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# Alleged Transmission Undersupply

## *Is Restructuring the Cure or the Cause?*

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RESOURCES FOR THE FUTURE

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## Abstract

Widespread concern over transmission capacity requires theoretical support to infer inadequacy from observed trends indicating reductions in the ratio of transmission to generation capacity over time. If integrated utilities had been regulated with allowed returns exceeding capital costs, transmission-generation ratios would have been excessive, and observed trends might be a correction. However, numerous commentators claim that post-restructuring transmission rates have been too low, with NIMBY also discouraging investment. We model the possibility that inadequate separation between generation and transmission may result in reduced investment, in order to preserve incumbent market power in generation. However, consideration of transmission price caps and coordinated generation investment support other analyses that conclude that vertical separation itself may be a culprit.



**Key Words:** electricity transmission, regulation, deregulation, vertical integration

**JEL Classification Numbers:** L94, L51, L22

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# Alleged Transmission Undersupply: Is Restructuring the Cure or the Cause?

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## I. Introduction

Many electricity industry observers regard transmission capacity as inadequate (Fox-Penner 2005). Rates of capacity expansion are below growth rates in generation. The U.S. transmission grids were designed for spatially partitioned monopoly utilities with only occasional trading for reliability, not for open wholesale markets with significant long-distance wheeling. Rapid spreading and the persistence of the August 2003 outage in the northeastern United States and Canada engendered further concern.

A basis for the view that transmission capacity is inadequate is that it has fallen in the last 20 years in absolute amounts and relative to the quantity of energy supplied over the transmission network. Hirst, using North American Electric Reliability Council (NERC) and Edison Electric Institute data, finds that, normalized to summer peak loads, transmission capacity has fallen at a rate of about 1.5 percent per year from a peak in 1982 (Hirst 2004, 7).[1] In absolute terms, new annual transmission investment from investor-owned utilities fell at an inflation-adjusted rate of $83 million per year from 1975 to 1999, from a peak value in the late 1970s of about $4.5 billion to about $2.7 billion in the late 1990s.[2] Since 1999, however, investment has increased at an annual rate of $286 million per year (Hirst 2004, 7). Since 1999, this investment appears to have

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[1] Based on NERC data on planned transmission expansions, Hirst expects this trend to continue until at least 2012. See also Fama (2004, 18).

[2] Citing another study by Hirst and Kirby, Stagliano and Hayden (2004, 37) report that investment has been "declining by almost $120 million per year for the past 25 years."

not reversed the decline of capacity relative to load, though, as also indicated by a sixfold increase in the number transmission loading relief (TLR) calls from 1998 to 2003 (Hirst 2004, 8).[3]

Although these findings and episodes suggest a problem, none is dispositive. Optimal investment in transmission is probably not so high as to render outages impossible. In principle, there can be too much transmission capacity relative to load. At least with respect to reliability, transmission investments need not be severely at risk. The North American Electric Reliability Council (NERC 2004, 3) recently found that "seven of ten [NERC Regions] and all ISO [independent system operators]/RTOs [regional transmission organizations] have Regional transmission planning criteria that go beyond NERC standards." However, NERC has also suggested that economic considerations may warrant grid expansion beyond that dictated by reliability concerns (NERC 2002, 7). ICF, in a study for the owner of the International Transmission Company, found that transmission investment of $8.2 billion could save $12.6 billion in energy costs, with savings up to $18 billion if reserve margins are appropriately reduced and up to $50 billion if the costs of avoided outages are taken into account.[4]

Justifying policy intervention requires theoretical reasons why suppliers of transmission capacity would underinvest.[5] Perhaps regulated rates for transmission would not produce revenues sufficient to cover expansion cost, but ability to pass through costs would suggest that there might be few limits to expansion. More likely possibilities involve the degree to which generation companies control expansion. A now-traditional concern, rationalizing the creation of ISOs and RTOs, is that integrated utilities will limit capacity to deter entry or limit expansion by

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[3] Hirst offers no explanation of the inconsistency between the increase in investment and the apparent simultaneous increase in TLR calls.

[4] "ICF Study Concludes that $8 Billion Investment in Nation's Transmission Grid Could Yield $12 Billion in Savings," *Foster Electric Report* (May 26, 2004): 15.

[5] We do not attempt to test the underinvestment proposition by estimating whether the marginal benefits from transmission expansion exceed marginal cost. Hale, Overbye, and Leckey (2000) and Kleit and Reitzes (2004) empirical estimations of the marginal benefits expanding transmission capacity http://ssrn.com/abstract=645085.

competitors.[6] Creating financial transmission rights (FTRs) to hedge against variations in locational marginal prices may also vest generators (and other FTR holders) with an interest in limiting capacity to profit from congestion rents.

Unlike some other partially regulated sectors, however, vertical separation may discourage as well as encourage capital expansion in the regulated side.[7] Transmission investment is notoriously lumpy. The profitability of such investment and its value to the public depend on coordination with similarly lumpy investments in generation. As some generation will likely come online after a transmission line is constructed, efficient transmission investment and competitive generation requires the design and solution of a multistage game among the transmission provider and generators that can choose to build earlier or later. If such a game cannot be solved without vertical integration or its equivalent, competition and adequate investment may not be reconcilable. This observation restates Taylor and Van Doren's (2004) contention that because vertical integration may be the most efficient way of organizing the electricity sector, re-regulation of an integrated industry may be preferable to partial deregulation if full deregulation is politically infeasible.

The remainder of the paper is organized as follows. Section II offers a model indicating that excessive transmission investment would be the predictable outcome of earlier regulation if the allowed rate of return exceeds the costs of capital. Section III surveys claims that inadequate present returns, methodological uncertainty, and siting delays are responsible for reduced rates of investment. Section IV provides a simple model of discrimination by partially regulated vertically integrated firms to support the claim that residual vertical integration in the restructuring era would discourage transmission expansion. Section V describes two thought experiments and reviews other arguments suggesting that strict separation is ineffective and impedes the coordination necessary for appropriate transmission and generation investment. Section VI concludes.

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[6] Federal Energy Regulatory Commission (FERC) 1996, 1999.

[7] Pittman (2005) analyzes similar concerns regarding vertical coordination in rail.

## II. Excessive Transmission Investment as a Regulatory Artifact

A declining ratio of transmission capacity to generation capacity could indicate overbuilding prior to opening wholesale markets. Under cost-of-service regulation, utilities would have no direct incentive to limit transmission costs beyond that provided by regulatory oversight of the prudence of those investments. Moreover, to the extent that the political cost of an outage exceeds the political cost of higher electricity costs, utilities and their regulators will each have an incentive to overinsure against blackout risk by encouraging excess transmission capacity.

A second factor that could lead to excessive investment during the regulatory era would be the Averch-Johnson effect (Averch and Johnson 1962). Suppose that during the 1970s, prior to the period in the Hirst data, electric utilities received an excessive rate of return. As is well known, they would bias their inputs toward a greater capital/labor ratio than would be optimal (Baumol and Klevoric 1970). One would expect that if transmission is more capital intensive than generation, this would lead utilities to bias their technological choices toward transmission, i.e., to have a greater transmission/generation ratio than would be optimal.

A derivation of the technological choice with and without regulatory constraint suggests such a bias. Let the output Q of a utility be given by

$$Q(K, L) = F(G(K, L), T(K, L)),$$

where G and T refer, respectively, to generation and transmission, and K and L refer, respectively, to capital and labor.[8] We can interpret this function as implicitly representing how the regulated firm would allocate a total of K units of capital and L units of labor to produce G units of generation and T units of transmission, in turn to produce Q units of electricity. If R is the rental rate on capital and W is the wage, then the optimal capital/labor ratio satisfies

[8] "Labor" refers to any non-capital expense, and "W" to its price.

$$\frac{F_G G_K + F_T T_K}{F_G G_L + F_T T_L} = \frac{R}{W}.$$

To explain this expression, $T_K$ is the increase in transmission that the utility would undertake if it has an additional unit of capital to allocate toward transmission or generation; and the expressions $G_K$, $T_L$, and $G_L$ are similarly interpreted. Where this is satisfied, the ratio of the marginal product of transmission to generation will be given by

$$\frac{F_T}{F_G} = \frac{[R/W]G_L - G_K}{T_K - [R/W]T_L}.$$

Generally, the lower this ratio, the greater will be the ratio of transmission to generation.

If the utility is allowed a rate of return S > R, it will maximize profits

$$\Pi(K, L) = [S - R]K + \lambda[P(Q(K, L))Q(K,L) - WL - SK].$$

The first term is profit as a function of the capital installed, and the second is the constraint that revenues (price P(Q) times output Q) equal labor expense plus the allowed return on capital. Because profit increases as S increases, we have that $\lambda < 1$; because profit falls as W increases, we have that $\lambda > 0$.

The two first-order conditions for a profit maximum will be

$$\Pi_K = 0: S - R + \lambda[[P'Q + P][F_G G_K + F_T T_K] - S] = 0$$

$$\Pi_L = 0: \lambda[[P'Q + P][F_G G_L + F_T T_L] - W] = 0.$$

Assuming that the constraint binds, we can use the labor first-order condition to substitute for marginal revenue in the capital first-order condition and rearrange terms to obtain

$$\frac{F_G G_K + F_T T_K}{F_G G_L + F_T T_L} = \frac{S}{W} - \frac{S - R}{\lambda W}.$$

Let Z be the expression on the right hand of the equal sign. If $\lambda = 1$, $Z = R/W$, as in the unconstrained case.[9] As $\lambda$ decreases toward 0, the subtracted term becomes larger; hence Z decreases.

As in the unconstrained case, one can solve this expression for the ratio of the marginal products of transmission to generation

$$\frac{F_T}{F_G} = \frac{ZG_L - G_K}{T_K - ZT_L}.$$

If $T_K/G_K > T_L/G_L$, then $F_T/F_G$ falls as Z falls. Because Z is less than R/W, we have that if the firm is allowed to earn an excessive return, the ratio of the marginal product of transmission to generation is less than that in the unconstrained case. The expression

$$\frac{T_K}{G_K} > \frac{T_L}{G_L}$$

states that an extra unit of capital has a greater effect than does an extra unit of labor on installed transmission relative to generation. It is in this sense that transmission is defined as more capital intensive than generation. Consequently, when transmission is relatively more capital intensive than generation in this sense, the regulated firm chooses a ratio of transmission to generation greater than in the unconstrained case.[10]

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[9] $\lambda$ takes a value of 1 in the unconstrained case because we, in effect, incorporated the constraint in defining profit as [S – R]K.

[10] If S is sufficiently large, the constraint will be nonbinding, with $\lambda = 1$, and there will be no distortion; see note 9 above.

Although it is not definitive, this analysis suggests that transmission might have been overbuilt relative to generation during the cost-of-service era. The decline in the transmission-to-generation ratio beginning in the early 1980s could be consistent with this finding. During the early 1980s, inflation rates were at unprecedented levels. Experience with a rate case at the time suggests that regulators would have had to allow unprecedented high rates of returns to keep real returns constant.[11] If real returns fell below the real cost of capital, the utility sector afterward would no longer have had the incentive to overuse capital relative to other inputs in general, and to overbuild transmission relative to generation in particular.

## III. Postderegulation Regulation

Following the Public Utility Regulatory Policies Act (PURPA) in 1978, the Energy Policy Act (EPAct) in 1992, and FERC's Orders 888 and 889 in 1996, the electricity sector has moved toward a situation where, in much of the county, wholesale generation is deregulated while transmission remains regulated. As we saw above, continued regulation of transmission in and of itself could lead to overinvestment. However, perhaps courts are unlikely to be able to hold regulators to the legal standard that "the return to the equity owner should be commensurate with returns on investments in other enterprises having corresponding risks. That return, moreover, should be sufficient to assure confidence in the financial integrity of the enterprise, so as to maintain its credit and to attract capital."[12] Absent enforcement of this standard, rates need not be above the cost of capital, at least in the short to medium term, once investments are sunk in place.

Some commentators argue that present returns are inadequate to induce appropriate investment (Fama 2004). NERC reports that "some entities responsible for the reliability of the interconnected systems are concerned about the timely recovery of transmission investment at a

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[11] In the late 1970s through the early 1980s, I was the staff economist on the Antitrust Division's group litigating the rates for the Trans-Alaska Oil Pipeline. The need for unprecedented nominal rates of return led to the consideration of alternative measures of providing returns, e.g., allowing firms to earn a real rate of return on a rate base that was allowed to increase with the rate of inflation (Brennan 1991).

[12] *Federal Power Commission v. Hope Natural Gas* 320 U.S. 591 (1944).

fair rate of return" (NERC 2002, 9). The Federal Energy Regulatory Commission has proposed increasing the return on equity for any new transmission facility investments undertaken by an RTO by 1 percent.[13] Absent a finding that transmission investments are more expensive for an RTO than for traditionally structured utilities, this suggests either that the proposed returns on RTO investment would be excessive (leading to excessive transmission, for reasons outlined in the previous section) or that returns on non-RTO transmission investments are inadequate.

The potential for returns to be inadequate would be greater during a restructuring transition, when methods on how to determine appropriate rates of return and recover costs remain uncertain. Davis quotes industry experts to the effect that uncertainty about responsibility for upgrades, cost recovery (including allowed returns and depreciation), reliability standards, and siting authority discourage investments (Davis 2005; Fox-Penner 2005, 34–36). Methods of charging for transmission, e.g., postage-stamp or distance-based methods; nodal or zonal pricing; and claims on congestion rents, present issues that may be unresolved (Trebilcock and Hrab 2004; Brennan, Palmer, and Martinez 2002, chap. 9). Finding that "the U.S. transmission system is in urgent need of modernization," the U.S. Department of Energy (2002, xi, xii, 76) concludes that the incomplete transition to competitive wholesale markets created regulatory uncertainty, and that "innovative methods for recovering the costs of new transmission-related investments" still need to be encouraged.

Siting authority that is cited by Davis has two aspects that may discourage investment. One is the simple "NIMBY" effect, the undesirability of having transmission towers near one's home or workplace.[14] These effects need not be more intense now than when there was a relative boom in transmission investment 20–25 years ago. Greater exurban population growth and the use of the

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[13] Federal Energy Regulatory Commission. 2003. "Proposed Pricing Policy for Efficient Operation and Expansion of Transmission Grid," Docket No. PL03-1-000 (January 15), 2.

[14] This is not just a problem in the United States. New Zealand is facing a controversy about how or whether to build a transmission line from the south to deliver additional power to Auckland, its largest city. Landowners south of Auckland are resisting the efforts of TransPower, New Zealand's transmission company, to build this line. Compare the Green Party of New Zealand's views (http://www.greens.org.nz/campaigns/energy/transmissionlines.asp, accessed April 3, 2005) with those of TransPower's chief executive Ralph Craven (2004).

least-cost rights-of-way might be increasing those costs over time. However, those costs are not inherently illegitimate: They need to be factored appropriately into the overall test of whether a particular transmission investment is economically justified.

The second issue regarding siting is that the benefits to having a transmission line in one state are likely to fall across other states with transmission lines on the same grid. Expanding capacity in one state not only increases direct deliveries into neighboring states, but, because of loop flow, it may also have indirect effects in increasing transmission capacity over lines in other states. (It may reduce capacity of some lines, as well.) As long as decisions rest with individual states or utilities on a larger regional grid, transmission expansion will be short of the optimum unless those undertaking the construction are able to capture the benefits of that expansion.[15] This is the primary reason why RTOs should be regional, crossing state and perhaps national boundaries (Brennan 2003). Legal and political uncertainty in the relations between state regulators, utilities, and RTOs will only exacerbate reluctance to invest.

## IV. Insufficient Vertical Separation: Discrimination Against Entrants

One might regard the above impediments as arising from imperfections in the regulatory implementation of restructuring. A second set of problems arises from the implementation of the restructuring itself. In particular, restructuring may not have successfully broken the bonds between the regulated transmission sector and the unregulated generation sector. That such bonds create difficulties is well known. A regulated monopolist operating also in an upstream or downstream market has an incentive to discriminate against its competitors in the vertically related market by delaying or denying access to the regulated service. In effect, this creates a tie that allows the regulated firm to extract profits from its monopoly that the regulation otherwise prevents (Brennan 1987a).[16]

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[15] The competitive benefits of even a small increment to the transmission grid may be substantial (Borenstein, Bushnell, and Stoft 2000).

[16] This argument shows that regulation creates incentives to act anticompetitively, and thus that antitrust enforcement is particularly warranted in partially regulated sectors. A recent U.S. Supreme Court decision takes the opposite view (*Verizon v. Trinko*, 540 U.S. 398, 411–15 [2004]).

One can illustrate the effects with a simple model. Suppose a regulated service (e.g., transmission capacity) is used in fixed one-to-one proportions with an unregulated downstream good (electric energy). The regulated firm operates in both markets. Its competitors in the unregulated market obtain the regulated good at regulated price R.[17] The minimum average cost of providing the unregulated product by those competitors is M. Assuming perfectly elastic supply by the competitors absent any discrimination by the regulated firm, the downstream price would be M + R.[18] However, we assume that the regulated firm can increase its competitors' cost M by T, through discriminatory access policies. Hence, the downstream price will be M + R + T.

The quantity sold in the downstream market is given by demand $D(M + R + T)$; $D' < 0$. The regulated firm can choose to sell X in the downstream market, leaving $D(M + R + T) - X$ of the downstream market for the competitors. If so, it obtains $R[D(M + R + T) - X]$ from sales of the unregulated product.[19] T is discriminatory in that it affects the costs of the competitors but does not represent a higher price for the regulated service than the price that the regulated firm could take in directly. The regulated firm's costs specific to serving the unregulated market are $H(X)$; its costs of providing the regulated product will be $C(D(M + R + T))$. Both cost functions have positive first and second derivatives.

The regulated firm's profits depend on its choice of X and T. Assume first an internal solution, that the optimal level of X and T would leave some sales to the unaffiliated downstream competitors, i.e., that

$$D(M + R + T) > X.$$

[17] For simplicity, we make the regulated price exogenous (as under a price cap) rather than endogenous (as under cost-of-service regulation). Brennan (1987b) provides a more complex model with endogenous pricing.

[18] Crew, Kleindorfer, and Sumpter (2005) model discrimination using Cournot competition in the downstream market between the regulated firm and a competitor.

[19] We can neglect sales to itself of the regulated product as a purely internal transfer.

The regulated firm's profits will be given by

$$\Pi(X, T) = X[M + R + T] + R[D(M + R + T) - X] - C(D(M + R + T)) - H(X).$$

The first-order conditions are

$$\Pi_X = 0: M + R + T - R - H' = M + T - H' = 0$$

$$\Pi_T = 0: X + [R - C]D' = 0.$$

The first condition says that if the unaffiliated producers are in the market, the regulated firm takes the downstream market price as given and produces up to the point where the added revenue from selling downstream (M + T) equals the marginal cost of selling in the downstream market (H'). The second condition is that the firm sets the discrimination penalty T on rivals at the point where the gains from the tax (X, downstream sales) equals the lost profit from sales of the regulated good to the downstream firms (–[R – C]D').[20] On the one hand, and not surprisingly, the greater the price the regulated firm can already obtain from the regulated service, the less incentive it has to discriminate against unaffiliated competitors (Weisman 1995).[21]

On the other hand, if R equals C, or is "close" to it, the regulated firm would have no incentive not to raise the discrimination penalty to the point where the unaffiliated competitors would be foreclosed from the downstream market. If so, the downstream market is left entirely to

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[20] This is consistent with the result that the incentive to discriminate falls the greater the price that can be charged for the regulated service.

[21] Although that part of Weisman's analysis is correct, regulated firms will still have an incentive to discriminate against competitors to the detriment of consumer welfare if they are vertically integrated. Reiffen (1998) shows that Weisman gets a contrary result, in part by assuming that it is less costly to provide high-quality access to unaffiliated competitors.

it, implying that X = D(M + R + T). With T raised to the point where the unaffiliated firms are foreclosed, the regulated firm's profit becomes

$$\Pi(X, T) = XQ(X) - C(X) - H(X),$$

with $Q(X) = D^{-1}(X)$ being the price at which X units are purchased. The first-order condition becomes

$$\Pi_X = 0: Q - C' - H' + XQ' = 0.$$

Marginal revenue in the downstream market (Q + XQ') is equated to marginal cost (C' + H'). Regulation is evaded completely, with the firm setting the monopoly quantity of X and capturing all of the profits from its regulated monopoly in the downstream market.[22]

Prior examples of antitrust concern with vertical integration or controls between regulated and competitive sectors go back at least to concerns with undersizing of pipelines in order to reduce downstream supplies or to exercise monopsony power upstream (Brennan 2005, 10–12). This theory later served as the leading rationale for breaking up AT&T in 1984 and subsequently keeping the divested regulated local telephone companies out of the long-distance market (Brennan 1995). In electricity, the desire to discourage discrimination has led regulators to encourage (but not yet mandate) ISOs and RTOs so that the control of regulated monopoly transmission networks is nominally out of the hands of utilities that also own generation (Moss 2005, 22–27).

[22] Apart from these effects, vertically separated regulated firms may have less incentive to invest in quality than if they were unregulated; the effect depends on the extent to which consumers respond to quality increases at high (unregulated) prices compared to lower (regulated) prices and the degree to which downstream markets pass through lower upstream access charges (Buehler, Schmultzler and Benz, 2004).

Whether this has worked is questionable. RTOs do not provide a complete separation, but only "functional unbundling" of generation from transmission. One might expect that with retained generation owners retaining control over transmission grids, RTOs may have incentives other than maximizing economic welfare. Oren (1997) and Joskow and Tirole (2000) find that generator claims on higher transmission congestion revenues, in order to hedge against high transmission prices, can lead to inefficient outcomes. This result is not surprising; ownership of transmission rights gives generators a greater claim on the extra profits produced by withholding output.

Even with these limitations and imperfections, Kelly and Moody (2005) note that RTO formation has "hit the wall," with only one new RTO formed since FERC's Order 2000, and little prospects for more. With this record, it is not surprising that there are some empirical indicators that transmission capacity may be held back to limit competition. Moss (2004, 22) finds that the majority of TLR calls, indicating limited transmission capacity, have been made by "either single system security coordinators … or multiple-system security coordinators dominated by large, vertically integrated utilities."

## V. Insufficient Vertical Integration? Coordinating Lumpy Investments

The discrimination model and the policy discussion it implicitly motivates suggest that residual vertical integration is the cause of transmission underinvestment, because incumbent utilities resist grid expansion that would largely facilitate competition from new entrants. However, the need to coordinate transmission and generation, both in the short run and the long run, suggest that a lack of vertical integration could also discourage otherwise warranted expansion. The central problem is that for partial deregulation to work efficient production and expansion decisions in the regulated sector need to be made independently of specific adjustments to prices and supplies in the unregulated sector. If the regulated sector cannot operate efficiently without the ability to control supplies and investments in the unregulated sector, the latter cannot exploit the decentralized, entrepreneurial environment that markets can create.

Two related thought experiments illustrate the problem in electricity.

**Short run—designing transmission price caps.** A hallmark of efficient regulatory design is the ability to adapt incentive-based regulatory structures, such as price caps. Price caps provide incentives for regulated firms to control costs, discourage cross-subsidization, and maximize welfare subject to the profits that the regulated firm may get (Brennan 1989).[23] The feasibility of price caps, however, also provides an illustration of the extent to which the unregulated sector buying the regulated services at capped prices can operate independently of the caps. In the case of access to local telephone markets, which was the original application, price caps work because long-distance companies can add, expand, and purchase relatively small increments at a time. The long-distance industry could develop efficiently, taking access price caps as given.

Whether transmission price caps can accommodate the huge variations in both the short run (demand peaks) and long run (large new generators) is less than clear. Price caps can work well when demand for transmission is stable. When transmission capacity is constrained, however, efficient dispatch requires nodal prices for transmission to rise as far as necessary to induce appropriate supply responses to line congestion (Hogan 1992). On the surface, such prices are incompatible with price caps that set limits on the charges that a transmission line can impose on its users.[24]

**Long run—the transmission investment game.** To consider the long-run problem, imagine the following game.[25] The players are one regulated transmission company and two potential generation entrants, facing an electricity market with growing demand. The decisions that the regulator must make is when to have the transmission company install a line capable of eventually carrying power from both generators, and what prices to set to cover the cost of that

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[23] The major practical difficulty with price caps is that they require a regulatory commitment not to adjust prices if the regulated firm's realized profits become too high or low.

[24] Some propose instituting price caps only for cost-recovery purposes. However, the price a generator pays to use a transmission grid at any time would then be the combination of both the cap and a congestion charge. Thus, the relevant price to use the monopoly asset would remain effectively unconstrained during congested periods.

[25] The following scenario is based on a transmission investment problem facing provincial energy regulators in Alberta (Brennan, T., and J. Doucet. "More Power Creates Puzzle," *Edmonton Journal* (November 23, 2001): F1, F7.).

generation. The decision that the generation companies must make is when to build. Optimally, one generation company would build first; as demand grew, the second would later come on-line.

The regulator's task is to set prices that would induce efficient timing of entry by the generators. We do not offer a solution to the game; we suspect that there is no robust, general solution that takes physical constraints, cost, and demand conditions into account. The thought experiment is whether there's a way to solve this game without the regulator or transmission company knowing at least the specific costs of the generators in such a way to, in effect, take control of the entry decision through the pricing structure to ensure optimality.

These short-run and long-run thought experiments suggest that the transmission and generation sectors may not be able to run independently, mediated by a relatively simple and predictable tariff. Although, to paraphrase Adam Smith, extent of the market may be sufficient to allow specialization in transmission and generation, the concerns raised originally by Coase (1937) and later by Williamson (1975) on the virtues of internal, hierarchical control may dominate. The primary virtue of the market—the ability to function without having to aggregate and communicate information for planning purposes—may be foregone if the transmission planner requires such extensive knowledge of the generation sector to operate efficiently (Hayek 1945).[26]

Vertical coordination between sectors may be more important in electricity than in other partially deregulated industries (oil, gas, telecommunications). Using data on operating expenses, Kaserman and Mayo (1991, 499) found that "the costs of vertically disintegrated production [at the sample mean] are 11.96 percent higher than for vertically integrated production." They attribute such economies to the features that make solutions to the above games so difficult—

[26] I thank Paul Kleindorfer for suggesting Hayek's perspective as a way to frame this argument.

high transaction costs, supply and demand uncertainty, small numbers bargaining, and opportunism from sunk specific investments.[27]

More recent analyses support a concern with the loss of vertical coordination in the electricity sector. Kwoka (2002, 2003) has found significant efficiency costs from disintegration. He notes that coordination by RTOs may be able to restore some of these lost efficiencies, but that would call into question the ability of the generation sector to act competitively without control by the monopolist in the middle. Michaels (2004) suggests that markets can supersede actual or contractual integration between generation and transmission, but that restructuring rested on an unwarranted assumption that such integration produced no benefits. He surveys 11 econometric studies of vertical integration (including Kaserman and Mayo’s and Kwoka’s) finding that all but one discovered cost reductions, many of which are both statistically and empirically significant.

If vertical integration or, equivalently, extensive central coordination of transmission and generation is necessary for an efficient energy sector, a stand-alone transmission system will inherently be unable to reap the full benefits from expansion produced for an independent generation sector. Absent appropriate coordination, then, there may be too little investment in transmission relative to the ideal. Notably, these concerns about vertical separation in the utility industry stand apart from other arguments that introducing competition into the sector may conflict with supplying reliability.  As a public good in electricity due to the inability to store electricity and, because of grid interconnectedness, to restrict blackouts to only those customers of generators that fail to meet their demand, competitive electricity markets may tend to provide too little reliability on their own (Brennan, Palmer, and Martinez 2002, 194–97).

[27] Uncertainty can delay transmission investment relative to what might seem optimal with certain demand growth, to preserve the benefits of the option of choosing when to expand (Martzoukos and Teplitz-Sembitzky 1992). Such delays are, however, consistent with an absence of scope economies between generation and transmission.

## VI. Conclusion

A frequently voiced complaint is transmission inadequacy. Data showing a decline in capacity relative to energy shipments may be an artifact of excessive transmission investment during the pre-restructuring era. However, as restructuring has developed, uncertainty regarding rates of return, cost recovery, pricing methods, siting, and interstate externalities may all have contributed to underinvestment. Most notably, partial deregulation and vertical restructuring may have discouraged investment. To the extent that vertical separation is not complete, e.g., because RTOs are not sufficiently widespread or independent, integrated utilities may have the motivation and means to limit expansion, particular to merchant generators. However, vertical separation may have led to coordination difficulties that, too, would discourage new transmission investment.

The hard lesson all of this may be that effective partial deregulation may be chimerical. In particular, we may be unable to institute independent competition in generation sector, where each generator takes as given a price of transmission set through an independent process. Early in the U.S. experience with open wholesale markets, Joskow noted an open question is the design and degree of vertical control necessary to make restructuring work (Joskow 1997). As noted above, that open question is whether vertical control necessary to ensure reliability in the interconnected grid is consistent with such competition. However, the concern over transmission adequacy suggests that perhaps the sacrifice of vertical economies necessary for wholesale competition is not worth the benefits. As Taylor and Van Doren (2004) suggest, if transmission can or should not be deregulated outright, then perhaps the best alternative is to keep both vertical integration and regulation.

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