Technical Details of the Incentive Power Study

This paper presents the technical details of our incentive power model. We emphasize the assumptions that underlie the model calculations and the development of regulatory scenarios. There is also a brief description of the program used to "solve" for the firm's optimal behavior given the regulatory environment it faces.

A.1.1 The Firm's Objective

We assume that the utility offers only one service. Demand is constant and there is no input price inflation. Input prices and the level of service demanded cannot be influenced by company actions. The price of the utility's service is set by regulators. However, the utility is able to reduce capital expenditures (capex) and operating expenditures (opex) over time through effort.

The objective of utility management is to maximize the NPV of profits less its valuation of the distress costs of cost containment initiatives. More formally, the firm will maximize

$$NPV = \sum_{t=1}^{\infty} \beta^t FCF_t(\varepsilon) - \sum_{t=1}^{\infty} \beta^t \varphi_t(\varepsilon). \qquad (1)$$

Over the space of possible efforts ε, where β is a discount factor, $FCF_t(\varepsilon)$ is the impact of effort ε on the firm's free cash flow in year *t*, and $\varphi_t(\varepsilon)$ is the implicit (*i.e.* non-monetary or distress) costs due to effort. Any explicit (*e.g.* upfront) costs associated with cutting costs in the long run are included in measured free cash flow.

Free cash flow is the amount of economic (non-accounting) profit due to the cost reduction effort that the firm can keep after taxes and any earnings sharing provisions of the regulatory system. The standard formula for free cash flow is:

$$FCF_t = (1-T)EBIT_t + depreciation_t - capex_t \qquad (2)$$

where $EBIT_t$ is the accounting measure of earnings before interest and taxes, *T* is the applicable tax rate, $depreciation_t$ is the capital deprecation in year *t* and $capex_t$ is the capital expenditure in year *t*. The idea behind this formula is to adjust the accounting measure $EBIT_t$ to what the firm actually receives by removing taxes, adding back $depreciation_t$ and subtracting off $capex_t$.

When maximizing NPV , the firm wants to consider the free cash flow due to effort level ε given the regulatory regime. So the firm uses:

$$FCF_t(\varepsilon) = (1-T)EBIT_t(\varepsilon) + depreciation_t(\varepsilon) - capex_t(\varepsilon) \quad (3)$$

Where each component is a function of effort and represents the impact of effort, not the value for the entire firm. For example, $depreciation_t(\varepsilon)$ is not the firm-wide level of depreciation but the impact of the cost reduction projects at effort level ε on depreciation. Each of these functions vary between regulatory regimes.

A.1.1 The Technology of Cost Reduction Activities

Management is able to reduce capex and/or opex over time. However, such cost reduction activities require effort. Let x_t and y_t denote the amount of capex and opex reduction efforts in period t. Values of x and y are chosen in each year t. However, the number of years between when a cost reduction activity is undertaken and the time of the next price review will vary. The amount of time before the next price review can affect the benefits associated with actions taken to reduce costs, and the model also reflects this fact. We restrict the firm's chosen values of x and y to be non-negative and small enough that they still result in cost reduction instead of cost increase. This assumption rules out scenarios where firms can engage in wasteful spending in the reference year of a rate plan to raise their costs, and prices, at the next regulatory review.

The impacts of cost reduction efforts on cost are given by the equations

$$capex_t - capex_{t-1} = -(\alpha_x x_t - \alpha_{xx} x_t^2) \quad (4a)$$

$$opex_t - opex_{t-1} = -(\alpha_y y_t - \alpha_{yy} y_t^2) \quad (4b)$$

The squared terms together with the signs assure that costs are a decreasing function of effort, but as effort increases the effect on costs is less prominent.

Reducing opex or capex requires up-front implementation cost. For capex, these up-front costs are given by the equation

$$UFC = p_x x . \quad (5)$$

Here, p_x is the "price" associated with the cost reducing activity. It is important to note that these are "real" monetary costs that both affect profits and are observed by the regulator and, therefore, can be considered at price reviews.

In addition to these monetary costs, the firm also bears “distress” costs associated with cost reduction activities. These costs are designed to capture the notion that cost reduction is taxing work for managers, perhaps because it is unpleasant to fire people or because some costs are actually perks for the manager. Weassume that distress costs are captured in a linear function in effort

$$\varphi_t = \sigma_x x_t \,. \qquad (6)$$

Our approach is very flexible. For both opex and capex reduction activities, we can change the values of parameters α, σ, p, (both linear and squared terms), and the length of time when costs are reduced. The two lengths of time considered are one year (which we call one-off cost reductions) and forever (permanent cost reductions). .

Opex and capex reductions can be modeled separately (by setting some parameters to zero) or considered together. There are a total of 7 parameters that can be varied and that jointly determine the costs and benefits associated with particular cost reduction activities.

Coefficients on the linear terms play a crucial role in this model, since they affect whether or not any initiatives will be undertaken. For example, for a given regulatory environment, the desirability of undertaking efforts to reduce capex depends on the relationship between α and $(\sigma + p)$. If the former is too low relative to the latter parameter, the firm will not find it profitable to engage in capex reductions.

A.1.3 Regulatory Regimes

Let us now consider the possible systems used to set prices. In the beginning, before the firm makes its choices for the amount of cost reduction activities, the regulator sets up a regulatory plan (regime), which is a combination of rules:

- What portion of earnings (accounting or real, both can be modeled) the firm is allowed to keep every year;
- How often the price can be updated (every 3, 5, or 10 years) to reflect recent changes in cost; and
- How the revenue requirement is updated when updates do occur, particularly whether it is based on:

– costs in the last year before the review
– an average of the costs over several prior years (a “rolling” mechanism)
– a combination of the costs that actually incurred in prior years and some externalized measure such as the revenue requirement at the end of the previous plan
– a combination of a “rolling” measure and some externalized measure

The provision used to determine the amount of profit retained by the firm is called an earnings-sharing mechanism (ESM). ESMs used in modern regulation can include bands that allow a firm to retain a greater share of incremental profit as returns increase (a progressive ESM) or bands that allow a firm to retain a lower share of incremental profits as returns increase (a regressive ESM). In this study we consider only ESMs with the same company/customer split for all earnings variances.

Let us now discuss mathematical treatments of the revenue requirement update (allowed revenue update) options. To illustrate the possibilities we consider a plan term of 5 years. In all years of the plan *allowed revenue* is fixed at the pre-determined (in year 0) level Rev_1. At the end of year 5, the regulator updates the price level to a new value, Rev_6, which will be allowed from year 6 to year 10. Consider the following regulatory options:

$$Rev_6 = (1-\gamma) Costs_5 + \gamma b \tag{7a}$$

or

$$Rev_6 = (1-\gamma)\frac{Costs_1 + Costs_2 + Costs_3 + Costs_4 + Costs_5}{5} + \gamma b \tag{7b}$$

where b is an externalized measure outside the firm’s control and γ is a number between 0 and 100%.

The former option is a weighted average of the last year’s cost and the externalized measure, with fraction γ applying to the external measure. When $\gamma = 0$, this corresponds to a “standard” PBR plan price update. The latter is a “rolling” mechanism, where instead of the last year’s cost, the simple average of the costs over the term of the plan is used.

These two update options are not the only ones possible. For example, we can consider the following definition of a rolling mechanism

$$Rev_6 = (1-\gamma)\frac{Costs_3 + Costs_4 + Costs_5}{3} + \gamma b \qquad (7c)$$

Here, only the three last years at the end of the term of a plan are "rolled" forward.

In the above specifications, to make the regulator less myopic and the model more realistic, test year costs should consider not just costs immediately before the plan is updated ($e.g.\, Costs_5$) but also the up-front, monetary costs associated with cost reduction activities as well as the cost savings that are expected to be incurred in the next regulatory plan because of programs that have occurred in the past. We therefore specify a *Corrected Costs* measure that includes these elements. The formula that describes corrected costs is

$$Corrected\ Costs_5 = Cost\ Trend + \frac{UFC}{Plan\ Term} - Anticipated\ Cost\ Reductions$$

Here, the cost trend is defined as the cost level that the firm would have in the absence of cost reduction initiatives. Since the cost trend does not change with effort, firms ignore this component when calculating the impact of cost reduction effort on their allowed revenue. *Anticipated Cost Reductions* are the actual reductions in costs that have not occurred yet but *will* occur over the term of the next regulatory plan because of initiatives that are observed at the time of the plan update. This essentially assumes that the regulator has foresight, can calculate cost reductions accurately, and in the absence of an enhanced incentives or similar mechanism, will transfer these efficiency gains to customers. The term (*UFC/Plan Term*) implies that the upfront costs associated with cost reduction initiatives will also be reflected in costs that are used to set future prices and, for simplicity, these costs are amortized evenly throughout the term of the next regulatory plan.

We consider two "polar" forms of regulation: the cost-plus regulation, under which no incentives for cost reductions are induced andthe firm gets 0 *NPV* of profits from any cost reduction activity , and the riskiest form of "full externalization" of future rates, that can be thought of as a 10-year plan with rates fully de-linked from costs. Full externalization produces maximal incentives, so we say $NPV_{fullextern} = NPV_{\max}$.

In closing this discussion, please note that the model does not currently permit the regulator to impose a "stretch factor" that would cause prices to fall gradually in real terms. This is a potential area for future research.

A.1.3 Quantifying Incentives

The regulatory system is announced to the firm in advance before it decides on a cost containment plan. The manager is therefore aware of the values of earnings sharing, plan length, and the other regulatory parameters. The initial values of capex, opex, and capital stock are also known. Then the optimization problem in this model is to choose a sequence of efforts *x* and *y* to maximize the value of the firm's objective function (1) subject to constraints (2)–(9).

Different plans can lead to different levels of cost reductions, and since they are modeled under the same framework, they can be compared to each other. For each plan *i* we consider $NPVF_i$ (the firm's NPV of after tax earnings from cost reduction projects), $NPVCB_i$ (the NPV of what customers get through reduced bills), and $NPVTX_i$ (the net present value of the additional tax revenue generated). The total net present value, or social welfare, of a plan is:

$$NPV_i = NPVF_i + NPVCB_i + NPVTX_i \,.$$

The greater the firm's incentive to reduce cost, the higher the total NPV will be. We define the (relative) incentive power of a plan *i* as the ratio of $NPVT_i$ to the maximum $PVCS_{\max}$, which is achievable under the full-externalization plan,

$$IP_i = \frac{NPVT_i}{NPVT_{\max}} \times 100\%$$

A.1.3 Parameter Choices

In calibrating the model, we bear in mind two major goals: a close match of economically significant parameters to the actual data and the interpretability. In particular, the following constants were chosen to set initial values for the model:

- Cost of funds r = 7% so that the discount factor (β) is 0.93
- Depreciation rate d = 5%

The other parameters α, p, and σ are calibrated to represent the following:

- We consider two types of opex or capex reduction projects: (1) initiatives that reduce costs permanently, and (2) one-off initiatives in a particular year
- For permanent cost reduction initiatives we consider cases with payback periods of 1, 3, and 5 years with effort level of 1. The payback period is defined here as the number of years needed for the company to break even, i.e. the time when total cost reductions up to date will recoup the up-front costs related to the project
- Capex and opex reductions are considered separately, which leads to 8 cases in total
- All 8 projects are additive, that is, are available for the pursuit by the company, independently from each other. The actual intensity of the projects undertaken and the choice of projects to pursue will depend on the regulatory regime. The final summary composes all projects.
- Project parameters are chosen so that the optimal effort level of each project is 10, and so at that level the firm reduces costs by about 7.5 million over all 8 projects. This represents about a 1.5% decrease each year for the typical firm.
- The implicit (regulatory/nuisance) costs φ comprise 20% of the explicit monetary up-front costs UFC, i.e. $\sigma = 0.20p$

Obviously, the payback period measure is very important in the model. When it is higher than the term of the plan, the opportunities for cost reductions will not be pursued at all. On the other hand, if the payback period is lower than the term of the plan, most of activities will be pursued at the beginning of the plan, with incentives falling towards the end of the plan.

A.1.3 Model Solution

The model is hard to handle analytically (especially given the variety of the plans), so we use a computer procedure that searches over possible values of *x* and *y* to maximize the value of the objective function under a given plan (i.e. for specified values of plan length, γ, *s*, etc.) and computes and reports the resulting changes in capital, costs, and eventually the present values of profits, cost savings, and total social benefits. This procedure is run for as many different plans of interest as specified by an input file, and the results for each plan are saved automatically into a csv-file (file with comma-separated values), from which they are incorporated then into an Excel file to produce final tables and graphs.

To describe how such a procedure works for a specified plan, let us first make a few comments on the nature of the optimization problem. For a given plan, it is a quadratic optimization problem with non-negative choice variables $\{x_t\}_{t=1}^{\infty}$ and/or $\{y_t\}_{t=1}^{\infty}$. We use a modified line-search algorithm to find the firm's optimal effort levels (those that maximize their profits). Because of the quadratic nature of the problem, we know that any local maximum we find will in fact be a global maximum.