The Hidden Cost of Investment: The Impact of Adjustment Costs on Firm Performance Measurement and Regulation

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Infraday 2014, Berlin
October 9, 2014

Regulation of natural monopolies in network industries

Rate of Return regulation

- Firms are allowed to cover their operational costs plus earning a specified rate of return on their invested capital
- Lack of cost reduction incentive
- Incentive to excessive investment (Averch and Johnson, 1962)

$$\Downarrow$$

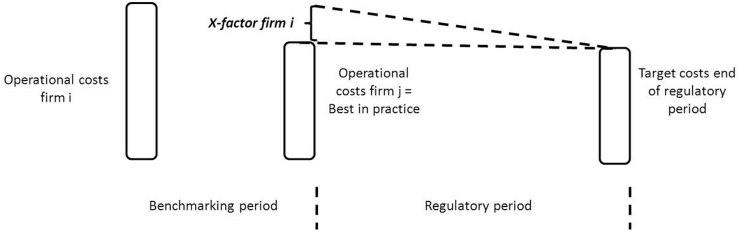
Incentive-based regulation

- Idea of Yardstick competition (Shleifer, 1985)
- Implementation of price- or revenue caps

Benchmarking in incentive-based regulation schemes

Adjustment of price- or revenue cap: $P_{t+1} = P_t(1 + RPI - X)$

Required decrease in inefficiency derived from a static benchmarking model ⇒ 'Snapshot' of input-output combination



Mismatch of 'Snapshot' and multi-period optimization

Multi-period cost minimization:

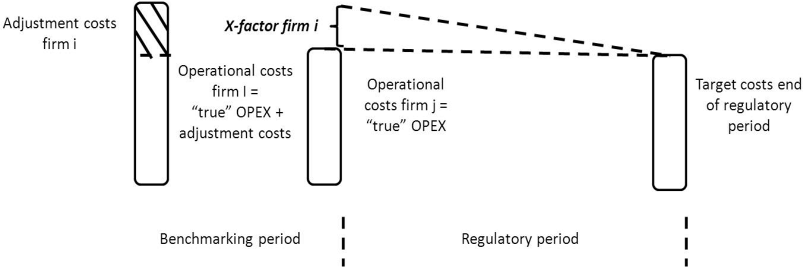
$$W(y, K_t, w, c, r, \delta) = min_{(x,I)} \int_t^{\infty} e^{-r(s-t)}[w'x(s) + c'K(s)]ds$$

$$\Downarrow$$

Changes in quasi-fixed inputs (investments) may decrease costs in the long-run, but increase inefficiency in the short-run due to adjustment costs.

- Regulator is unable to disentangle 'true' inefficiency from transitory inefficiency caused by adjustment costs.
- X-factors derived from static benchmarking models may be inconsistent with long-term cost minimization.

Adjustment costs may cause biased X-factors



Overcoming the bias
⇒ Account for the adjustment costs of investments in the benchmarking process

Production technology with adjustment costs

(Silva/Stefanou (2003, 2007) and Oude Lansink/Silva (2009, 2013))

Standard input requirement set

$$V(y:K) = \{(x, I) : (x, I) \text{ can produce } y \text{ given } K\}$$

with three additional properties:

- Adjustment costs

$$\textit{if}\,(x, I) \in V(y:K) \text{ and } I' \leq I, \text{ then } (x, I') \in V(y:K)$$

- Long-run savings from investments in the capital stock

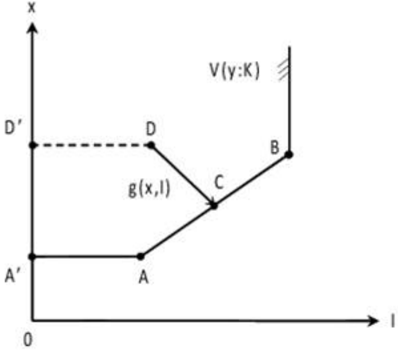
$$\text{if } K' \geq K, \text{ then } V(y:K) \subset V(y:K')$$

- Increasing marginal adjustment costs

$$V(y:K) \text{ is a strictly convex set}$$

Dynamic directional distance function

$$\vec{D}(y, K, x, I : g_x, g_I) = max\,\{\beta \in \Re : (x - \beta g_x, I + \beta g_I) \in V(y : k)\}$$



Firm can approach the efficient frontier by simultaneously contracting variable input usage and expanding gross investments

Dynamic DEA: technical inefficiency

$$\vec{D}(y^i, K^i, x^i, I^i; g_x, g_I) = \max_{(\beta^i, \gamma^j)} \beta^i$$

$$\begin{aligned}
s.t. \quad & \sum_{j=1}^{J} \gamma^j y_m^j \geq y_m^i, && m = 1, \ldots, M, && (i) \\
& \sum_{j=1}^{J} \gamma^j K_f^j \leq K_f^i, && f = 1, \ldots, F, && (ii) \\
& \sum_{j=1}^{J} \gamma^j x_n^j \leq x_n^i - \beta^i g_{x_n}, && n = 1, \ldots, N, && (iii) \\
& \sum_{j=1}^{J} \gamma^j I_f^j \geq I_f^i + \beta^i g_{I_f}, && f = 1, \ldots, F, && (iv) \\
& \gamma^j \geq 0, && j = 1, \ldots, J, && (v)
\end{aligned}$$

Dynamic cost inefficiency

Hamilton-Jacobi-Bellmann (H-J-B) equation for the intertemporal cost minimization problem:

$$rW(y, K, w, c) = \min_{(x,I)} \left\{ w'x + c'K + W_K'(I - \delta K) : \vec{D}(y, K, x, I; g_x, g_I) \geq 0 \right\}$$

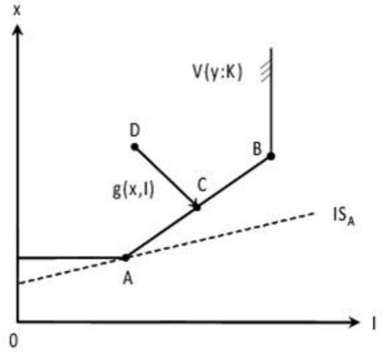
- Yields optimal quantities of variable inputs and gross investments
- Long-run benefits of investments are incorporated via the shadow value of capital W_K
- W_K is estimated from historical cost data

Dynamic DEA: cost inefficiency

$$rW(y^i, K^i, w^i, c^i) = \min_{(x, I, \gamma^j)} \quad [w^{i\prime} x + c^{i\prime} K^i + W_K^{i\prime}(I - \delta K^i)]$$

$$
\begin{aligned}
s.t. \quad & \sum_{j=1}^{J} \gamma^j y_m^j \geq y_m^i, && m = 1, \ldots, M, && (i) \\
& \sum_{j=1}^{J} \gamma^j K_f^j \leq K_f^i, && f = 1, \ldots, F, && (ii) \\
& \sum_{j=1}^{J} \gamma^j x_n^j \leq x_n, && n = 1, \ldots, N, && (iii) \\
& \sum_{j=1}^{J} \gamma^j I_f^j \geq I_f, && f = 1, \ldots, F, && (iv) \\
& \gamma^j \geq 0, && j = 1, \ldots, J, && (v) \\
& x_n \geq 0, && n = 1, \ldots, N, && (vi) \\
& I_f \geq 0, && f = 1, \ldots, F, && (vii)
\end{aligned}
$$

Dynamic technical, cost and allocative inefficiency



- A: cost efficient
- B and C: technically efficient, but allocatively inefficient
- D: technically and allocatively inefficient

The sample

- FERC-Data (Form 1) on US electricity transmission and distribution firms
- Unbalanced panel from 2004 to 2011, 61 firms, 464 observations

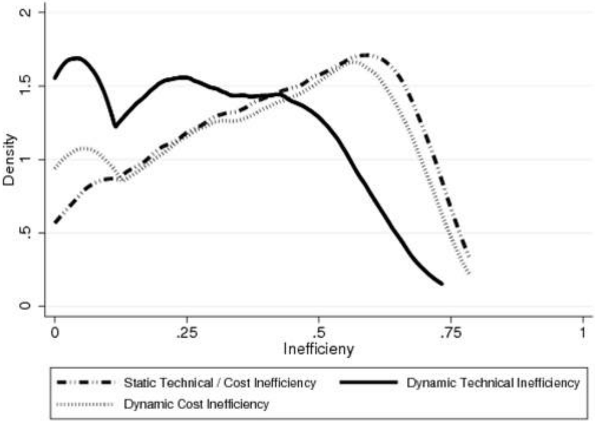
Outputs	Inputs	
	Variable	Quasi-fixed
Electricity transmitted Total number of customers	Operational expenditures	Capital (adjustable by gross investments)

Results (I)

Table: Average Dynamic and Static Inefficiency Scores

Year	TIE Dynamic	CIE Dynamic	AIE dynamic	TIE/CIE static
2004	0.29	0.44	0.15	0.42
2005	0.29	0.37	0.08	0.42
2006	0.26	0.36	0.10	0.41
2007	0.28	0.38	0.10	0.43
2008	0.26	0.39	0.13	0.33
2009	0.29	0.37	0.08	0.41
2010	0.25	0.33	0.08	0.45
2011	0.19	0.30	0.11	0.36
Mean	0.26	0.37	0.10	0.40

Results (II)


2
1.5
1
.5
0
Density
0
.25
.5
.75
1
Inefficieny
Static Technical / Cost Inefficiency
Dynamic Technical Inefficiency
Dynamic Cost Inefficiency

Results (III)

Table: Average Dynamic and Static Inefficiency Scores for Investment Ratio Percentiles

Cumulative Percentile of Investment Ratio	Obs.	TIE Dynamic	CIE Dynamic	AIE Dynamic	TIE/CIE Static
Total Sample	464	0.26	0.37	0.10	0.40
5	441	0.25	0.36	0.11	0.40
25	348	0.22	0.33	0.11	0.39
50	232	0.21	0.33	0.12	0.41
75	116	0.17	0.28	0.11	0.44
95	24	0.07	0.20	0.13	0.44

Conclusions

- The explicit consideration of adjustment costs significantly affects the outcome of benchmarking.
- X-factors derived from static benchmarking models may induce incentives for the regulated firms to deviate from long-run cost minimization.
- Regulators may overcome the mismatch between the multi-period optimization of firms and 'snapshot' benchmarking by using dynamic approaches that account for adjustment costs.
- Significant dynamic technical and cost inefficiency within the US electricity transmission and distribution sector.

Thank you for your attention!

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