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Stock-price Based Regulation

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Stock-Price based Regulation

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Abstract

While regulated firms tend to exaggerate their inability to reduce costs to influence the rates they are allowed to charge, firms that quote in the stock market tend to exaggerate their ability to reduce costs in order to increase the price at which their stock is traded. This suggests to us that there may be gains from incorporating stock market reactions into regulatory schemes, particularly when cost padding is a source of concern. We show that a simple linear scheme that punishes the firm for stock market gains during review periods can outperform the traditional regimes (cost plus, price cap and the combined regime). When the noise introduced by the stock market is low, the gains from *stock-price based regulation* can be significant: a loss of 0.89% relative to first best, compared to 8% under cost plus, 6% under a price cap and 3.6% under the best linear regime (combining cost-plus and a price cap).

Keywords: cost padding, stock market discipline, good regulatory regime.
JEL Classification: L43, L50.

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I. Introduction

A basic problem for regulators is that they often ignore the regulated firm's true cost of production. Asking firms about them is of no use as firms have an incentive to exaggerate their costs. By doing so, firms hope to influence regulators to be more permissive and, in particular, to set higher regulated prices. A vast literature has emerged, suggesting various ways in which this problem can be mitigated. Interestingly, non-regulated firms that quote in the stock market exhibit exactly the *opposite* tendency. Almost invariably they tend to play down their costs. The reason is that a high cost announcement would tend to depress profits and stock market prices. This would constitute negative information concerning how well a job the managers are doing and, consequently, how much rewards they deserve or how wise it is for individual investors to fund them further. The point of our paper is simply to point out that this tension can be exploited by the regulator with a scheme that is both extremely easy to use and that, from a social welfare perspective, always allows the regulator to do as well as under traditional forms of regulation (such as price cap or cost-plus) or better.

The problem of cost padding can be particularly severe in less developed countries. An obvious reason is that accounting standards are typically applied with less vigor. Moreover, the possibility of regulatory capture on the one hand, and that of regulatory expropriation on the other, has led both consumers and industry to embrace regulatory regimes where there is little discretion in the hands of the regulator (see, for example, Spiller and Martorell (1996)). The possibility of strategic behavior by the regulated firm paired with a rigid regulatory system (albeit with high commitment) that translates cost reports into regulated rates somewhat mechanically opens the door to anti-consumer bias in the system. A case in point is Chile, where the system explicitly restricts regulatory discretion through a number of pre-specified steps that turn cost information into regulated rates. Since discretion has been removed, cost reports by firms during regulatory review periods has a high probability of affecting future regulated prices.[1] The performance of the system is somewhat mixed. On the one

[1] The system has an element of yardstick where a "model" company is constructed, so the probability is not one. But in practice regulated prices have to keep a connection with real (reported) costs if they are going to be legally enforced by the courts.

hand large efficiency gains in terms of average costs have taken place while the improvements in rates has been more moderate. Moreover, measures of reported costs tend to deteriorate prior to regulatory reviews. The evidence available suggests that the reaction of the stock market price of the regulated firms to these cost announcements is different in review years than in non-review years.[2] First, industry participants have declared in interviews that during review periods regulated firms *tell* analysts and market investors to disregard cost and revenue announcements this period as they are made to influence future regulated rates. Second, cost surprises calculated without any knowledge of the occurrence of review periods tend to depress stock market prices in a normal year, while they tends to *increase* stock prices in a review year.

Surprisingly, the possibility of using the stock market price of the regulated firm to enhance the information set of the regulator when setting the new rates has not been widely studied in the literature. An exception is the interesting recent paper of Faure-Grimaud (2002). The problem he is concerned is somewhat different, however. He sees the inability of the regulator to commit not to confiscate the firm as the main problem. He then argues that if there is a set up cost of monitoring the firm, the information provided by the sock price may be enough to make paying this cost not worthwhile for the regulator. Hence, the availability of unbiased information about the true costs of the firm, even if noisy, end up helping the firm by preventing the more intrusive exercise by the regulator.[3] We focus on the benefits of using stock prices not to solve a commitment problem, but to solve a related information problem. In any case we see our papers as complementary contributions on the broader issue of the design of institutions that incorporate information produced by the market.[4]

[2] See Di Tella and Dyck (2001, 2002). The effect has fallen over time, suggesting that the market has incorporated this gaming into the stock price of the regulated firm.

[3] FABIO: doesn't this depend on the assumption that the monitoring regime of the regulator is MORE precise than the analysis of the market? Which sounds bizarre..

[4] Another difference, of course, is that Faure-Grimaud (2002) looks for the optimal regime, whereas we lokk only for a good regulatory regime that uses stock prices, as in Schmalensee (1989). In a general sense, our papers are both part of a broader agenda where multiple sources of information are used to regulate firms, as explored in Martimort (1999). To our knowledge, the first empirical paper to use the stock market to evaluate the effect of regulation is Schwert (1981). See also Rose (1981) and Whinston and Collins (1992).

The traditional approach to deal with cost padding involves auditing and the application of large fines for firms that get caught cheating.[5] But high fines are not observed in practice, particularly in less developed countries. Thus, we exogenously assume that high fines are not feasible and do not set out to derive the *optimal* regulatory regime with stock prices. Rather, we analyze a simple regulatory regime that incorporates stock market price information and compare its performance to the main alternatives, cost-plus and a price cap. In other words, our general approach to analyzing these issues is in the tradition of Schmalensee (1989) who uses quantitative analysis to study the performance of different regulatory regimes. He shows that in general, the performance of cost plus schemes and of pure price caps is dominated in social welfare terms by a combination of both, in what Schmalensee called a "good regulatory regime".[6]

In section II we present the model while section III presents the methods and main parameters. Section IV provides some preliminary analysis and presents the main results. Section V concludes.

II. The Model

We consider a risk-neutral, infinitely lived, regulated monopoly. In each period, it produces one unit of a good, with costs given by α_t. We assume α_t is a random variable that follows a Markov process. In particular, α_t can take on two values, $\alpha_t \in \{\alpha_L, \alpha_H\}$, that evolve according to the probability transition matrix

$$\begin{pmatrix} \rho & 1-\rho \\ 1-\rho & \rho \end{pmatrix}$$

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[5] See, for example, Baron and Besanko (1984, 1987), Riordan and Sappington (1988), (FABIO: you also cited Laffont and Tirole (1992) Ch 12, is it correct here?) *inter alia*. This is not the place to do justice to the relevant literature. A number of key papers on price cap regulation appeared on the 1989 symposium in the *Rand Journal of Economics*. See also Riordan and Cabral (1989) on incentives for cost reductions and Sappington (1980) and Sappington and Sibley (1992) on strategic behavior of the regulated firm.

[6] In practice, optimal regulatory policies are not always the focus as it is often hard to characterize all relevant information and some of the required instruments are not always available to the regulator. Instead, part of the literature has focused on simple, practical regulatory policies. For an excellent review see Armstrong and Sappington (2002), especially section 2.

where $\rho \in [0, 1]$. That is, the probability that $\alpha_{t+1} = \alpha_H$ in period $t+1$ given that $\alpha_t = \alpha_H$ in period t is ρ, and the probability that $\alpha_{t+1} = \alpha_H$ in period $t+1$ given that $\alpha_t = \alpha_L$ in period t is $(1 - \rho)$.

In each period the firm has to declare its costs, but it is able to manipulate the accounting procedure so that instead of just α_t, the declared costs, C_t, are given by

$$C_t = \alpha_t + \delta_t \tag{1}$$

where δ_t denotes the amount of cost padding chosen by the firm.[7] However, in order to inflate the declared costs, the firm looses control of its operations and misallocates its resources.[8] This implies a waste (in monetary units) given by

$$\psi(\delta_t, \theta_t) = \delta_t^2 / (2\theta_t) \tag{2}$$

where the parameter θ_t is an independently and identically distributed random variable. We assume $\theta_t \in \{\theta_L, \theta_H\}$ and that the probability that $\theta_t = \theta_L$ is one half.

We can then write the profit of the monopoly in each period as,

$$\pi_t = p_t - \alpha_t - \psi(\delta_t, \theta_t) \tag{3}$$

where p_t is the regulated price of the produced unit.

Before studying the feasible regulatory regimes, it is useful to obtain the stock price of the firm S. We assume that this price S_t is available in every period after the firm has distributed its profits and declared its costs.[9] Hence, it contains the market information about the declared costs, and is equal to the expected value of (discounted) future profits of the firm,

$$S_t = E_t \sum_{i=t+1}^{\infty} \frac{\pi_i}{(1+r)^{i-t}} + \xi_t \tag{4}$$

where r is a constant (real) risk-adjusted interest rate, and ξ_t is an independently and identically distributed random variable that corresponds to non-fundamental[10]

[7] Fabio: are we assuming that padding can only be positive?
[8] A further reason why firms in this setting may find it costly to inflate costs is that market participants, such as potential investors, may loose faith in the accounting standards used.
[9] In an extension that considers aggregate market risk, the interesting price would be net of changes in the average stock market price.
[10] FABIO: what about firms that manage to produce some real improvement in a review year. They get punished or do they shift (at some cost) to the next period?

disturbances on the stock prices. For simplicity, ξ_t is considered to be uniformly distributed in the interval [-σ, σ].

The regulator can specify a single linear relation that determines the price charged by the regulated firm as a function of its declared costs and the stock prices in the last period. However, since the non-fundamental part of stock price can be quite volatile, we also consider that the regulator could use a cap on the stock price that appears in this relation. Formally, the pricing rule is given by,

$$p_{t+1} = \gamma_0 + \gamma_1 C_t - \gamma_2 S_t \quad \text{, if } S < \gamma_3 \tag{5a}$$

$$p_{t+1} = \gamma_0 + \gamma_1 C_t - \gamma_2 \gamma_3 \quad \text{, if, otherwise, } S \geq \gamma_3$$

(5b)

In words, this pricing rule reduces the amount charged when the stock price increases, but only when this stock price is inferior to a certain limit.[11]

As usual, the pure cost-plus regulation involves $\gamma_1 = 1$ and $\gamma_2 = 0$. A pure price-cap regime corresponds to $\gamma_1 = 0$ and $\gamma_2 = 0$. In general, the regulator chooses (γ_0, γ_1, γ_2, γ_3) in order to maximize the consumers' surplus, or equivalently, to minimize the expected price charged E[p_t]. Regulators are usually assumed to minimize some weighted sum of consumers' surplus and profit but since we do not need a demand specification to make the main points of the paper, we have opted to consider only the extreme case in which consumers' welfare is the only relevant objective.[12]

In the beginning of each period, after observing the actual costs α_t, a firm can choose to abandon the contract, decline to produce and sell its assets. Because we assume that the product involved is a necessity (such as water or electricity), this possibility forces the pricing rule to satisfy a profitability (individual-rationality) constraint that requires the regulated firm to expect a rate of return on its assets that is

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[11] FABIO: don't we need to assume something about the INITIAL value of the firm? In the sense that there may be two equilibria here. In the first, INITIALY the value of the firm is derived thinking that it can fool the regulator with a lot of cost padding. Going forward the system works great but at a very high level of padding. I guess it works if one makes sure that we START with the correct valuation, no?

[12] FABIO: Idon't understand this. If we only look at consumer welfare we would need a demand curve in order to calculate consumer welfare no?

at least equal to its hypothetical market value. If we denote the firms' assets value by K, the market expected period return equals rK. We can then write the individual rationality constraint as,

$$\pi_t + E_t \sum_{i=t+1}^{\infty} \frac{\pi_i}{(1+r)^{i-t}} \geq \sum_{j=0}^{\infty} \frac{rK}{(1+r)^j} = (1+r)K \qquad (6)$$

which has to be satisfied for any period t.

Timing

The game played by the regulator and the regulated firm unfolds as follows:

0) In the beginning of *time* the regulator chooses (γ_0, γ_1, γ_2, γ_3). All the probability distributions and parameters are common knowledge. The values for (γ_0, γ_1, γ_2, γ_3) remain unchanged forever.
1) In the beginning of each period t, nature plays α_t according to the specified Markov process. Based on this value, the firm decides if it quits or not.
2) In case the firm does not quit, nature plays θ_t
3) The firm chooses δ_t, produces its product, charges p_t for it, and receives a profit π_t
4) The market determines the price of the stock S_t
5) The regulator, using the pricing rule determined by (γ_0, γ_1, γ_2, γ_3), sets the next period price p_{t+1}

III. Methods and Parameters

Even though the specific functional forms and distribution functions were chosen to make the model relatively simple, analytical constrained minimization of the expected prices with respect to (γ_0, γ_1, γ_2, γ_3) is not feasible.[13] The discussion that follows thus relies heavily on numerical derivation of best-linear regulatory regimes. But in order to resort to numerical techniques, we first have to calibrate the parameter values.

We start by normalizing all the parameters with respect to the mean value of α, by making it equal to one. Because the Markov process that describes the evolution of α_t is symmetrical, we set $\alpha_L = 0.8$ and $\alpha_H = 1.2$ which corresponds to a variation of +- 20%. Additionally, in order to have a persistent process for α, that creates a reason for knowing the true costs, we set $\rho = 0.9$.

For the calibrating waste parameter θ, it is useful to note that when $\gamma_1 = 1$ and $\gamma_2 = 0$ (as we will derive later on) the equilibrium cost padding is $\delta = \theta/(1 + r)$. Assuming that that cost padding can reach 20% of the costs, we set $\theta_L = 0$, and $\theta_H = 0.2(1 + r)$.

For the interest rate r we choose an annual value of 10%. Since each period here corresponds to a regulatory review period, which in general lasts about four years, we set $r = 40$ %. Assuming that the (yearly) capital-output ratio of the firm is 4, a typical number for capital-intensive sectors, we set $K = 1$ (the four year period capital-output ratio is equal one).

Because the results can be very sensitive to the distribution of ξ, we report our solutions for various values of σ. In order to search for the optimum values for (γ_0, γ_1, γ_2, γ_3), we construct a grid for its possible values and evaluate the expected price for each combination. The minimum expected price that satisfies the individual-rationality constraint corresponds to the solution. To find the expected prices we make some additional numerical simplifications, described in the appendix, that allow us to reduce the problem to a non-linear equation on the expected profit of the firm.

IV. Results

IV.a. Preliminary Analysis

Since we assumed that the regulator has full commitment over the pricing rule, and that the stock market is perfectly competitive, the problem of the firm is a simple (monopoly) maximization one. The only technical difficulty that arises from having stock prices in the pricing scheme is related to the feedback that occurs from the regulated prices to the stock price, through profits.

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[13] The crucial equation is neither polynomial nor any known transcendental one. But it may have some electrons (yes, yes, you can laugh but my self-esteem would increase a lot if I

When choosing the amount of cost padding, the firm has to consider not only the increase in the future price due to higher declared costs, but also the decrease in future regulated prices due to higher stock prices.[14] The stock prices, in turn, take into account that due to its own value, the future profits of the firm can be reduced, what is compatible with lower stock prices today. In other words, the equation that determines the optimum cost padding can be thought as being composed by two effects on future prices,

$$p_{t+1} = f(C_t) - g(S(\pi_{t+1}(p_{t+1})))$$

The first effect of cost padding on future prices occurs via the increase in the declared costs, $f(C_t)$. The second effect of cost padding in future prices occurs via the increase in stock prices, which is due to the increase in future profits that in turn are increasing in the future prices, $g(p_{t+1})$.

To grasp intuition for the use of stock price in the pricing rule, it is useful to derive the analytic solution for δ_t, given the parameters (γ_0, γ_1, γ_2, γ_3). The regulated firm chooses δ_t to maximize

$$U_t = E_t[p_t - \alpha_t - \psi(\delta_t, \theta_t) + \frac{p_{t+1} - \alpha_{t+1} - \psi(\delta_{t+1}, \theta_{t+1})}{1+r} + ...] \tag{7}$$

Recall that the value of p_t is already determined in the moment of choice, and α_t and α_{t+1} are exogenous, but futures prices (p_{t+1}) are functions of S_t and hence can be affected by δ_t. As discussed, the stock price is given by

$$S_t = E_t[\frac{\pi_{t+1}}{(1+r)} + \frac{\pi_{t+2}}{(1+r)^2} + ... | C_t] + \xi_t \tag{8}$$

Because the value for S_t that is used to price p_{t+1} already incorporates the information of C_t, the expected future profits of the firm, π_{t+1}, π_{t+2}, …are the same in formulae (7) and (8). We can therefore combine the two formulae and obtain

$$S_t = U_t - [p_t - \alpha_t - \psi(\delta_t, \theta_t)] + \xi_t \tag{9}$$

could have ONE paper with atoms, just like Anand…….I think I have atom-envy).

[14] Cite to self referential systems Woodford, Mankiw NBER, preguntar Julio

In order to get a simple and intuitive formula, it is convenient to assume that $S_t < \gamma_3$ for all ξ_t. Plugging formulae (8) and (4) into (6), and rearranging terms, one obtains

$$[1+\frac{\gamma_2}{(1+r)}]U_t = E_t[p_t - \alpha_t - \psi(\delta_t,\theta_t) + \frac{\gamma_0 + \gamma_1(\alpha_t + \delta_t) - \gamma_2(-p_t + \alpha_t + \psi(\delta_t,\theta_t) + \xi_t)}{1+r} + ...] \quad (10)$$

The first order condition with respect to δ_t is

$$\frac{\gamma_1}{1+r} - (1+\frac{\gamma_2}{1+r})\frac{\partial\psi(\delta_t,\theta_t)}{\partial\delta_t} = 0 \quad (11)$$

The first term indicates that the marginal benefit of increasing cost padding is the increase in the regulated price (next period) due to the increase of the declared costs. The second term shows that the marginal cost of increasing cost padding includes both the increase in waste this period, and also the decrease in the price (next period) due to an increase in the stock price. Using the expression for waste (2) one obtains,

$$\delta_t = \frac{\theta_t\gamma_1}{1+r+\gamma_2} \quad (12)$$

The numerator of formula (12) indicates that cost padding increases when the waste costs decrease (θ_t is smaller), and when declared costs enter more aggressively in the price formula (γ_1). But the most important lesson from (12) is that the presence of stock prices in the regulated pricing rule can reduce the amount of cost padding. This, in turn, reduces the amount of uncertainty due to the variation of their related waste, increases the amount of information about the true costs, and hence the control over the regulated firm. The interest rate enters negatively because padding is an activity that has the characteristics of an investment: more padding today only increases profits at later dates when this information is incorporated into future price caps.

In the case that $S_t \geq \gamma_3$ for some ξ_t, the reduction in cost padding is not as effective. Higher values of γ_3 imply that $S_t \geq \gamma_3$ more often (????Fabio: is it not LESS often?), reducing cost padding. However, as we will see in the numerical experiments below, the optimal is to set γ_3 to moderate values, losing in the reduction of cost padding, but also reducing the loss in information originating in the non-fundamental stock disturbances ξ_t.

IV. b. Best Linear Regimes

This section describes the best linear regulatory regimes for a variety of numerical experiments. Results are depicted in table 1. The first column describes the experiment assumptions, and the following four columns the obtained optimum values for (γ_0, γ_1, γ_2, γ_3). We then report the average cost padding δ and, most importantly, the welfare loss. The welfare loss is simply the excess average price over a benchmark: $E[p_t]-\bar{p}$. As a benchmark, we choose a first best situation, in which there are no shocks. We measure welfare loss and cost padding as a percentage of the average firm's costs ($E[\alpha_t]$).

Our first experiment is to obtain the best regime in a case without any shocks, to be our benchmark (1st best). For that we set $\alpha_L = \alpha_H = 1$, and $\theta_L = \theta_H = 0.1(1 + r)$. This particular case can be solved analytically, implying in $\gamma_0 = 1.4$ and $\gamma_1 = \gamma_2 = \gamma_3 = 0$. The amount of cost padding is zero, the regulated price is always equal to 1.4, and profits cover exactly the opportunity cost of capital. Welfare loss is normalized to zero.

We then add shocks to our firm, and numerically find the expected regulated price that corresponds to a regime of "Cost Plus" ($\gamma_1 = 1$, $\gamma_2 = 0$). We obtain $E[p_t] = 1.48$, what implies in a welfare loss equal to 8% (of the average costs, $E[\alpha_t] = 1$). Similarly, for a "Price Cap" regime ($\gamma_1 = 1$, $\gamma_2 = 0$), we find that the welfare loss is 6%.

We then search for the best linear regime that does not take stock prices into account, in a fashion similar to Schmalensee (1989). We obtain that the optimum scheme has $\gamma_1 = .4$, which indicates that there are advantages to using the declared costs in the price. The reason for this is the persistence in the true costs process. By setting a positive value for γ_1 the regulator tracks the expected costs of the firm, and can set future prices lower. The disadvantage of a high value for γ_1 is that it induces higher cost padding (see equation (12)) which, in turn, implies less information about the true costs. That is probably the reason for the relatively small optimum value for γ_1. We find that for this case the welfare loss is 3.6%. We should think of this number as a reference, to evaluate how much welfare loss reduction a scheme that considers stock price can achieve.

We start our investigation of stock prices by setting $\sigma = .0001$, a case with extremely small non-fundamental disturbances in the stock price.[15] We numerically look for the optimum scheme by setting the parameter γ_2 to increasingly higher values. Initially we set $\gamma_2 = 1$, a pricing rule that takes stock prices into account, but with a small coefficient. We obtain $\gamma_1 = .6$, higher than before, which means that costs are more heavily tracked. The effect of using stock prices in the regulated price is to reduce the amount of cost padding. [A case in which $\gamma_1 = .6$ and $\gamma_2 = 0$ would imply in average cost padding of 6%. The use of stock prices makes the average cost padding equal to 4.75%, in spite of having $\gamma_1 = .6$] More importantly, the welfare loss is reduced from the previous 3.60% to 2.36%.

The main conclusion here is that the use of stock prices in the pricing scheme is a way to reduce the loss of information due to cost padding, allowing for more cost tracking (higher γ_1). When we increase γ_2 to higher values, the same intuition shows up. The optimum values for γ_1 further increase (to .7) whereas the amount of cost padding decreases. The loss in welfare decreases to as low as .89%, when γ_2 is set to values of 1000 or higher. This corresponds to a reduction in welfare loss of 75%, when compared to the best linear case without stock prices (as in Schmalensee (1989)).

[15] FABIO: shouldn't we add a line or two here on why gamma 2 is not maximised together with the others. After all we are presenting the value of one of the choice variables with the other parameters (in the main table). Also I would add a line saying that it is always goodto raise the gamma2 and that no gains are due after gamma2 exceeds 1000. Any intuition for this (related to the fact that the intercept also raises with gamma2)?

It is also interesting to notice that the optimum γ_3 stays constant at 1.0, which implies that $S_t > \gamma_3$ in about half the periods (recall that, in the absence of any shocks, $S_t = K = 1$). Higher values of γ_3 increase the effect of γ_2 over the amount of cost padding. However they also generate more scope for the shocks ξ_t to reduce the information about the true costs. This trade-off seems to result in an intermediate solution, in which the optimum γ_3 is close to the expected stock price value. A practical implication of this result is that pricing schemes that use stock prices can be useful even if the stock volatility due to ξ is unbounded.

In the next set of experiments we gradually increase the values for σ. As expected, this undermines the use of the stock prices in the regulation scheme. When $\sigma = .05$, even for higher values for γ_1, the welfare loss can only be reduced to 1.16%. For $\sigma = .1$, it can only be reduced to 2.65%. Finally, when we set $\sigma = .2$, the advantage of using stock prices in the regulatory scheme completely disappears. The welfare loss is equal to the case analyzed by Schmalensee, for any γ_1 we tried.

V. Conclusions

Regulated firms tend to exaggerate costs and understate revenues. They do this in an effort to induce lenient regulated rates. Publicly traded firms do exactly the opposite. They naturally wish to exaggerate performance in order to have the stock market believe that the managers are of superior ability and to induce investors to fund them more generously. A regulator who faces a regulated firm with a publicly traded stock can exploit this to reduce the strategic behavior of the firm. Thus, even if cost padding were totally unobservable to the regulator and other outside observers, firm managers have an incentive to reveal these activities to the stock market. In other words, observing the stock market may provide valuable information to the regulator.

We propose a simple mechanism that a regulator who faces a firm that tends to overstate costs and understate revenues can use to exploit this tendency when the firm's stock is traded in the stock market. To keep things simple, we only look at linear schemes in an environment that is as close as possible to the one analyzed in Schmalensee (1989). Costs are assumed to follow a Markov process and regulators are assumed to be unable to impose taxes or make transfers, or observe the disutility of cost padding. The scheme proposed has future regulated rates depend on today's cost reports and today's stock market price. It also allows for the possibility that the stock market has too much variability, a case where it is optimal to ignore stock market prices and revert to standard forms of regulation. Cost padding for the firm is like an investment, it is costly today but may generate more profits in the future through higher allowed rates. But since this also increases the stock market value, a rule that reduces rates with stock prices will control the desire to exaggerate costs.[16]

We find that stock-price based regulation can yield significant improvements over traditional forms of regulation. Using numerical methods we show that the loss from a cost-plus and a price-cap regime are 8 and 6 percent respectively. The combined regime, proposed by Schmalensee, yields a loss of 3.6 percent. In contrast, the loss under stock-price based regulation can be as low as 0.89 percent when the variability inherent in the stock market is low. As the informational content of stock prices falls, the gains from stock-price based regulation fall and converge to the gains from the combined regime.

Although a number of extensions remain to be considered, such as an analysis with explicit demand conditions and where we calculate total (consumer plus producer) welfare, or experiments for alternative calibrations of the transition probability matrix, it seems that a stock-price based regulatory regime is promising in terms of its ability to control strategic behavior by firms.

[16] FaBIO: is this explanation OK?

Table 1: Numerical Experiments

Experiment	γ_0	γ_1	γ_2	γ_3	δ (%)	LOSS (%)
No shocks (1st best)	1.40	.0	0	-	0.00	0.00
$\gamma_1 = 1, \gamma_2 = 0$ (Cost Plus)	0.38	1	0	-	10.00	8.00
$\gamma_1 = 0, \gamma_2 = 0$ (Price Cap)	1.46	0	0	-	0.00	6.00
$\gamma_2 = 0$ (Schmalensee)	1.02	.4	0	-	4.00	3.60
Stock Price Based regulation						
$\sigma = .0001, \gamma_2 = 1$	1.82	.6	1	1.0	4.75	2.36
$\sigma = .0001, \gamma_2 = 10$	10.82	.7	10	1.0	3.93	1.26
$\sigma = .0001, \gamma_2 = 1000$	1000.72	.7	1000	1.0	3.50	0.89
$\sigma = .05, \gamma_2 = 1$	2.00	.5	1	1.1	3.75	3.24
$\sigma = .05, \gamma_2 = 10$	10.60	.8	10	1.0	4.49	1.49
$\sigma = .05, \gamma_2 = 1000$	1000.60	.8	1000	1.0	4.01	1.16
$\sigma = .1, \gamma_2 = 1$	1.60	.6	1	.8	6.00	3.60
$\sigma = .1, \gamma_2 = 10$	10.60	.8	10	1.0	5.19	2.74
$\sigma = .1, \gamma_2 = 1000$	1000.60	.8	1000	1.0	4.80	2.65
σ=.2, $\gamma_2 = 1$	1.82	.4	1	.8	4.00	3.60
σ=.2, $\gamma_2 = 10$	9.02	.4	10	.8	4.00	3.60
σ=.2, $\gamma_2 = 1000$	801.02	.4	1000	.8	4.00	3.60

Appendix

We here describe the procedures and simplifications used in our calculations. As already mentioned, to solve for the optimal linear regime we make a grid for the values of (γ_0, γ_1, γ_2, γ_3), and evaluate the expected price for each of them. We try for wide range of intervals for γ_0, but kept the step between to consecutive γ_0 values always equal to 0.02. For γ_1 we always chose the interval from 0 to 1.5 with step 0.1. For γ_2 we tried only some special values, as described in table 1. For γ_3 we always chose the interval from 0.8 to 1.3 with step 0.1.

In order to obtain the expected price, we have first to solve for the expected profit. For that, we write the stock price equation as

$$S_t = E_t\left[\frac{\gamma_0 + \gamma_1 C_t - \gamma_2 S_t - \alpha_{t+1} - \psi(\delta_{t+1}, \theta_{t+1})}{1+r}\right] + \frac{\pi^e}{r(1+r)} + \xi_t \quad \text{, when } S_t < \gamma_3$$

(A1)

$$S_t = E_t\left[\frac{\gamma_0 + \gamma_1 C_t - \gamma_2 \gamma_3 - \alpha_{t+1} - \psi(\delta_{t+1}, \theta_{t+1})}{1+r}\right] + \frac{\pi^e}{r(1+r)} + \xi_t \quad \text{, when, otherwise, } S_t \geq \gamma_3$$

where π^e is the expected profit. The implicit approximation made here is that "Markov process" for α lasts only two periods. That is, the expected profit from $t + 2$ onwards is independent of the values for the cost C_t. We then write

$$\pi^e = \gamma_0 + \gamma_1 E[C_t] - \gamma_2 \{qE[S_t / S_t < \gamma_3] + (1-q)\gamma_3\} - E[\alpha_t + \psi(\delta_t, \theta_t)]$$

(A2)

where q is the probability that $S_t < \gamma_3$. To solve numerically for π^e we first find determine q as a function of the other variables by finding the "limiting values" for ξ for each combination (α, θ), i.e., the values for ξ which make $S = \gamma_3$. Then we create a grid for q (from zero to one with step 0.1) and plug (A1) into (A2). After π^e is found for all q's, we search for the pair (q, π^e) that implies in the best solution for the system (A1)-(A2).

Finally, we tested for all (γ_0, γ_1, γ_2, γ_3) combinations if the individual rationality was satisfied for all (α, θ) cases. The reported values for (γ_0, γ_1, γ_2, γ_3) correspond to the minimum expected price that satisfy the individual rationality constraint.

To check for the amount of computational error that comes from the approximations, we solved numerically for the case without any shocks (1st best). We obtain that the welfare loss in this case is 0.1%, rather than zero. This error is rather small compared with the other welfare loss values, what indicates that the approximations we made are not generating important errors.

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