Economics Department of the University of Pennsylvania
Institute of Social and Economic Research -- Osaka University

Efficient Regulation with Little Information: Reality in the Limit?
Author(s): John W. Logan, Robert T. Masson and Robert J. Reynolds
Reviewed work(s):
Source: *International Economic Review*, Vol. 30, No. 4 (Nov., 1989), pp. 851-861
Published by: Blackwell Publishing for the Economics Department of the University of Pennsylvania and Institute of Social and Economic Research -- Osaka University
Stable URL: http://www.jstor.org/stable/2526755
Accessed: 28/05/2012 16:27

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at http://www.jstor.org/page/info/about/policies/terms.jsp

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Blackwell Publishing, Economics Department of the University of Pennsylvania, Institute of Social and Economic Research -- Osaka University are collaborating with JSTOR to digitize, preserve and extend access to *International Economic Review.*

http://www.jstor.org

INTERNATIONAL ECONOMIC REVIEW
Vol. 30, No. 4, November 1989

EFFICIENT REGULATION WITH LITTLE INFORMATION: REALITY IN THE LIMIT?

BY JOHN W. LOGAN, ROBERT T. MASSON AND ROBERT J. REYNOLDS[1]

We present a regulatory scheme that converges to Ramsey pricing and productive efficiency, even if regulators have little information about technology or demand. The model has firms selecting prices subject to the regulator's requirement that the firm earn a "fair return" on capital at today's capital stock and output levels. Regulators then review later performance, and are more likely to request new rate hearings as the firm's return deviates more from the fair return. As long as regulators do not review negative returns too fast relative to positive returns, these conditions are sufficient for convergence to Ramsey prices and productive efficiency.

1. INTRODUCTION

Public utility regulators generally set prices, not rates of return per se. These prices, however, often are meant to achieve approximately some "target rate of return." But when projecting how prices will affect rates of return, regulators are often at the mercy of the firms for economic projections about the effects of various price vectors (e.g., across customer classes) upon profits. So if realized rates of return deviate from targets, regulators may call new rate hearings, and they may expedite these hearings if the deviations are large.[2]

By formalizing these real world observations some rather surprising efficiency results appear. Suppose that regulators have no knowledge of demands and technologies, but can observe past realizations of prices and quantities. If the review probabilities are as noted above, and satisfy an asymmetry condition, then this regulatory process may converge not only to productive efficiency (overcoming Averch-Johnson over-capitalization effects), but to Ramsey prices. These conclusions are derived from unifying and extending work by Bawa and Sibley (1980) and Vogelsang and Finsinger (1979).

2. THE MODEL

Suppose that regulators have very little industry specific knowledge. They may be aware of the fact that the true cost of capital for a firm with the given industry

[1] The model was developed at ICF in response to agency queries about a merger between two regulated firms. We would like to thank Paul Geroski and Ananth Madhavan and both anonymous reviewers for helpful comments.

[2] Roberts, Maddala and Enholm (1978) found that as the rate of return rose, the probability of regulatory review rose also. Joskow (1974) argues that review occurs if profits are unusually low. These results are consistent with review probabilities rising with derivations from target levels. It should be noted that these studies must be interpreted in light of longer term utility investments being regulated following changed conditions induced by both the oil price shocks and the higher nominal interest rates in the 1970's.

characteristics must be in a range $r \in (\underline{r}, \bar{r})$. Suppose that the regulators wish to assure operation; at lowest cost in profits "given away," they should then select a regulated target rate of return $s = \bar{r}$. Hence, whatever the true opportunity cost of capital r is $s > r$. If the regulators do not know the production function, and therefore cannot efficiently regulate capital usage, the Averch and Johnson distortion—over-capitalization—may result. Furthermore, if regulators do not know demand elasticities they cannot select the second best, or Ramsey prices even if provided with the true cost functions.

This section integrates insights on regulating to achieve productive efficiency from Bawa and Sibley [B-S] with those on how to achieve Ramsey prices from Vogelsang and Finsinger [V-F]. These two models are, strictly speaking, inconsistent with each other, one requiring present discounted value maximization and no pricing discretion, but allowing capital flexibility; the other requiring myopia and productive efficiency, but allowing pricing discretion. By adding more structure than either B-S or V-F, and possibly more realism, to the regulatory review process, the models may be integrated: present value maximizing firms with both capital and pricing discretion (influence on selected regulated price levels) will converge to efficiency and Ramsey pricing.[3]

To demonstrate this result in its most transparent form the multimarket model is presented in simplest form: a single product and multiple markets with independent demands (e.g., commercial and residential). Generalization to interdependent demands follows straightforwardly from V-F's results, as will be apparent in the discussion of convergence.

Returning to the regulators' lack of industry knowledge, this too can be modified. Regulators may have some knowledge of the technology and or demand, enabling them to "initialize" the convergence process we describe here in much the same fashion that they initialize $s = \bar{r}$. This regulatory knowledge may come from technological information. It might also be generated by looking at other markets, and constructing a "synthetic" simulation of an identical firm, as in Schleifer (1985) or the "relative-performance evaluation" as in the "theory of teams" (Holmstrom 1982).[4] It may also be generated by "auctioning" of regulatory franchises, as in Demsetz (1968). This prior knowledge may play an important role in regulation, as asymptotic results may not be very interesting if they are never approximated over

[3] The prices are not strictly Ramsey prices. They are the Ramsey prices for an efficient firm that was granted "tax revenues" equal to the *level* of profits the firm attains in the long run. As noted by a reviewer, these need not be the second-best prices given the profit *constraint*. By decreasing capital usage by $\varepsilon \downarrow 0$, production costs would go up, but the *level* of profit subsidy under the constraint would go down. The production cost effect is closer to zero in the limit than the subsidy effect in the neighborhood of cost minimization.

As $s \downarrow r$, productive efficiency and the Ramsey prices at the long-run profit levels ($\pi \downarrow 0$) and the second best welfare level converge.

[4] Such "yardstick competition" is tricky and controversial, and is rejected for most real world applications (see Sappington, 1982, 1983). However, for initializing a system (e.g., setting an *initial* price or capacity that will assure operation), a yardstick approach, an engineering approach or simple "common sense," may be capable of setting initial values that constrain firm initial choices in a fashion that raises initial welfare, even if these values are still not close to steady-state levels. That is essentially the logic used throughout the regulation literature in selecting an $s > r$, by finding min $\{s: s \geq \bar{r}\}$.

any reasonable horizon. Therefore imbedding our model in a more realistic framework, in which at least some information is known, may be a worthy future exercise. For clarity, we suppose that regulators have no prior knowledge beyond $r \in (\underline{r}, \bar{r})$. Suppose that at any rate review the regulator permits the firm to select its own prices. Further suppose that the regulator is willing to accept any set of prices which would not lead to projected profits in excess of the target return.

Finally, suppose that demand and input prices are assumed to be stable, so the regulator projects future profits by seeing what effect the proposed prices would have were they applied to current quantities. Hence at time t the firm must select future prices, P_{t+1}, such that it would earn no more than target returns if quantities of inputs and outputs were unchanged. This is:

$$\sum_i q^i(P_t^i)P_{t+1}^i - \hat{C}_t \leq 0, \tag{1}$$

where $q^i(P_t^i)$ is the demand for product i, P_t^i is the price of i at t, $\hat{C}_t$ is the cost of the firm at t evaluated at actual cost *plus target return*. Separating $\hat{C}$ into its capital and labor components (1) becomes:

$$\sum_i q^i(P_t^i)P_{t+1}^i - wL_t - sK_t \leq 0 \tag{2}$$

where w is the wage rate and s is the allowed rate of return on dollars of capital invested (recalling $s > r$). Now suppose that the firm faces a production function $\Sigma_i\, q^i = F(K, L)$ for each time period (and no storage). Further suppose that once a rate schedule is set, the prices remain fixed until the next rate review. Each time period the regulator cursorily examines firm profits and decides whether to initiate a review. It initiates a review as a stochastic rising function of deviations of profits from target profit levels.[5] Calling the deviation of profits from target levels Δ_t, the probability of review is $\Phi(\Delta_t)$, where:

$$\Delta_t = \sum_i q^i(P_t^i)P_t^i - wL_t - sK_t,\text{[6]} \tag{3}$$

The regulatory review probability has the form:

$$\Phi\begin{Bmatrix} = 0 & \text{if} & \Delta = 0, \\ > 0 & \text{if} & \Delta \neq 0. \end{Bmatrix}, \qquad \Phi'\begin{Bmatrix} = 0 & \text{if} & \Delta = 0, \\ > 0 & \text{if} & \Delta > 0, \\ < 0 & \text{if} & \Delta < 0. \end{Bmatrix} \tag{4}$$

Thus Φ can be thought of as continuous and monotonically declining as profits rise up to their target levels, reaching a minimum of zero at $\Delta = 0$, and then monotonically rising thereafter.

An asymmetry constraint will be required for Φ. For any positive number Δ^*, $\Phi(-\Delta^*) < \alpha\Phi(\Delta^*)$, where α is a number which is certainly less than one. In other

[5] In a continuous time model a known or stochastic lag could be used as long as it varied by profit deviations from target levels.

[6] Target profits cannot be observed, as these are $(s - r)K_t$, where r is unknown. The deviations are $\Delta = [\Sigma\, p^iq^i - wL - rK] - [(s - r)K]$, so Δ can be written as a function of observable variables as in (3).

words, regulators are slower to respond to a shortfall in target returns than to over shooting the target. This is discussed further once the steady state properties are analyzed.

Price is assumed to be set by a rate review, and all rate reviews occur on the first "day" of a time period and remain effective until the next rate review.

The firm's selection of its regulatory price vector will be codetermined with its expected use of inputs, L_t and K_t. In period t the firm's maximization problem can be expressed as a recursion equation in a dynamic programming problem. The value of the firm at t is:

$$(5)\quad V_t(P_t, K_t, L_t) = \sum_i P_t^i q^i(P_t^i) - wL_t - rK_t + \rho\phi(\Delta_t)V_{t+1}^R + \rho(1 - \phi(\Delta_t))V_{t+1}^N$$

This can be maximized subject to the regulatory target constraint

$$(6)\qquad \sum_i q^i(P_{t-1}^i)P_t^i - wL_{t-1} - sK_{t-1} \leq 0$$

and the technical constraint

$$(7)\qquad \sum_i q^i(P_t^i) - F(K_t, L_t) \leq 0$$

where ρ is the discount factor equal to $1/(1 + r)$, and V_{+1}^R and V_{t+1}^N are the value functions for the monopolist when it is reviewed and not reviewed, respectively.

It is worth noting that if the firm is not reviewed, V_{t+1}^N is identical to V_t, and since the regulatory constraint prices cannot change without a review, $P_{t+1} = P_t$. Due to the stationarity, it will also be true that the firm will select $L_{t+1} = L_t$ and $K_{t+1} = K_t$. If it is reviewed, it must select a new P_{t+1}, and generally will also revise L and K.

When a firm is reviewed, its maximization, in Lagrange form (with positive Lagrange multipliers), is:

$$(8)\qquad \Psi_t = \sum_i q^i(P_t^i)P_t^i - wL_t - rK_t + \rho\phi(\Delta_t)V_{t+1}^R + \rho(1 - \phi(\Delta_t))V_{t+1}^N$$
$$+ \lambda_1\left[sK_{t-1} - \sum_i q^i(P_{t-1}^i)P_t^i + wL_{t-1}\right] + \lambda_2\left[F(K_t, L_t) - \sum_i q^i(P_t^i)\right]$$

Recalling the definition of Δ_t in (3), this yields the following first order conditions:

$$(9)\qquad \frac{\partial \Psi_t}{\partial P_t^i} = q^i(P_t^i) + P_t^i \cdot q^{i'}(P_t^i) + \rho\phi'[q^i P_t^i) + P_t^i \cdot q^{i'}(P_t^i)]$$
$$\times [V_{t+1}^R - V_{t+1}^N] + \rho\phi \frac{\partial V_{t+1}^R}{\partial P_t^i} + \rho(1 - \phi) \frac{\partial V_{t+1}^N}{\partial P_t^i}$$
$$- \lambda_1[q^i(P_{t-1}^i)] - \lambda_2[q^{i'}(P_t^i)] = 0, \qquad \text{for all } i,$$

$$\text{(10)} \quad \frac{\partial \Psi_t}{\partial L_t} = -w - \rho\phi' w[V_{t+1}^R - V_{t+1}^N] + \rho\phi \frac{\partial V_{t+1}^R}{\partial L_t} + \rho(1-\phi)\frac{\partial V_{t+1}^N}{\partial L_t} + \lambda_2 F_L = 0,$$

$$\text{(11)} \quad \frac{\partial \Psi_t}{\partial K_t} = -r - \rho\phi' s[V_{t+1}^R - V_{t+1}^N] + \rho\phi \frac{\partial V_{t+1}^R}{\partial K_t} + \rho(1-\phi)\frac{\partial V_{t+1}^N}{\partial K_t} + \lambda_2 F_K = 0,$$

$$\text{(12)} \quad \frac{\partial \Psi_t}{\partial \lambda_1} = sK_{t-1} - \sum_i P_t^i q^i(P_{t-1}^i) + wL_{t-1} = 0,$$

and

$$\text{(13)} \quad \frac{\partial \Psi_t}{\partial \lambda_2} = F(K_t, L_t) - \sum_i q^i(P_t^i) = 0.$$

Comparative statics are examined next. The dynamics of convergence are discussed in subsection B.

A. *Some Comparative Statics.*

A.1. *Productive Efficiency.* We first note that the terms $\partial V_{t+1}^N/\partial L_t$, $\partial V_{t+1}^N/\partial K_t$, and $\partial V_{t+1}^N/\partial P_t^i$ are all equal to zero. The terms $\partial V_{t+1}^N/\partial P_t^i$ are zero because price $P_{t+1} = P_t$ if there is no review. Then, by the envelope theorem $\partial V_{t+1}^N/\partial P_t^i = 0$, because the model is stationary. That is, since the firm is not reviewed, given an infinite horizon it faces the same value function again. Were it free to select prices anew given its profit constraint from t, which it is not, it would select the same result again. Being constrained to these prices, gives the firm the same result it would choose if it were simply facing the profit constraint again.

Due to the stationarity, the envelope theorem again tells us that $K_{t+1} = K_t$ and $L_{t+1} = L_t$ if the firm is not reviewed. However, this is not the reason that $\partial V_{t+1}^N/\partial K_t$ and $\partial V_{t+1}^N/\partial L_t$ are zero (this only tells us $\partial V_{t+1}^N/\partial K_{t+1} = 0 = \partial V_{t+1}^N/\partial L_{t+1}$ at $K_{t+1} = K_t$ and $L_{t+1} = L_t$). In the case of no review, K_t and L_t have no influence on the value function V_{t+1}^N, they are intertemporally separable when there is no review, and in no way constrain future factor use if there will be no review.

Now from (10) and (11) one may write:

$$\text{(14)} \quad \frac{F_K}{F_L} = \frac{r + s\rho\phi'[V_{t+1}^R - V_{t+1}^N] - \rho\phi \dfrac{\partial V_{t+1}^R}{\partial K_t}}{w = w\rho\phi'[V_{t+1}^R - V_{t+1}^N] - \rho\phi \dfrac{\partial V_{t+1}^R}{\partial L_t}}.$$

There are two cases of interest to analyze, (1) the steady state in which the monopolist selects prices and inputs such that $\Delta_t = 0$ and (2) where the selection leads to $\Delta_t > 0$. The third logical possibility is the case in which $\Delta_t < 0$. This case need never arise in the model as presented here. If for $\Delta^* > 0$, $\phi(-\Delta^*)$ is sufficiently lower than $\phi(\Delta^*)$, then $\Delta_t < 0$ will never be observed, as firms will purposely avoid returns below target levels. Although similar results arise if at times $\Delta_t < 0$, those are suppressed by supposing that $\phi(-\Delta^*)$ is "low."

In case (1) $\Delta_t = 0$, $\phi'(0) = 0$ and $\phi(0) = 0$. Hence for any steady state, even if $s > r$

$$\frac{F_K}{F_L} = \frac{r}{w}. \tag{15}$$

This means that any monopolist who selects prices and inputs such that the deviation from target profits is zero will be in a steady state in which it is not overinvesting in capital, compared to the efficient level. The intuition behind this is simple. Note that as profits approach target levels, ϕ goes to zero more rapidly then does the deviation, Δ (because $\phi'(\Delta) = 0$). Thus were capital distorted at $\Delta = 0$, a marginal decrease in capital could raise value through higher profits while decreasing future value (through the probability of review leading to lower prices) by a lesser amount.

Now suppose that the monopolist has selected prices and inputs such that $\Delta_t > 0$ as in case (2). To analyze this requires decomposing the elements of (14) which are nonzero when $\Delta \neq 0$. To do so it is necessary to examine $\partial V^R_{t+1}/\partial K_t$ and $\partial V^R_{t+1}/\partial L_t$. From the pricing constraint $\Sigma_i P_{t+1}\, q^i_t(P^i_t) = sK_t + wL_t$, the only effect of present K or L on future value will be through their effect on the next review's prices (permitted revenues). Calling these $R_{t+1} = sK_t + wL_t$, we can write these as:

$$\frac{\partial V^R_{t+1}}{\partial L_t} = \left(\frac{\partial V^R_{t+1}}{\partial R_{t+1}}\right)\frac{\partial R_{t+1}}{\partial L_t} = \frac{\partial V^R_{t+1}}{\partial R_{t+1}}\, w \tag{16}$$

$$\frac{\partial V^R_{t+1}}{\partial K_t} = \left(\frac{\partial V^R_{t+1}}{\partial R_{t+1}}\right)\frac{\partial R_{t+1}}{\partial L_t} = \frac{\partial V^R_{t+1}}{\partial R_{t+1}}\, s. \tag{17}$$

Now (14) can be simplified by identifying a number which is common to the numerator and the denominator. Factoring out s, w and ρ, this is:

$$A_t = \rho\left\{\phi'[V^R_{t+1} - V^N_{t+1}] - \phi\,\frac{\partial V^R_{t+1}}{\partial R_{t+1}}\right\}. \tag{18}$$

It is clear that $A_t < 0$. The first term in braces is $\phi' > 0$, because $\Delta_t > 0$, and this is multiplied by the value if reviewed, and minus that if not reviewed. Since a review narrows the profit constraint, this term is negative. (If $\Delta_t < 0$, then $\phi < 0$ and the term in braces is positive, since a review raises the firm's value.) The second term in braces is $\phi > 0$, as $\Delta_t > 0$, times the increase in value if the revenue constraint under future review is relaxed (as R_{t+1} is greater). Since this is subtracted in the braces, and since $\rho > 0$, it follows that $A_t < 0$.

Next note that both the numerator and denominator of (14) are positive. This follows from (10) and (11) recalling that $\lambda_2 > 0$. (The constraint on λ_2 is set up as nonnegative in a maximization problem.) Equation (14) can be simplified using A, and because the numerator and denominator are both positive, the result is:

$$\frac{F_K}{F_L} = \frac{r + sA}{w + wA} = \frac{r\left(1 + \frac{s}{r}A\right)}{w(1 + A)} < \frac{r}{w}, \qquad \text{for } s > r. \tag{19}$$

Thus in case (2) the firm exhibits A-J like over investment in capital.

With the exception of the steady state, there will be over investment in capital, profits above target levels, and a positive probability of rate review. In any steady state, defined by no deviation of profits above target levels, and hence no expectation of review, the firm is (no longer) over investing in capital.

A.2. *Ramsey Pricing*. The proposition in this paper is that the regulatory mechanism converges to an equilibrium with productive efficiency *and* Ramsey prices. Steady state implies productive efficiency. Ramsey prices also occur in steady state. To see this we return to the first order conditions.

If the firm in equilibrium selects $\Delta_t = 0$, it will select $\Delta_{t+1} = 0$ etc. Thus it has no regulatory reviews and faces $P_t^i = P_{t+1}^i$ which uniquely determines the q^i's, and it will also have productive efficiency. Productive efficiency and the fixed $\Sigma\, q^i$ leads to time invariant L and K. Evaluating (9) for the steady state ($\phi' = 0 = \phi$ and $\partial V^N/\partial P = 0$) gives us

$$q^i(P_t^i) + P_t^i q^{i'}(P_t^i) - \lambda_1[q^{i'}(P_t^i)] - \lambda_2[q^{i'}(P_t^i)] = 0, \qquad \text{for all } i. \tag{20}$$

Dividing by $q^{i'}(P_t^i)$ and rearranging we get

$$P^i - \lambda_2 = (\lambda_1 - 1)q^i/q^{i'}. \tag{21}$$

Using the steady-state values of $\phi = \phi' = 0$, (10) yields $\lambda_2 = w/F_L$. Thus in steady-state equilibrium λ_2 is the marginal cost of expanding production by the use of labor. Thus "short-run marginal cost" is equal to "long-run marginal costs" of expansion by the use of capital, as can be seen from (11) evaluated with $\phi = \phi' = 0$. It follows that λ_2 is the unique firm MC. (Note that this is, simply, the productive efficiency result.)

Thus, dividing by P^i (21) may be written:

$$\left(\frac{P^i - MC}{P^i}\right) = (\lambda_1 - 1)\,\frac{q^i/P^i}{\partial q^i/\partial P^i}. \tag{22}$$

It follows that

$$PCM^i = [\text{constant}]/\eta^i \qquad \text{for all } i, \tag{23}$$

where η^i is the elasticity of demand for i, and PCM^i is the price cost margin for i. Equation (23) is the "inverse elasticity" form of the Ramsey pricing rule.

The final task is to demonstrate that the equilibrium does indeed converge to case (1) in which deviations from target profits are zero ($\Delta_t = 0$ in the limit as $t \to \infty$).

B. *Convergence.* The steady state with no deviations from target profits may be feasible, but convergence depends upon the form of $\phi(\cdot)$. Two types of nonconvergence appear to be possible. One type is that the firm may be able to cycle prices over time in such a fashion that profits are always over target levels. The other type is that the firm may be able to use periods of below target profits to convince regulators to permit them to raise prices, achieving periods of above target profits of greater value. This section demonstrates first that regulators can readily set conditions which would keep the latter "around the target-price cycle" from occurring. Then, building in part on this, the former "above the target-price cycle" will be shown to be strategically impossible, and convergence will be demonstrated.

B.1. *Around the Target Price Cycles?* Cycles can arise in a B-S model by a very simple mechanism. A firm may achieve negative profits by driving up its costs. The elevated costs will trigger a rate review, and permission to raise prices. With high prices the firm may operate efficiently and earn high profits. If the duration of the high-profits period is sufficiently long relative to the low-profits period, the cycle will be profitable. For the intuition, recalling that they have only one market, suppose that the firm selected a low price, p_l, but distorted high costs AC_d. Once it was reviewed, it could select a high price such as $p_h = AC_d$, and by operating efficiently achieve low costs, AC_e. Once it was reviewed again, it would be forced to set price below AC_e, and for the illustration, suppose that $AC_e = p_l$, so the cycle was repeated exactly.[7] If the high profits are defined as $G = (p_h - AC_e)Q_h$ and the losses as $L = (AC_d - p_l)Q_l$, the intuition for how to avoid cycles can be made clear. Firms are not permitted to use nonprice rationing, so $Q_h < Q_l$. Also note that in this illustration $(p_h - AC_e)$ equals $(AC_d - p_l)$, so $L > G$. If the *duration* of the high and low price periods were equal, a cycle would not be profitable. But if $\phi(G)$ is sufficiently low relative to $\phi(-L)$, then a cycle could be profitable. Clearly a sufficient condition for no cycles with negative profits is that $\phi(\pi) = 0$, if and only if $\pi \leq 0$, but the necessary conditions are much weaker. For example, if $\phi(G)$ were equal to $\phi(-L)$,[8] there would be no cycle in this example, as $G < L$. For the rest of the paper we shall assume that the probability of review during profitable periods is sufficiently high relative to that during loss periods, so that it is never profitable to strategically induce loses.

Whether the review probabilities are appropriately asymmetric in practice, is beyond the scope of this paper. To properly analyze this question would require imbedding the model in a more realistic setting. Joskow (1974) finds that regulators responded more rapidly to profit shortfalls. This is not inconsistent with our noncycling conditions, but is in the direction of a possibility of strategic cycling if the shortfalls equal the gains. Even a strong tendency towards this empirical finding might not mean that cycles are profitable. One "real world" explanation might

[7] Even though the regulators set the firm's price, the firm can achieve a stable cycle by selecting how much to distort costs when prices are low. The more it distorts costs, the higher the price after review, and the lower the next price after the subsequent review of the high profits.

[8] This is not the same condition as a symmetric review function. Symmetry implies that $\phi(G) < \phi(-L)$, because the greater magnitude of L induces a higher review probability.

reconcile this empirical result and our model. Output prices are set in absolute terms. If inputs are observed, and AC is calculated on the basis of these inputs times the input prices *at the time of a review* (not their average between reviews), then Joskow's result is consistent with our asymmetry when input cost inflation (e.g., oil or coal) is strong. (This argument is stronger if regulators permit projections of future input prices rising as well.) That is, small observed negatives would be projected to indicate substantial expected negatives, and substantial positives would be projected to indicate small positives.

B.2. *Above the Target Price Cycles?* Suppose that such a cycle were possible, that firms could simply raise and lower different prices in each review, always achieving positive profits. This supposition will be shown to lead to a contradiction, demonstrating these cycles cannot exist. Construct a cycle starting with a deviation above target profits of

$$\Delta_t = \sum P_t^i q_t^i - wL_t - sK_t > 0 \tag{24}$$

then new prices will be set by the constraint,

$$\pi_{t+1}^c = \sum P_{t+1}^i q_t^i - wL_t - sK_t \leq 0 \tag{25}$$

leading to a deviation above target profits of:

$$\Delta_{t+1} = \sum P_{t+1}^i q_{t+1}^i - wL_{t+1} - sK_{t+1} > 0. \tag{26}$$

This could create a cycle if, for example, prices could at some future date, $t + \tau$, return to $P_{t+\tau}^i = P_t^i$, for all i. That this cannot occur can be seen by the strong axiom of revealed preference.

Suppose that consumers buy the products of the regulated firm plus a composite commodity, y_t with a price index of 1. Then at time t, when returns are given by (24), consumers with wealth W purchase commodities valued at

$$W = y_t + \sum P_t^i q_t^i. \tag{27}$$

The regulator requires that the new price vector permits the consumers to buy the commodity bundle q_t^i at the new prices. In fact the consumers can now consume the amounts

$$W = [\, y_t + (\Delta_t - \pi_{t+1}^c)] + \sum P_{t+1}^i q_t^i, \tag{28}$$

but instead prefer to consume

$$Y_{t+1} + \sum P_{t+1}^i q_{t+1}^i. \tag{29}$$

Two things may be illustrated here. First, consumer's surplus must in every regulatory review rise by *at least* $(\Delta_t - \pi_{t+1}^c)$, plus the "triangle effect" from readjusting quantities.[9] In revealed preference terms, it must be that (y_{t+1}, q_{t+1}) is revealed preferred to (y_t, q_t). Now one may address the question of whether the

[9] Note, that the need for $\phi(-\Delta)$ to be "small" is again playing a role here, as $(\Delta_t - \pi_{t+1}^c)$ need not be positive in the context of around-the-target cycles.

firm in a single time period or in a multiple time period price cycle may ever return to a price vector with elements $P^i_{t+T} \geq P^i_t$. The answer is clearly "No." Each step must yield consumption bundles which are revealed preferred to those in the last step, so by the strong axiom of revealed preference, none can ever be repeated (or dominated). There can be no such cycle. The system must converge, monotonically raising consumer surplus upon each review.[10]

It is worth noting that total societal surplus rises monotonically as well (if around-the-target cycles are eliminated). Producers can always attain at least π^c_{t+1} in time $t + 1$. Hence consumers' surplus rises by an amount $(\Delta_t - \pi^c_{t+1}) > 0$, and producers' surplus falls by an amount less than $(\Delta_t - \pi^c_{t+1})$. This continues until the system converges to the steady state. This convergence-with-monotonically-rising-welfare property, unlike the illustration in the comparative static section above, does not rely upon independent demands.

3. CONCLUSIONS

The model demonstrates that target profit policies, with variable regulatory lag, can lead to efficiency with Ramsey pricing, even if regulators have very little knowledge of demand and cost conditions. Extra knowledge may, of course, speed convergence.

The interesting point is that many regulatory agencies appear to act much like the agency in this model: starting rate reviews more frequently when profits deviate more from targets and basing revised prices upon recent past experience. Of course many real world problems influence real world decision making. Regulators must deal with changing factor prices (e.g., oil), demand growth projections, equitable/distributional judgments, etc. When factor prices or technology are expected to have large-discontinuous changes, the desirable properties of this model are vastly attenuated. If the tendencies we model here exist, and are imbedded in models in which regulators are better informed (or markets are more stable), this model suggests that some factors of real decision making may lead to a natural tendency towards productive efficiency and Ramsey prices. Many other aspects of regulation may be interpreted as adding rules to achieve more rapid convergence, procedures for projecting future levels of target costs or demands, or even attempts to overcome the tendency towards Ramsey optimal prices for "equity" reasons.

Rutgers University, U.S.A.
Cornell University, U.S.A.
ICF, Consulting Associates, U.S.A.

[10] The essence of this proof is captured in the V-F model of proof. Their proof, however, is limited to declining ray average costs and efficient production. These are not needed when $\phi(\cdot)$ is selected to eliminate around-the-target cycles.

REFERENCES

AVERCH, H. AND L. JOHNSON, "Behavior of the Firm Under Regulatory Constraints," *American Economic Review* 52 (1962), 1052–1069.

BAILEY, E., *Economic Theory of Regulatory Constraint* (Lexington, MA: DC Heath, 1973).

BARON, D. P., AND R. B. MEYERSON, "Regulating a Monopolist with Unknown Costs," *Econometrica*, 50 (1982), 911–930.

BAWA, V. S. AND D. S. SIBLEY, "Dynamic Behavior of a Firm Subject to Stochastic Regulatory Review," *International Economic Review* 21 (1980), 627–642.

DEMSETZ, H., "Why Regulate Utilities?" *Journal of Law and Economics* 11 (1968), 55–66.

HOLMSTROM, B., "Moral Hazard in Teams," *Bell Journal of Economics* 13 (1982), 324–340.

JOSKOW, P., "Inflation and Environmental Concern: Structural Change in the Process of Public Utility Price Regulation," *Journal of Law and Economics* 17 (1974), 291–327.

——— AND R. NOLL, "Regulation in Theory and Practice: An Overview," in Gary Fromm, ed., *Studies in Public Regulation* (Cambridge: MIT Press, 1981).

KLEVORICK, A., "The Optimal Fair Rate of Return," *Bell Journal of Economics and Management Science* 2 (1971), 122–153.

PACE, J. D. AND J. H. LANDON, "Introducing Competition into the Electric Utility Industry: An Economic Appraisal," *Energy Law Journal* 3 (1982), 1–65.

ROBERTS, R., G. MADDALA AND G. ENHOLM, "Determinants of the Requested Rate of Return and Rate of Return Granted in a Formal Regulatory Process," *Bell Journal of Economics* 9 (1978), 611–621.

SAPPINGTON, D., "Strategic Firm Behavior Under a Dynamic Regulatory Adjustment Process," *Bell Journal of Economics* 11 (1980), 360–372.

———, "Optimal Regulation of Research and Development Under Imperfect Information," *Bell Journal of Economics* 13 (1982), 354–368.

———, "Optimal Regulation of a Multiproduct Monopoly with Unknown Technological Capabilities," *Bell Journal of Economics* 14 (1983), 453–463.

SCHLEIFER, A., "A Theory of Yardstick Competition," *Rand Journal of Economics* 16 (1985), 319–327.

VOGELSANG, I. AND J. FINSINGER, "A Regulatory Adjustment Process for Optimal Pricing by Multiproduct Monopoly Firms," *Bell Journal of Economics* 10 (1979), 157–171.