UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

Network Regulation by Norm Model:

Empirical Equivalence, Pricing, and Performance of Electric Utilities in Sweden

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Outline

- Background
- Electricity sector reform and network regulation by norm model in Sweden
- Research questions
- Data, method, results
- Conclusions

First Economic Visions

W. Gladstone: "*Of what use is this electricity?*"

M. Faraday: "I do not know, but I suspect that one day you will tax it."

"*We will make electric light so cheap that only the rich will be able to burn candles*".

Edison (1879)

Incentive Regulation

- Regulation of the sector and incentive schemes date back to early days of the industry:
  - Sheffield Company, sliding scale for town gas (1855), Metropolis Gas Act to prevent "wasteful" competition among natural monopolies (1860), House of Commons (1882)

- More recent developments in incentive regulation:
  - Practice: Littlechild (1983), RPI-X based price/revenue cap
  - Theory: Shleifer (1985), yardstick regulation

- 1980-90s Reforms - Network regulation an afterthought

- Benchmarking in incentive regulation:
  - Real firms (DEA, SFA, COLS) - UK and Norway
  - Norm or reference models - Spain, Chile, Peru, Brazil, Sweden

Swedish Reform & Incentive Regulation

- Electricity sector reform in year 1996.
- Unbundling of the system:
  - generation and supply (competitive),
  - transmission and distribution (regulated natural monopolies)
- Forming the Nordic wholesale market (w. Norway) in 1990

- The Electricity Act, (SFS 1997:875) states that "network tariffs shall be based on objective criteria."

- The Act requires that distribution tariffs be based on:
  - (1) No. of connections, (2) Geographic co-ordinates of connections, (3) Distributed generation, (4) Subscribed power, (5) Cost of regional / HV network, and (6) Quality of service.

Network Performance Assessment Model

- NPAM (an engineering bottom-up model of a “reasonably” efficient network) is used as benchmark for assessing efficiency of real networks.

- Revenue cap, ex-post regulation.

- Charge Grade = Actual firm revenue / Cost of norm model
  - CG > 1 indicates inefficient firm
  - CG < 1 indicates efficient firm

- Threshold CGs set for detailed regulatory investigation:
  - 1.3 in 2003
  - 1.2 in 2004 and 2005
  - 1.1 in 2006.

NPAM: Design

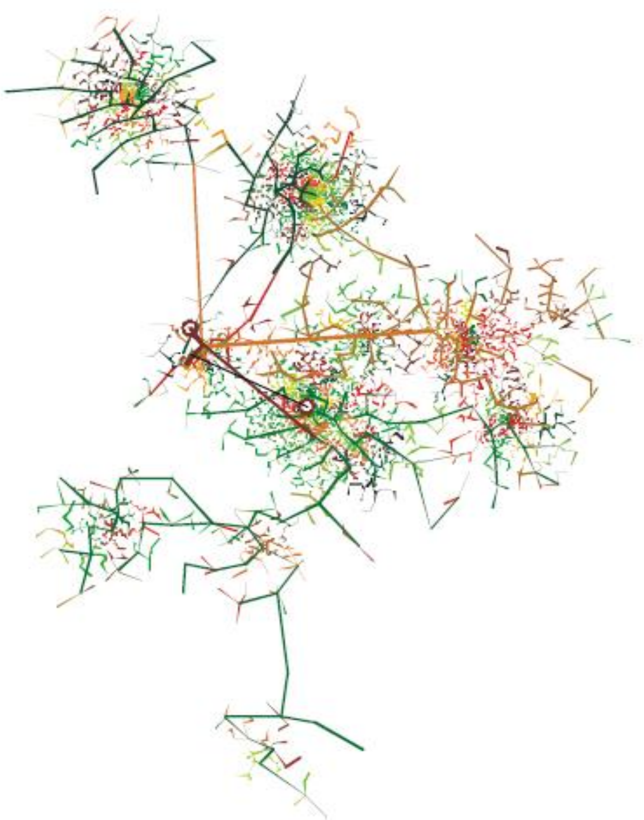
- Several critical parameters derived from hyperbolic tangent functions that are based on customer density and 5 constant terms to resemble empirical data.
- Parameters dependent on customer density:

  (1) Lines, (2) Back-up lines, (3) Back-up transformers, (4) Cost of land for transformers, (5) Geometrical adjustment, (6) Energy losses, (7) Interruption cost, (8) Expected interruption cost.

- For each parameter at each voltage level, the functions are estimated using “reference values”.

$$\mathrm{ModTanh}(x) = (k_1 + k_2 * \tanh(k_3 * (x - k_4)))^{k_0}$$

–x density (meters of line/customer)
–*k0, …, k4* constants



Source: Larsson (2004)

Research Questions

- Do norm models capture the main features of the actual networks?
- How do they affect the pricing behaviour?
- How is network performance affected?
  - Average cost
  - Quality of service
  - Network energy losses
- Are there differences in private vs. public utilities?

		Mean (Std.dev.)		Min		Max	
Variable	**Description and measurement unit**	**Eq (1)**	**Eqs (2)-(5)**	**Eq (1)**	**Eqs (2)-(5)**	**Eq (1)**	**Eqs (2)-(5)**
ANCost	Average norm cost (SEK/kWh)	0.1951 (0.0442)		0.1157		0.4125	
ACost	Average cost (SEK/kWh)		0.1730 (0.0439)		0.0868		0.3748
Price	Average price (SEK/kWh)		0.2084 (0.0468)		0.0967		0.4096
Cust	No. of customers	20 783 (39 520)	18 877 (36 541)	770	770	455 230	459 668
Leng	Network length (km)	1 577 (2 438)	1 409 (2 093)	116	113	25 180	25 180
LV	Share of deliveries on low volt network	0.7534 (0.1310)	0.7585 (0.1284)	0.2931	0.2711	1	1
ACon	Average customer consumption (kWh/cust)	19 793 (4 531)	19 866 (4 531)	9 642	9 642	44 148	44 148
Dens	Customer density (no./area)	95.751 (178.10)	93.739 (171.59)	0.8606	0.8606	2 104	2 124
Q	Electricity delivered (MWh)	402.6 (684.1)	367.0 (630.4)	11.998	11.692	7 215	7 473
Load	Network load factor	0.4881 (0.0698)	0.4977 (0.0697)	0.2424	0.2424	0.9039	0.9039

Pele	Price of electricity; (SEK/kWh)[a]	0.3270 (0.2337)	0.3188 (0.2279)	0.1000	0.0958	1.1617	1.1897
Pcap	Price of capital; (SEK/SEK)	0.0948 (0.0371)	0.0983 (0.0404	0.0228	0.0228	0.3095	0.4142
Plab	Price of labour; average total labour cost (SEK/employee)	19 176 (598.6)	18 690 (893.0)	17 811	16 900	20 913	20 913
OT	Outage time (total outage time / no. of outages)	114.7 (329.8)	91.978 (202.13)	0.0300	0.0300	5 667	4 330
OF	Outage frequency (no of outages / no. of customers)	1.0053 (2.4040)	0.9466 (2.0621)	0	0	58.39	58.39
T	Trend	6.0093 (1.4020)	4.7058 (2.2404)	4	1	8	8
Reg	Indicator for regulatory regime based on NPAM		0.6720 (0.4697		0		1
CG'	1 - charge grade		0.0304 (0.1395)		-0.3760		0.7910
IO	Investor owned utility		0.1344 (0.3413)		0		1
Loss	Amount of energy losses (kWh)		15 389 (25 700)		421		341 181
Out	OT·OF		147.04 (518.56)		0		11 345
Ws20	Number of days maximum daily wind speed has exceeded 20 m/s		0.2159 (0.8586)		0		6
Fore	Share of service area covered by forest		0.4050 (0.2332		0		0.9528

[a] Eq(1) and eqs(2)-(5) cover the 2003-07 (n=643) and 2000-07 (n=945) periods respectively.

Model Equivalence, Pricing, and Cost Effect

Variables	Dep var: *ANCost* Eq (1) Coeff.		Dep var: *ANCost* Eq (1) HAC std. err.	Dep var: *ACost* Eq (2) Coeff.		Dep var: *ACost* Eq (2) HAC std. err.	Dep var: *Price* Eq (3) Coeff.		Dep var: *Price* Eq (3) HAC std. err.
L1_ACost							0.2955	***	0.0757
Cust	$-4.89\cdot10^{-6}$	*	$2.75\cdot10^{-6}$	$-4.19\cdot10^{-6}$	**	$2.02\cdot10^{-6}$			
Cust^2	$1.86\cdot10^{-11}$	*	$9.83\cdot10^{-12}$	$1.93\cdot10^{-11}$	**	$8.31\cdot10^{-12}$			
Leng	$-1.03\cdot10^{-5}$		$1.31\cdot10^{-5}$	$-6.91\cdot10^{-6}$		$6.55\cdot10^{-6}$			
Leng^2	$4.18\cdot10^{-10}$		$3.11\cdot10^{-10}$	$3.29\cdot10^{-10}$	*	$1.82\cdot10^{-10}$			
LV	-0.0298		0.0225	-0.0448	**	0.0180			
ACon	$-6.72\cdot10^{-6}$	***	$1.09\cdot10^{-6}$	$-2.17\cdot10^{-6}$	***	$7.76\cdot10^{-7}$			
Dens	$6.13\cdot10^{-4}$		$4.51\cdot10^{-4}$	0.0012	***	$3.70\cdot10^{-4}$			
Dens^2	$-1.04\cdot10^{-6}$	*	$5.37\cdot10^{-7}$	$-1.09\cdot10^{-6}$	***	$4.21\cdot10^{-7}$			
Q^{-1}	2.4182	**	1.0224	3.4463	***	1.0493			
Q	$5.36\cdot10^{-5}$		$3.41\cdot10^{-5}$	$-5.18\cdot10^{-5}$	*	$2.66\cdot10^{-5}$	$-5.67\cdot10^{-4}$	***	$8.56\cdot10^{-5}$
Q^2							$1.56\cdot10^{-7}$	***	$3.76\cdot10^{-8}$
Load	-0.0114		0.0302	-0.0228		0.0205			
Pele	0.0240	*	0.0123	0.0423	***	0.0087			
Pcap	-0.0182		0.0375	0.0876	***	0.0317			
Plab	$-7.37\cdot10^{-7}$		$2.87\cdot10^{-6}$	$6.63\cdot10^{-6}$	***	$2.53\cdot10^{-6}$			
OF	$-2.51\cdot10^{-4}$		$2.03\cdot10^{-4}$	$-5.69\cdot10^{-4}$	**	$2.86\cdot10^{-4}$	$-3.61\cdot10^{-5}$		$1.10\cdot10^{-4}$
OT	$-3.87\cdot10^{-6}$	**	$1.93\cdot10^{-6}$	$2.64\cdot10^{-5}$	***	$7.44\cdot10^{-6}$	$-7.95\cdot10^{-8}$		$2.43\cdot10^{-6}$
T	0.0118	***	0.0010	-0.0017	**	$8.03\cdot10^{-4}$	0.0035	***	$4.73\cdot10^{-4}$
T-small							0.0014	**	$6.26\cdot10^{-4}$
Reg				0.0065	***	0.0018	-0.0058	***	0.0017
L2_CG				-0.0059		0.0073	-0.0195	***	0.0076
L2_CG-B				0.0112		0.0173	0.0250		0.0225
IO-L2_CG				-0.0393	***	0.0113	-0.0039		0.0186
IO-L2_CG-B				-0.3793	*	0.2304	2.4703		4.5248
R^2 (within)	0.771			0.455			0.431		
n	643			945			775		

Test of Similarity - Eqs. (1) and (2) (Avg Cost vs. Norm Cost)

Wald test on	X^2 value	$P>\chi^2$
All common slope parameters	895.83	0.000
Cust	1.22	0.269
$Cust^2$	0.93	0.336
Leng	0.23	0.628
$Leng^2$	0.19	0.661
LV	7.13	0.008
ACon	65.20	0.000
Dens	0.52	0.473
$Dens^2$	0.75	0.386
Q^{-1}	0.28	0.598
Q	4.73	0.030
Load	0.91	0.339
Pele	1.78	0.182
Pcap	2.96	0.085
Plab	122.83	0.000
OF	0.02	0.901
OL	0.57	0.449

Effect on Quality & Energy Losses

	Dep. variable: Outage Eq (4)			Dep. variable: Losses Eq (5)		
Variable	Coeff.		Robust Std. err.	Coeff.		Robust Std. err.
L1_Out	-0.0889	***	0.0215			
L1_Loss				-0.4333	***	0.0786
L2_Loss				-0.1945	***	0.0617
Q				27.650	**	12.549
Q^2				-0.0028		0.0027
Dens	2.9234		4.7515			
Asset	$-9.25\cdot10^{-4}$	**	$3.94\cdot10^{-4}$			
Y05	95.011	**	44.518			
T	-0.6102		7.8886	-81.929		70.186
Plab	84.438		138.68			
Ws20	12.797	*	7.7430			
Fore	744.65		1991.2			
Reg	4.3492		17.308	-320.41		236.08
Load	789.39	*	459.44	-315.28		2190
Leng	0.2678	***	0.0921	-2.1222		2.7583
L2_CG	143.83		343.33	-1125.9	*	617.36
L2_CG·B	-312.50		572.20	3626.3		2957.3
IO·L2_CG	-378.43		565.73	298.98		2905.0
IO·L2_CG·B	5087.6		3942.4	-119410	*	62284
Constant	-1081.4		946.86	24425	**	11083
Wald χ^2	63.68[a]			67.98 [a]		
n	781			648		

[a] Significantly different from 0.

Conclusions 1

- Norm models reflect main features of actual networks
- But there are shortcomings in incentive properties:
  - Input prices may need to be taken into account.
  - Quality of service has not influenced the performance benchmark, indicating possible sign of weak incentives.
- Overall utilities responded to incentive regulation and reduced their prices and costs.
- However, efficient IOUs firms have behaved strategically, and
  - increased their prices.
  - increased their costs.
- IOUs more responsive to incentives, and
  - inefficient IOUs improve QoS and energy losses.
  - efficient IOUs utilities reduce QoS (outage length).

Conclusions 2

- General observations on norm models:
  - Static/deterministic as opposed to dynamic benchmarks
  - Don't reflect the evolution of the network
- Less likely to promote innovation
- Interesting example of differences between engineering vs. economic approach to regulation
- Not most useful in their current application
  - But, offer scope as regulatory tool
    - When samples are very small
    - Investment assessment and analysis
    - …

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