Reconciling Incentive Regulation and Investment in Network Industries

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5th Conference on Applied Infrastructure Research

Berlin, October 7, 2006

An old, but timely regulatory problem

- In the U.S. regulation started with the investment issue: Franchise contracts.
- Doubts about investment incentives were replaced by “Hope” (1944).
- The Averch-Johnson effect (1962) was about regulatory incentives for excessive investment under rate-of-return regulation.
- Rate-of-return regulation has been replaced by incentive regulation. Has investment been neglected? What about the over-investment before 2000/2001?
- Today, regulation is accused of preventing or retarding investment: Deutsche Telekom wants a regulatory holiday as a prerequisite for extending its fibre network to the curb.

Overview

- Introduction
- Basic Considerations about Regulation and Investment
- Price-Cap Regulation Under Full Commitment
- Long-term Investment and Variable Commitment
- Conclusions

Specific investment problems in network industries

- Economies of scale lead to lumpiness
  - in size of increments
  - in lead time and duration
- Sunkness implies risks associated with real options
- Examples
  - Electricity transmission and distribution networks
  - Broadband telecommunications access

Different types of investment may be affected differently by regulation

- **Investment in cost reduction**
  - **Arrow effect**
- **Investment in quality improvements**
  - **Lower quality is substitute for price increase**
  - **Empirical effects inconclusive**
- **Investment in new products: Regulation constrains upside opportunities.**
  - **End user regulation**
  - **Regulation of bottleneck inputs**
- **Investment of alternative competitors**
  - **In complementary infrastructure**
  - **In bottleneck bypass (ladder of investment)**
- **Investment in capacity expansion (infrastructure investment) by incumbent : Focus of this talk**

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Regulation and investment

- **Incentives and governance**
  - **Prices as regulatory incentive variables**
    - **Current price regulation provides signal for expected price, which in turn determines output and therefore investment**
  - **Regulatory governance variables**
    - **(Lack of) regulatory commitment as source of investment risk**

Types of incentive regulation

- **Basis for incentives is asymmetric information.**

- **Non-Bayesian approach:**
  - **Based on simple principles**
  - **Directed towards welfare improvement, not optimization**
  - **Geared for application, but investments have generally not been addressed explicitly**

- **Bayesian approach:**
  - **Uses principal-agent framework**
  - **Full constrained welfare optimization:**
    - **No direct applicability, but addresses investment incentives via commitment**
    - **Qualitative insights usable for non-Bayesian approach in this talk**

Multiproduct issues

Price level regulation vs. price structure regulation (Germany seems to treat electricity transmission as a single product w.r.t. time and location!)

- **Price level regulation → average price →**
  - **Inverted 'U'-relationship between average price and investment**
    - **High price: Demanded quantity constrains investment**
    - **Low price: Low profit contribution/high risk constrains investment**
- **Price structure regulation → marginal price →**
  - **Capacity utilization (Peak-load pricing)**
  - **Direction and amount of capacity expansion**

Risk/price tradeoff from price level regulation

Rate-of-return regulation/cost-plus regulation

- **Low risk/incentives**
- **Medium/high average price**

Profit-sharing regulation

- **Medium risk/incentives**
- **Medium average price**

Price-cap regulation

- **Medium/high risk/incentives**
- **Low/medium average price**

Yardstick regulation

- **High risk/incentives**
- **Low average price**

In each case, regulator can make compensating risk adjustments.

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Price index approach (under vertical separation)

Linear price caps

- **Advantages**
  - Easy to understand
  - Incentives for cost reduction
  - Can lead to Ramsey pricing
- **Disadvantages**
  - Inefficient pricing between adjustment periods
  - Upward rigidity of prices can lead to under-investment and non-price rationing under uncertainty (Dobbs, 2004). Can obligation-to-serve overcome this problem?

Price index approach (under vertical separation)

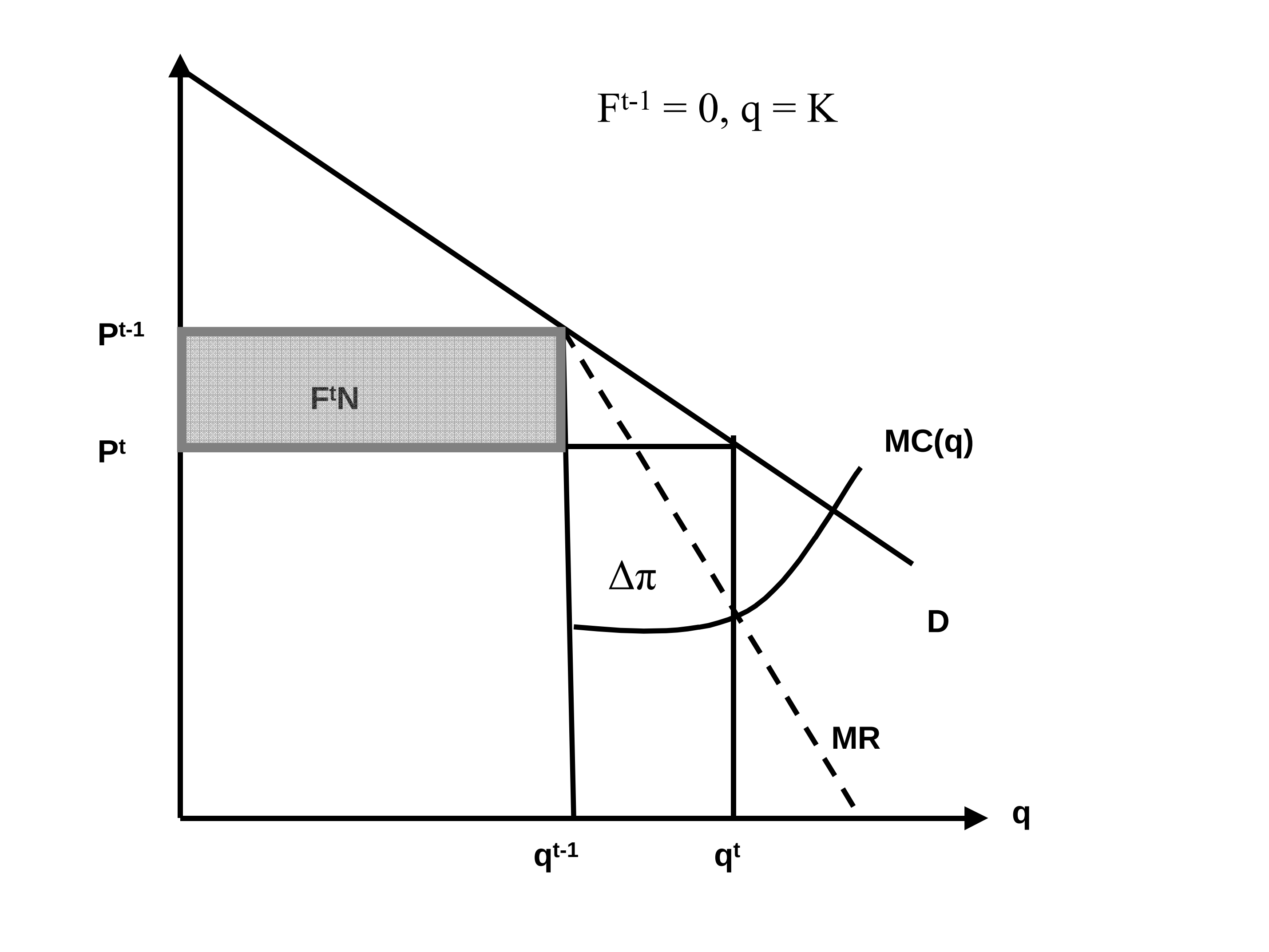
Two-part tariffs defined as a price index of variable and fixed fees

- **Variable fees: Utilization**
  - **Congestion**
  - **Peak-load pricing**
- **Fixed fees: Capacity expansion**
  - **Truly fixed fees**
  - **Discriminatory and partly variable: Access charges**
  - **Compensating adjustments for fluctuating variable fees**

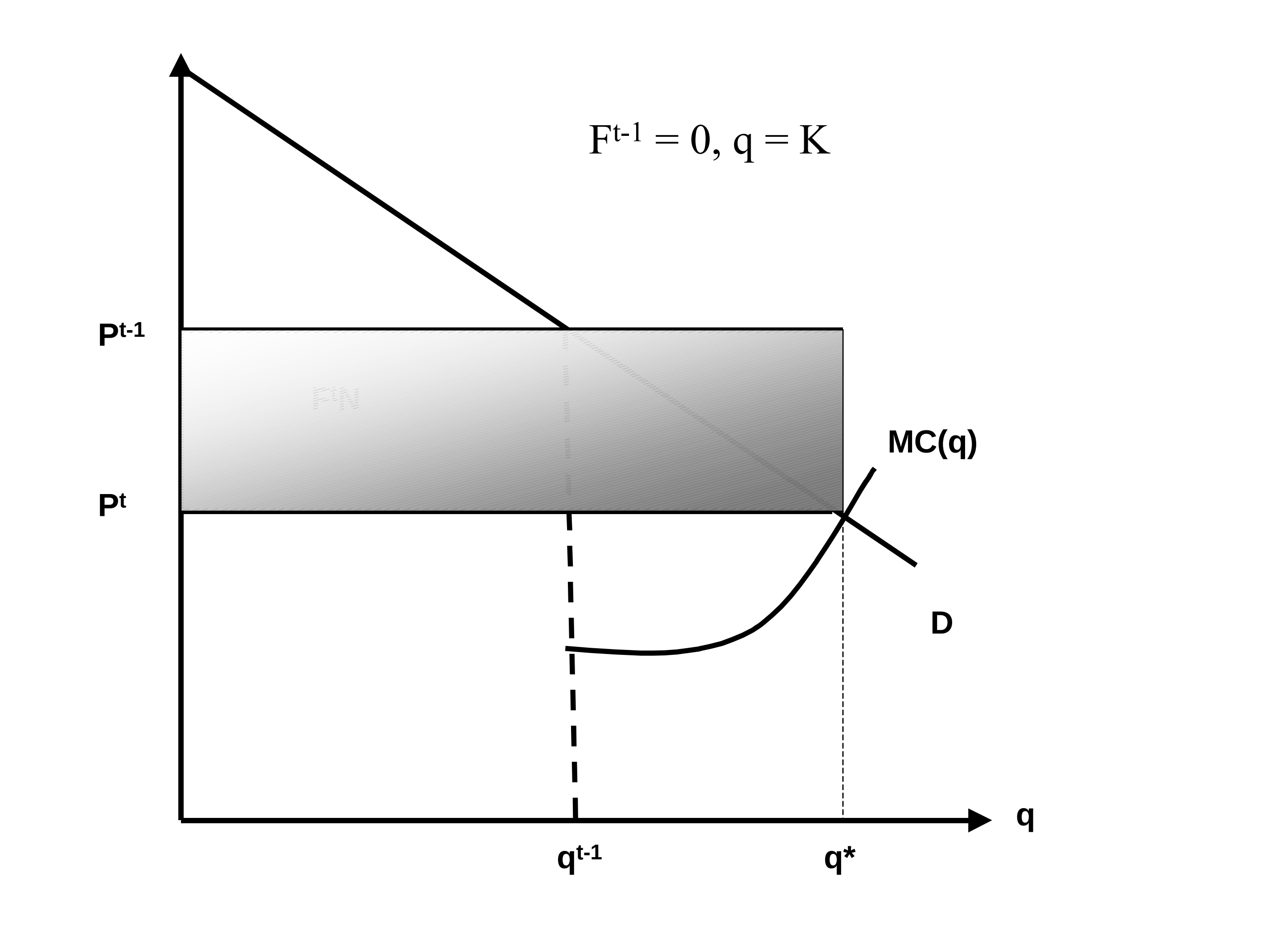
Weights of the price-cap index

- **Quantities of the previous period (chained Laspeyres price index)**
- **Projected quantities (idealized weights)**
- **Average of Laspeyres and Paasche**

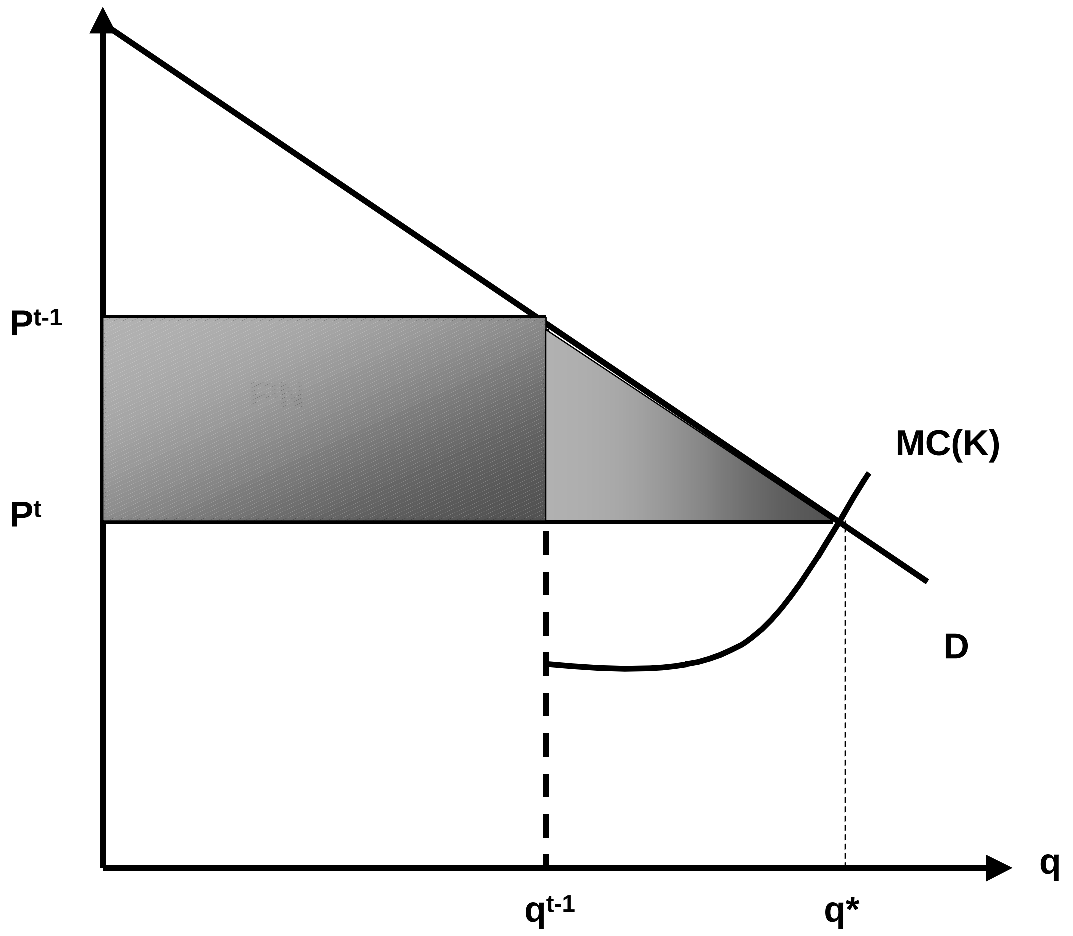
Price cap with Laspeyres index: $q^w = q^{t-1}$



Price cap with idealized weights ($q^w = q^*$)



Price cap with averaged Laspeyres/Paasche weights



Conclusions on two-part tariff price-cap constraint

- **Marginal price as main determinant of demanded quantity affects amount and direction of expansion investment (for given number of customers)**
- **Fixed fee helps keep average price constant and thereby allows for financing of investment.**
- **Two-part tariffs can reduce price truncation problem under uncertain demand.**
- **Price-cap weights substantially affect marginal price and average revenue (revenue/usage quantity)**

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The Bayesian approach: Main results on commitment

- The less the regulator can commit to incentives (and the associated profits and losses) the weaker should incentives be.

- The ability of regulators to commit (and the set of available instruments) should be constrained if regulatory capture is a possibility.

Regulatory governance for efficient investment

Regulatory governance aspects relevant for investment

- Safeguards against arbitrary changes
  - Due process
  - Contents
- Predictable criteria for regulation and deregulation
- Independence (credibility)
- Private ownership of incumbent
- Appropriate incentive structures
  - Fairness
  - Term structure of commitments

A synthesis approach based on a three-period framework

- The ultra-short period
  - Real-time pricing or peak-load pricing
  - Only allocative efficiency matters: No possibility for reducing operational or investment costs
  - Full regulatory commitment
  - Steep incentives to reach allocative efficiency feasible
- The short period
  - Pricing of fixed fees and (RPI-X)-type adjustments or profit sharing
  - Firm decisions on operations, repairs and maintenance costs
  - Full regulatory commitment
  - Steep incentives for cost reductions feasible
- The long period
  - Revisions of (RPI-X)-adjustments and of incentive mechanisms at the end of each long period
  - Infrastructure investments go beyond several long periods
  - Only very basic regulatory commitment beyond a long period
  - Little or no cost-reducing incentives feasible beyond a long period

A synthesis approach based on a three-period framework

- **Consequences of the three-period framework:**
  - **Find appropriate mechanism for each type of period**
    - **Revenue smoothing for fluctuating congestion prices through adjustment of fixed fees**
    - **Combine profit sharing with RPI-X adjustment or yardstick regulation for short periods**
    - **Long-term adjustments and adjustments for expansion investments via rate-of-return and “used and useful” criteria (with risk adjustment)**
      - **Regulation as shock absorber (Peltzman, 1976)**
      - **Two-part tariff can weaken excess capacity.**
  - **Affect period length (and commitment) through type of mechanism, but set it exogenously**

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Conclusions

- The longer the term of investments the less the applicability of incentive regulation
- Incentives for expansion investments depend
  - on short-term formula for price setting,
  - on the medium term price adjustment and
  - on the institutional setup for changing regulation.
- We only scratched the surface for expansion investments in a monopoly setting.
- Other types of investment may require different regulatory approaches to pricing.

Backup 1: Objectives

Regulator's objective:

- **Maximize consumer surplus plus profit, subject to breakeven constraint**
- **First order conditions (Coase)**

$p^t = \partial C/\partial q^t$ and $F^t = (C(q^t) - p^t q^t)/N$ **(3)**

Firm's objective function:

- **Maximize current profit, subject to price cap constraint (2)**
- **Firm's first order conditions imply**

$-(\partial q^t/\partial p^t)(p^t - \partial C/\partial q^t) = q^t – q^w$ **(4)**

$\partial q^t/\partial p^t$ **= slope of demand**

Firm could also make one-time investment and change prices in small steps.

Backup 2: Simplest two-part tariff price-cap constraint

Single Output, Stable Demand

$$p^t q^w + F^t N^w \leq (p^{t-1} q^w + F^{t-1} N^w)(1+ \Delta RPI - X) \qquad (1)$$

$$\frac{(p^t q^w + F^t N^w)}{(p^{t-1} q^w + F^{t-1} N^w)} \leq (1+ \Delta RPI - X) \qquad (1a)$$

$X = \Delta RPI = 0$ and with $N^t = N^w = N$

$$F^t \leq F^{t-1} + (p^{t-1} - p^t) q^w / N \qquad (2)$$

$$\Delta F / \Delta p \leq -q^w / N \qquad (2a)$$

Backup 3: Average of Laspeyres and Paasche price-cap index

$F^tN \leq F^{t-1}N + ½(p^{t-1} – p^t)(q^t + q^{t-1})$

Implies F.O.C.:

$-(\partial q^t/\partial p^t)(p^t - \partial C/\partial q^t) = q^t – q^{t-1} + (\partial q^t/\partial p^t)(p^{t-1} - \partial C/\partial q^t)$

$\Rightarrow p^t = \partial C/\partial q^t$ **for linear demand**

Backup 4: What happens if $\partial N / \partial F \neq 0$?

→ **Coase Tariff may no longer be feasible**

F.O.C. for π max become:

$$\frac{F^t \partial N^t / \partial p^t + (p^t - \partial C / \partial q^t)\, \partial q^t \partial p^t}{F^t \partial N^t / \partial F^t + (p^t - \partial C / \partial q^t)\, \partial q^t \partial F^t} = \frac{\mu^t q^w + q^t}{\mu^t N^w + N^t}$$

Corresponding Ramsey pricing condition:

$$\frac{F^t \partial N^t / \partial p^t + (p^t - \partial C / \partial q^t)\, \partial q^t \partial p^t}{F^t \partial N^t / \partial F^t + (p^t - \partial C / \partial q^t)\, \partial q^t \partial F^t} = \frac{q^t}{N^t}$$

Ramsey condition holds for idealized weights.

Backup 5: Price caps for multi-product network

$(\mathbf{p}^t\mathbf{q}^w + \mathbf{F}^t\mathbf{N}^w)/(\mathbf{p}^{t-1}\mathbf{q}^w + \mathbf{F}^{t-1}\mathbf{N}^w) \leq 1$,

with **p** an 1xM vector, **q** an Mx1, **F** an 1xL, and **N** an Lx1 vector.

For $\partial\mathbf{N}/\partial\mathbf{F} = \mathbf{0}$, we get first order conditions

$\partial\pi/\partial\mathbf{p}^t = \mathbf{q}^t + \mu^t\mathbf{q}^w + (\partial\mathbf{q}^t/\partial\mathbf{p}^t)(\ \mathbf{p}'^t - \ \partial\mathbf{C}/\partial\mathbf{q}^t) = \mathbf{0}$

and $\partial\pi/\partial\mathbf{F}^t = \mathbf{N} + \mu^t\mathbf{N} = \mathbf{0}$,

implying

$\mathbf{q}^t - \mathbf{q}^w = -(\partial\mathbf{q}^t/\partial\mathbf{p}^t)(\ \mathbf{p}'^t - \ \partial\mathbf{C}/\partial\mathbf{q}^t)$

Backup 6: Fluctuating demand with single output: Peak-load pricing

max $\pi^t = {}_j\Sigma p^t_j\, q^t_j + q^t_k\, {}_k\Sigma p^t_k + F^t N – C(q^t_k, K^t)$

s.t. ${}_j\Sigma p j_t q^w j + q^w_k\, {}_k\Sigma p^t_k + F^t N \leq {}_j\Sigma p^{t-1}{}_j q^w_j + q^w_k\, {}_k\Sigma p^{t-1}{}_k + F^{t-1} N$

j: off peak subperiods, k: peak subperiods

F.O.C.:

$(\partial q^t_j / \partial p^t_j)\, p^t_j = q^w_j – q^t_j$ **for all j**

and

${}_k\Sigma p^t_k - \partial C/\partial K^t = (q^w_k – q^t_k)\, {}_k\Sigma(\partial p^t_k/\partial q^t_k)$

Backup 7: Fluctuating demand with single output: Real-time pricing

Efficient Capacity Utilization ⇒ Spot Pricing ⇒ Average Revenue Constraint

Variable prices set by Transco, fixed fee determined ex post

$Q = {}_j\Sigma q_j + {}_k\Sigma q_k$, j = off-peak period, k = peak period

max $\pi^t = {}_j\Sigma p^t_j\, q^t_j + q^t_k\, {}_k\Sigma p^t_k + F^tN - C(q^t_k)$

s.t. ${}_j\Sigma p^t_j q^t_j Q^w/Q^t + q^t_k(Q^w/Q^t)\, {}_k\Sigma p^t_k + F^tN$

$\leq {}_j\Sigma p^{t-1}{}_j q^{t-1}{}_j Q^w/Q^{t-1} + q^{t-1}{}_k(Q^w/Q^{t-1})\, {}_k\Sigma p^{t-1}{}_k + F^{t-1}N$

First-order conditions for peak and off-peak:

${}_k\Sigma p^t_k - \partial C/\partial K^t = q^t_k(Q^w/Q^t - 1)_k\Sigma(\partial p^t_k/\partial q^t_k) + (1 - {}_kq^t_k/Q^t)(Q^w/Q^t)_k\Sigma p^t_k$

$p^t_j = q^t_j\,(\partial p^t_j/\partial q^t_j)(Q^w/Q^t - 1) + p^t_j(1 - q^t_j/Q^t)Q^w/Q^t$

→ **inefficiently high prices and small capacities, even with idealized weights**

Backup 8: Fluctuating demand with single output: Real-time pricing with market power

Competitive market rule and peak quantity weights

- $p_j = 0$, $p_k = P_k(q_k)$ and $Q^w = {}_k\Sigma q^w{}_k$ and $Q^t = {}_k\Sigma q^t{}_k$, where *k* is number of peak periods.
- Transco only sets capacity, not prices

First order conditions

- Off-peak prices: $p^t{}_j = 0$
- Peak prices: ${}_k\Sigma p^t{}_k - \partial C/\partial K^t = (q^w{}_k - q^t{}_k)\ {}_k\Sigma(\partial p^t{}_k/\partial q^t{}_k)$

Backup 9: Effect of Positive X-Factor

Price cap constraint (2) with ‘X’ $\neq$ 0**:**

$F^t \leq (1 - X)F^{t-1} + [(1 - X)p^{t-1} - p^t]q^w/N$

$\Rightarrow$ **Under max π^t no change in p^t compared to X = 0**

$\Rightarrow$**Linear price caps could be more efficient than two-part tariffs if** $X > L^{t-1}/2$**, where** L **= Lerner Index.**

$\Rightarrow$**Quantity growth factor $q^w(1+g)$ instead of X-factor**

Backup 10: "Variable" Fixed Fees and Optimal Investment

Based on average capacity demanded: $F^t = f^t K^t / N$

$\Rightarrow {}_k\Sigma p^t_k - \partial C / \partial K^t = -f^t$ (overinvestment)

Based on individual capacity demanded: $F^t = f^{\,t} q^t_{k,i}$

$\Rightarrow p^t_k + f^{\,t} = D^{-1}_k(q^t_k)$ for $q^t_k = K^t$ (underinvestment)

Based on a growth factor 'g' for the fixed fee: If price cap allows F^t then allowed revenue from fixed fee becomes $F^t(1 + g)N$

$\Rightarrow {}_k\Sigma p^t_k - \partial C / \partial K^t = {}_k\Sigma(\partial p^t_k / \partial q^t_k)([1+g]q^{t-1}_k - q^t_k)$

(investment depends on g)

Benchmarking of 'g': Use of exogenous growth factors

- Regional GDP growth
- Growth in electricity consumption