The Convergence of Simple Regulatory Incentive Mechanisms for Electricity Transmission Pricing/Investment

Ingo Vogelsang

April 14, 2016

Motivation

- I have worked on simple regulatory incentive mechanisms for almost 40 years and almost 20 years on such mechanisms for electricity transmission regulation.
- The purpose is to design mechanisms such that profit maximization by the regulated firm leads to goal fulfilment of the regulator, where the objective is assumed to be social surplus*) maximization.
- Such mechanisms are desirable, because the regulator typically is less well informed about costs and demands facing the firm and because the regulator can only do limited monitoring and enforcement. The mechanisms should therefore be self-enforcing.
- In particular, such mechanisms can induce optimal electricity transmission investments.

*) *Social surplus = consumer surplus + profits* = $V(p) + \pi$

Overview

- Sophisticated vs. simple approaches
- The simple approach
- Application of simple approach to electricity transmission networks
- Properties of the HRG mechanism
- Dealing with environmental and spill-over effects
- Private incentives versus Government planning
- Conclusions

Sophisticated vs. simple approaches

- Two basic types of approaches have been developed in the academic literature.
- The informationally sophisticated or "Bayesian" approach has dominated the theoretical literature and is associated with two Nobel prizes in economics to Myerson (2007) and Tirole (2014). The main early milestones here are Barron/Myerson (1982) and Laffont/Tirole (1986).
- Informationally demanding mechanisms are often called "Bayesian" because ***regulators***
  - start with a subjective a priori type distribution of firms
  - use Bayesian updating to reach posterior distribution.

Critique of sophisticated mechanisms

- Regulators cannot be monitored well by the public, because the type distribution is based on subjective probabilities, which makes it somewhat arbitrary.
- It is hard to gain quantitative results that can be used in the real world, which would make it highly complex for an application.
- However, the sophisticated approach provides strong insights into the incentive properties of regulation. For example,
  - Firms have to receive an information rent in order to be induced to "reveal" their type.
  - It is impossible to reach a first best outcome.
  - The less the regulator can commit to future policies the weaker incentives should be.
- → This approach is not very practical but insightful.

Simple approaches

- The informationally simple or non-Bayesian approach does not use a formal probabilistic model but uses mechanisms that translate the regulator's objective function into the firm's profit-maximizing objective.
- These mechanisms are typically more practical, easy to understand and are at least partially based on observable or even verifiable data.
- They come in two forms, one based on subsidies/taxes the other based on constraints/price caps.
  - The subsidy approach goes back to Loeb/Magat (L-M, 1979)
  - The constraint/price cap approach goes back to Vogelsang/Finsinger (V-F, 1979).

Simple approaches

- In spite of a number of improvements and a good empirical track record simple approaches so far remain imperfect.
- However, M.R. Hesamzadeh, J. Rosellon and S. Gabriel (HRG, 2015) have come up with a new proposal that
  - blends the mechanisms in the Loeb-Magat tradition with those in the V-F tradition and
  - is very promising for the application to electricity transmission pricing and investment.

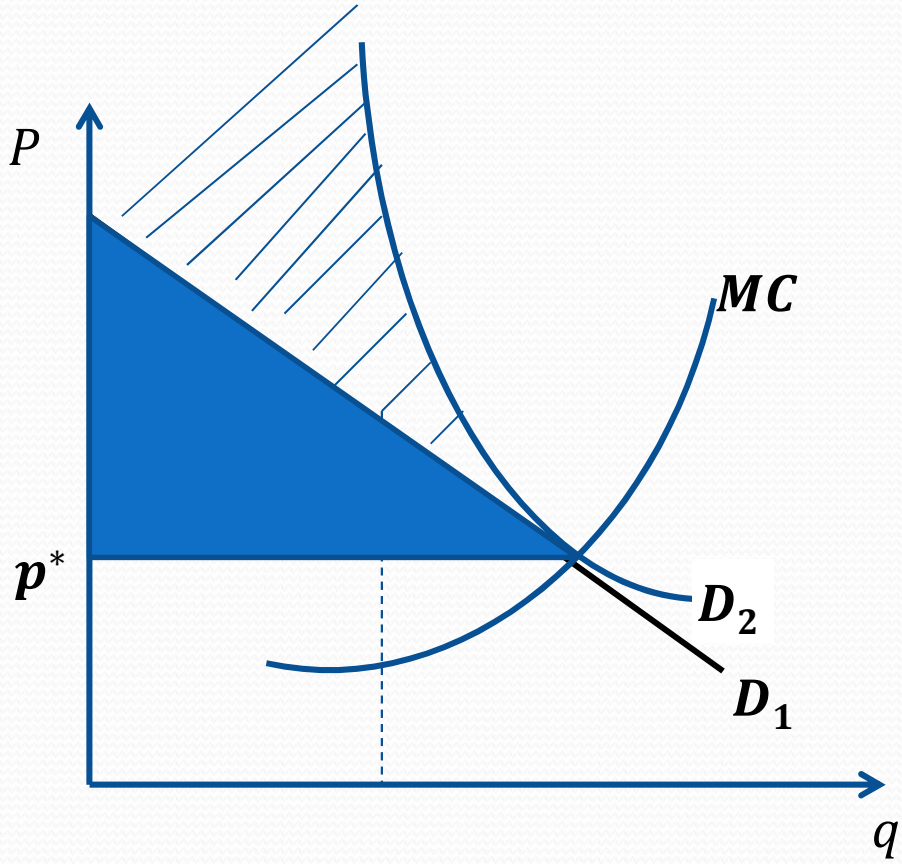
Overview

- Sophisticated vs. simple approaches
- The simple approach
- Application of simple approach to electricity transmission networks
- Properties of the HRG mechanism
- Dealing with environmental and spill-over effects
- Private incentives versus Government planning
- Conclusions

The simple approach: Loeb-Magat (1979)

- **L-M mechanism is very simple**: By providing the firm with a subsidy equal to the consumer surplus, regulator can achieve the first best outcome: Regulator and firm share the same objective function. →
  - Monopoly firm behaves like in competitive market, maximizing profit by charging $P = MC$.
  - Also, firm will minimize cost.
- Main assumptions:
  - ✓ Demand is common knowledge
  - ✓ Cost is private information, only known by the regulated firm
  - ✓ Financing a subsidy is cost free

Loeb-Magat mechanism if demand is uncertain



If demand can either be D_1 or D_2 the difference in subsidy between the two can be enormous → Since demand is not easily observable, there can be disputes about size of subsidy.

Refinement of Loeb-Magat: Incremental surplus subsidy (Sappington/Sibley, 1988)

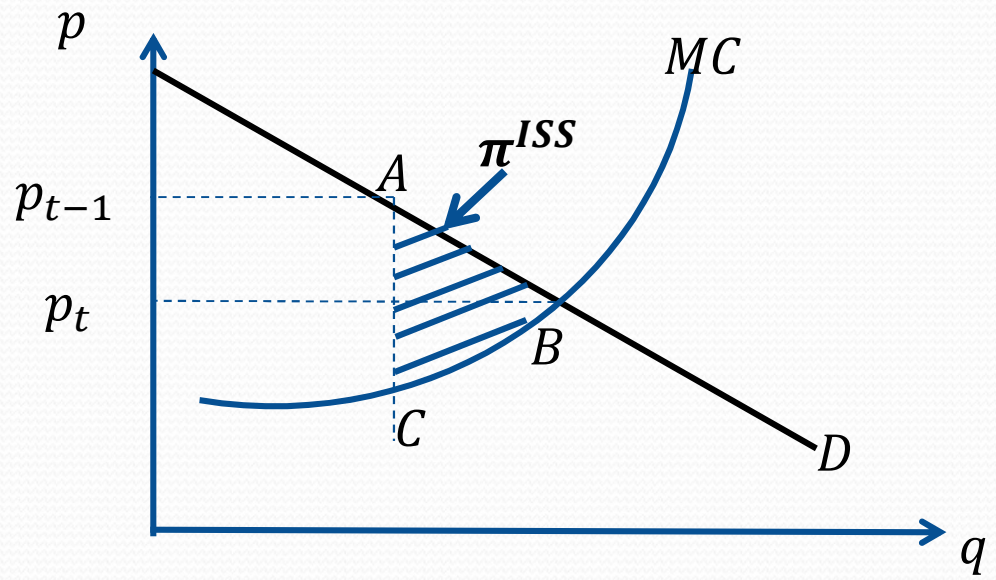
- Incremental surplus subsidy (ISS) reduces the subsidy problem and the problem of demand measurement: By providing the firm with a subsidy or taxing the firm such that its total profit equals the *change* in social surplus:
  - $ISS_t = V(p_t) - V(p_{t-1}) - \pi_{t-1}$

    $\pi_t^{ISS} = ISS_t + \pi_t = \Delta V_t + \Delta \pi_t = \Delta W_t$

p	transmission price	*V(p)*	consumer surplus
π	profit	*W*	social surplus = V(p) + π
MC	marginal cost	ISS	subsidy (tax)

Refinement of Loeb-Magat: Incremental surplus subsidy (Sappington/Sibley, 1988)

Firm: $\max_{\{p_t\}_{t=1}^{\infty}} \sum_{t=1}^{\infty}(\Delta V_t + \Delta\pi_t)\cdot(1+r)^{-t}$



- Summed over all periods the firm could earn at most $S_{ABC} = \Delta W* = W_{max} - W_0$. Any discounting over time will make the sume of profits less than S_{ABC}. Therefore, firm will immediately lower price to marginal cost so that

$$p_0 > MC, p_1 = p_2 = \cdots = p_\infty = MC$$

The simple approach: ISS

- Benefits:
  - ✓ Immediate optimal pricing/investment
  - ✓ No rents earned after first period
- Issues:
  - ✓ Imperfect cost-reducing incentives
  - ✓ How to measure the change in consumer surplus?
  - ✓ There're two general issues with subsidies:
    - ✓ Where does regulator raise money for the subsidy?
    - ✓ Whom does regulator want to subsidize?

The simple approach: Vogelsang-Finsinger (1979)

- V-F use a price index approach: Price index of the firm's prices should be lowered by last period's (excess) profit margin

$$\underbrace{\frac{\sum_{i=1}^{n} p_i^t q_i^{t-1}}{\sum_{i=1}^{n} p_i^{t-1} q_i^{t-1}}}_{\text{Laspeyres price index}} \leq 1 - \frac{\pi_{t-1}}{\sum_{i=1}^{n} p_i^{t-1} q_i^{t-1}}$$

- Key idea: Firm should be able to reduce its price level if it makes (excess) profits.
- Using a **Laspeyres price index** the welfare increase is always greater than profit. Thus welfare increases as long as firm makes a positive profit.
- Total welfare reaches its maximum when firm is no longer making profit (Ramsey pricing condition).
- Price converges to Ramsey prices over time (not to marginal cost prices!).

The simple approach: Vogelsang-Finsinger (1979)

- V-F has weak cost-reducing incentives.
- Strategic issue:
  - If firm expects there will be V-F regulation, it may increase prices beyond monopoly prices or may increase costs prior to regulation.
- Convergence issue:
  - Mechanism only approaches welfare optimum over time. → Fundamental problem with regulation: World is changing → Regulation needs to update with changes in inflation, cost, demand, etc.

The simple approach: Littlechild (1983)

$$\frac{\sum_{i=1}^{n} p_i^t q_i^{t-1}}{\sum_{i=1}^{n} p_i^{t-1} q_i^{t-1}} \leq 1 + i - X$$

- Key idea: Instead of setting price based on last period's profit, price regulation should be adjusted to inflation minus expected productivity increases (based on Baumol, 1982).
  - Price also converges to Ramsey prices, however, with $\pi > 0$.
  - Price doesn't depend on cost, therefore, any reduction in cost will generate more profit for firm. Strong incentive of cost reduction.
- However, because the world changes in unforeseen ways, "X" has to be revisited from time to time.
  - An adjustment of X every few years (predetermined) creates "ratcheting problem".
  - Somewhere between pure price caps and rate of return regulation →
  - No full cost-reducing incentive and room for strategic behavior.

Overview

- Sophisticated vs. simple approaches
- The simple approach
- Application of simple approach to electricity transmission networks
- Properties of the HRG mechanism
- Dealing with environmental and spill-over effects
- Private incentives versus Government planning
- Conclusions

The simple approach: Two Part Tariff for Investment and Capacity Utilization

- Investment vs. usage: Vogelsang, JRE 2001
  - Investment by transmission company (Transco)
  - Independent system operator (ISO) calculates congestions prices and Transco receives network merchandising surplus.
  - Linear price caps would need to exceed marginal congestion costs by a lot to cover total costs.
  - → Explicit use of two-part tariffs in wholesale price caps in order to assure cost coverage, induce balanced network expansion and network utilization
    - If congestion charges increase (decrease) fixed fee decreases (increases) → Investment that decreases congestion is rewarded with an increase in fixed fee.
    - Approach has similarities with a capacity market

The simple approach: Two Part Tariff for Investment and Capacity Utilization

Vogelsang (2001) proposes the following approach:

$$\frac{\sum_{i=1}^{n} p_i^t q_i^w + F^t N^w}{\underbrace{\sum_{i=1}^{n} p_i^{t-1} q_i^w + F^{t-1} N^w}} \leq 1 + i - X$$

Price index defined on two-part tariffs

p	transmission price	*q*	transmission output
F	fixed fee	*N*	number of consumers
i	inflation rate	*X*	regulatory X-factor

The simple approach: Two Part Tariff for Investment and Capacity Utilization

- Hogan/Rosellon/Vogelsang (HRV, 2010) refine Vogelsang 2001 and show the applicability in a realistic electricity transmission context.
- Rosellon with various co-authors has applied and simulated this approach.
  - They showed that HRV was generally superior to other applied mechanisms.
  - A large role in this context have played the quantity weights of the underlying price index.
  - Averaged Laspeyres/Paasche weights turned out to dominate most other approaches. Since such weights are ideal for linear demand curves, this may have induced Rosellon to develop HRG.

The simple approach: Gans/King (2002) Applying ISDS to transmission investment/pricing

- Gans and King (2002) suggest using the ISS to induce efficient transmission investment. They note that the ISS would provide the firm with a reward (penalty) equal to the social surplus increase (decrease) in each period. They claim that the ISS would also be capable of alleviating market power by generators efficiently.
- All this is based on the assumption that the relevant information is at the disposal of the regulator. Gans and King suggest that this information can be readily inferred by the ISO from demand bids and generator bids.
- A question that has been raised with this approach is to what extent the short-run bidding behavior can be used as a guide for long-term investments.
- A further issue is that the approach could require extraordinarily high fixed fees or subsidies, when new lines would be added.

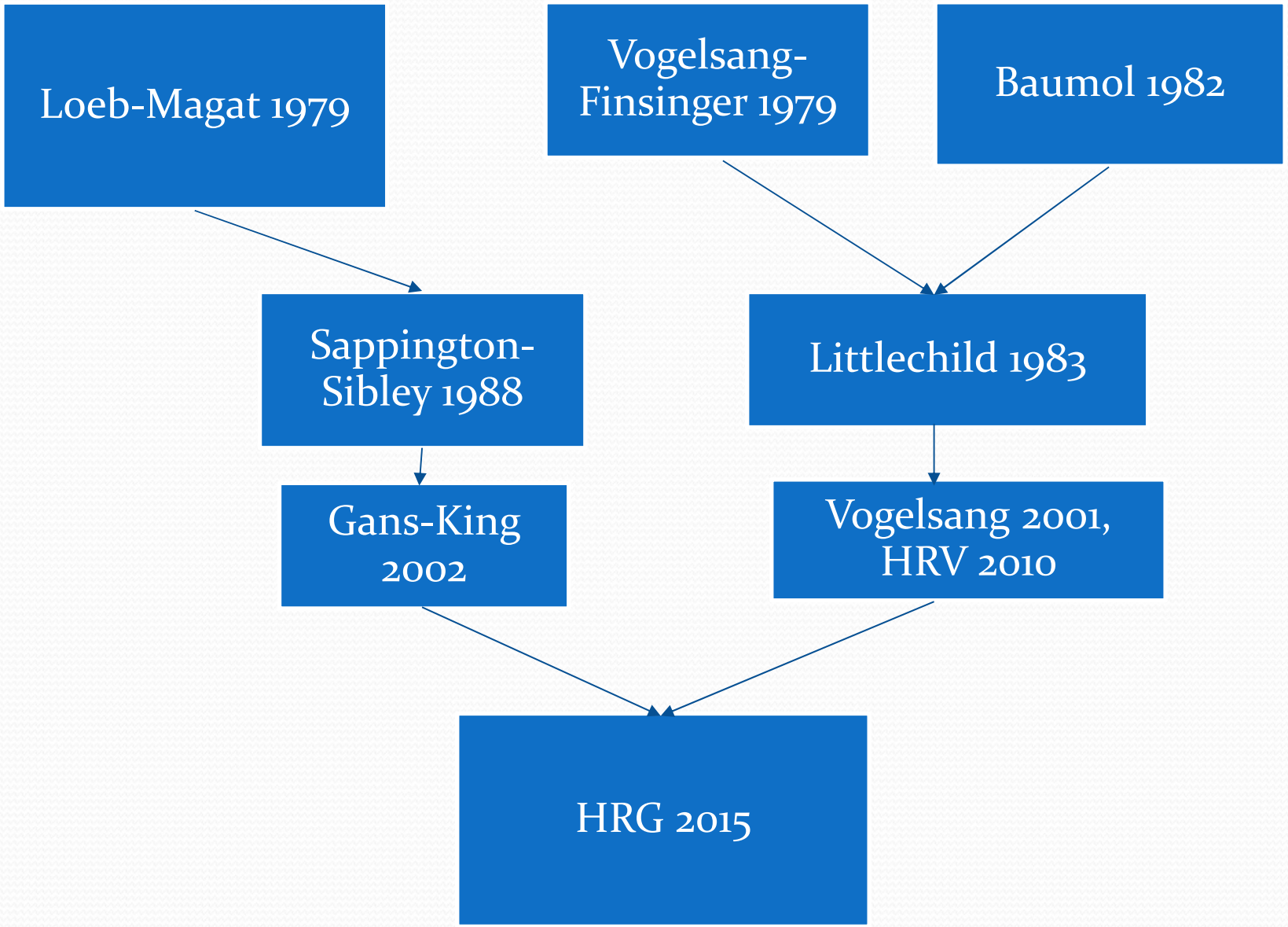
Applying the simple approach to transmission investment/pricing

- Remaining drawbacks of the HRV and Gans/King approaches:
  - Gans/King: Subsidies/taxes
  - HRV: Slow convergence
  - }→ New approach desirable
- New approach by M.R. Hesamzadeh, J. Rosellon and S. Gabriel (HRG, 2015) combines Gans/King (or ISS) and HRV:
  - Transco can choose congestion prices (indirectly, via investment), while the fixed fee at time t is set as $F_t = F_{t-1} + \Delta V$.
  - HRG differs from ISS by adding last period's profit to the firm's reward and differs from HRV by replacing $(p_{t-1} - p_t)q_{t-1}$ with the accurate consumer surplus change. The HRG mechanism therefore represents the convergence of the development of the two types of mechanisms taking from L-M the consumer surplus approach and from V-F the price-cap approach.

Applying the simple approach to transmission investment/pricing: HRG

- Compare total profits under the three mechanisms
  - ISS: $\boldsymbol{\pi_t}^{\boldsymbol{ISS}} = ISS_t + \pi_t = \Delta V_t + \Delta\pi_t = \Delta W_t$
  - HRV: Assuming binding HRV constraint and i - X = 0
  - $\rightarrow \boldsymbol{\pi_t}^{\boldsymbol{HRV}} = \pi_t + N_t[(p_{t-1} - p_t)q_{t-1}/N_{t-1} + F_{t-1}]$
  - Assuming further that N = given
  - $\rightarrow \boldsymbol{\pi_t}^{\boldsymbol{HRV}} = \Pi_{t-1} + \Delta\pi_t + (p_{t-1} - p_t)q_{t-1} \leq \Pi_{t-1} + \Delta W_t$
  - HRG: $\boldsymbol{\pi_t}^{\boldsymbol{HRG}} = \Pi_{t-1} + \Delta V_t + \Delta\pi_t = \Pi_{t-1} + \Delta W_t$
  - Here π represents profits from variable fees, while Π includes fixed fees, and π is total profit after applying the mechanism.

Relationship between simple incentive mechanisms



Overview

- Sophisticated vs. simple approaches
- The simple approach
- Application of simple approach to electricity transmission networks
- Properties of the HRG mechanism
- Dealing with environmental and spill-over effects
- Private incentives versus Government planning
- Conclusions

Main properties of HRG in the absence of externalities and spill-overs

- Desirable properties
  - Provided that no users are excluded, always optimal investment/pricing, because firm captures (and keeps) all allocative efficiency effects
  - Cost minimization, because firm suffers full losses (gains full benefits) from cost increases (from cost reductions)
  - No subsidies/taxes: Firm depends only on market-based income.
  - Mechanism is simple and easy to understand: That does not mean that application to transmission networks is simple, but complications result from the nature of transmission cost and demand functions.
  - The variables necessary for implementation of the mechanism are observable and verifiable in the context of transmission networks.

Main properties of HRG in the absence of externalities and spill-overs

- Undesirable properties
  - Strategic investment/pricing possible before mechanism is implemented
    - Firm can permanently increase its profits under the mechanism through over-pricing (withholding of investment) before mechanism starts. → Monitoring is required, once the mechanism is considered and before it is implemented, or one could use a prior base year.
    - This is also an issue with ISS but to a lesser degree.
  - Users may be excluded through high fixed fees.
  - In a stationary environment firm gets all the incremental benefits.
  - Potentially excessive profits or losses if costs are reduced or increased or if demands shift
    - Requires skillful use of i-X type formula: Add Y-factor for demand growth or demand reduction

Long-term investment vs. short-term demand determination under HRG

- Just like for Gans/King (2002) a question with this approach is to what extent the short-run bidding behavior of demand determination can be used as a guide for long-term investments.
  - Rewarding the Transco ex post by using the consumer surplus based on actual demands will induce Transco management to do everything to learn about all factors influencing demand and to use their best predictions.
    - Transco has no incentive to misrepresent best demand predictions.
    - Ex post, if the prediction was wrong the Transco will make less profit than it would have under correct prediction.
    - However, loads may strategically use demand shading in auctions to avoid high fixed fees (Henze, 2016). Also, discrete bids may not fully describe demand.
    - There is some moral hazard possibility for Transco from the X- and Y-factor adjustments.
    - Also, long-term contract prices usually differ from average spot prices.

Comparative evaluation of the mechanisms

Mechanism / Objective	L-M	V-F	ISS	H-R-V	HRG
Static price efficiency	☺ always optimal	😐+ converges to optimum	☺ always optimal	😐+ converges to optimum	☺ always optimal
Productive efficiency	☺ always optimal	☹ weak	😐 weak incentives	☺always optimal	☺ always optimal
Dynamic efficiency in a stationary environment	☺ always optimal	😐+ converges to optimum	☺ always optimal	😐+ converges to optimum	☺ always optimal
No subsidies	☹ high subsidies	☺no subsidies	😐-some subsidies	☺ no subsidies	☺ no subsidies
No excess profits	☹ high excess profit	😐+ excess profit eliminated	☺ arbitrarily low profit	😐+ intermediate profit	😐- high profit possible
No strategic behavior	☺ none	😐- optimum can be delayed	☺ only before	😐- optimum can be delayed	☺ only before
Simplicity	☺ simple	☺ simple	☺ simple	☺ simple	☺ simple
Verifiable	☹ full consumer surplus hard to observe	☺ uses only observable variables	😐+ change in consumer surplus could be observed	☺ uses only observable variables	😐+ change in consumer surplus could be observed
Score	2	3	5	5	6

Overview

- Sophisticated vs. simple approaches
- The simple approach
- Application of simple approach to electricity transmission networks
- Properties of the HRG mechanism
- Dealing with environmental and spill-over effects
- Private incentives versus Government planning
- Conclusions

Dealing with environmental and spill-over effects

- Optimality of HRG is based on
  - measured costs = social costs
  - measured consumer surplus = social benefits.
- Externalities that could lead to deviations from optimum largely derive from environmental effects and spill-overs from the general-purpose technology property of electricity.
  - Environmental externalities can be negative (burning of fossil fuels to generate electricity) or positive (use of electric instead of gasoline-based vehicles).
  - Spill-overs are generally positive: Cheap electricity benefits uses of all kind.
- Transmission investment can increase competition in generation.

Dealing with environmental and spill-over effects

- Including external effects in the mechanism would mean to add benefits to or subtract social costs from the fixed fees of the regulated two-part tariff.
  - That requires cost-benefit analysis.
  - It is generally difficult to include several objectives in the same regulatory instrument and achieve good results.
    - Example: Revenue caps (see Brennan's – De-coupling papers)
- Better to resolve the externality issue with separate instruments.
  - If emissions from fossil fuels are restricted by carbon tax or cap-and-trade or other quantitative constraints → The firm's costs should reflect social costs.
    - *Check if market price for clean energy certificates equals social benefit.*
  - Similarly, government may subsidize solar or wind energy, leading to lower costs for the electricity generators.
  - Established mechanisms are still lacking for environmental costs of high-voltage transmission lines.

Overview

- Sophisticated vs. simple approaches
- The simple approach
- Application of simple approach to electricity transmission networks
- Properties of the HRG mechanism
- Dealing with environmental and spill-over effects
- Private incentives versus Government planning
- Conclusions

Private incentives versus Government planning

- Many governments including Mexico use planning instead of private incentives for electricity transmission investment.
  - Is the incentive approach therefore useless?
  - Incentive approach assumes that Transco has all the relevant information about
    - Its own costs and investment timing/financing
    - The investment plans and costs of electricity generators
    - The investments in distribution grids and demands of load-serving entities (LSEs)
  - In reality complexity of transmission investment may require the involvement of all affected parties and therefore requires coordination between various stakeholders.

Private incentives versus Government planning

- I see three principal ways of transmission investment coordination between stakeholders
  1. Government planning that brings together stakeholders and lets government decide (current Mexican approach)
  2. (Coasean) bargaining approach between stakeholders with some voting rule about investment decisions and financing (Argentinian approach as described and analyzed by Littlechild, JRE 2012).
  3. Incentive approach for investment by a monopoly network provider, who is assumed to negotiate with/get information from other stakeholders (HRG approach)

Private incentives versus Government planning

- In my view, all three approaches need to achieve some incentive compatibility for the stakeholders involved.
  - Thus, approaches I and II need to think about incentives for all stakeholders, while approach III needs to be complemented by appropriate incentives for generators and distribution grids/LSEs.
  - In approach I the "residual claimant" is the government, while in approach II a residual claimant needs to be determined and in approach III it is the Transco.
  - In a smart grid framework the residual claimant could also be the distribution grid.

Overview

- Sophisticated vs. simple approaches
- The simple approach
- Application of simple approach to electricity transmission networks
- Properties of the HRG mechanism
- Dealing with environmental and spill-over effects
- Private incentives versus Government planning
- Conclusions

Conclusions

- The HRG mechanism is highly appealing in its static and dynamic properties.
  - In order to make it work in practice emphasis needs to be placed on controlling the profitability of the regulated firm over time through suitable X- and Y-factors that reflect cost and demand changes.
  - I have not specifically considered the effect of the HRG mechanism on optimal generation and distribution grid investment. In my view HRG will efficiently address those, provided generators, distribution grids and LSEs do not have distorted incentives and externalities are taken care of through separate instruments.
  - Effects of transmission investments on electricity reliability and on increased competition between electricity generators may have to be dealt with as separate services provided under the HRG price cap.
- The HRG mechanism is very specific about incentives of a Transco and treats other stakeholder incentives as a "black box".
- In contrast, a government planning approach is concerned with all stakeholders but has to make their incentives compatible in order to reach similarly efficient outcomes.

Backup 1: Controlling firm's profitability under HRG: Three-period framework

- The ultra-short period
  - Real-time pricing or peak-load pricing
  - No possibility of reducing operational or investment costs
  - Full regulatory commitment → Steep incentives for price setting → Implement real-time pricing by ISO
- The short period
  - Pricing of fixed fees and RPI-X type adjustments
  - Transco decisions on operations, repairs and maintenance costs
  - Full regulatory commitment → Steep incentives for cost cutting → Implementation by regulator
- The long period
  - Revisions of X- and Y-factors at the end of each long period.
  - Only very basic regulatory commitment beyond a long period → There exists no incentive mechanisms for resetting X- and Y-factors. → Revert to rate-of-return regulation with "used-and-useful" criterion?