Mergers and Cost Efficiency: Evidence from the Electricity Distribution Industry

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Introduction

- **Motivation:** In an effort to lower costs of provision, governments have *encouraged* consolidation of providers for a number of services
  - Examples include: school boards, hospitals, **l**ocal electricity **d**istribution **c**ompanies (LDCs), municipalities
- **Our focus:** Ontario's electricity distribution market
  - The government wants to incentivize significant reorganization (from 76 LDCs to 10) by subsidizing consolidation
- **Questions:**
  - What sort of consolidation will occur under the proposed subsidy scheme?
  - Is the proposed reorganization optimal?

Introduction

- How to answer these questions?
- **Retrospective analysis:**
  - Make predictions about outcomes based on past observations
- But past experience doesn't inform as to the impact of unconsummated amalgamations or predict whether and which mergers will occur (Einav & Levin, 2010)
- **Our approach:**
  - Develop an empirical framework for forecasting which mergers will take place and for evaluating the consequences of consolidation

Introduction

- Merger forecasting framework:
  - Serious methodological challenges:
    - Any firm can merge with any other
    - Merger decisions are interdependent:
      A's acquisition of C prevents B from acquiring C
  - Our approach overcomes these challenges by borrowing from the theory literature on endogenous mergers (Gowrisankaran, 1999)
    - Specify a sequential acquisition process
  - Our setting provides some advantages:
    - Each LDC is a monopoly: no competition among LDCs
    - Prices are capped and so we do not need to consider post-restructuring competition

Approach: specifics

1. Specify a sequential merger algorithm
    - Buyers make offers that can be accepted or rejected
    - Merging combines customer bases and efficiency levels
        - **Scale**: Tradeoff when increasing customer base (higher revenue vs higher cost if in diseconomies of scale region)
        - **Relative-influence**: merging firms' pre-merger efficiency levels influence efficiency levels of merged-entity
2. Estimate stochastic frontier for costs
    - AC of merged entity determined using the *relative-influence* function that shifts the AC of the new firm relative to the industry's cost frontier for that firm size
3. Calibrate parameters using a minimum distance approach
    - Compare consolidation patterns predicted by the model to those observed in the data
4. Analyze effects of a tax incentive in current configuration using calibrated parameters

Summary of findings:

- Buyers (assumed the larger of the two firms) have a smaller influence (32%) on the newly merged firm's cost efficiency than sellers
- Mergers do not achieve the desired average cost reductions, and, in fact, can even lead to cost increases
- Even a substantial subsidy reduces the number of LDCs by only 20%, nowhere near the stated objective (a reduction of 84%)

Related literature

- Electricity distribution
  - Yatchew (2000), Kwoka (2005), Kwoka & Pollitt (2010), Fyfe et al. (CD Howe, 2013)
- Retrospective analysis of merger waves
  - Finance: Mitchell & Mulherin (1996), Harford (2005); Service provision: Brasington (1999), Harrison (2006), Park & Town (2014);
- Endogenous mergers
  - Theory: Perry & Porter (1985), Deneckere & Davidson (1985), Gowrisankaran (1999), Qiu & Zhou (2007)
  - Empirical: Jeziorski (2013), Stahl (2015), Mermelstein, Nocke, Satterthwaite & Whinston (2016), Igami & Uetake (2017)
  - Matching models: Weese (2015), Gordon & Knight (2009)
- Government-encouraged mergers
  - Gaynor et al. 2012 (hospital mergers), Harman & Harman (2003) (education)

Electricity distribution market

- Electricity markets consist of three segments:
    - Generation
    - Transmission
    - Distribution
- The distribution segment buys electricity from high voltage lines and sells electricity at a lower voltage to final consumers.
- This paper: Distribution sector

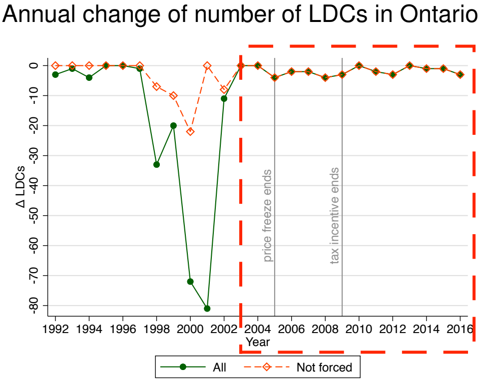
Electricity distribution in Ontario

- Prior to the Electricity Act of 1998:
  - About 300 municipal electric utilities (MEUs) operated as departments within municipalities
  - Regulated by Ontario Hydro (rates and terms of service)
- Electricity Act
  - Grants new powers to Ontario Energy Board (OEB) to regulate distribution
  - OEB moves towards incentive regulation (from cost of service) in year 2000

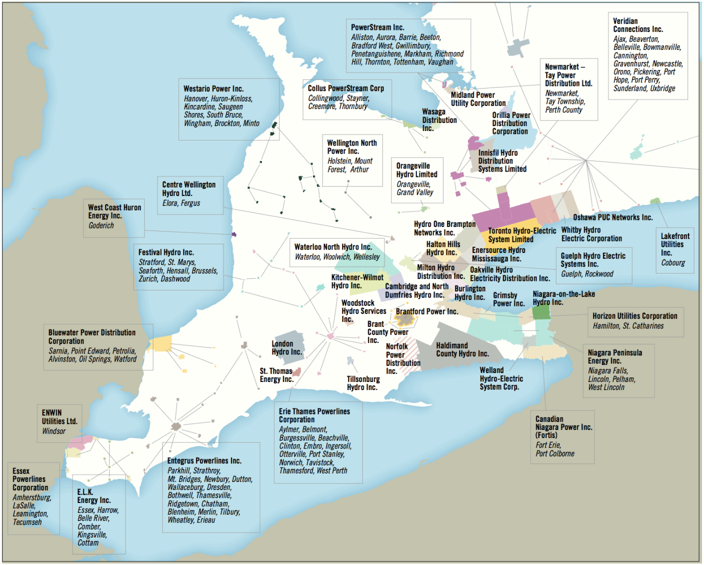
Consolidation in the electricity distribution market

- LDCs have been the object of policies to incentivize consolidation
  - U.S. 1990s through Energy Policy Act: up to 23 LDC mergers per year
  - Ontario: late 1990s, decreasing # of LDCs from 305 to 76
    - Forced acquisitions by Hydro One, amalgamation of cities (1990s and early 2000s)
    - 33% tax incentive on the transaction amount

Consolidation in Ontario's distribution market



LDC Map 2016


PowerStream Inc.
Alliston, Aurora, Barrie, Beeton, Bradford West, Gwillimbury, Penetanguishene, Markham, Richmond Hill, Thornton, Tottenham, Vaughan
Veridian Connections Inc.
Ajax, Beaverton, Belleville, Bowmanville, Cannington, Gravenhurst, Newcastle, Orono, Pickering, Port Hope, Port Perry, Sunderland, Uxbridge
Newmarket – Tay Power Distribution Ltd.
Newmarket, Tay Township, Perth County
Westario Power Inc.
Hanover, Huron-Kinloss, Kincardine, Saugeen Shores, South Bruce, Wingham, Brockton, Minto
Collus PowerStream Corp
Collingwood, Stayner, Creemore, Thornbury
Midland Power Utility Corporation
Wasaga Distribution Inc.
Orillia Power Distribution Corporation
Wellington North Power Inc.
Holstein, Mount Forest, Arthur
Innisfil Hydro Distribution Systems Limited
Orangeville Hydro Limited
Orangeville, Grand Valley
Centre Wellington Hydro Ltd.
Elora, Fergus
West Coast Huron Energy Inc.
Goderich
Oshawa PUC Networks Inc.
Hydro One Brampton Networks Inc.
Toronto Hydro-Electric System Limited
Whitby Hydro Electric Corporation
Lakefront Utilities Inc.
Cobourg
Waterloo North Hydro Inc.
Waterloo, Woolwich, Wellesley
Halton Hills Hydro Inc.
Enersource Hydro Mississauga Inc.
Festival Hydro Inc.
Stratford, St. Marys, Seaforth, Hensall, Brussels, Zurich, Dashwood
Guelph Hydro Electric Systems Inc.
Guelph, Rockwood
Milton Hydro Distribution Inc.
Oakville Hydro Electricity Distribution Inc.
Kitchener-Wilmot Hydro Inc.
Cambridge and North Dumfries Hydro Inc.
Burlington Hydro Inc.
Grimsby Power Inc.
Niagara-on-the-Lake Hydro Inc.
Woodstock Hydro Services Inc.
Brantford Power Inc.
Horizon Utilities Corporation
Hamilton, St. Catharines
Bluewater Power Distribution Corporation
Sarnia, Point Edward, Petrolia, Alvinston, Oil Springs, Watford
Brant County Power Inc.
London Hydro Inc.
Norfolk Power Distribution Inc.
Haldimand County Hydro Inc.
Niagara Peninsula Energy Inc.
Niagara Falls, Lincoln, Pelham, West Lincoln
St. Thomas Energy Inc.
Tillsonburg Hydro Inc.
Welland Hydro-Electric System Corp.
ENWIN Utilities Ltd.
Windsor
Erie Thames Powerlines Corporation
Aylmer, Belmont, Burgessville, Beachville, Clinton, Embro, Ingersoll, Otterville, Port Stanley, Norwich, Tavistock, Thamesford, West Perth
Canadian Niagara Power Inc. (Fortis)
Fort Erie, Port Colborne
Essex Powerlines Corporation
Amherstburg, LaSalle, Leamington, Tecumseh
E.L.K. Energy Inc.
Essex, Harrow, Belle River, Comber, Kingsville, Cottam
Entegrus Powerlines Inc.
Parkhill, Strathroy, Mt. Bridges, Newbury, Dutton, Wallaceburg, Dresden, Bothwell, Thamesville, Ridgetown, Chatham, Blenheim, Merlin, Tilbury, Wheatley, Erieau

Ontario's new push for further consolidation

- Consolidation trend slows down: stable starting in about 2008 (between 0-2 mergers per year)
- 2012: Govt recommends that the 76 LDCs should consolidate into 8-12 to reduce costs and incentivize investment

  "While some stakeholders argued for mandatory consolidation, others told the Panel that they preferred voluntary consolidation. The Panel's preference is for voluntary consolidation, but action must be swift. The Panel recommends that licence applications of all new regional distributors be submitted to the OEB within two years of the government adopting the recommendations of this report."

Ontario Distribution Sector Review Panel.

Data

- We obtain accounting books for each LDC from the Ontario Energy Board (OEB) for 2003-2016
    - For each LDC we observe:
        - costs
        - # customers
        - fraction rural area
        - km lines underground/above ground
        - energy losses
        - SAIDI
        - # of employees
    - Disaggregated costs into administration, operation and maintenance, depreciation and amortization, and financing only available since 2009
- LDC location data: used to determine potential merger sets
- Acquisition prices

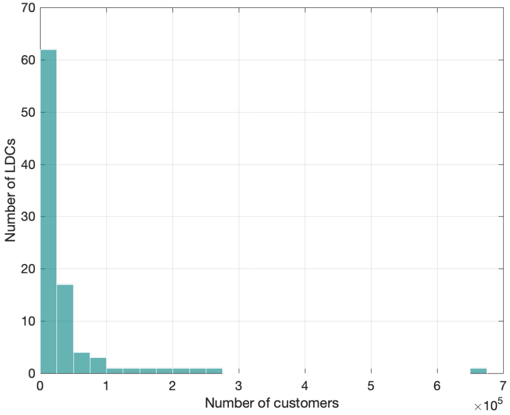
Data: Summary Statistics

	Panel A: 2003				
	Mean	Std. Dev.	Min	Median	Max
Avg. cost ($/MWh)	12.86	5.70	4.06	11.87	45.96
Density line (cust./km)	46.37	19.22	6.27	45.66	85.39
Price of capital ($/km)	88,333	36,248	15,319	90,781	188,997
Electricity sold (kWh/customer)	25.81	6.93	10.67	24.93	45.07
Total customers	35,760	81,027	189	12,810	668,625
Net income (mill. $)	0.019	29.8	−274	0.8	42.6
Fraction urban serv. area	0.69	0.38	0.0	1	1
Fraction overhead lines	0.73	0.20	0.04	0.77	1
Publicly owned	0.98	0.15	0	1	1
Avg. # potential merging partners	27.4				
N	92				

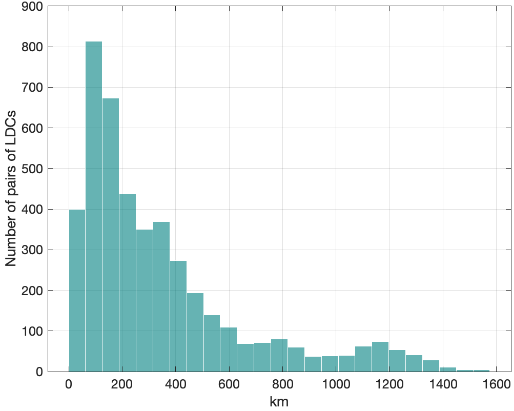
	Panel B: 2016				
	Mean	Std. Dev.	Min	Median	Max
Avg. cost ($/MWh)	15.95	7.83	6.19	14.59	69.62
Density line (cust./km)	47.30	17.32	6.33	47.17	81.97
Price of capital ($/km)	111,819	41,228	24,397	107,433	244,611
Electricity sold (kWh/customer)	22.57	4.91	10.02	21.90	36.57
Total customers	47,969	105,754	1,247	19,731	761,920
Net income (mill. $)	4.81	18.0	−0.26	1.15	142
Fraction urban serv. area	0.68	0.37	0.0	0.94	1
Fraction overhead lines	0.68	0.18	0.26	0.69	0.99
Publicly owned	0.97	0.17	0	1	1
N	64				

Notes: Statistics do not include Hydro One Networks Inc.

Distribution of LDC sizes in 2003

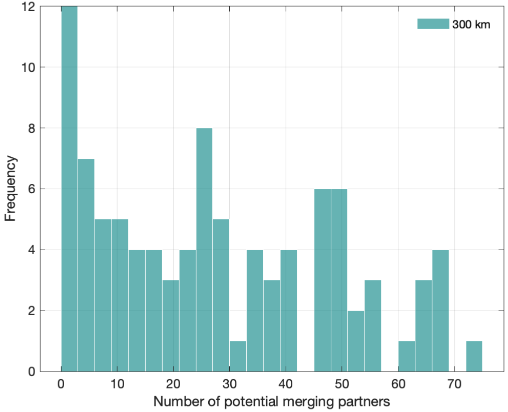


Distribution of pairwise distances for set of LDCs in 2003



Notes: The distance for each pair among the LDCs in 2003 is calculated assuming that the headquarters are located in the most populous city or town within the geographic region of each LDC.

Potential merging partners



Notes: For each LDC, we count how many other LDCs are found within a radius of 300 km. This histogram shows the frequencies of potential number of merging partners. The average is 27.4 potential merging partners.

Table: List of observed mergers during the sample period

Year	Name	Nbr custs	Avg. cost	Distance
2004	1: Asphodel Norwood Distribution Inc.	682	13.12	(1, 2): 24.45
	2: Peterborough Distribution Inc	33,438	9.90	(1, 3): 26.01
	3: Lakefield Distribution Inc.	1,378	11.03	(2, 3): 13.04
	1: Hamilton Hydro Inc.	177,495	7.03	52.16
	2: St. Catherines Hydro Utility Services	51,979	8.76	
	1: Scugog Hydro Energy Corporation	2,340	10.64	26.98
	2: Veridian Connections Inc.	101,867	11.08	
2005	1: Aurora Hydro Connections Limited	16,039	8.08	18.72
	2: PowerStream Inc.	203,749	13.15	
	1: Wellington Electric Distribution	3,416	27.57	0
	2: Guelph Hydro Electric Systems inc.	54,520	8.93	
	1: Gravenhurst Hydro Electric Inc.	5,928	18.39	120.57
	2: Veridian Connections Inc.	100,802	12.46	
2006	1: Newmarket Hydro Ltd.	26,647	15.11	84.58
	2: Tay Hydro Electric Distribution Company Inc.	4,037	27.78	
2007	1: Dutton Hydro Limited	600	17.52	33.98
	2: Middlesex Power Distribution Corporation	6,957	12.28	
	1: Niagara Falls Hydro Inc.	34,704	16.59	32.24
	2: Peninsula West Utilities Limited	15,491	22.58	
	1: West Nipissing Energy Services Ltd.	3,284	9.34	84.91

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Year	Name	Nbr custs	Avg. cost	Distance
	2: Greater Sudbury Hydro Inc.	43,167	22.67	
	1: Grand Valley Energy Inc.	681	24.57	20.36
	2: Orangeville Hydro Limited	10,200	13.33	
2008	1: Barrie Hydro Distribution Inc.	69,628	14.85	61.44
	2: Powerstream Inc.	244,573	13.07	
	1: Newbury Power Inc.	199	16.25	33.86
	2: Middlesex Power Distribution Corporation	7,026	11.16	
2010	1: Erie Thames Powerlines Corporation	14,373	14.42	(1,2): 54.14
	2: West Perth Power Inc.	2,049	16.14	(2,3): 32.26
	3: Clinton Power Corporation	1,639	20.86	(1,3): 83.41
2011	1: Canadian Niagara Power Inc.	15,708	28.50	(1,2): 19.36
	2: Port Colborne Hydro Inc.	9,138	22.58	(2,3): 295.56
	3: Eastern Ontario Power Inc.	3,551	22.87	(1,3): 277.82
	1: Chatham-Kent Hydro Inc.	32,132	16.51	76.92
	2: Middlesex Power Distribution Corporation	7,988	12.23	
2013	1: Lakeland Power Distribution Ltd.	9,765	16.91	64.05
	2: Parry Sound Power Corporation	3,463	24.89	
2014	1: Brant County Power Inc.	10,058	14.27	28.09
	2: Cambridge and North Dumfries Hydro Inc.	53,106	12.18	
2015	1: Enersource Hydro Mississauga Inc.	204,728	11.56	(1, 2): 42.08
	2: Horizon Utilities Corporation	244,114	13.92	(1, 3): 13.19
	3: Hydro One Brampton Networks Inc.	158,630	11.47	(1, 4): 28.61
	4: PowerStream Inc.	364,505	13.53	(2, 3): 48.16
				(2, 4): 70.69
				(3, 4): 27.15

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Year	Name	Nbr custs	Avg. cost	Distance

Notes: No observed mergers in 2009 or 2012. Average total cost is in \$ per MWh. Distance is measured in km. The notation $(m, n) : x$ means that the distance between LDCs m and n from the corresponding set of merged entities is x.

Endogenous Merger Model

- Profits for firm i selling quantity q_i:

$$\pi_i = q_i \times (\bar{p}_i - AC(q_i, \text{density}_i, \text{price of capital}_i))$$

where $\bar{p}_i$ is the price cap, AC is avg cost function, $density_i = \#$ customers / km of line, price of capital$_{ij}$ = sum of total assets / km of line

- Optimal firm size q^* would be given by

$$AC(q^*) + q^* \times AC'(q^*) = \bar{p}$$

which might require reshuffling customers from one LDC to another
  - Our sequential algorithm finds an approximation to q^*

Endogenous Merger Model

- Want to forecast which firms merge and with whom
- Specify a sequential algorithm which allows buyers to make acquisition offers to potential sellers (Igami & Uetake (2017), Seim & Waldfogel (2013))
  - Sort LDCs according to observed net income
  - Most profitable LDC moves first, makes take-it-or-leave-it (TIOLI) offer to the best available target in its *feasible set*
  - Move down the list sequentially until no more offers occur
- LDCs compare profits from merger to profits from staying alone
- **Empirical challenge**: determine firm *i*'s *AC*
  - For existing firms: use actual *AC* observed in the data
  - What about merging firms? Harder.

Endogenous Merger Model

If firms i and j merge, profits for the merged entity:

$$\pi_{ij} = \bar{p}_i q_i + \bar{p}_j q_j - (\widetilde{AC}(q_i + q_j, \text{density}_{ij}, \text{price of capital}_{ij}) \times H(\xi_i, \xi_j)) \times (q_i + q_j) - Z_{ij}$$

- $\widetilde{AC}(q_i + q_j, \text{density}_{ij}, \text{price of capital}_{ij}) \times H(\xi_i, \xi_j)$ is estimated average cost for a firm serving customers$_i$ + customers$_j$
- ξ_i is firm's *relative inefficiency* from a stochastic frontier for costs
- $H(\xi_i, \xi_j) = \alpha(q_i, q_j)\xi_i + (1 - \alpha(q_i, q_j))\xi_j$
  - $\alpha(q_i, q_j) = \frac{1}{1+\beta \frac{q_j}{q_i}}$: relative influence of the buyer's efficiency on the merged entity
- Parametrize interconnection costs as $Z_{ij} = \lambda I_{ij}^2$ where I_{ij} is the number of firms in conglomerate when i acquires j (and including j)

Endogenous Mergers

- Net gains for a buyer:

$$NG_{buyer} = \pi_{ij} - b_{ij} - \tau a_j - \pi_i + s_{ij}$$

- Net gains for seller:

$$NG_{seller} = b_{ij} - \pi_j$$

- s_{ij} is a cost/synergy random shock (Gowrisankaran (1999), Jeziorski (2013))
- b_{ij}: annualized price paid by the buyer
- a_j: annualized value of firm j's assets
- τ is the acquisition tax

Endogenous Mergers

- Buyer solves

$$\max_{b_{ij}} NB = \max_{b_{ij}}\{(NG_{buyer})^{\eta}(NG_{seller})^{1-\eta}\}$$
$$= \max_{b_{ij}}\{(\pi_{ij} - b_{ij} - \tau a_j + s_{ij} - \pi_i)^{\eta}(b_{ij} - \pi_j)^{1-\eta}\}$$

- η: bargaining weight

- Assume synergy random shock $s_{ij} \sim U[-s^{\max}, s^{\max}]$

- Then,

$$b^*_{ij} = (1-\eta)(\pi_{ij} - \tau a_j + s_{ij} - \pi_i) + \eta\pi_j. \quad (1)$$

Acquisitions

1. For a given sorting of firms, if firm l appears in this sorting before firm l', then $l < l'$. Firm at the top of the list moves first.

2. An acquisition attempt occurs only if firm l has profits above the minimum profitability threshold $\underline{\pi}$. l can make offers to firms $k > l$ in the feasible set, which is defined by a maximum distance between k and l given by a fixed threshold, $\bar{D}$. Otherwise we restart with firm $l + 1$.

3. Firm l computes b^*_{lk} for each firm in the feasible set, given a random draw of s_{lk}, and computes NG_{lk} for each of the potential acquirees.

Acquisitions (continued...)

4. If all values of $NG_{l\cdot}$ are negative, no merger possible. Start over with firm $l+1$ making offers. If $\max NG_{l\cdot} > 0$, execute the merger between l and the LDC that yields this maximal value, $\bar{k}$. We add the number of customers, compute the new density of customers per km of line, and compute the new average cost.

5. If a merger occurred in the previous step to create $\{l\bar{k}\}$, then if $\pi_{l\bar{k}} > \underline{\pi}$, $\{l\bar{k}\}$ computes $b^*_{\{l\bar{k}\}m}$ for every firm $m > l$, $m \neq \bar{k}$ in the feasible set of $\{l\bar{k}\}$. Then repeat prev step. This is a conglomerate or path.

6. At end of path, we move to the next firm $l+1$ (if $l+1$ has already been acquired, we continue with $l+2$, etc.) and return to step 1 keeping the sorting of unacquired firms the same

Estimation and calibration

- Steps:
  1. Stochastic frontier estimation
  2. Calculate synergies using info on bids from consummated mergers
  3. Find buyer influence parameter and interconnection costs using merger algorithm
  4. Use these parameters to simulate mergers under counterfactual conditions

Stochastic Frontier Estimation

- Following Kwoka (2005) we estimate an AC curve in 3 dimensions: electricity output q_i and $density_i$ (# customers per km of line) and price of capital (value of assets / length of lines)

- First we estimate a stochastic frontier for costs (see Knittel (2002) for an application to the U.S. electricity industry)

  $$C(q_{it}, \text{density}_{it}, \text{price of capital}_{it}) = f(q_{it}, \text{density}_{it}, \text{price of capital}_{it}, \mathbf{W}_{it}; \boldsymbol{\theta})\xi_{it}\exp(\epsilon_{it})$$

  $\mathbf{W}_i$ is a vector of observables, θ is a parameter to be estimated, ϵ_i is the unobservable error term

- $\xi_i \geq 1$ is the firm's level of inefficiency: if $\xi = 1$ the firm is at the cost frontier

  Deviations from this cost frontier are associated to values of $\xi > 1$

Stochastic Frontier Estimation

- By taking logs on both sides and assuming a linear functional form for f we get

$$\begin{aligned} \log C(q_{it}, \text{density}_{it}, \text{price of capital}_{it}) &= \theta_0 + \theta_1 \log q_{it} + \theta_2 \log \text{density}_{it} + \\ &+ \theta_3 \log \text{price of capital}_{it} + \\ &+ \sum_{k=4}^{K} \theta_k \log W_{itk} + \log \xi_{it} + \epsilon_{it}, \end{aligned}$$

where $\epsilon_i \sim N(0, \sigma_\epsilon^2)$ and $-\log \xi_{it} \sim$ normal distribution truncated at 0 with pre-truncation params μ_ξ, σ_ξ^2

- Allow us to write a maximum likelihood function for the composite residual $\log \xi_{it} + \epsilon_{it}$

- Can recover a set of estimates $\hat{\xi}_i$ which gives a ranking of the different firms in terms of their inefficiency: higher values correspond to more inefficient firms

Stochastic Frontier Estimation

- By making use of the estimates for μ_ϵ, σ_ϵ^2, σ_ξ^2, $\boldsymbol{\theta}$, and the predicted values for $C(q_{it}, \text{density}_{it}, \text{price of capital}_{it})$ we compute average costs as

$$\widehat{AC}(q_{it}, \textit{density}_{it}, \text{price of capital}_{it}) \equiv \frac{\hat{C}(q_{it}, \text{density}_{it}, \text{price of capital}_{it})}{q_{it}}$$
$$= \widetilde{AC}(q_{it}, \text{density}_{it}, \text{price of capital}_{it})\hat{\xi}_{it}$$

  where $\widetilde{AC}(\cdot) = \hat{f}(\cdot)/q_{it}$ is the predicted average cost associated with the cost frontier (at $\xi = 1$)

- Note that the predicted average cost, $\widehat{AC}$, is the product of the average cost at the frontier, $\widetilde{AC}$, times the inefficiency term.

Stochastic frontier analysis 2003-2016

	(1)	(2)	(3)	(4)	(5)	(6)
log *q*	0.839***	0.838***	0.847***	0.984***	0.976***	1.012***
	(0.0352)	(0.0256)	(0.021)	(0.0155)	(0.0203)	(0.0367)
log density	−0.120**	−0.343***	−0.370***	−0.319***	−0.371***	−0.350***
	(0.0591)	(0.0577)	(0.0547)	(0.0183)	(0.0501)	(0.0656)
log price capital		0.236***	0.244***		0.0703	0.0449
		(0.0332)	(0.0347)		(0.0627)	(0.0785)
log fr. urban area			−0.0210			0.0166
			(0.0150)			(0.0146)
log fr. over. lines			−0.0571			0.172*
			(0.0397)			(0.0835)
constant	4.082***	2.362***	2.282***	4.071***	3.572***	3.391***
	(0.408)	(0.440)	(0.446)	(0.213)	(0.336)	(0.342)
log σ_ξ^2	−1.885***	−2.079***	−2.193***			
	(0.232)	(0.177)	(0.143)			
log $\frac{\gamma}{1-\gamma}$	1.230***	1.009**	0.795***			
	(0.332)	(0.267)	(0.228)			
μ_ξ	1.092***	0.993***	0.930***			
	(0.210)	(0.225)	(0.251)			
RMSE	1.17	1.07	1.00	0.31	0.30	0.31
MAPE	7.06	6.43	6.03	1.48	1.47	1.51
N	1,032	1,032	944	1,011	1,011	925

Notes: Dependent variable: log cost. Results for columns (1) - (3) obtained by maximum likelihood. We present the estimates for log σ_ξ^2, the logit of $\gamma = \frac{\sigma_\xi^2}{\sigma_\xi^2+\sigma_\epsilon^2}$, and

Results: Inefficiency scores ξ

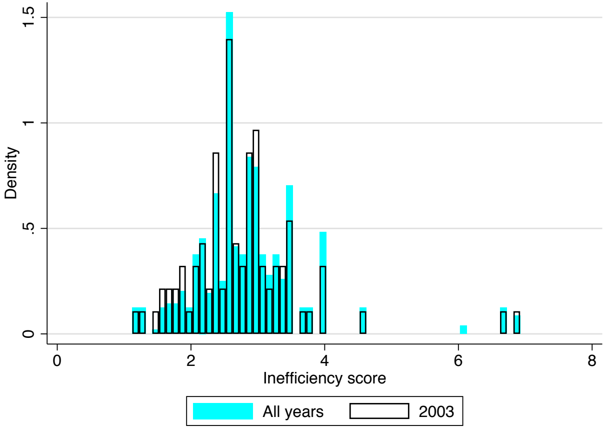
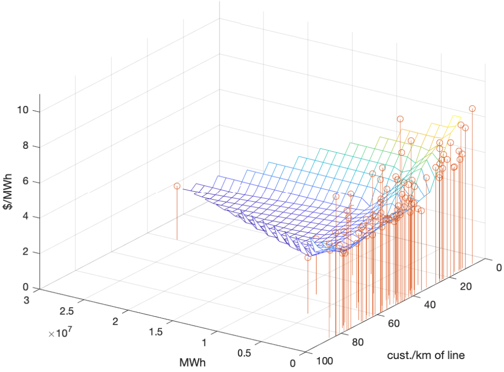


Figure: Inefficiency scores for the pooled sample and for year 2003 only

Notes: Inefficiency scores implied by the main specification of the stochastic frontier analysis (column (2) of main table).

Results: AC estimation (2003)

Average Cost curve as a function of q_i and line density, at median(price of capital)



Notes: Circles represent actual data points. The surface is the interpolated average cost curve using estimates from Column (2) at median of price of capital.

Fixed parameters for grid search

Parameter	Description	Value
s^{max}	Upper bound of the random synergy shocks	\$4.88 million
$\bar{p}_i$	Price cap for LDC i (ij)	i's average revenue
$\bar{D}$	Upper bound on dist. between merging firms	300 km
$\underline{\pi}$	Lower bound on profits of buyer	0
τ	Policy parameter	0 if public to public, 22% if one of the firms is privately owned

Merger algorithm

- Suppose 5 LDCs sorted as: ABCDE
- Suppose conglomerate of LDCs B,C, and D (i.e. BCD) is the only one observed in the data
- Suppose model predicts only ABC and DE
- Penalize
  1. the model's prediction of AB
  2. the model's prediction of ABC
  3. the model's prediction of DE
  4. the model's inability to predict BCD
- However, we should reward that model predicted BC when it formed ABC

Calibration of the merger algorithm

- We solve:

$$\min_{\substack{\beta>0\\ \lambda>0}} \left\{ F(\beta,\lambda) = \sum_{J\in\mathcal{J}_1} \left(\underbrace{\sum_{c\in\sigma(J)} (NG_c(\beta,\lambda))^2}_{\text{mergers predicted but NOT observed}} - \underbrace{\sum_{c\in\mu(J)} (NG_c(\beta,\lambda))^2}_{\text{mergers predicted AND observed}} \right) + \underbrace{\sum_{J\in\mathcal{J}_2} \sum_{c\in\sigma(J)} (NG_c(\beta,\lambda))^2}_{\text{mergers observed but NOT predicted}} \right\},$$

c is a path (not necessarily at the end of its construction)

- $\mathcal{J}_1$ contains final conglomerates but not observed. May or may not contain a subset that matches observed conglomerates
  - Ex. $\mathcal{J}_1$ contains AB, ABC, and DE
- $\mathcal{J}_2$ contains the final conglomerates observed in the data, but not predicted by the algorithm
  - Ex. $\mathcal{J}_2$ contains BCD

Calibration of the merger algorithm (2)

- $\sigma(\cdot)$ takes an ordered list of firms and outputs all the sequences formed by adding, in the same order as the list, each of the members of the list. So $\sigma(\{A, B, C\}) = \{\{A, B\}, \{A, B, C\}\}$ and $\sigma(\{D, E\}) = \{D, E\}$.
- $\mu(\cdot)$ only acts over the members of its argument that belong to observed mergers: $\mu(\{A, B, C\}) = \{B, C\}$
- If $\mu(J) = \varnothing$ then its corresponding term in the expression above is set to 0
- The negative sign in front of the term with $\mu(\cdot)$ reflects that these combinations should be rewarded

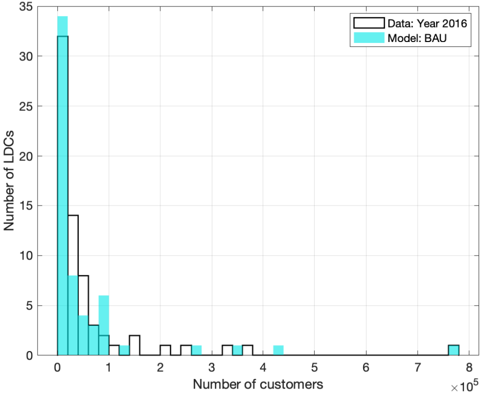
Values of β, α, and λ from grid search

Specification	β	Implied α	λ
Baseline	46.3263	0.3186	1.489×10^6
	(74.8536)	(0.2166)	(0.490×10^6)
NB weight			
$\eta = 1.00$ (TIOLI)	39.4917	0.3381	1.463×10^6
	(69.9931)	(0.2220)	(0.470×10^6)
Sortings			
Largest to smallest	1.3573	0.6430	1.875×10^6
First 5 LDCs account	11.9196	0.2588	1.444×10^6
for 50% of customers	(6.6496)	(0.2257)	(0.426×10^6)
First 15 LDCs account	29.5385	0.3597	1.294×10^6
for 75% of customers	(58.6289)	(0.2273)	(0.463×10^6)
Distance			
Max. distance 500km	46.1695	0.2537	1.333×10^6
	(67.8846)	(0.2057)	(0.463×10^6)

Notes: Standard deviations across the 100 random orderings in parentheses. The values for the "Largest to smallest" case do not have standard deviations because only one sorted list was used.

- Buyer's influence is larger than the seller's.

Data vs. BAU distribution



Notes: Comparison of the distribution of LDC sizes between the model BAU's predictions and the data for a representative initial sequence.

Mergers under different policy environments

			Counterfactuals					
	Data 2016	BAU	Tax 25%	Prop. tax	Subs. 25%	Subs. 50%	Subs. 100%	Subs. 200%
Survival ratio	0.7	0.64	0.7	0.64	0.6	0.58	0.55	0.51
Nbr conglomerates	19	23.36	24.58	23.58	20.52	19.1	17.34	15.53
Nbr merged firms (rel. to bench.)			-5.52	0	3.68	5.52	8.28	11.96
Nbr conglom. (rel. to bench.)			1.22	0.22	-2.84	-4.26	-6.02	-7.83
Avg. Nbr LDCs/conglom.	2.26	2.42	2.13	2.43	2.81	3.05	3.43	3.95
Avg. size (1000 Cust)	47.97	55.8	51.4	56.1	59.6	62	65.6	70.5
S.D. size (1000 Cust)	105.75	115.1	95.2	115.2	139.5	150.8	166.7	186.3
Avg. size buyer (1000 Cust)		61.3	59	60.4	74.3	90.2	117.9	151.3
Avg. size seller (1000 Cust)		33.3	6.8	33.5	53.3	53.2	51.9	49.9
Avg. AC ($/MWh)	15.95	13.68	12.91	13.67	13.93	13.93	14	14.09
S.D. AC ($/MWh)	7.83	6.49	6.15	6.51	6.7	6.79	6.9	7.07
Avg. inefficiency ξ		2.72	2.78	2.72	2.68	2.67	2.67	2.68
S.D. inefficiency ξ		0.84	0.79	0.83	0.86	0.87	0.88	0.91
Avg. ineff. Buyer		2.79	2.82	2.79	2.8	2.79	2.78	2.76
Avg. ineff. Seller		2.56	2.34	2.56	2.78	2.82	2.83	2.83
Nbr remaining LDCs	64	58.88	64.4	58.88	55.2	53.36	50.6	46.92

Notes: Averages are non-weighted. We used 2003-2016 for estimation of AC. All years pooled for calibration. BAU is public to private taxed at 22% and public to public at 0%. Prop. tax is an elimination of the 22% tax levied in 2016 between public and private LDCs. Subsidy X% is a negative transfer tax of X% (X=25, 50, 100, and 200). Tax 25% imposes a transfer tax of 25%.

Mergers under different specifications for the BAU scenario

	Data	Baseline	Alternative specifications				
	Data 2016	Baseline	$\eta =$ 1.00	Largest to smallest	First 5 50% cust.	First 15 75% cust.	Max. dist. 500 km
Survival ratio	0.7	0.64	0.64	0.67	0.64	0.62	0.62
Nbr conglomerates	19	23.36	23.36	27	23.01	22.9	23.97
Nbr merged firms (rel. to baseline)			0	-2.76	0	1.84	1.84
Nbr conglom. (rel. to baseline)			0	3.64	-0.35	-0.46	0.61
Avg. Nbr LDCs/conglom.	2.26	2.42	2.42	2.13	2.45	2.55	2.47
Avg. size (1000 Cust)	47.97	55.8	55.8	53.6	55.9	58	58
S.D. size (1000 Cust)	105.75	115.1	115.1	112.3	110	117.5	114.2
Avg. size buyer (1000 Cust)		61.3	61.3	60	61	63.2	61.8
Avg. size seller (1000 Cust)		33.3	33.3	24.8	29.9	32.8	27.5
Avg. AC ($/MWh)	15.95	13.68	13.68	13.23	13.87	13.71	13.98
S.D. AC ($/MWh)	7.83	6.49	6.49	6.39	6.49	6.58	6.54
Avg. inefficiency ξ		2.72	2.72	2.75	2.73	2.73	2.73
S.D. inefficiency ξ		0.84	0.84	0.82	0.84	0.85	0.84
Avg. ineff. Buyer		2.79	2.79	2.8	2.83	2.8	2.83
Avg. ineff. Seller		2.56	2.56	2.57	2.52	2.56	2.44
Nbr remaining LDCs	64	58.88	58.88	61.64	58.88	57.04	57.04

Notes: Averages are non-weighted. We used 2003-2016 for estimation of AC. All years pooled for calibration. BAU is public to private taxed at 22% and public to public at 0%. The last two columns correspond to baseline scenarios where the first n LDCs in the sorted list account for X% of total customers, with $n = 5, 15$ and $X = 50, 75$.

Summary of findings (1)

- The results with subsidies are comparable to the result in Kwoka & Pollitt (2010) that shows that inefficient LDCs buy more efficient ones
- However, our model allows for varying returns to scale by permitting different levels of curvature in the average cost curve
- The methodology employed in Kwoka & Pollitt (2010) implicitly assumes constant returns to scale, which eliminates any incentives to limit growth in size

Summary of findings (2)

- Acquisitions occurred at transaction prices of \$0.43 million in the BAU. This small average transfer falls to \$0.42 million for a 25% subsidy, and then increases for bigger subsidies
- Our experiments suggest that it would require a huge subsidy to generate anywhere near the sort of consolidation hoped for by the government panel
- The fact that there are not more mergers can be explained by the shape of the *AC* curve. The AC curve would have to have be much flatter in order for larger economies of scale to be achieved through consolidation.

Conclusion

- We propose a method that endogenizes the merger process in the electricity distribution industry with take-it-or-leave-it offers
- Method is easily computable even if number of firms is large
- Can be used to evaluate current recommendation as well as tax incentives and changes in price regulation
- Findings: tax reduction provides insufficient incentive to achieve policy objective