.42	.724	.849	.660	.800
0.48	.657	.814	.591	.764
0.54	.585	.775	.517	.724

Table 5. Numerical Results for $p_0 = p^M(c)$, $\beta = 0.9$, and $s = 0.3$

Fixed Costs as Share of Monopoly Earnings	Fraction of Second-Best Welfare Achieved	Consumer Surplus Share of Second-Best Welfare

F	ISS	H	ISS	H
0%	.940	.964	.916	.946
10%	.936	.962	.910	.943
20%	.931	.959	.904	.939
30%	.926	.956	.897	.934
40%	.920	.952	.889	.929
50%	.913	.948	.879	.922
60%	.904	.943	.867	.915
70%	.894	.937	.852	.905
80%	.881	.929	.834	.894
90%	.865	.920	.812	.879
100%	.843	.907	.782	.860

Table 6. Numerical Results for $\beta = 0.9$, $s = 0.3$, and $F = 100\%$ of monopoly earnings

consumer surplus and total surplus, respectively, of 86% and 91% of second-best welfare when $s = 0.3$.

To assess the sensitivity of these results to changes in F, table 5 revisits table 2 with $s = 0.30$. Once again, if $p_0 = p^M(c)$ and F is a fixed fraction of the monopoly rent, the parameters a, b, and c have no effect on the welfare comparisons.

The results in table 5 are less dramatic than those of table 4, since s is constrained to a moderate level. Throughout table 5, H outperforms ISS in both consumer surplus and total surplus, though both mechanisms do less well as the firm's costs rise. Total surplus under ISS (Hagerman) may fall below 85% (91%) of the second-best, while the consumer surplus share of second-best welfare may fall below 80% (87%)of second-best welfare.

Finally, table 6 examines performance as the pre-reform price goes gradually from marginal cost to the monopoly price, taking $s = .30$ and holding F at 100% of monopoly earnings. The results in the table are very different from those that would appear when $s = 0$. Now, the performance of ISS declines as the pre-reform price increases. For H, welfare increases as the pre-reform markup rises to 70% of the monopoly markup, and then declines again. Similarly, the relative consumer surplus from H increases as the initial markup rises to 50% of the monopoly level, and then declines. This relationship can be seen directly in (7) and (8), which are both concave in p_0 for $s \in [.18,.54]$. The implication is that when $s > 0$, the relative performance of ISS improves when p_0 is less than 80% of the monopoly price.

Taken together, the results of this section suggest that Hagerman's modification of the V-F mechanism may well outperform ISS in practice. For example, table 6 shows that if the pre-reform markup is 20% of the monopoly markup, $s = .30$, and F is 100% of the one-shot monopoly rent, then H generates roughly 3% greater welfare and 4% greater consumer surplus than ISS. This performance difference declines if F is only 50% of monopoly rent, in which case additional calculations show that H generates only about 1.7% more welfare and 1.8% more consumer surplus. In a sense, then, the overall message of the numerical results may be that the two mechanisms produce surprisingly similar performance levels for wide ranges of the exogenous parameters.

5. Conclusions

This paper has compared two prominent non-Bayesian regulatory mechanisms, focusing on the case of a single-product firm facing linear demand. There are three main findings. First, the two mechanisms are equally vulnerable to abuse. Second, when subsidies to the firm can be financed in a relatively non-distortionary manner, the ISS mechanism Pareto-dominates Hagerman's modification of the Vogelsang-Finsinger mechanism. Third, for a wide range of reasonable estimates of the cost of making transfers to the firm, the Hagerman mechanism generates greater consumer surplus and total welfare than does ISS. In principle, the Hagerman mechanism can generate consumer surplus levels more than 40% greater than those of ISS when fixed costs are large and transfers are very costly. For most plausible parameter values, however, the quantitative difference in performance between the two mechanisms is likely to be modest.

This paper provides only a first look at the comparative performance of alternative non-Bayesian mechanisms. Intensive simulation work might allow the analysis of more general cost and demand functions in the context of a multiproduct firm. Additional work might also study in more detail how particular sources of the shadow cost of transfers affect the choice between non-Bayesian mechanisms. For example, when a reduced customer base is the primary concern, the mechanisms might be extended to incorporate optional tariffs or lifeline rates for low-demand customers. A particularly important topic for further work is the effects of non-stationary costs and demand on mechanism performance.[26] Meaningful comparisons, however, will require that the mechanisms be extended to make them less vulnerable to factor price increases. Possible modifications include the use of automatic adjustment mechanisms (like the fuel adjustment clauses in many electric utility rate structures) to pass through actual cost increases,[27] adjustment of prices to reflect *expected* rates of inflation and technological change (e.g., the $RPI - X$ scheme proposed in Littlechild (1983)), or profit-based review of the firm. Each of these procedures is likely to have its own problems, however, among them the reduction of incentives for productive efficiency and/or the introduction of adverse selection problems into the regulatory process. Nevertheless, such an analysis is needed to establish whether non-Bayesian mechanisms can be expected to perform well in practice.

Appendix 1

An explicit solution for the firm's optimal pricing path under the Hagerman mechanism can be found for the case of linear demand with $C_t(q_t) = F + c_t q_t$. Let $p_{0,t}$ be the "service payment" in period t; I place no constraints on the sign of the service payment, so as to facilitate comparison between ISS and the Hagerman mechanism. Constraint (1) now becomes $(p_t - p_{t+1})q(p_t) + p_{0,t} - p_{0,t+1} \geq (p_t - c_t)q(p_t) - F + p_{0,t}$. Rearranging terms and using the equality (since the firm always selects prices where the constraint binds) yields $p_{0,t+1} = -(p_{t+1} - c_t)q(p_t) - F$, so that the optimal service payment can be expressed in terms

26 Stefos (1990) has taken some steps in this direction.

27 Vogelsang (1989) explicitly proposes such a measure.

of the per unit price. Substituting this into the expression for the firm's earnings yields $R_t = (p_{1,t} - c_t)q(p_{1,t}) - (p_{1,t} - c_{t-1})q(p_{1,t-1})$. Notation can now be simplified, since the service payment has been eliminated from the expression, by writing simply p_t for $p_{1,t}$. The firm's problem is to find a sequence of prices $p^t = \{p_t\}_{t=1}^{\infty}$ to solve:

$$\max_{p^t} V_0 = \sum_{t=0}^{\infty} \beta^t[(p_t - c_t)q(p_t) - (p_t - c_{t-1})q(p_{t-1})] \tag{9}$$

The first-order conditions are

$$\frac{\partial V_0}{\partial p_t} = \beta^t[q(p_t) - q(p_{t-1}) + (p_t - c_t)q'(p_t) - \beta(p_{t+1} - c_t)q'(p_t)] = 0, \quad \text{for all } t \geq 1 \tag{10}$$

which imply

$$q(p_t) - q(p_{t-1}) + q'(p_t)[(p_t - c_t) - \beta(p_{t+1} - c_t)] = 0, \quad \text{for all } t \geq 1. \tag{11}$$

When demand is linear, i.e., $q(p) = a - bp$, the above become second-order difference equations with constant coefficients:

$$\beta p_{t+1} - 2p_t + p_{t-1} + (1 - \beta)c_t = 0, \quad \text{for all } t \geq 1. \tag{12}$$

Suppose costs are constant over time, so $c_t = c$ for all t. Then (12) can be solved explicitly using standard dynamic methods.[28] Boundary conditions are given by p_0, and the transversality condition (from Hagerman's proof) $\lim_{t \to \infty} p_t = c$. Postulating a solution to the corresponding homogeneous equation of the form $p_t = \lambda^t$ and using the boundary conditions yields $\lambda = (1/\beta)\,[1 - \sqrt{1 - \beta}]$. A solution to the non-homogeneous equation (12) is then $p_t = c$ for all t; combining this with the homogeneous solution shows the optimal price sequence is $p_t = p_0\lambda^t + (1 - \lambda^t)c$, or alternatively, $p_t = \lambda p_{t-1} + (1 - \lambda)c$. Thus, price is a geometric sequence that decreases from p_0 to c.

Appendix 2

Proposition 1. When the service payment under the Hagerman mechanism is unconstrained in sign, the level of abuse in each period, A_t, is the solution to $B'(A_t) = 1 - \beta$, as it is under ISS.

Proof: Paralleling the analysis of Appendix 1, let $p_{0,t}$ be the "service payment" in period t and p_t be a vector of the firm's other prices. Constraint (1) now becomes $(p_t - p_{t+1})q(p_t) + p_{0,t} - p_{0,t+1} \geq p_t q(p_t) - C_t(q(p_t)) - A_t + p_{0,t}$. Rearranging terms and using the equality (since the firm always selects prices where the constraint

28 See Chiang (1984).

binds) yields $p_{0,t+1} = -p_{t+1}q(p_t) + C_t(q(p_t)) + A_t$. Substituting this into the expression for the firm's earnings yields $R_t = p_tq(p_t) - C_t(q(p_t)) - p_tq(p_{t-1}) - C_{t-1}(q(p_{t-1})) + A_{t-1} - A_t$, and the firm's payoff in period t is $V_t = R_t + B(A_t)$. The firm's problem is to choose sequences $p^t = \{p_t\}_{t=1}^{\infty}$ and $A^t = \{A_t\}_{t=1}^{\infty}$ to solve:

$$\max_{p^t,\, A^t} V_0 = \sum_{t=0}^{\infty} \beta^t[p_tq(p_t) - C_t(q(p_t)) - p_tq(p_{t-1}) - C_{t-1}(q(p_{t-1})) + A_{t-1} - A_t + B(A_t)] \quad (13)$$

The first-order conditions for abuse are

$$\frac{\partial V_0}{\partial A_t} = \beta^t[B'(A_t) - 1 + \beta] = 0, \quad \text{for all } t \geq 1. \quad (14)$$

Thus, the firm selects a constant level of abuse over time which is given by $B'(A_t) = 1 - \beta$.

Q.E.D.

Proposition 2. Suppose the shadow cost of transfers is zero, and $\beta \in (0,1)$. Then (a) $\Pi_{ISS} > \Pi_H$, (b) $W_{ISS} > W_H$, and (c) $CS_{ISS} > (<) CS_H$ if $\beta > (<) .5$.

Proof: (a) Algebraic manipulations of (3) and (6) yield

$$\frac{\Pi_H}{\Pi_{ISS}} = \frac{2}{\beta} - \frac{1}{1 - \sqrt{1-\beta}} .$$

Combining terms reveals that $\Pi_H / \Pi_{ISS} < 1$ is equivalent to $\varphi(\beta) \equiv 2\sqrt{1-\beta} - 2 + \beta < 0$. Now note that $\varphi'(\beta) = 1 - 1/\sqrt{1-\beta} < 0$. Thus, if $\varphi(0) < 0$, then $\varphi(\beta) < 0$ for all $\beta \in [0,1]$. It is easy to see that $\varphi(0) = 0$. (b) For $s = 0$, comparison of (5) and (8) shows that

$$W_{ISS} - W_H = \frac{b(p_0 - c)^2}{2} \frac{\lambda^2}{1 - \lambda^2\beta} .$$

Direct calculation shows that $\lambda^2 / (1 - \lambda^2\beta) = (2 - \beta - 2\sqrt{1-\beta}) / (2\beta\sqrt{1-\beta}\,[1 - \sqrt{1-\beta}])$, the sign of which is simply the sign of $2 - \beta - 2\sqrt{1-\beta}$ for $\beta < 1$. But $2 - \beta - 2\sqrt{1-\beta} > 0$ is equivalent to $(2-\beta)^2 > 4(1-\beta)$, which reduces to $\beta^2 > 0$. (c) From (4) and (7), and the definition of λ,

$$CS_{ISS} - CS_H = \{b(p_0 - \frac{c)^2}{2}\left[\frac{\lambda(2-\lambda)}{1 - \lambda^2\beta} - 1\right]$$

$$= \frac{b(p_0 - c)^2}{2} [-1 + \frac{1}{\beta} + \frac{1 - 2\sqrt{1-\beta}}{2\beta - 2 + 2\sqrt{1-\beta}}] .$$

Define $\psi(\beta) \equiv (5\beta/2 - 1 - \beta^2 + [1 - 2\beta]\sqrt{1-\beta})$. Some tedious algebra shows that $sgn\,(CS_{ISS} - CS_H) = sgn\,\psi(\beta)$. A direct check shows that $\psi(1/2) = 0$. Numerical calculations (available from the author) show that $\psi(\beta) < 0$ for $\beta < .5$ and $\psi(\beta) > 0$ for $\beta > .5$.

Q.E.D.

Proposition 3. Suppose the shadow cost of transfers is zero. Then $\Pi_{ISS} - \Pi_H$ and $W_{ISS} - W_H$ is (a) increasing in the initial price p_0, (b) increasing in the absolute value of the slope of the demand curve b, and (c) decreasing in the firm's marginal cost c; if $\beta > .5$, then (a)–(c) hold for consumer surplus as well.

Proof: Note that

$$\Pi_{ISS} - \Pi_H = b(p_0 - c)^2\left[\frac{1}{2} - \frac{\lambda^2}{1 - \lambda^2\beta}\left(\frac{1}{\lambda} - 1\right)\right],$$

while similar expressions for $W_{ISS} - W_H$ and $CS_{ISS} - CS_H$ are given above. Since the term $b(p_0 - c)^2$ factors out of all three expressions, the proposition follows immediately.

Q.E.D.

Proposition 4. Suppose the shadow cost of transfers is zero, and that the firm would be viable as an unregulated monopoly, i.e., $(p^M - c)q(p^M) - F \geq 0$. Then $W_H/W_{ISS} \geq .875$.

Proof: Comparing (5) and (8) shows that

$$\frac{W_H}{W_{ISS}} = 1 - \frac{b(p_0 - c)^2}{2(\omega^* - F)} \frac{(1-\beta)\lambda^2}{1 - \lambda^2\beta} . \tag{15}$$

This expression can be simplified. Recall that $\omega^* = (a - bc)^2/2b$. Note also that the relative performance of H falls with p_0; hence, assume $p_0 = p^M = (a + bc)/2b$. Finally, requiring that $\pi^M \geq 0$ implies that $(a - bc)^2/4b - F \geq 0$, so $F \leq (a - bc)^2/4b$. From (15) it is clear that H performs worse when F is larger, so assume $F = (a - bc)^2/4b$. Now (15) reduces to

$$\frac{W_H}{W_{ISS}} = 1 - \frac{1}{2} \frac{(1-\beta)\lambda^2}{1 - \lambda^2\beta} . \tag{16}$$

Some tedious calculations show that $(1 - \beta)\lambda^2/(1 - \lambda^2\beta)$ is decreasing in β and that

$$\lim_{\beta \to 0} (1-\beta)\lambda^2/(1-\lambda^2\beta) = .25. \text{ Hence } W_H/W_{ISS} \geq .875.$$

Q.E.D.

References

Ballard, Charles L., John B. Shoven, and John Whalley. 1985. "General Equilibrium Computations of the Marginal Welfare Costs of Taxes in the United States." *American Economic Review* 75: 128-138.

Baron, David P. 1989. "Optimal Regulatory Mechanism Design." In *Handbook of Industrial Organization*, edited by Richard Schmalensee and Robert Willig. Amsterdam: North-Holland.

Bawa, Vijay S., and David S. Sibley. 1980. "Dynamic Behavior of a Firm subject to Stochastic Regulatory Constraint." *International Economic Review* 21: 627-642.

Blackmon, B. Glenn, Jr. 1992. "The Incremental Surplus Subsidy and Rate-of-Return Regulation." *The Journal of Regulatory Economics* 4: 187-196.

Cain, Paul and James M. MacDonald. 1991. "Telephone Pricing Structures: The Effects on Universal Service." *The Journal of Regulatory Economics* 3: 293-308.

Chiang, Alpha C. 1984. *Fundamental Methods of Mathematical Economics*, Third Edition. New York: McGraw-Hill.

Cox, James C., and R. Mark Isaac. 1987. "Mechanisms for Incentive Regulation: Theory and Experiment." *The RAND Journal of Economics* 18: 348-359.

Griffin, James M. 1982. "The Welfare Implications of Externalities and Price Elasticities for Telecommunications Pricing." *Review of Economics and Statistics* 64: 59-66.

Hagerman, James. 1990. "Regulation by Price Adjustment." *The RAND Journal of Economics* 21: 72-82.

Kaserman, David L., and John W. Mayo. 1994a. "Cross-Subsidies in Telecommunications: Roadblocks on the Road to More Intelligent Telephone Pricing." *Yale Journal on Regulation* 11: 119-147.

Kaserman, David L., and John W. Mayo. 1994b. "Long-Distance Telecommunications: Expectations and Realizations in the Post-Divestiture Period." In *Incentive Regulation for Public Utilities*, edited by Michael A. Crew. Boston: Kluwer Academic Publishers.

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

Littlechild, Steven C. 1983. *Regulation of British Telecom's Profitability*. London: Department of Industry.

Loeb, M., and Wesley A. Magat. 1979. "A Decentralized Method for Utility Regulation." *The Journal of Law and Economics* 22: 399-404.

Lyon, Thomas P. 1994. "Incentive Regulation in Theory and Practice." In *Incentive Regulation for Public Utilities*, edited by Michael A. Crew. Boston: Kluwer Academic Publishers.

Perl, Lewis J. 1983. "The Residential Demand for Telephone Service." White Plains, NY: National Economic Research Associates.

Posner, Richard. 1971. "Taxation by Regulation." *The Bell Journal of Economics and Management Science* 2: 22-50.

Sappington, David. 1980. "Strategic Firm Behavior Under a Dynamic Regulatory Adjustment Process." *The Bell Journal of Economics* 11: 360-372.

Sappington, David, and David S. Sibley. 1988. "Regulating without Cost Information: The Incremental Surplus Subsidy Scheme." *International Economic Review* 29: 297-306.

Sharkey, William W. 1979. "A Decentralized Method for Utility Regulation: A Comment." *Journal of Law and Economics* 22: 405-407.

Sibley, David S. 1989. "Asymmetric Information, Incentives and Price-Cap Regulation." *The RAND Journal of Economics* 20: 392-404.

Stefos, Theodore. 1990. "Regulating Without Cost Information: A Comment." *International Economic*

Review 31: 1021-1025.

Taylor, Lester D. 1994. *Telecommunications Demand in Theory and Practice*. Boston: Kluwer Academic Publishers.

Vogelsang, Ingo. 1989. “Price Cap Regulation for Telecommunications Services: A Long-Run Approach.” In *Deregulation and Diversification of Utilities*, edited by Michael A. Crew. Boston: Kluwer Academic Publishers.

Vogelsang, Ingo, and Jorg Finsinger. 1979. “A Regulatory Adjustment Process for Optimal Pricing by Multiproduct Monopoly Firms.” *The Bell Journal of Economics* 10: 157-171.