Long-term effects of revenue decoupling for electric utilities

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This Is What the Utility Death Spiral Looks Like

In Germany, utility revenues are spiraling down the rabbit hole. Will American power companies follow?

by Stephen Lacey
March 04, 2014

The German mega-utility RWE provided another dismal reminder today of the painful transition European power companies are undergoing.

Greentech Media, March 4, 2014

Utility death spiral?

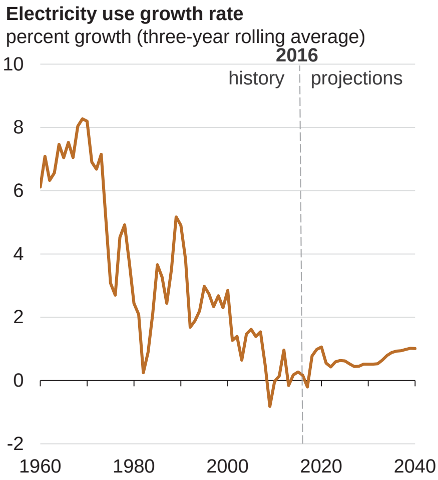
"[A]s grid maintenance costs go up and the capital cost of renewable energy moves down, more customers will be encouraged to leave the grid. In turn, that pushes grid costs even higher for the remainder of customers, who then have even more incentive to become self-sufficient. Meanwhile, utilities are stuck with a growing pile of stranded assets."
(Greentech Media, March 4, 2014)

What do we observe?

Downward pressure on electric utilities' sales in the United States

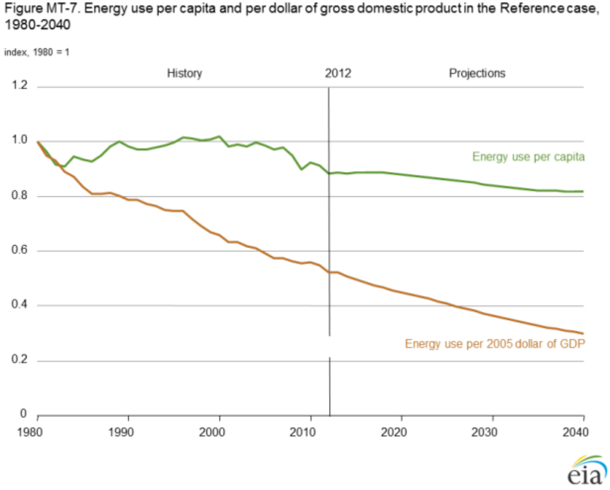
- Slowing growth in energy/electricity demand
- Improvement in energy efficiency
- Policy focus on distributed generation (as opposed to centralized generations by utilities via the grid) and energy-efficiency improvement

Slowing growth in the U.S. electricity demand



Source: U.S. Energy Information Administration, Annual Energy Outlook 2017.

Energy efficiency improvement in the United States



Source: U.S. Energy Information Administration, Annual Energy Outlook 2014, May 7, 2014.

Questions to be addressed

- **Big Picture**: What regulation aligns utilities' incentives with demand-reducing technology/programs (i.e., distributed generation, energy efficient technology)?
- **Focus of this presentation**: How does RD influence consumers and the utility?

What is Revenue Decoupling

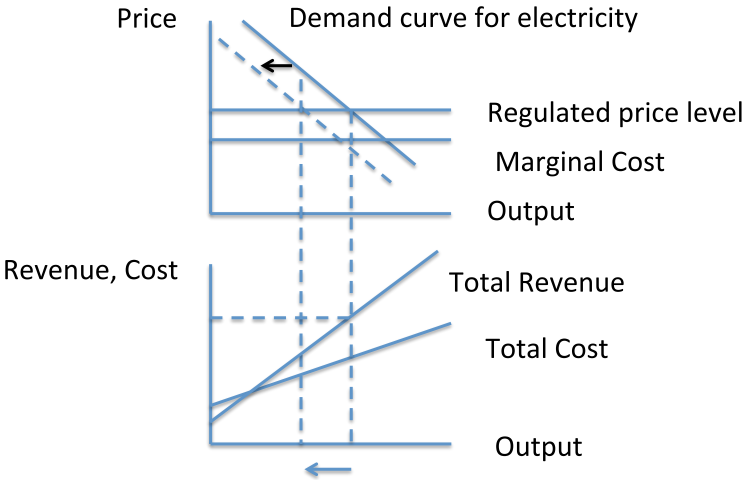
- Under traditional utility regulation, electric rates are fixed by regulation (between rate cases); updated only upon changing circumstances
- Under revenue decoupling (RD), utility is allowed to adjust electric rates (between rate cases) to maintain its revenue when its sales decrease

How Revenue Decoupling Works (An Example)

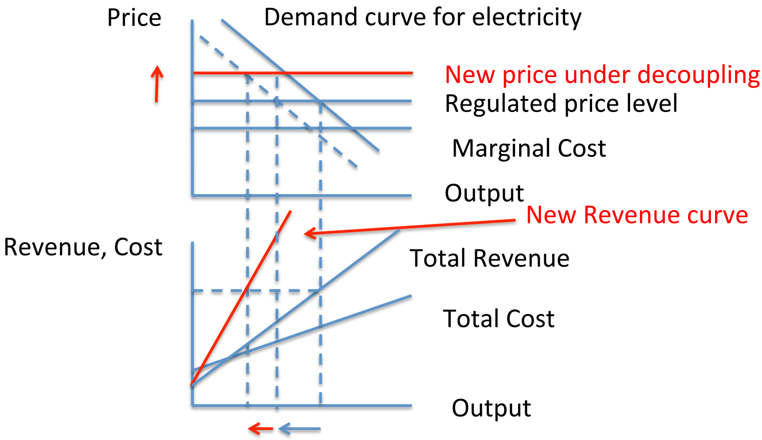
	No RD in place	RD in place
Revenue Requirement Calculation		
(Based on expenses, allowed return, taxes)		
Price Calculation		
Revenue Requirement	$115,384,615	
Sales Forecast (kWh)	1,000,000,000	
Actual Sales (kWh)	990,000,000	
Unit Price ($/kWh)	0.1154	0 .1166
Decoupling Adjustment ($/kWh)	– –	0 .0012
Actual Revenue	$114,230,769	$115,384,615

Source: The Regulatory Assistance Project (RAP), 2011.

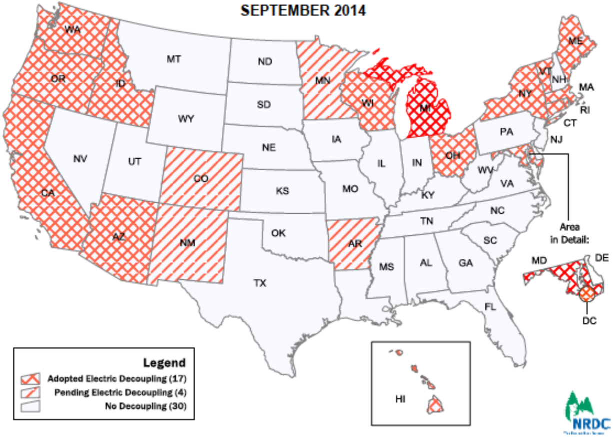
How RD works


Price
Demand curve for electricity
Regulated price level
Marginal Cost
Output
Revenue, Cost
Total Revenue
Total Cost
Output

How RD works II



Revenue Decoupling in the United States



Source: Natural Resources Defense Council (http://www.nrdc.org/energy/decoupling/).

Implementation of RD in the United States

1990s-2012

Since 1990s	2006	2007	2008	2009	2010	2011	2012
California	California	California	California	California	California	California	California
	Vermont*	Idaho	Idaho	Connecticut	Connecticut	Connecticut	Connecticut
		Maryland	Maryland	Idaho	Hawaii	Hawaii	Hawaii
		New York	New York	Maryland	Idaho	Idaho	Idaho
		Vermont*	Vermont*	Michigan	Maryland	Maryland	Maryland
				New York	Michigan	Massachusetts	Massachusetts
				Oregon	New York	Michigan	Michigan
				Vermont*	Oregon	New York	New York
				Washington, DC	Vermont*	Oregon	Ohio
				Wisconsin	Washington, DC	Vermont*	Oregon
					Wisconsin	Washington, DC	Rhode Island
						Wisconsin	Vermont*
							Washington, DC
							Wisconsin

Note: The above implementation reflects that State Commission's approval of the first decoupling mechanism. Passing of a legislation may have been completed earlier. Some states may have pending RD implementation to date.

* Utilites under Vermont's policy may adjust rates every year based on forecast costs and sales. There is an adjustment mechanism for earnings that fall outside of a dead-band of 75 basis points around the allowed return on common equity. Outside of the dead-band, any excess or shortfall is first shared between the utility and customers and, beyond a certain amount, passed through in full to customers. If consumption reductions have

Source: Morgan, 2013.

Relevant findings

- On immediate impacts: both refunds and increased charges to end users have been observed; RD adjustments have been small (Lesh 2009 Electricity Journal)
- Short-term price impacts of decoupling has been small or insignificant (Kahn-Lang 2016 Ene Journal)—the effects may not be idenfitied due to endogeneity of decoupling

Model of utility regulation with revenue decoupling

- Consumers choose electricity consumption from the grid; decide whether to invest in energy efficiency (e.g., home weatherization, solar panels)
- An electric utility provides electricity subject to regulation (natural monopoly)
- Two forms of regulation: traditional rate-of-return regulation and revenue decoupling

Household-level decision I

- Consumer i's utility: $u_i(e_i, y_i) = v_i(e_i) + y_i$ with total electricity consumption e_i and consumption of numeraire y_i ($v_i' > 0, v_i'' < 0$)
- Each household chooses consumption of electricity from electric utility (x_i); chooses whether to invest in energy efficiency improvement, $d_i = 0$ or 1
- If $d_i = 1$, generates electricity service worth $g_i \geq 0$
- So total electricity consumption is $e_i = x_i + d_i g_i$.
- Income m_i (wage and share of profits from electric utility)

Household-level decision II

- Consumer i solves

$$\max_{x_i \geq 0, d_i \in \{0,1\}} v_i(x_i + d_i g_i) + y_i$$

$$\text{s.t.} \quad px_i + f + qd_i + y_i \leq m_i$$

where $p > 0$: price of electricity from the grid; $f > 0$: fixed fee to access grid; $q > 0$: price of energy efficiency improvement

- Utility-maximizing conditions:

$$\begin{aligned} & v_i'(x_i + d_i g_i) = p; \\ & d_i = 1 \quad \text{if } g_i \geq q/p; \\ & d_i = 0 \quad \text{if } g_i < q/p. \end{aligned}$$

Aggregate consumer decision

- Order consumers in terms of energy efficiency improvement potential: $g_i > g_j$ if $i < j$
- $h(n)$: total efficiency improvement when households 0 to n invest: $h(n) \equiv \int_0^n g_i di$ (and hence $g_n = h'(n)$).
- With v defined as

$$v(e) = \max_{(e_i)_{i\in(0,N)}} \int_0^N v_i(e_i)di \quad \text{s.t.} \quad \int_0^N e_i di \leq e,$$

consumers' utility-maximizing choice maximizes

$$v(x + h(n)) + y$$

subject to an aggregate budget constraint $px + qn + y \leq M$ (where $M \equiv \int_0^N m_i di$)

$$v'(x + h(n)) = p; \quad (1)$$

$$v'(x + h(n))h'(n) = q. \quad (2)$$

$\rightarrow$ yields demand x, n given prices p, q.

Electric utility

- Natural monopoly, with marginal cost $c > 0$ and a fixed cost $F > 0$
- (Integrated utility; or a distributor with IRS and market power)
- Utility's profit is

$$\pi = px + r + Nf - cx - F.$$

- Assume $p > c$
- r, f small ($r + Nf$ is smaller than F): volumetric price involves a markup and fixed fees are not sufficient to cover the fixed cost
(Friedman, 2011; Borenstein and Davis, 2012)

Regulatory regimes

Alternative regulation on p between rate cases

1. Traditional rate-of-return regulation **(noRD)**: electric rate is fixed in the short run at $\bar{p}$, a level approved by the public utilities commissions (Joskow, 1974)
2. Revenue Decoupling **(RD)**: electric rate is adjusted so that the revenue is maintained at a pre-approved level

Economic impacts with and without decoupling

What happens when q, the cost of energy-efficiency investment, drops?
Or when the subsidy on investment, s, increases?
Between rate cases, with utility's capital fixed:

	Utility's sales	Price	Utility's profit
Without RD	$\downarrow$	—	$\downarrow$
With RD	$\downarrow$	$\uparrow$	—

(Larger r implies smaller p)

Welfare effects of revenue decoupling

What happens to welfare when s, the subsidy on energy-efficiency investment, increases:

$$W_r = u(x_r + h(n_r)) - px_r - qn_r + [px_r - cx_r - F] - sn_r$$

$$= u(x_r + h(n_r)) - cx_r - \bar{q}n_r - F,$$

where $\bar{q} = q - s$

Proposition 6 Welfare decreases with and without RD; the excess burden is larger under RD than under no RD.

Welfare impacts of EE investment subsidies (no RD)

$$\frac{dW_{noRD}}{ds} = s\eta_n \frac{n}{\bar{q}} - (p - c)\eta_{x,q}\frac{x}{\bar{q}},$$

where η_n: (own) price elasticity of EE investment (n);
$\eta_{x,q} > 0$: cross-price elasticity of x w.r.t. q

- The first term: captures the usual Harberger excess burden formula for a subsidy ('primary welfare effect,' Goulder and Williams, 2003)
- The second term: 'electricity markup effect'
  - Zero if $p = c$ (marginal-cost pricing)
  - With $p > c$, captures the effect of EE investment subsidy on the demand for EE (due to an increase in subsidies)—subsidy on EE generates an extra distortion on the use of grid-generated electricity

Welfare impacts of EE investment subsidies (under RD)

$$\frac{dW_{RD}}{ds} = s\frac{\eta_n \frac{n}{\bar{q}}}{1-|\eta_x|} - (p-c)\frac{\eta_{x,q}}{1-|\eta_x|}\frac{x}{\bar{q}} + s\frac{-\left\{-\eta_x + \eta_n \frac{\bar{q}n}{px}\right\}\eta_n \frac{n}{\bar{q}}}{1-|\eta_x|}$$

$$= s\eta_n \frac{n}{\bar{q}}\left\{1 - \frac{\eta_n \frac{\bar{q}n}{px}}{1-|\eta_x|}\right\} - (p-c)\frac{\eta_{x,q}}{1-|\eta_x|}\frac{x}{\bar{q}}$$

The first term: captures the primary welfare effect
The second term: electricity markup effect
Both terms are larger in magnitude than under no RD

Long-term impacts

- In the short run (between rate cases), further distributed generation (DG) raises price; is neutral on utility's profits—why might utilities resist DG?
- Impacts beyond rate cases?

Dynamic model: Utility's problem

- Q. How does RD play out in a dynamic context?
- Apply a dynamic game between regulator and utility (cf. Lim and Yurukoglu 2016 *JPE* forthcoming)
- Assume the rate is adjusted just to cover the cost of service, with an allowed rate of return to capital (Biglaiser and Riordan, 2000)
- In period t, given capital (rate base) k_t, utility chooses how much to invest z_t while regulator chooses the allowed rate of return on capital r_t. Then electricity demand might change due to a drop in q_t
- Utility's functional equation

$$v_u(k) = \max_{z \geq 0} rk - z - cz^2 + \beta v_u(k')$$

$$\text{s.t.} \quad k' = (1 - \delta)k + z.$$

Dynamic model: Regulator's problem

The regulator's periodwise payoff is a weighted average of utility's profit π and consumer surplus (minus "rate of return" costs)

$$\pi_t = r_t k_t, \quad CS_t = \int_{p_t}^{\bar{p}} x(\omega; q_t) d\omega$$

Assume CES demand for electricity from utility: $x(p) = A_x p^{-\gamma}$ where $\gamma \in (0, 1)$ is the price elasticity of demand

Then

$$CS = \int_{p}^{\bar{p}} x(\omega) d\omega = \frac{A_x \bar{p}^{1-\gamma}}{1-\gamma} - \frac{A_x p^{1-\gamma}}{1-\gamma}$$

Price p is set so the revenue just covers the capital expenditure: $r_t K_t = p_t x(p_t; q_t) = A_x(q_t) p^{1-\gamma}$, and hence

$$CS_t = A(q_t) - B r_t K_t,$$

where $A(q_t) \equiv \frac{A_x(q_t)\bar{p}^{1-\gamma}}{1-\gamma}$ and $B \equiv 1/(1-\gamma)$

Dynamic model: Regulator's problem

The regulator's functional equation:

$$v_r(k) = \max_{r \geq 0} \alpha[rk - z - cz^2] + (1-\alpha)[A - Brk] - d(r - \bar{r})^2 + \beta v_r(k'),$$

$$\text{s.t.} \quad k' = (1 - \delta) + z,$$

where $\bar{r}$: market rate of return on capital, $d > 0$

Solve for the Markov perfect equilibrium of the game, with regulator's rate-of-return policy function (decision rule) and utility's invetsment policy function

Solve the regulator's problem and find its rate-of-return policy function:

$$r^e(k) = \bar{r} + \frac{\alpha - (1 - \alpha)B}{2d} k.$$

r is decreasing in k if α, the welfare weight on utility, is not too large

Dynamic model: Markov perfect equilibirum

With the linear-quadratic specification, find an analytical solution for utility's investment policy:

$$z^e(k) = A_z + B_z k$$

with $A_z > 0, B_z < 0$ provided α is not too large

$$A_z = \frac{\{\beta \bar{r} - (1 - \beta(1 - \delta))\} d}{2c(1 - \beta(1 - \delta))d - \beta[\alpha - (1 - \alpha)B]},$$

$$B_z = \frac{\beta[\alpha - (1 - \alpha)B](1 - \delta)}{2c(1 - \beta(1 - \delta))d - \beta[\alpha - (1 - \alpha)B]}.$$

Dynamic model: Observations

- With an unexpected drop in the opportunity cost of DG or energy efficiency (q), the increase in p is larger under RD.
- (Extension)

More on long-term impacts of decoupling

Rate of return versus price cap:

- Rate of return regulation enables the regulator to shift rents from utility to consumers; but does not provide incentive for cost reduction; may provide incentive for capital over-accumulation
- Price cap tends to induce utility to pursue cost minimization; but may leave rents to utility

What's different with decoupling?

- Rate of return (or cost-of-service) regulation, with (in)frequent rate cases, is a hybrid: RoR at cases, with price cap between rate cases (Joskow 1974, 2006)
- Decoupling may remove the cost-minimization incentives under price cap

Long-term impacts

Other considerations

- Rate of return regulation with “regulatory lag” would resemble a price-cap regulation between rate cases
- A price cap tends to encourage the utility to invest in cost-reducing efforts
- Such efforts may not be observable to the regulator
- Decoupling may reduce such incentive

Long-term impacts (ii)

Increased distributed generation may require more investment for grid stability

"*[PV systems] can actually destabilize distribution circuits when they pump too much power back into the grid. In Hawaii, where 12% of houses now have rooftop solar, that's already a serious concern.*" (Borenstein 2015)

"*The stability of the German grid is also being put at risk: it has relied more heavily on variable, renewable generation at the same time that grid resources capable of rapidly balancing supply and demand have been shutting down due to anomalous market price signals. Energiewende has also taken a toll on the utility companies that may have to make the grid investments to fix these operating problems.*" (Raskin 2013)

Long-term impacts (ii)

Factors to consider:

- Increased distributed generation and renewables integration
  - suppose utility can invest in energy efficiency (operational or end-use) or “grid modernization” upon larger renewables penetration, both through current and capital inputs
  - Rate-of-return regulation would encourage increased capital base; so the long-term impact of RD on capital is ambiguous
- Consider the utility’s efforts for cost minimization, which may not be observable to the regulator