Adjustment Mechanisms

James Woods

Some Problems with Rate Setting

- Rate of return regulation is periodic
  - Either the utility or the PUC can start a new rate case
  - PUC if profits seem high
  - Utility if profits seem low
- Usually 3-5 years between – called “regulatory lag”.
- This may limit incentives to make cost reducing investments.
- May cause wide swings in regulated prices (Fuel prices changing)

Evaluating Lag Requires Us to Deal with Time

- This is time consistent time value of money
- Standard topic in some intro economics courses
- Engineers will have seen it in their engineering economics courses, EC314 at PSU.

Assumptions

These are demonstrably false but give us tractable methods.

- Costs and benefits of equal size have equal value in all time periods. *Can evaluate without worrying about wealth or taste changes.*
- The value of costs and benefits is independent of costs and benefits in other time periods. *No habit, addiction or hangovers.*
- Benefits offset costs. *Ever fought a parking ticket?*
- Future values are known with certainty. *Math is easy*

What it looks like

$$\sum x_n d(n)$$

- $d(n)$ is a discounting function.
- Many are possible but only a few are time consistent.
  - $d(n) = \frac{1}{(1+r)^n}$ for discrete time.
  - $d(n) = \frac{1}{e^{rn}}$ for continuous time.

Example of Time Inconsistency

Back in the day I did this in class with real beer. Now, it's a policy violation.

- Chose 6-pack of beer a month and a day from now or 1 beer a month from now.
- A beer right now or a 6-pack tomorrow.
- Many of you changed your mind.

Integer time

- Will say “Time 1”, “Time zero” because “1st time period is confusing”
- “Now” means time zero.
- Intervals are half open on the right, e.g., $[0, 1)$
- Jan 1, 1908 and Dec 31, 1908 are in the same period, but Jan 1, 1909 is not, when the unit of analysis is a year.

Time Consistent Integer Time Discounting

$$F = P(1 + i)^N$$

Symbolic notation depends on context.

- i = The interest rate
- P = Present worth *or* some value in time zero.
- N = N time periods from Now *or* Time N
- F = Future Value *or* Present Value in time N *or* A value in time N.

Easy Future Value Calculation

"If you deposit \$26 into an account that earns 2% a month, how much will be in the account after 500 months?"

$$F = 26(1 + .02)^{500} = 5.188708 \times 10^5$$

Easy Present Worth Calculation

"How much would you have to deposit now into an account that earns 10% per year to have 100K in 10 years?"

$$P = \frac{100K}{(1+.1)^{10}} = 38.5543289K$$

Incentives to Innovate

- Utilities have to impose a cost on themselves to innovate in time zero
- The cost to innovate is I_0
- The innovation reduces constant marginal costs in future periods of Δ_c
- The utility enjoys the cost savings until time t
- The regulators then reduce price by Δ_c
- The firm faces a discount rate of δ

Regulator never changes prices

A regulated firm will expend effort I_0 in time zero for change in cost Δ_c in future periods when:

$$I_0 \leq \sum_{n=1}^{\infty} \frac{\Delta_c}{(1+\delta)^n} = \frac{\Delta_c}{\delta}$$

Basically, as long as the sum of discounted benefits in the future is at least as big as the cost.

Now The Regulator Revises Prices Every Three Years

This means that all benefits of the investment, I_0, vanish after three years

$$I_0 \leq \frac{\Delta_c}{(1+\delta)^1} + \frac{\Delta_c}{(1+\delta)^2} + \frac{\Delta_c}{(1+\delta)^3} \leq \frac{\Delta_c}{\delta}$$

Note that savings in each year, Δ_c, must be larger than before to warrant expense, or I_0 must be smaller.

Longer Period Between Adjustments

The more investments you will see.

$$I_0 \leq \frac{\Delta_c}{(1+\delta)^1} + \frac{\Delta_c}{(1+\delta)^2} + \frac{\Delta_c}{(1+\delta)^3} \leq$$
$$\frac{\Delta_c}{(1+\delta)^1} + \frac{\Delta_c}{(1+\delta)^2} + \frac{\Delta_c}{(1+\delta)^3} \frac{\Delta_c}{(1+\delta)^4} \leq$$
$$\frac{\Delta_c}{\delta}$$

So, encourage innovation, more regulatory lag is good.

In Summary

- Because all cost savings are reflected in lower prices at the next rate case, there are some cost saving investments that are not made.
- More lag, encourages more cost saving investments.

Lag Can Also Be Bad

If there is general inflation, then lag can cause the utility to not capture the cost of service in price.

- Costs increase constantly
- Prices are only set periodically to match those current costs

Bad Lag

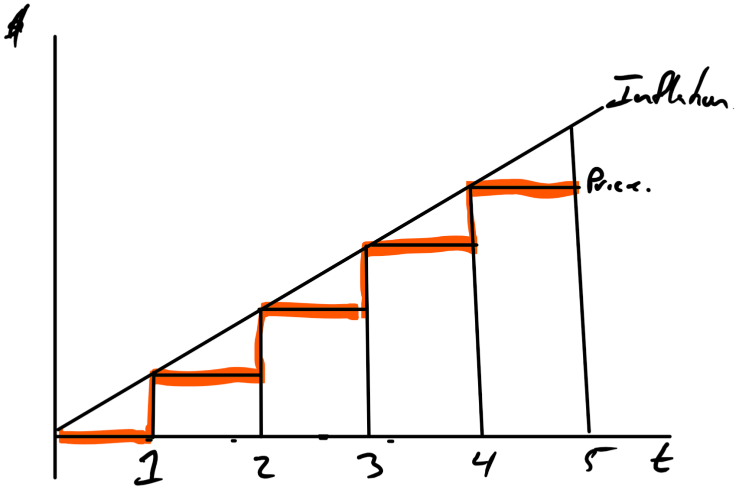

Figure 1:

Yes, there are fixes to this

- Set prices not to current costs, but expected average over until the next rate case taking into account the cost of funds.
- Have automatic adjustments based on actual inflation.
- Have costs that have a market basis pass through to consumer. More common with Natural Gas (https://www.nwnatural.com/uploadedFiles/25150-1.pdf)

Adjustment for Anticipated Inflation

- P: Rate (Price) at start of new rate period, time one (Note time convention difference.)
- π: Expected inflation
- r: Regulated rate of return
- T: Years between rate adjustment
- P^*: Fixed Inflation adjusted rate

$$\sum_{t=1}^{T} \frac{P(1+\pi)^{t-1}}{(1+r)^{t-1}} = P^* \sum_{t=1}^{T} \frac{1}{(1+r)^{t-1}}$$

Result is a porportional increase

$$\sum_{t=1}^{T} \frac{P(1+\pi)^{t-1}}{(1+r)^{t-1}} = P^* \sum_{t=1}^{T} \frac{1}{(1+r)^{t-1}}$$

$$\frac{P^*}{P} = \frac{\sum_{t=1}^{T} \frac{(1+\pi)^{t-1}}{(1+r)^{t-1}}}{\sum_{t=1}^{T} \frac{1}{(1+r)^{t-1}}}$$

- Book goes on to continuous time discounting but ...
- Note quite the average of starting and ending, closer to start than end.

The General Method of Automatic Adjustment

- Many names, I knew this as “CPI-X”.
- Book calls it “RPI-X”
- Says prices increase by some measure of the rate of inflation less some percentage amount X determined by:
  - K: Capital investments
  - Q: (Q)uality of service
  - Z: Input price changes and other factors
- The factors are often summarized through
  - Regression to give Total Factor Productivity (TFP), or
  - Data Envelopment Analysis (DEA)

This is rare in the US but most common in UK

How Automatic Adjustment Helps

- It unlinks *specific* investments in cost savings from the price.
- Assumes a general rate of investment in cost savings.
- If the utility invests more than assumed, more profits
- If the utility invests less than assumed, less profits

Yes, you do fight over the assumed rate. Yes, you do reset the rates based on cost but there is a longer lag period.

How to interpret the X

- There is an economy wide increase in productivity that increases output
- There is also monetary inflation.
- The price level goes up by monetary inflation less productivity

The X is the amount by which the industry exceeds the average increase in productivity.

Creating an X

- This is mostly through finding a good estimate of future total factor productivity (TFP)
- Many cautions here:
  - Lots of things go by the name TFP.
  - An economist would not recognize all of them as TFP

Economist Point of View

- You are estimating a regression equation.
- Some measure of output
- Some measures of inputs
- You may make some ad hoc adjustments.

You can do this from FERC Form 1 for the most part *Example PGE Form 1*

Make a Regression

- Include an output measure, for example total kWh.
- Include measures of input, labor hours, the capital stock of the plant and other factors.
- Include one last variable, the constant term. That will be your TFP measure.
- The rules differ by jurisdiction, UK, AU, NZ, etc.

For example:

$$KWh = AK^{\alpha}L^{\beta}$$

or

$$KWh = ln(A) + \alpha ln(K) + \beta ln(L)$$

Your regression will estimate A, α, and β. ln(A) is the growth in TFP.

Data Envelopment Analysis

- We had a brief introduction to Data Envelopment Analysis (DEA) earlier in the class.
- Our context was input-output space, i.e., index of inputs on the horizontal and index of outputs on vertical axis.
- DEA can also work in input space with isoquants

Example DEA in Input-Isoquant Space

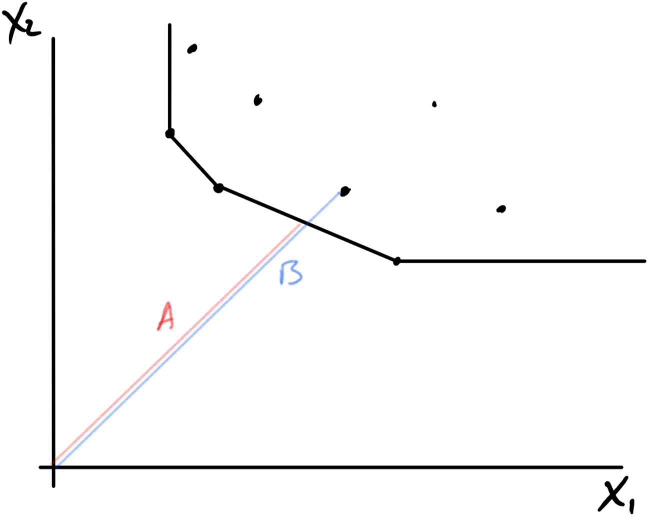

Figure 2:

Comment

- Technical Efficiency is A/B,i.e., best divided by you. [0,1].
- Assumption of homothetic production functions, optimal proportion of inputs is constant over a wide range of output levels.
  - Homothetic means, $f(ax) = a^n f(x)$
  - n $=$ 1 is constant returns to scale
  - n $<$ 1 is decreasing returns to scale
  - N $>$ 1 is increasing returns to scale
- Not a DEA expert but
  - How do you assess goodness of fit?
  - How do you evaluate input parameter choices?
  - What is random, the population or the sample?
  - Yes, you can bootstrap, but parameter estimates from data should come with:
    - Distribution of belief, or
    - Distribution of uncertainty.

Homothetic Production

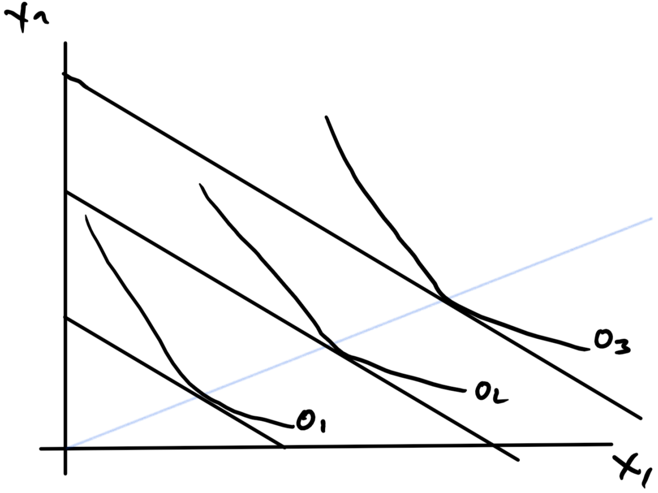

Figure 3:

Properties of homothetic production

- The ratio of inputs is constant over all scales
- If you know the optimum at one level, you can just multiply

Non-homothetic

- The most common kind are quasi-linear, $f(x, y) = a + g(y)$
- Proportions of inputs change with output levels.

Non-homothetic

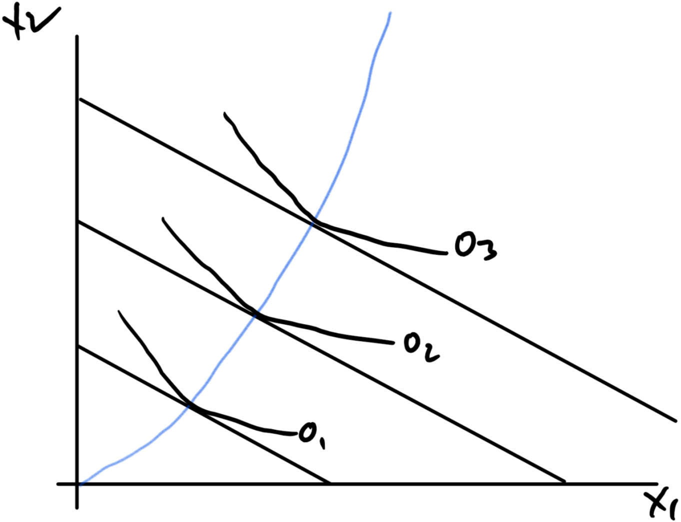

Figure 4:

How Efficiency Index Can Break

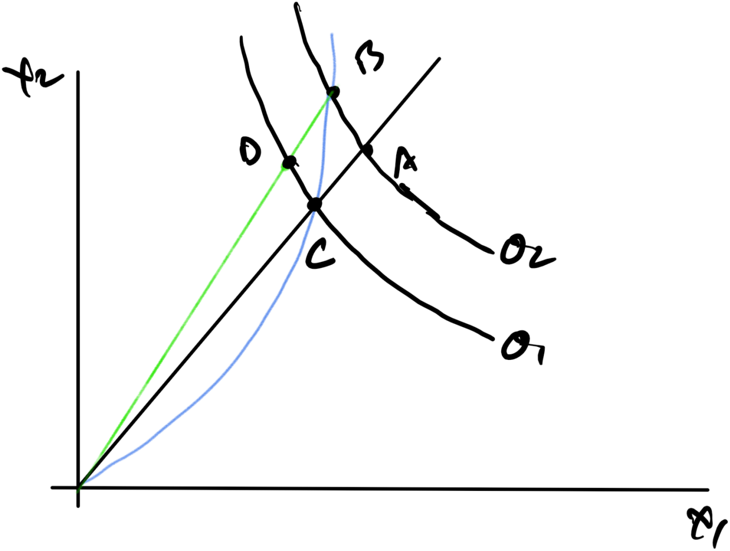

Figure 5:

How it Breaks

- Suppose you are at A with output slightly higher than baseline level
  - Technical Efficiency is OB/OA
  - But you should be at B
- Even if you were at B, you would still be technically inefficient
- Captures only the scale difference
- Does not get that the ratio of X_1/X_2 is wrong at those input price levels.
- That is the consequence of the homotheticity assumption.