Adaptation and the Financial Structure of Long-term Exchange Relations: Evidence from Electricity Marketing Contracts

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May 2007

Abstract

What can parties achieve by long-term contract that they cannot achieve by a sequence of short-term contracts? The research illuminates the role of contract renegotiation in enabling efficient investment over the course of long-term exchange. I provide evidence from a dataset of electricity marketing contracts about how electricity generators and electricity “marketers” use risk-sharing schemes and financial structure (debt or equity financing) to channel investment incentives, and I provide evidence about how parties use contract duration, risk-sharing schemes and veto provisions to address both programmable and unprogrammable demands for contract adjustments. Both the theoretical and empirical results demonstrate how contracting parties may commit to a combination of longer terms and veto provisions to facilitate project financing in environments featuring highly-redeployable assets. The results lend themselves to a simple, counterfactual policy experiment: were the antitrust authorities to bar parties from instituting veto provisions, contracting parties would adapt by crafting shorter term contracts, and they would dissipate surplus through overly frequent renegotiation and greater monitoring costs.

Keywords: adaptation, renegotiation, contract duration, veto provisions, financial structure.

JEL Classification: L14, D92, L42, L94

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0. Introduction

The research takes up an old, enduring question about what contracting parties can achieve in a long-term contract that they cannot achieve by a sequence of short-term contracts. In the environment examined here, the action depends on the role of both programmed renegotiation and *un*programmable demands for renegotiation in enabling contracting parties to adapt terms of exchange over time to changing conditions. As a matter of course, short-term contracts enable parties to renegotiate and adapt terms of exchange after a short term (Myers 1977, pg. 158; Williamson 1971, pg. 116). Thus, if adaptation over the long term is important, why would parties ever commitment to long terms? One part of the answer advanced here is that long-term contracts allow parties to program fewer, rather than more, costly instances of renegotiation. A familiar tradeoff obtains between enabling flexibility in contractual relations and the costs of supporting that flexibility: a sequence of short-term contracts may afford greater flexibility, but programming a sequence of short-term contracts also entails programming a sequence of costly renegotiations (Masten and Crocker 1985, Crocker and Masten 1988). Longer terms may not neutralize the prospect of unprogrammable demands for renegotiation, but they diminish the frequency of programmed renegotiations.

Managing tradeoffs between flexibility and renegotiation suggests that efficient adaptation can be an interesting economic problem (Crocker and Masten 1991), but that is just one consideration in a much larger contracting problem. The first-order action pertains to investment incentives (Williamson 1971, pg. 116). In the environment examined here, adaptation may involve expanding, withdrawing, or tuning up production capacity over the course of (possibly) long-term exchange. A difficulty is that one party's decision to expand, withdraw, or tune up capacity can diminish the payoffs of counterparties joined in long-term contracts. Thus, the prospect of changing production capacity might induce demands by counterparties to either adjust other terms of contract in response to changes in capacity or to circumscribe any one party's plans to change capacity. Specifically, counterparties might demand safeguards in long-term contracts in the form of provisions that enable them to impose renegotiation in response to other parties' proposals to expand, withdraw, or tune up capacity. Alternatively, they might demand shorter-term contracts. We thus come full circle. Contract duration is one instrument parties can use for containing the frequency of costly renegotiations, but renegotiation itself constitutes an instrument parties may use for adapting terms of contract as well as production capacity over the course of long-term exchange – which in turn may affect the duration of contracts and the incentives of parties to invest in production capacity in the first place.

I examine an environment in which contract duration constitutes but one of four instruments parties use for managing investment in production capacity over the course of long term exchange. I examine an environment in which parties tailor (1) contract duration, (2) veto provisions, (3) risk-sharing schemes, and (4) financial structure (debt or equity) to support "project financing" – the financing of specific, discrete production facilities. Much theoretical and empirical research working out of a transaction costs logic has established how long terms can mitigate problems relating to relationship-specific investment (e.g., Joskow 1987) in contexts in which adaptation constitutes an important economic problem (e.g., Masten and Crocker 1985). Like Crocker and Masten (1988), this paper accommodates the prospect that there can be important interactions between contract duration and the contractual mechanisms parties use to enable adaptation. I borrow from Williamson (1988) the hypothesis that debt financing requires fewer costly monitoring mechanisms than equity financing.[1] With this hypothesis in hand, one can craft an organic explanation of, among other things, the role of both programmed and unprogrammed renegotiation in enabling parties to adapt terms of contract over the course of long term exchange and the prevalence of debt over equity in the financing of highly redeployable assets. Moreover, one can do this *without* having to appeal to risk-aversion.

I provide evidence from a dataset of 101 electricity marketing contracts. Electricity marketing contracts join electricity "marketers" and other parties who often own generating assets ("generators") in pair-wise exchange relations.[2] Generators contribute generating assets and the technical know-how to operate such assets, and marketers contribute capabilities in selling electricity on wholesale markets and in managing the risks associated with trading electricity. Parties structure contracts to support generators' financing of electricity generation assets. Investing in generation capacity can pose interesting contracting problems, because one party's investments (those of the generator) can affect the payoffs of the counterparty (the marketer). A marketer will yield to a generator a stream of payments in return for the right to dispatch electricity from the generator's units on demand.[3] Bringing new capacity online can complicate the efforts of the marketer to commercialize capacity that is already under contract.[4] At the very least, a marketer might be compelled to demand adjustment of the risk-sharing scheme according to which it compensates the generator. Indeed, such schemes commonly require the marketer to

[1] The discussion of Hansmann and Kraakman (2000, pp. 399-401) on monitoring and "asset-partitioning" is apposite. See also D.V. Williamson (2005).
[2] Sometimes contracts pertain to the exchange of electricity between marketers, but the focus in this paper is on contracts between generators and marketers that implicate specific generating assets that the generators own.
[3] Typically, a contract will exclusively assign generator-specific dispatch rights to a marketer. Otherwise a generator may find itself struggling to serve competing dispatch demands.
[4] For example, output from new capacity can induce congestion on transmission networks thus complicating transmission of electricity from capacity under contract. Output from new capacity may also depress prices in wholesale markets or knock existing capacity "out of the money." More on this below.

bear all risk and to yield to the generator a stream of fixed payments. In such circumstances, the marketer might demand adjustment of the fixed payments. Anticipating this, the parties might craft contracts that enable them to jointly internalize the effects of changing capacity. But that is just the beginning of a much richer problem. The way contracting parties manage capacity over time would seem to be amenable to complete, state-contingent contracting. Contracts might, for example, include state-contingent "options" according to which one party or the other could unilaterally expand or improve capacity as well as retire older, less efficient capacity. In contrast, contracting parties might agree to renegotiate selected terms of contract in the event one party or the other proposes unprogrammed changes in capacity. As it is, contracts often feature mechanisms, such as veto provisions, that enable one party or the other to impose renegotiation.

The principal results of the paper pertain to pair-wise patterns of substitution and complementarity between veto provisions, contract duration, risk-sharing, and financial structure.[5] Both the theory and evidence are consistent with "efficient adaptation" being an important economic problem, and the results demonstrate a role for contract duration and renegotiation. The results also suggest that it is important to distinguish between programmable and unprogrammable demands for adaptation. It is not obvious that programmable demands alone would induce tradeoffs between shorter and longer term contracts, but admitting the prospect that some demands are unprogrammable does, and the empirical results are corroborative.

[5] An alternative research strategy might have been to explore relationships between contract duration and measures of asset-specificity. In some environments long terms of contract or vertical integration may remedy problems of relationship-specific investment. In other environments, such as the environment explored here, parties may have instruments in addition to contract duration for remedying problems of relationship-specific investment. Accordingly, efforts to distinguish monotonic patterns between contract duration and asset-specificity may fail if much of the action involves interactions between instruments.

The patterns of complementarity and substitution are also interesting for two practical reasons. First, "substitution" may preclude appeal to monotone comparative statics, and that complicates the effort to yield policy-relevant conclusions. In the environment explored here, the economics include discrete choices – decisions to include or exclude certain contractual provisions – as well as continuous choices such as contract duration. Discrete choices preclude appeal to traditional comparative statics based on the envelope theorem. Even so, I explore an environment that is simple enough so that one can examine the mixed, discrete-continuous envelope of contracts and yield results. Chief among these results is the conclusion of a policy experiment: were the antitrust authorities to bar parties from instituting veto provisions, contracting parties would adapt by crafting shorter term contracts, and they would dissipate surplus by programming overly frequent renegotiation and by incurring greater monitoring costs. Again, the empirical results are corroborative.

Second, the patterns of substitution and complementarity are interesting, because they lend themselves to a simple narrative about how electricity marketing contracts work. Veto provisions and contract duration complement each other in that long terms increase the prospect of unprogrammed demands for adaptation, and veto provisions allow parties to impose renegotiation as a way of addressing unprogrammed demands. At the same time, short-term contracts tend not to feature veto provisions, because short terms afford parties the option of renegotiating after a short term. Meanwhile, imposing the residual claim on marketers allows investors to concentrate costly monitoring on marketers and to relieve themselves of having to monitor generators' fixed streams of payoffs. Lower monitoring costs increase the vertical rent that marketers and generators extract. Nonetheless, there is an advantage to imposing some risk on generators. Imposing some risk would induce them to internalize at least some of the rent-diminishing effects (if any) of expanding capacity, but parties can address generators' distorted investment incentives by imposing shorter terms. Shorter terms, however, give rise to a greater frequency of programmed renegotiations. The upshot is that different combinations of contract duration, veto provisions and risk-sharing feature different advantages and disadvantages.

The remainder of the paper proceeds in three parts. The first part lays out a simple model of a contracting problem in which contract duration, veto provisions, risk-sharing and financial structure are endogenous. The model is *not* specific to electricity marketing but rather subsumes the generator's and marketer's contracting problem in a more general framework. The advantage of the generalized framework is that it can accommodate analysis in environments that feature either highly-redeployable assets or assets that are highly relationship-specific. Consequently, the framework can allow one to characterize tradeoffs between debt and equity financing. I simplify analysis by posing a simple taxonomy of eight types of contracts and by characterizing the duration of each type. The results demonstrate patterns of complementarity and substitution between contract duration, veto provisions, and risk-sharing. The results also yield stark predictions, one of which is that four of the eight types of contracts are strictly dominated by the other four types and thus should never appear. The second part of the paper describes the structure of electricity marketing contracts and presents empirical results. The empirical results demonstrate, among other things, that dominated types of contracts never appear. The results are also consistent with the predicted outcome of the policy experiment. The last part concludes.

1. Model and Hypotheses

Two risk-neutral parties, labeled simply U ("Upstream") and D ("Downstream" or "Distributor," say), craft a contract that extends over an interval of duration $T \geq 0$. Parties contribute assets that may or may not be highly redeployable outside of their specific relationship. Party U contributes production assets that involve significant sunk costs. Party D contributes complementary assets or capabilities, and the parties produce in as many as two states. In the initial state, the parties anticipate a continuous and stationary stream of payoffs $z(t)$ with $\mathrm{E}[z(t)] = z$. The state may change in that at any time $t^* \in [0, T]$ the stream of payoffs may change. I am agnostic on how the payoffs change, but I characterize the change by a continuation value $S(t^*) = S$. One can, for example, understand the continuation value as the expected "salvage" value. Realizing the continuation value entails either redeploying assets or adding, withdrawing or tuning up capacity as well as adapting the terms of contract. I am agnostic on how parties respond to the change in states, but I do suggest that implementing a cost-effective response may involve some dissipation of surplus. The extent of rent-dissipation will depend partly on how parties design their contract.

Terms of contract include contract duration T and three binary choices. First, parties decide whether or not to impose the residual claim on party D, in which case the party U receives a fixed payoff at every $t < t^*$. I pose the alternative as "sharing risk," although the alternative could entail imposing the residual claim on party U. Second, the parties decide whether or not to impose a veto provision in the contract. Specifically, they decide whether or not to impose a provision according to which either party might veto the proposal of the other to add, withdraw or tune up party U's production capacity. Hence, a contract is a quadruple (s, v, d, T) with

T = Contract duration

$$s = \begin{cases} 1 & \text{D bears all risk} \\ 0 & \text{U bears some risk} \end{cases}$$

$$v = \begin{cases} 1 & \text{Veto provision included} \\ 0 & \text{No veto provision} \end{cases}$$

$$d = \begin{cases} 1 & \text{Debt financing} \\ 0 & \text{Equity financing} \end{cases}$$

Parameters

Parties can use the veto provision to impose renegotiation over the terms of contract and over the prospect of adding, withdrawing or tuning up production capacity. The interpretation is that renegotiation forces the parties to realize adjustments in capacity, including the prospect of liquidation, that maximize the vertical rent. The adjustments the parties have to make may be unprogrammable which renders them noncontractible. Thus, renegotiation may serve the purpose of enabling the parties to realize rent-maximizing adjustments. The key point is that renegotiation may itself entail some dissipation of rent, which I indicate by the parameter *R*. Failure to realize the vertical rent invites some dissipation of rents, which I indicate as a tax of proportion d of the continuation value S. Meanwhile, imposing a risky stream of payoffs on party U raises the (instantaneous) auditing/monitoring costs of outside investors by increment *m*.

I justify this characterization of monitoring costs as follows: party D may have its hand in a broad portfolio of projects with any number of parties of type U. Pooling streams from different projects amounts to pooling risks, but pooling risks may make it more difficult for outside investors to disentangle and monitor streams thus creating demands for costly auditing schemes.

Party U, however, may separately incorporate each of its production projects.[6] In the language of Hansmann and Kraakman (2000), party U may be able to "partitions assets" across separately incorporated entities so that outside investors may forgo the costs of disentangling any one project's streams from those of other projects. But risky streams still require monitoring, because parties of type U might cheat investors by misrepresenting their payoffs. However, relieving party U of project-specific risk relieves outside investors of having to bear incremental monitoring and auditing costs (D.V. Williamson 2005). Thus, imposing the residual claims on party D still enables risk pooling, but it also enables parties to economize on auditing and monitoring costs; investors need only concentrate the lens of costly auditing and monitoring on party D.

I indicate K as the sunk costs of instituting a mechanism to monitor party U's payoffs[7], and I indicate c as the instantaneous marginal cost of producing instantaneous output z. I indicate r as a discount rate and l as a hazard rate reflecting the instantaneous likelihood of the state reverting to the continuation state. Next, I indicate g as the instantaneous rate at which the cost of producing output increases.[8]

Finally, I indicate $a \in [0,1]$ as the proportion of the vertical rent that is relationship-specific – that is, a indicates "asset-specificity," the degree to which assets committed to the relationship

[6] In the electricity generation context, generators uniformly incorporate generating projects in distinct production LLC's.

[7] The sunk costs are important, and the appeal to them is consistent with the framework of Williamson (1988).

[8] Imposing $g > 0$ may seem artificial, but it constitutes a simple way of securing the second-order conditions for an interior solution of the optimal contract duration. The key point, however, is that there any number of isomorphic ways to secure an interior solution. For example, the term g constitutes an indirect way of modeling depreciation of production capacity. I suggest that imposing g constitutes little loss of generality and does not otherwise constitute an interesting, instructive assumption.

cannot be redeployed without dissipating value. The appeal to asset-specificity will provide a way to characterize tradeoffs between debt and equity financing of the sort anticipated in Williamson (1988).

To recap, the parameters of the system are:

z	=	Instantaneous income at time $t \in [0, T]$
c	=	Instantaneous cost of producing z
m	=	Instantaneous monitoring costs
K	=	Cost of instituting monitoring mechanism
R	=	Dissipation due to renegotiation
S	=	Continuation value
d	=	Dissipation, proportional to the continuation value S, that results from distorted investment incentives
r	=	Discount rate
a	=	Degree of asset-specificity
g	=	Rate of cost appreciation
l	=	Hazard rate

Given a "contingency" occurs at time t^*, the parties at time $t = 0$ perceive a discounted vertical rent V:

$$V(t^*;T) = \int_0^{t^*} \left(z - ce^{gt} - (1-sd)a^d m\right)e^{-rt}\,dt + Se^{-rt^*} - vR\,e^{-rt^*} - daS\left(e^{r(T-t^*)} - 1\right)$$
$$- (1-v)sdS\left(e^{r(T-t^*)} - 1\right)$$

$$= \int_0^{t^*} \left(z - ce^{gt} - (1-sd)a^d m\right)e^{-rt}\,dt + [S - vR]e^{-rt^*} - [da + (1-v)sd]S\left(e^{r(T-t^*)} - 1\right)$$

While this expression appears to be complex, its interpretation is straight-forward. Contracting parties would realize an (expected) vertical rent

$$V(t^*;T) = \int_0^{t^*} \left(z - ce^{gt}\right)e^{-rt}\,dt + Se^{-rt^*}$$

but for a series of negative deviations from the vertical rent that depend on how parties structure their financing and design their contract. The interpretation is that imposing veto provisions $(v=1)$ allows the parties to avoid the (discounted) rent dissipation dS that occurs at time t^*, but setting $v=1$ forces them to bear the (discounted) renegotiation tax R.[9] Parties secure the (discounted) continuation value S, and they secure the expected stream of payments z through time t^* less the costs of producing that stream. Finally, imposing risk on party U$(s=0)$ forces the parties to bear incremental monitoring costs m, but imposing risk forces party U to internalize the effects of inefficient investment at time t^*, thus enabling the parties to avoid the tax dS. In contrast, relieving party U of risk and imposing the residual claim on party D enables the parties to avoid incremental monitoring costs but introduces the prospect of distorted investment at time t^*. Note, that either imposing the veto or imposing risk on party U allows the parties to avoid the tax dS.

Asset-specificity enters V in two places. First, parties perceive monitoring costs $a^d m$. Thus, in the absence of other remedies, parties perceive monitoring costs m under equity financing $(d=0)$ but perceive lower monitoring costs am under debt financing $(d=1)$. The difficulty with debt, however, is that it frustrates efforts to "work things out" (Williamson 1988) and salvage relationship-specific value in the event the stream of payoffs revert to the continuation payoffs. Specifically, parties perceive a tax daS proportional to the continuation value S.[10] The advantage of equity – indeed, the entire purpose of equity in this environment – is to allow

[9] Note that the rent dissipation that attends distorted investment at time t^* is diminishing with time. This is not an important assumption.
[10] The rent dissipation that attends failure to "work things out" is also diminishing with time.

parties to avoid the rent dissipation aS that attends ventures featuring some degree of relationship-specific value.

If one lets $F(t^*;\cdot)$ indicate the probability of an unprogrammable contingency occurring by time t^* – with corresponding probability mass function $f(t^*;\cdot)$ – and if one lets EV indicate the expectation of V, then one can characterize the parties expected payoff at time $t = 0$ as:

$$\begin{aligned} Ep &= EV - (1 - sd)a^{d}K \\ &= \int_{0}^{T} V(t^*;T)\, f(t^*;\cdot)\,dt^* + \left(1 - F(T;\cdot)\right)V(T;T) - (1 - sd)a^{d}K \end{aligned}$$

Note that imposing $s = 1$ (party D bears all risk) and $d = 1$ also allows the parties to avoid the up-front sunk costs K of instituting a monitoring mechanism.

Now, if one lets l indicate the hazard rate, then the density function corresponds to the exponential density $f(t;l) = le^{-lt}$ and $\left(1 - F(t;l)\right) = e^{-lt}$. Economic modelers often use the Poisson distribution to model the number of unprogrammed events that may occur within a given interval of time, but the exponential distribution constitutes the reverse side of the coin; it constitutes a way of modeling the time that lapses until the next contingency occurs. In the environment explored here, we are interested in the time it takes for a single event, the realization of the continuation value, to occur.

With exponential hazards in hand, we have

$$\begin{aligned} V(t^*) = &\left[\frac{z - (1 - sd)a^{d}m}{r}\right]\left(1 - e^{-rt^*}\right) + \left[\frac{c}{g - r}\right]\left(1 - e^{(g-r)t^*}\right) + \left[S - vR\right]e^{-rt^*} \\ &+ \left[da + (1 - v)sd\right]S\left(1 - e^{r(T - t^*)}\right) \end{aligned}$$

and

$$Ep(s, v, d, T) = \left[\frac{z-(1-sd)a^{d}m}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)-(1-sd)a^{d}K$$
$$+\left[\frac{S-vR}{r+l}\right]\left(l+re^{-(r+l)T}\right)-\left[\frac{da+(1-v)sd}{r+l}\right]S\left[r\left(e^{-lT}-1\right)+l\left(e^{rT}-1\right)\right]$$

This last expression for the expected vertical rent $Ep(s, v, d, T)$ yields complementarity and substitutability results.

Proposition 1: Given a, d, r, K, R, S each greater than zero, then

(1) *v* and *T* are strict complements,
(2) *v* and *s* are strict complements,
(3) *v* and *d* are weakly substitutes and complements,
(4) *s* and *d* are strict complements,
(5) *s* and *T* are *not* complements, but, given $am = 0$, *s* and *T* are weakly substitutes.
(6) *d* and *T* may be neither complements nor substitutes, but for low degrees of asset-specificity (low a) and *m* > 0, *d* and *T* may be complements.

Proof: One can prove each item by characterizing whether or not the function $Ep(s, v, d, T)$ has increasing or decreasing differences in each of the six possible pairs of inputs (Topkis 1998, p. 42). In Appendix 1 I demonstrate the results for items (1) and (5).

Remark: Item (1) in Proposition 1 indicates that *v* and *T* are complementary, and it would be tempting to pose a counterfactual policy experiment suggestive of an appeal to the LeChatelier Principle and conclude that barring parties from including veto provisions in their contracts – that is, imposing *v* = 0 on the contracting parties – would induce them to craft shorter term contracts. Such a conclusion would be appropriate were the function $Ep(s, v, d, T)$ supermodular in (s, v, d, T) – that is, were each of the four inputs complements to each other.

(See Topkis 1998, pp. 80-81, 92-93.)   Items (5) and (6) in Proposition 1 imply that the function $Ep(s, v, d, T)$ is not supermodular, in which case imposing $v = 0$ may induce parties to adopt a bundle of adaptations (s', d', T') that features T' greater than the contract term featured in the original contract. Accordingly, I have to develop more results in order to motivate a counterfactual policy experiment.

Note that one can partition contracts into $2^3 = 8$ types $(s, v, d) \in \{(0,1) \times (0,1) \times (0,1)\}$. I motivate a counterfactual policy experiment by characterizing the envelope of contract duration $T(s, v, d) = \arg\max_{\hat{T}} Ep(s, v, d, \hat{T})$ and by evaluating $T(s, v, d)$ along the envelope of undominated triples (s, v, d). I will be able to show that barring parties from using veto provisions does indeed induce a reduction in contract duration. In the next proposition I characterize $T(s, v, d)$ for a given triple (s, v, d), and then I characterize the envelope of undominated triples. I close the section by graphically demonstrating the proposition in Williamson (1988) that equity lines up with higher degrees of asset-specificity and debt lines up with lower degrees of asset-specificity.

In the first lemma I show that contract duration $T(s, v, d)$ is greater than zero and finite under plausible parameterizations. I then show that four of the eight types of contracts can never be efficient, but I will need $T(s, v, d) > 0$ for all s, v, and d to demonstrate that the remaining four types can be efficient.

Lemma 1: Given $z - c - m - rS > 0$ and g, r and c each greater than zero, then contract duration $T(s, v, d)$ achieves a unique optimum conforming to the identity

$$T(s, v, d) = \frac{1}{g}\ln\left\{\frac{\left[z-(1-sd)a^{d}m\right]-r\left[S-vR\right]}{c} - \left(\frac{l\,r}{r+l}\right)\left[da+(1-v)sd\right]\left(\frac{Se^{rT(s,v,d)}}{c}\right)\left[e^{(r+l)T(s,v,d)}-1\right]\right\}$$

with $0 < T(s, v, d) < \frac{1}{g}\ln\left[\frac{z+rR}{c}\right]$.

Moreover, inspection yields

$$T(1,1,0) = T(0,1,0) \geq T(0,0,0) \geq T(1,0,0) > 0$$
$$T(1,1,1) \geq T(1,0,1) > 0$$
$$T(1,1,1) \geq T(0,1,1) \geq T(0,0,1) > 0$$

Proof: Differentiating Ep with respect to T yields

$$\frac{\partial Ep}{\partial T} = V(T;T)\,f(T;\cdot) - f(T;\cdot)V(T;T) + \int_0^T V_2(t^*;T)\,f(t^*;\cdot)dt^* - \left(1-F(T;\cdot)\right)\left(V_1(T;T)+V_2(T;T)\right)$$
$$= \int_0^T V_2(t^*;T)\,f(t^*;\cdot)dt^* - \left(1-F(T;\cdot)\right)\left(V_1(T;T)+V_2(T;T)\right)$$

or

$$\frac{\partial Ep}{\partial T} = \left[z-(1-sd)a^{d}m\right]e^{-(r+l)T} - r\left[S-vR\right]e^{-(r+l)T} - ce^{(g-r-l)T} - \left(\frac{l\,r}{r+l}\right)\left[da+(1-v)sd\right]S\left(e^{rT}-e^{-lT}\right)$$

Evaluating the first-order condition $\frac{\partial Ep}{\partial T} = 0$ yields the identity indicated above. The identity can be rearranged as $e^{gT} = k_0(s, v, d) - k_1(s, v, d)e^{rT}\left[e^{(r+l)T}-1\right]$ where

$k_0(s,v,d) = \dfrac{\left[z-(1-sd)a^d m\right] - r\left[S - vR\right]}{c}$ and $k_1(s,v,d) = \left(\dfrac{lr}{r+l}\right)\left[da + (1-v)sd\right]\left(\dfrac{S}{c}\right)$. The premises $z-c-m-rS>0$ and $c>0$ imply $k_0>1$ which amounts to saying that the stream z outweighs the cost of producing that stream (c + m) and the opportunity cost of foregoing the salvage value S (rS). The premises $r>0$ and $c>0$ imply that $k_1 \geq 0$ is well defined. The second-order condition is

$$\frac{\partial^2 Ep}{\partial T^2} = -gce^{(g-r-l)T} - lr\left[da + (1-v)sd\right]S\left\{e^{rT} + r\left(\frac{e^{rT} - e^{-lT}}{l+r}\right)\right\}$$

Thus imposing $g>0$ implies that the second-order condition for a unique solution $\dfrac{\partial^2 Ep}{\partial T^2} < 0$ strictly holds. In turn, implicit differentiation yields $\dfrac{\partial T}{\partial k_0} = \dfrac{1}{ge^{gT} + k_1 e^{rT}\left[(2r+l)e^{(r+l)T} - r\right]} > 0$.

Note that the first-order condition implies $T=0$ given $k_0=1$. Thus, imposing $k_0>1$ yields optimal contract duration $T>0$. Inspection of the first-order conditions over the eight types of contracts $(s,v,d) \in \{(0,1)\times(0,1)\times(0,1)\}$ yields the sequence of inequalities and the upper bound $T(s,v,d) < \dfrac{1}{g}\ln\left[\dfrac{z+rR}{c}\right]$. See Appendix 2.

Now, Lemma 2 and Lemma 3 demonstrate that four types of contracts are never efficient under certain plausible parameterizations.

Lemma 2: Given R and r greater than zero, contracts conforming to $(s,v,d) = (0,1,d)$ are never efficient.

Proof: There exist contracts conforming to $(s, v, d) = (0, 0, d)$ that strictly dominate any one contract conforming to $(s, v, d) = (0, 1, d)$. See Appendix 3.

Lemma 3: Given R and r each greater than zero, contracts conforming to $(s, v, d) = (1, 0, 0)$ and $(1, 1, 0)$ are never efficient.

Proof: There exist contracts conforming to $(s, v, d) = (0, 0, 0)$ that strictly dominate any one contract conforming to $(s, v, d) = (1, 0, 0)$ or $(1, 1, 0)$. See Appendix 3.

I now show that the remaining four types of contracts can be efficient.

Proposition 2: Assume that at least one type of other contract other than the null contract is efficient. Any one contract conforming to $(s, v, d) \in \{(0, 0, 0), (0, 0, 1), (1, 0, 1), (1, 1, 1)\}$ may dominate.

Proof: Let $T_{svd} = T(s, v, d) = \arg\max_{\hat{T}} Ep(s, v, d, \hat{T})$ indicate the envelope of contract duration. Lemma 2 and 3 imply that we have only four out of the eight types of contracts to consider. The object is to find parameterizations under which any one of the four remaining types of contracts would be efficient. Thus, for each of these four contracts one must characterize a particular parameterization and make three pair-wise comparisons.

(1) First I show that there exists a parameterization under which $(0, 0, 1)$ is efficient. Let $a = 0$, $g > 0$, $d > 0$, $r > 0$, $l > 0$, $c > 0$, $R > 0$, $S > 0$, $K > 0$, and $z - c - m - rS > 0$. Then $Ep(0, 0, 1, T) - Ep(0, 0, 0, T) \geq K > 0$. Further, optimization implies that

$Ep\left(s, v, d, T_{svd}\right) \geq Ep\left(s, v, d, T_{s'v'd'}\right)$ for all (s, v, d) and $(s', v', d') \in \{(0,1)\times(0,1)\times(0,1)\}$.

Thus, all along the contract duration envelope we have

$$Ep\left(0, 0, 1, T_{001}\right) \geq Ep\left(0, 0, 1, T_{000}\right) > Ep\left(0, 0, 0, T_{000}\right) \geq Ep\left(0, 0, 0, T_{001}\right)$$

Thus the contract $(0, 0, 1)$ dominates the one equity contract conforming to $(0, 0, 0)$.

Next, observe that $Ep(0, 0, 1, T) - Ep(1, 0, 1, T) = \left(\frac{dS}{r + l}\right)\left[l\left(e^{rT} - 1\right) + r\left(e^{-lT} - 1\right)\right] > 0$ for any $T > 0$. Under the premises of Lemma 1 we know that $T_{101} > 0$ which in turn implies $Ep(0, 0, 1, T_{101}) - Ep(1, 0, 1, T_{101}) > 0$ This inequality and optimization imply that along the contract duration envelope

$$Ep\left(0, 0, 1, T_{001}\right) \geq Ep\left(0, 0, 1, T_{101}\right) > Ep\left(1, 0, 1, T_{101}\right) \geq Ep\left(1, 0, 1, T_{001}\right)$$

Thus $(0, 0, 1)$ dominates $(1, 0, 1)$.

Finally one must show that $(0, 0, 1)$ dominates $(1, 1, 1)$. Observe that

$Ep(0, 0, 1, T) - Ep(1, 1, 1, T) = \left(\frac{R}{r + l}\right)\left(l + re^{-(r+l)T}\right) > 0$. This inequality and optimization imply that along the contract duration envelope

$$Ep\left(0, 0, 1, T_{001}\right) \geq Ep\left(0, 0, 1, T_{111}\right) > Ep\left(1, 1, 1, T_{111}\right) \geq Ep\left(1, 1, 1, T_{001}\right)$$

Thus $(0, 0, 1)$ dominates $(1, 1, 1)$, and one can conclude that (0, 0, 1) is efficient.

Similar calculations along the contract duration envelope yield the following results:

(2) Under the premises of Lemma 1 one can show that $T_{000} > 0$. In turn, one can show that

$d = 0$, $l > 0$, $R > 0$, $S > 0$, $K > 0$ and $0 < a < \dfrac{m\left(1 - e^{-(r+l)T_{000}}\right) + K(r+l)}{S\left[r\left(e^{-lT_{000}} - 1\right) + l\left(e^{rT_{000}} - 1\right)\right]}$ imply

$(s, v, d) = (1, 0, 1)$ is efficient.

(3) Again, under the premises of Lemma 1 one can show that $T_{001} > 0$ and $T_{101} > 0$. One can then judiciously choose $a > 0$, $d > 0$, $l > 0$, $m \geq 0$, $R \geq 0$, $S > 0$ and $K > 0$ so that

$0 \leq R < dS\left[\dfrac{r\left(e^{-lT_{101}} - 1\right) + l\left(e^{rT_{101}} - 1\right)}{re^{-(r+l)T_{101}} + l}\right]$, $0 \leq R < a\left[\dfrac{m\left(1 - e^{-(r+l)T_{001}}\right) + K}{re^{-(r+l)T_{001}} + l}\right]$, and

$0 \leq R < \left[\dfrac{m\left(1 - e^{-(r+l)T_{000}}\right) + K(r+l) - aS\left[r\left(e^{-lT_{000}} - 1\right) + l\left(e^{rT_{000}} - 1\right)\right]}{re^{-(r+l)T_{000}} + l}\right]$. All of these

inequalities imply $(s, v, d) = (1, 1, 1)$ is efficient.

(4) Finally, $m = K = 0$, $r > 0$, $l > 0$, and $a > 0$ imply $(s, v, d) = (0, 0, 0)$ is efficient.

The next proposition amounts to restricting the results of Lemma 1 to the undominated contracts identified in Proposition 2.

Proposition 3: Given $z - c - m - rS > 0$ and a, d, l, r, m, c, R, S each greater than zero, then

$T(1,1,1) > T(1, 0, 1) > 0$ and $T(1,1,1) > T(0, 0, 1) > 0$.

In general, it is not possible to rank $T(0, 0, 0)$ and $T(1,1,1)$. However, if we impose a sufficiently small – take $a = 0$, for example – then one can rank the pair $T(0, 0, 1)$ and $T(1, 0, 1)$ and the pair $T(0, 0, 1)$ and $T(0, 0, 0)$. Specifically, we get our next proposition:

Proposition 4: Given $z - c - m - rS > 0$, d, l, r, m, c, R, S each greater than zero, and a small enough and monitoring costs m large enough such that

$$(1-a)m > aS\left(\frac{l\,r}{l+r}\right)\left(\frac{z-am-rS}{c}\right)^{\frac{r}{g}}\left\{\left(\frac{z-am-rS}{c}\right)^{\frac{r+l}{g}}-1\right\},\text{ then}$$

$$T(1,1,1) > T(0,0,1) > \begin{cases} T(1,0,1) \\ T(0,0,0) \end{cases}$$

See Appendix 4.

Remark: For a sufficiently small, contract duration *T* and *s* appear as substitutes among undominated contracts in that $T(0,0,1) > T(1,0,1)$. The key point, however, is that, other things equal, the duration of contracts featuring veto provisions exceeds that of all other undominated contracts.

Counterfactual Policy Experiment

Taken together, Propositions 2 and 4 yield a counterfactual policy experiment. According to Proposition 2, one can pose the hypothesis that $(s, v, d) = (1,1,1)$ is optimal. Suppose, now, that the antitrust authorities block $v = 1$. The contract parties then deviate to either $(s, v, d) = (0,0,1)$, $(s, v, d) = (1,0,1)$, $(s, v, d) = (0,0,0)$, or the null contract. If the parties continue to contract, then Proposition 4 implies that the new contract features a shorter term than that of the blocked contract. Thus parties end up underinvesting or, in expectation, dissipating too much surplus through more frequent contract renegotiations.

Financial Structure and Asset-specificity

Thus far the propositions make nothing more than passing contact with the choice of financial structure, yet some simple results are immediately available. Inspection of the expected vertical rents indicated in Appendix 2 shows that the contract (0, 0, 1) dominates when assets are completely redeployable. That is, given $a = 0$,

$$Ep\,(0, 0, 1, T_{001}; a = 0) > \begin{cases} Ep\,(0, 0, 0, T_{000}; a = 0) \\ Ep\,(1, 0, 1, T_{101}; a = 0) \\ Ep\,(1, 1, 1, T_{111}; a = 0) \end{cases}$$

Furthermore, given $a = 1$, $Ep\,(0, 0, 0, T_{000}; a = 1) > Ep\,(0, 0, 1, T_{001}; a = 1)$, although it is not the case that the equity contact $(0, 0, 0, T_{000}; a = 1)$ necessarily dominates $(1, 0, 1, T_{101}; a = 1)$ and $(1, 1, 1, T_{111}; a = 1)$. That is, even when all value is relationship-specific $(a = 1)$, the results suggest that debt financing might still prevail, although the prevailing contract would impose the residual claim on party D (s = 1).

One can graphically characterize the choice of financial structure by mapping the vertical rent Ep against the index of asset-specificity a. First note that Ep is linear in a so that the loci of points in $Ep - a$ space is linear for each type of contracts (s, v, d). Differentiating Ep with respect to a yields

$$\frac{\partial Ep\left(s, v, 1, T_{sv1}\right)}{\partial a} = -\left[\frac{(1-s)m}{r+l}\right]\left(1 - e^{-(r+l)T_{sv1}}\right) - (1-s)K$$
$$-\left[\frac{S}{r+l}\right]\left[r\left(e^{-l T_{sv1}} - 1\right) + l\left(e^{r T_{sv1}} - 1\right)\right] \leq 0$$

and

$$\frac{\partial Ep\left(s, v, 0, T_{sv0}\right)}{\partial a} = 0$$

Evaluating the derivatives for each of the four undominated modes of contracting yields

$$\frac{\partial Ep\left(1,1,1,T_{111}\right)}{\partial a}<\frac{\partial Ep\left(1,0,1,T_{101}\right)}{\partial a}<0=\frac{\partial Ep\left(0,0,0,T_{000}\right)}{\partial a}$$

and for *K* large enough

$$\frac{\partial Ep\left(0,0,1,T_{001}\right)}{\partial a}<\frac{\partial Ep\left(1,1,1,T_{111}\right)}{\partial a}<\frac{\partial Ep\left(1,0,1,T_{101}\right)}{\partial a}<0=\frac{\partial Ep\left(0,0,0,T_{000}\right)}{\partial a}$$

Thus the locus of points corresponding to $(s,v,d)=(0,0,0)$ in $Ep-a$ space is a horizontal line. The loci corresponding to $(1,0,1)$, $(1,1,1)$ and $(0,0,1)$ are lines with increasingly negative slopes.

Figure 1 features a possible configuration of contracts. The contract $(0,0,1)$ is efficient at $a=0$, and $(0,0,0)$ dominates it at $a=1$. As drawn here, the contracts $(0,0,1)$, $(1,1,1)$ and $(0,0,0)$ collectively dominate $(1,0,1)$ over the entire interval $a\in[0,1]$ and collectively constitute the contract envelope.

Now, let a^* indicate the cutoff point between debt and equity. Thus, if a^* exists, it solves $Ep(0,0,0)=Ep(s,v,1)$. Let $\bar{p}$ indicate the value of the parties' outside option. $Ep(0,0,0,T)>\bar{p}$ implies $Ep(0,0,1,T)>Ep(0,0,0,T)>\bar{p}$ – that is, $(s,v,d)=(0,0,1)$ is on the contract envelope. $Ep(0,0,1)<\bar{p}$ implies that only the null contract is on the contract envelope. More generally, if $a\le a^*$ and $Ep(0,0,0)\ge\bar{p}$, then *d* = 1 is efficient. If $a<a^*$, then d = 0 is never efficient.

The formal model itself does not immediately lend itself to hypothesis testing, but it does suggest that one should interpret the optimal choice of contract duration (*T*), risk-bearing (*s*), veto provisions (*v*), and financial structure (*d*) as functions of each other. In what follows, I pose the hypothesis that one can approximate the joint selection of *T*, *s*, *v*, and *d* by a system of linear equations:

$$\begin{aligned}
\ln T &= a_T + b_{Ts}s + b_{Tv}v + b_{Td}d + g_T W_T \\
s &= a_s + b_{sT}\ln T + b_{sv}v + b_{sd}d + g_s W_s \\
v &= a_v + b_{vT}\ln T + b_{vs}s + b_{vd}d + g_v W_v \\
d &= a_d + b_{dT}\ln T + b_{ds}s + b_{dv}v + g_d W_d
\end{aligned}$$

where W_T, W_s, W_v and W_d indicate vectors of predetermined variables with corresponding vectors of coefficients g_T, g_s, g_v and g_d. See Appendix 5 for details.

Let $Ep = \max_{s,v,d,T} Ep(s, v, d, T; \cdot)$ indicate the value function. The inputs *T* and *v* are Edgeworth complements if $\frac{\partial^2 Ep}{\partial T \partial v} > 0$ which implies $\frac{\partial T}{\partial v} > 0$ and $\frac{\partial v}{\partial T} > 0$. In this linear version of the model featured in Appendix 5, the hypothesis that contract duration *T* and veto provisions *v* are complements amounts to $\frac{\partial^2 Ep}{\partial T \partial v} = \frac{B^{Tv}}{T} = \frac{r_T b^{Tv}}{T} > 0$ where r_T is a constant of proportionality. While it is not possible to estimate r_T, the test of complementarity amounts to a test of the hypothesis $\frac{\partial T}{\partial v} = -\left(\frac{\partial^2 Ep}{\partial T \partial v} \Big/ \frac{\partial^2 Ep}{\partial T^2} \right) = T b_{Tv} > 0$ or simply $b_{Tv} > 0$. Similarly,

$$\frac{\partial v}{\partial T} = -\left(\frac{\partial^2 Ep}{\partial T \partial v} \Big/ \frac{\partial^2 Ep}{\partial v^2} \right) = \frac{b_{vT}}{T} > 0 \text{ implies } b_{vT} > 0.$$

Similar calculations, which I state without proof, yield the following: The complementarity of two-part risk-sharing *s* and veto provisions *v* implies $b_{sv} > 0$ and $b_{vs} > 0$; the complementarity of two-part risk-sharing *s* and debt *d* implies $b_{sd} > 0$ and $b_{ds} > 0$.

Hypotheses

The Propositions and discussion suggest a number of qualitative patterns one might observe in the contract data, including electricity marketing contract data. In this section I present hypotheses about patterns of complementarity and substitution between contract duration, veto provisions, profit-sharing, and financial structure and extend these hypothesis to the linearized system of four equations. I will, however, limit estimation to a system of three equations that excludes a fourth "debt" equation, because the data indicate little evidence of variation in the financial structure of electricity generating projects.[11]

H1: Contracts featuring $(s, v) = (0, 1)$ do not appear in the data. Instead, if parties use veto provisions $(v = 1)$, they use them to support debt financing and contracts in which marketers bear the residual claim $(s = 1)$.

[11] Some contracts make explicit reference to underlying credit agreements. Others indicate "lenders" in the background, and yet others indicate both underlying credit agreements and lenders. No contracts make explicit reference to equity financing, although some generating projects are organized by clusters of investors who likely make nominal equity infusions, yet even these investors explicitly line up debt financing. Finally, I note that even generators that are affiliated with their marketers depend on debt financing. Duke Energy, for example, maintains both a marketing subsidiary and generating subsidiaries. Duke sets up each generating project as an LLC responsible for organizing its own financing.

H2: Contract duration T and veto provisions v are complements. Within the context of the linear model, this amounts to $b_{Tv} > 0$ and $b_{vT} > 0$.

That is, allowing parties to impose unprogrammed renegotiation allows them to reduce the frequency of programmed renegotiation. Also, imposing the residual claim on marketers increases the prospect of distorted investment; neutralizing the prospect of unprogrammed renegotiation induces parties to increase the frequency of programmed renegotiation by imposing a shorter term.

H3: Two-part risk-sharing s and veto provisions v are complements. Within the context of the linear model, this amounts to $b_{sv} > 0$ and $b_{vs} > 0$.

H4: $T(s, 1, d) > T(s', 0, d')$ for all $s, d, s', d' \in \{0, 1\}$. That is, imposing $v = 0$ induces parties to adopt shorter-term contracts. Within the context of the linear model, this amounts to $b_{Tv} > -b_{Ts}$ and $b_{Tv} > 0$.

H5: Two-part risk-sharing s and debt d are complements. Within the context of the linear model, this amounts to $b_{sd} > 0$ and $b_{ds} > 0$.

2. Data and Estimation

I work out of a dataset of 101 electricity marketing contracts that contracting parties recognize either as "power sales agreements," "tolling agreements," or "power purchase agreements." These contracts join an entity that owns and operates generating assets and an energy marketer who acquires rights to dispatch electricity from the generating assets. Sixty-nine of the contracts were acquired from the filings parties made to the Federal Energy Regulatory Commission ("FERC").[12] I extracted one contract from one generator's filing to the Securities and Exchange Commission. The remaining 31 contracts derive from filings parties made to the Justice Department in connection with antitrust investigations.

Electricity marketing contracts often pertain to transactions between corporate affiliates or to transactions that are not specific to generating units. So, for example, one energy marketer might commit to deliver some volume of electricity to another marketer at some node in the electricity transmission grid, but such a transaction may not specify a source of the generation. In contrast, all of the contracts in the dataset involve specific generating assets. At the same time, corporate subsidiaries like Duke Energy Marketing may market electricity for other Duke subsidiaries that manage generation assets.[13] A few such contracts are featured in the dataset.

In Table 1 I distinguish the duration of contracts (in years) and the generation capacity placed under contracts (in megawatts [MW]) by type of generation. I distinguish generation by six types of fuel: gas-fired generation ("Gas"), nuclear, coal-fired generation ("Coal"), oil, wind-driven generation ("Wind"), and all other ("Other"). "Other" includes projects that burn waste from fiber products mills. Much gas-fired generation constitutes capacity that responds to marginal demands whereas nuclear and coal-fired generation is suited to serve "baseload"

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[12] See Appendix 6. The FERC stopped requiring marketers to file contracts in 2002. The dataset features every contract I could identify in all available filings.
[13] Duke Energy Corporation owns or leases generation in California through four "wholly-owned subsidiaries. These four subsidiaries maintain marketing contracts with Duke Energy Marketing. See the Duke Energy filing with the FERC dated June 25, 1998 at docket # ER98-2680-002, the FERC filing dated December 31, 1998 at docket # ER99-1199, and the Duke Energy Corporation SEC filing 10-K for the year 1999.

demands.[14] Baseload capacity generates electricity at the lowest marginal costs (lowest cost per MW). It is thus well suited to serving the "baseload" demand. The optimal program for baseload capacity is to fire it up and let it run indefinitely. In contrast, marginal capacity operates at higher marginal costs. Baseload capacity would seem to dominate marginal capacity, but marginal capacity is better suited to economically "ramping up" and responding to fluctuations in demand. Generators reserve it to serve peaks in demand that might, for example, attend the hottest hours of a hot day during which everyone turns on the air conditioning. Wind-driven generation is hybrid in that it does not easily fit into a marginal/baseload dichotomy. To begin with, it is less well suited to responding to peak demands, because the wind is not subject to generators' control.

Table 1 indicates the 101 contracts feature an average duration of 11.59 years, although the shortest ran about two weeks, and the longest ran 28.19 years. Contracts that included baseload capacity (nuclear and coal), tended to feature short terms whereas those that included gas-fired generation averaged 12.39 years in duration, and those pertaining to wind-driven generation averaged 14.87 years. On average, each contract covered 599.61 MW of generation capacity. Contracts pertaining to wind-driven generation or "Other" generation covered, on average, 81.75 MW and 71.58 MW respectively. Contracts that included gas-fired generation averaged 635.62 MW per contract.

[14] Not all gas-fired generation capacity operates at the margin. "Jet engine type" generators constitute capacity that is suited to serving "peaking" demands, because they are amenable to serving dispatch demands on short notice. "Combined cycle" gas-fired generation may less amenable to dispatch demands but is more efficient than peaking generators, because they include systems to recover the heat that jet engines dissipate.

Seventy-nine of the 101 contracts included gas-fired generation. Twenty-one of these eighty contracts featured provisions that allow at least one party, the marketer, to impose renegotiation. (See Table 2.) I count all 21 provisions as *de facto* "veto provisions," but, strictly speaking, only eight of these 21 provisions are *de jure* veto provisions. The 15 other provisions are composed of rights-of-first-refusal or "first-offer." A generator may, for example, propose an expansion of generation capacity. A right-of-first-refusal gives the incumbent marketer an opportunity to evaluate the proposal and, more importantly, to hold up the prospect of the generator contracting with a different marketer. For example, the marketer Williams Marketing Energy & Trading maintains rights of first-offer, but no veto rights, in its relationship with the generator Cleco Evangeline.[15] In another contract, the marketer Coral Power, LLC maintains the right to veto "upgrades" of generating units that the generator Baconton Power, LLC might propose. The parties agree to make "equitable adjustments" to the two-part compensation scheme in the event they proceed with such upgrades.[16] A contract between Williams and the generator AES Southland features an explicit veto in that both parties reserve the right to veto proposals by the other to expand or withdraw capacity.[17]

Only two other contracts, both pertaining to Wind, featured veto provisions. The two Wind contracts both feature explicit veto provision, probably because wind-driven generation tends to rely on subsidies to be economical. Parties may not be too keen to invest heavily in long-lived assets only to find subsidies taken away in the future.

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[15] See the FERC filing dated June 30, 2000 at docket # ER00-3058-001.
[16] See page 46 of the Baconton filing dated July10, 2000 at docket # ER00-3096.
[17] See page 2 of the Williams/AES agreement filed May 7, 2001 at docket # ER98-2184-006.

Overall, 66 of the 101 contracts imposed the residual claim on marketers (*s* = 1). Sixty-two of the 66 contracts pertained to gas-fired generation. Of the 21 non-gas contracts, only 4 imposed the residual claim on marketers. This is not surprising. Sometimes marketers share risk with generators (*s* = 0) by compensating them according to linear schemes; they pay fixed fees per unit output, usually a kilowatt-hour. Meanwhile, marginal generation, by virtue of being marginal, is more subject to variation in dispatch demands. A combination of variation in dispatch and linear compensation yields variation in compensation whereas schemes that impose the residual claim on marketers yield fixed streams to generators. In contrast, baseload capacity generally features little variation in dispatch, thus the combination of baseload capacity and linear compensation tends to yield streams that are subject to little or no variation. Wind is a little different in that generators do not control all dimensions of the technology; they cannot "ramp up" if the wind is inadequate. Wind tends to feature linear compensation which, in turn, implies some variation in the stream of payments marketers yield to generators.

I constructed 18 variables that I apply to estimation of the linear model:

Dependent Variables

(1) Term:	The duration of term of the contract, excluding options to extend.
(2) TwoPart:	A binary indication that the risk-bearing scheme assigns the residual claim to the marketer (*s* = 1) by means of a two-part scheme. Two-part schemes usually render a fixed fee to the generator and a set of payments that cover its marginal costs. Almost all other sharing rules are linear (*s* = 0).
(3) Veto:	A binary indication that the contract features a veto provision (*v* = 1).

Explanatory Variables

(4) New:	A binary indication that the contract covers new generation capacity.

(5) Capacity Factor:	A means of identifying marginal capacity from capacity subject to more regular dispatch. I gather from the Energy Information Agency (EIA) of the Department of Energy annual indications of the proportion of time capacity under contract was dispatched. I take the average of time dispatched over the years 1996 through 2002.[18]
(6) County Capacity Factor:	The proportion of time all capacity in the county was dispatched in a year.[19]
(7) PopsPerMW:	Another means of distinguishing marginal capacity from baseload capacity. The ratio of county population to nominal capacity (MW) under contract. It constitutes a proxy for marginal generation since large, baseload generation plants are often located outside of populated areas and small, and "peaking" units tend to be located within load pockets which themselves tend to be located within densely populated areas.[20]
(8) SubstationsPerArea:	An indication of local transmission capacity; the number of substations per unit area (square kilometer) in a county.[21]
(9) Gas Turbine:	A binary indication that the contract includes gas-fired generation that includes "jet engine" type peaking units.[22]
(10) Combined Cycle:	A binary indication that the contract covers combined cycle units.[23]
(11) Combustion Engine:	A binary indication that the contract covers units powered by an internal combustion engine.[24]
(12) Steam Turbine:	A binary indication that the contract covers units driven by steam turbines.[25]
(13) Wind:	A binary indication that the contract features wind-driven generation capacity.

[18] A few sites had not been equipped to dispatch electricity before 2002. I accommodate the missing data by indicating the "capacity factor" as the average capacity factor of all other data.
[19] Source: EIA.
[20] Sources: Census Bureau and the contracts themselves. The variable constitutes a compact way of distinguishing small units in the hinterlands and large units that feed baseload demand from small unit inside load pockets. For example, some small units outside of load pockets constitute the joint product or "cogeneration" of facilities that burn waste, including wood chips, at dumps or lumber mills located outside of densely populated areas.
[21] Source: EIA.
[22] Sources: The contracts themselves and the EIA. Corresponds to EIA nomenclature "GT."
[23] Sources: The contracts themselves and the EIA. Corresponds to EIA nomenclatures "CC," "CA," and "CS."
[24] Sources: The contracts themselves and the EIA. Corresponds to EIA nomenclature "IC."
[25] Sources: The contracts themselves and the EIA. Corresponds to EIA nomenclature "ST." Steam turbines may be fired by gas, coal, oil, other fuel, and heat from a nuclear generator.

(14) Population Density:	Population per unit area (square kilometer) of the county in which the generating units are situated.[26]
(15) MW:	Generation capacity (MW) under contract.
(16) FERC:	A binary indication that the contract was filed with the FERC, and the FERC opted to make the contract available to the public.
(17) Retail:	A binary indication that the "marketer" is a retail distributor of electricity or is an end user.[27]
(18) CountyMWPerArea:	The ration of county-wide capacity (MW) to unit area (square kilometer) in a county.[28]

The first three variables indicate the dependent variables in the system of three equations. These variables indicate how generators and marketers organize the supply of electricity to wholesale markets. Meanwhile, the explanatory variables reflect both supply-side and demand-side considerations. Some variables reflect marginal dispatch demands, and others reflect the feasibility of responding to marginal demands. Other variables indicate demands for both programmable and unprogrammable demands for adapting contracts.

I use the variables New, Capacity Factor, County Capacity Factor, PopsPerMW, SubstationsPerArea and CountyMWPerArea to reflect different types of demand for adaptation. Insofar as "New" reflects the expected economic life of generating units, then it reflects programmable opportunities to salvage assets. The variables Capacity Factor and PopsPerMW constitute means for distinguishing marginal generation capacity, capacity that intendedly serves

[26] Source: Census Bureau
[27] For example, I feature the California Department of Water Resources as an end-user in one contract.
[28] Sources: EIA and Census Bureau.

marginal demands, from inframarginal generation capacity ("baseload" capacity) that is subject to more regular demands (the "baseload").

I include these variables to control for the prospect that marginal capacity may be more susceptible three types of hazards and may, in turn, be subject to unprogrammable demands for adaptation. The hazards are (1) the unprogrammable prospect of being crowded out by new capacity and knocked "out of the money," (2) transmission congestion that may attend peaking demands for electricity, and (3) higher monitoring costs that can attend generation capacity that is more subject to variable dispatch demands. I illustrate the crowding-out hazard in Figure 2. Consider a market institution under which the marginal cost of marginal capacity imposes a uniform wholesale price. Adding inframarginal capacity may shift the supply curve from S_0 to S_1. Capacity located at B_0 gets displaced to B_1. In demand state D a price of P_0 would have prevailed, and capacity at B_0 would have been "in the money" – the marketer would have been able to realize a positive price-cost margin were it to exercise its option to dispatch electricity. After the addition of new capacity, a lower price of P_1 obtains, in which case the capacity at B_1 get knocked "out of the money." (The parties lose marginal revenue at a rate equal to the cross-hatched rectangle above B_1.) Meanwhile, the capacity at A remains in the money, but the marginal review diminishes by $P_0 – P_1 > 0$. (The parties lose marginal revenue at a rate equal to the cross-hatched rectangle above A.) The margin still gives the contracting parties some capacity to service underlying debt obligations in demand state D, but the parties responsible for managing capacity displaced to B_1 lose all capacity to service debt in demand states like D.

While marginal capacity might be more susceptible to crowding out, the hazard might be diminished in areas that already feature a high density of generation capacity. I use CountyMWPerArea to control for the prospect that crowding out may be less likely in counties that are already heavily endowed with generation capacity. A generator may simply not be able to secure new "greenfield" sites or even "brownfield" sites for new generation projects.[29]

The hazards attending transmission congestion also require some comment. Transmission constraints are interesting, because they can frustrate a marketer's demands for timely dispatch.[30]. One can imagine, however, that while marginal capacity might be more susceptible to congestion hazards, generators might accommodate the prospect of congestion by judiciously locating marginal capacity inside "load pockets" – that is, inside the areas that generate the peaking demands that induce congestion. I use the variable PopsPerMW to control for prospect that generators judiciously site marginal generation inside load centers. I use SubstationsPerArea to reflect the density of local transmission networks.

I use the variables Gas Turbine, Combined Cycle, Combustion engine, Steam Turbine, Wind and MW to control for the technological feasibility of time-sensitive dispatch, and I use Population Density to control for aspects of the demand for timely dispatch. The technology variables

[29] Generators might yet be able to expand capacity on existing sites.

[30] See, for example, Chapter 3 of "The Changing Structure of the Electric Power Industry: Selected Issues, 1998" by the Energy Information Agency at http://www.eia.doe.gov/cneaf/electricity/chg_str_issu/chg_str_iss_rpt/toc.html. "Congestion in the transmission system occurs when a transmission line reaches its transmitting capacity, limiting the system operator from dispatching additional power from a specific generator. Congestion may be caused by generation or power grid outages, increases in energy demand, or loop flow problems. When congestion occurs, the transmission system operator may have a number of options it can use to solve the problem. For example, it can curtail power from certain generators, or it can dispatch another generator outside the congested area to supply power. Curtailment of power from a generator may be referred to as redispatch, and the use of another generator to supply power is called out-of-merit dispatch." Transmission constraints can also frustrate competitors' efforts to dispatch electricity.

provide ways of distinguishing capacity that can technically accommodate dispatch demands from capacity that is less amenable to timely dispatch. Again, the important idea is that marginal generation can involve greater monitoring costs. Absent remedies such as two-part compensation, parties might have to engage more efforts to monitor and audit the streams of revenues that derive from the irregular dispatch of marginal units. It is reasonable, then, to expect that generating units that can accommodate dispatch demands, such as gas turbine units, will tend to align with two-part compensation. In contrast, combined cycle units feature heat recovery systems which allow them to be more fuel-efficient but ma y be less amenable to ramping up quickly to respond to dispatch demands. Generators might even dedicate such units to serving base load demands, especially in areas in which regulators favor gas-fired generation over other types of generation (e.g., coal) that contribute to emissions of nitrous oxide and sulfur dioxide. Wind-driven generation may be less amenable to timely dispatch in that it depends on an external factor, the wind, beyond generator's control thus limiting the capacity of wind-driven generation to ramp-up to serve peaking demands. Meanwhile, MW reflects upper bounds on the capacity that could be available for dispatch.

Finally, I use FERC and Retail in conjunction with CountyMWPerArea to capture aspects of demand for contract renegotiation. I use FERC to capture hidden attributes of transactions that the FERC may have systematically used to inform its decision to publicly post contracts. I use Retail to control for the prospect that retail end-users and distributors may present generators with less volatile demands and may thus pose fewer contracting hazards.

Methods of Estimation

I simultaneously estimate equations that correspond to a linear version of the model

$$\begin{aligned} \text{LogTerm}_{\text{i}} &= a_T + b_{Ts}\text{TwoPart}_{\text{i}} + b_{Tvi}\text{Veto}_{\text{i}} + g_T W_{Ti} + e_{Ti} \\ \text{TwoPart}_{\text{i}} &= a_s + b_{sT}\text{LogTerm}_{\text{i}} + b_{sv}\text{Veto}_{\text{i}} + g_s W_{si} + e_{si} \\ \text{Veto}_{\text{i}} &= a_v + b_{vT}\text{LogTerm}_{\text{i}} + b_{vs}\text{TwoPart}_{\text{i}} + g_v W_{vi} + e_{vi} \end{aligned}$$

where $i = 1, \ldots N$, W_{Ti} and W_{vi} are vectors of variables that reflect programmable or unprogrammable demands for adaptation, W_{si} includes variables that reflect the feasibility of timely dispatch, and the error terms e_{Ti}, e_{si}, and e_{vi} indicate potentially non-normal processes. I also report results from single-equation estimation that includes probit specifications for the binary choices TwoPart and Veto.

The theoretical model implies that contract duration (Term), TwoPart and Veto are jointly determined, which in turn implies that the equations should be estimated by methods that accommodate endogeneity of the regressors. I apply more than one method of estimation simply to demonstrate the robustness of the results. In Table 5 I present results from applying three-stage least squares (3SLS) with bootstrapped standard errors to the linearized model, and in Table 6 I present results from applying the two-stage conditional maximum likelihood method (2SCML) of Rivers and Vuong (1988).[31] 2SCML involves including three new generated variables, "LogTerm Residuals," "TwoPart Residuals," and "Veto Residuals" to single-equation estimation of the contract duration equation and to estimation of probits for TwoPart and Veto. The residuals derive from ordinary least squares regression of reduced-form equations – that is, from separately regressing LogTerm, TwoPart and Veto on all of the exogenous variables

[31] I also applied two-stage least squares and ordinary least squares. The results are robust across all methods and specifications.

featured in the system. Applying 2SCML to the duration equation yields the same coefficient estimates that one would obtain from two-stage least squares and yields virtually the same standard errors (Davidson and MacKinnon 1993, p. 240).

Appealing to 3SLS amounts to applying the linear probability model which in turn may induce heteroskedastistic residuals. Bootstrap methods can be applied to three-stage least squares estimation (Freedman and Peters 1984, MacKinnon 2002), and boostrapping data directly ("pairs" bootstrap), in contrast to bootstrapping residuals from the original estimation, constitutes a method of generating standard errors and confidence intervals that are robust to heteroskedasticity (MacKinnon 2006, p. 9; Johnston and Dinardo 1997, p. 369).[32] It also constitutes a method of accommodating error processes that may be non-normal. Meanwhile, as Petrin and Train (2003) observe, 2SCML constitutes an application of the "control function" approach to probit models. It is a single equation method that accommodates continuous endogenous explanatory variables and provides simple Hausman-like "endogeneity tests" (Hausman 1978) of both continuous and discrete explanatory variables (Rivers and Vuong 1998, p. 358.; Wooldridge 2002, p. 474). The tests amount to tests of the significance of the coefficients assigned to the generated variables LogTerm Residuals, TwoPart Residuals, and Veto Residuals.

Results

The first four results pertain to hypotheses H1 – H4. The next four results constitute empirical regularities. I close with the policy experiment.

[32] More generally, as Nevitt and Hancock (2001) observe, the bootstrap provides an alternative and often superior means of generating standard errors with small datasets featuring data that may be non-normal.

Result 1: Contracts featuring $(s, v) = (0, 1)$ do not appear in the contract data corresponding to non-Wind driven generation capacity.

The results featured in Table 3 constitute affirmation of hypothesis H1 that contracts featuring $(s, v) = (0, 1)$ do not appear in the data. Table 3 features four cells corresponding to $(s, v) \in \{(0, 0), (0, 1), (1, 0), (1, 1)\}$. In Table 3 I limit analysis to the 95 contracts that exclude wind-driven generation. None of the 95 feature risk-sharing $(s = 0)$ and veto provisions $(v = 1)$.

In Table 4 I expand analysis to all 101 contracts. Two of the contracts correspond to $(s, v) = (0, 1)$, but I can qualify the result that observing that the two contracts pertain to wind-driven generation. The economics of wind-driven generation are different in that it depends on subsidies to remain economically viable. The prospect of the loss of subsidies could jeopardize investments, thus inducing parties to be more careful about controlling investment over the course of long-term exchange.

Result 2: Contract duration and veto provisions are complements.

The results reported in Table 5 indicate $b_{Tv} = 1.4187$ and $b_{vT} = 0.1989$, both statistically significant at the 5% level. (Absent the bootstrap, the results appear significant at the 1% level.) The 2SCML results reported in Table 6 are consistent.[33]

[33] Estimation by 2SCML also provides only weak evidence of the exogeneity of LogTerm, TwoPart and Binary with respect to each other. The upshot is that the coefficient estimates themselves and standard errors may only be correct up to a scale factor. The t-ratios cancel the scale factors out and can be interpreted. See Wooldridge (2002),

Result 3: Two-part risk-sharing and veto provisions are complements.

The results indicate $b_{sv} = 0.8358$ and $b_{vs} = 0.3796$, both statistically significant at the 5% level. (Again, absent the bootstrap, the results appear significant at the 1%.) The 2SCML results reported in Table 6 are consistent.

Result 4: The results of the estimation are consistent with hypothesis H5 that $b_{Tv} > -b_{Ts}$ and $b_{Tv} > 0$ and, other things equal, $T(1,1) > T(s,0)$.

Estimation in Table 5 yields $b_{Tv} = 1.4187$ and $b_{Ts} = -0.5738$. These coefficient estimates imply $\text{Log}[T(1,1)/T(0,0)] = b_{Tv} + b_{Ts} = 0.8449 > 0$, although the result is not statistically significant. The results imply that $T(1,1)$ exceeds $T(0,0)$ by a factor $e^{0.8449} = 2.33$.[34] The estimates also imply $\text{Log}[T(1,1)/T(1,0)] = b_{Tv} = 1.4187 > 0$, which is significant at the 5% level. The results imply that $T(1,1)$ exceeds $T(0,0)$ by a factor $e^{1.4187} = 4.13$. The 2SCML results reported in Table 6 are consistent.

Empirical Regularities

Empirical Regularity 1: Contract duration is increasing in the life of generating assets.

pg. 474.

[34] Interestingly, it turns out that contracts in the data set featuring veto provisions and two-part risk sharing average 18.05 years duration whereas those that feature neither veto provisions nor two-part risk-sharing average 10.29 years.

Contracts featuring "New Units" are $e^{0.5904} = 1.81$ times longer than other contracts. The result reported in Tables 5 is significant at the 5% level. The results derived from estimation by 2SCML are consistent.

Empirical Regularity 2: Contract duration is decreasing as the prospect of unprogrammable demands for adaptation increase.

Contract duration is decreasing in Log PopsPerMW and increasing in Capacity Factor, although the second result is not statistically significant. The 2SCML results reported in Table 6 are consistent.

Empirical Regularity 3: Contracting parties are more likely to apply two-part compensation to contracts featuring generation that is amenable to timely dispatch.

Insofar as contracts cover diverse generation technologies, the technology variables may constitute but crude indicators of the degree to which capacity under contract can accommodate timely dispatch demands. Even so, the results suggest that contracts featuring "Gas Turbine" units are 19.89% more likely to feature two-part compensation. The result is significant only at the 10% level, but what matters are comparisons to other types of generation. Not surprisingly, wind-driven generation is not likely to feature two-part compensation. The results derived from estimation by 2SCML are consistent although note that the TwoPart probit does not include the variable Wind, because Wind perfectly predicts no two-part compensation.

Empirical Regularity 4: Contracts featuring generation capacity located in areas heavily endowed with generation capacity are less likely to feature veto provisions.

The coefficient on the variable Log CountyMWPerArea is -0.425 in the Veto equation. The coefficient is only significant at the 10% level, but the result implies that contracts featuring generation capacity located in the most heavily endowed counties are 30.2% more likely to feature veto provisions than contracts featuring generation capacity in the most sparely endowed counties. The results derived from estimation by 2SCML are consistent.

The Policy Experiment

The counterfactual policy experiment indicates that, were the antitrust authorities to bar contracting parties from imposing veto provisions, parties would adapt by appealing to shorter term contracts – indeed, they might even forgo investing and contracting – and they might also impose risk-sharing on the generator. Thus, if contracting parties had determined that $(s, v) = (1, 1)$ were optimal, then forcing them to set $v = 0$ entails reverting to an inferior contract that features a shorter duration and might also entail assuming the greater monitoring costs that would attend the imposition of risk on the generator.

3. Conclusion

The research takes up the ultimate problem of dynamic optimization: how to adjust production capacity and terms of trade over the course of long-term exchange given the prospect of unprogrammable shifts of the contract curve. As a matter of course, programmable shifts lend themselves to programmable adaptations. Indeed, were all shifts susceptible to programming, then it would not be obvious that any tradeoffs would obtain between short terms of contract and long terms. Contract duration might be irrelevant. Even so, some theoretical and empirical research (e.g., Crocker and Reynolds [1993], Bajari and Tadelis [2001] and Saussier [2000]) pose an efficient adaptation hypothesis that depends on the endogenous incompleteness of contracts: it might be efficient for parties to forgo programming adaptations for all foreseeable shifts of the contract curve. Endogenous incompleteness can resurrect a role for instruments such as contract duration. Parties might, for example, depend on renegotiation to sort out certain foreseeable demands for adaptation, and they induce renegotiation by appealing to a contract of shorter duration.

In this paper I present some isomorphic results and complementary results. I characterize an environment in which parties may use instruments such as contract duration and veto provisions to impose renegotiation to accommodate both foreseeable and unforeseeable demands for adaptation. The framework also accommodates the prospect that longer term contracts may themselves be more susceptible to unforeseeable demands – in which case parties might adjust contract duration downward. Even so, adjusting contract duration can induce a complex set a interactions with other terms of contract. Some of these interactions depend on the degree to which assets committed to production are redeployable outside of specific relationships. I demonstrate both as a matter of theory and empirical investigation patterns of complementarity and substitution between contract duration, veto provisions, risk-sharing and financial structure. I go on to demonstrate a policy-relevant conclusion: antitrust authorities might view veto provisions in long-term contracts with suspicion. The research suggests that veto provisions can be efficiency-enhancing and that analyzing them in isolation can lead to inappropriate interventions. Instead, the antitrust authorities might focus attention on situations in which a single marketer maintains veto provisions in contracts it has with *more than one competing* generator. In such cases, a marketer might be in the position to coordinate the investments of competing generators. Other than that, barring parties from using veto provisions induces them to revert to inefficient contracts and frustrates their efforts to invest in production capacity.

Figure 1

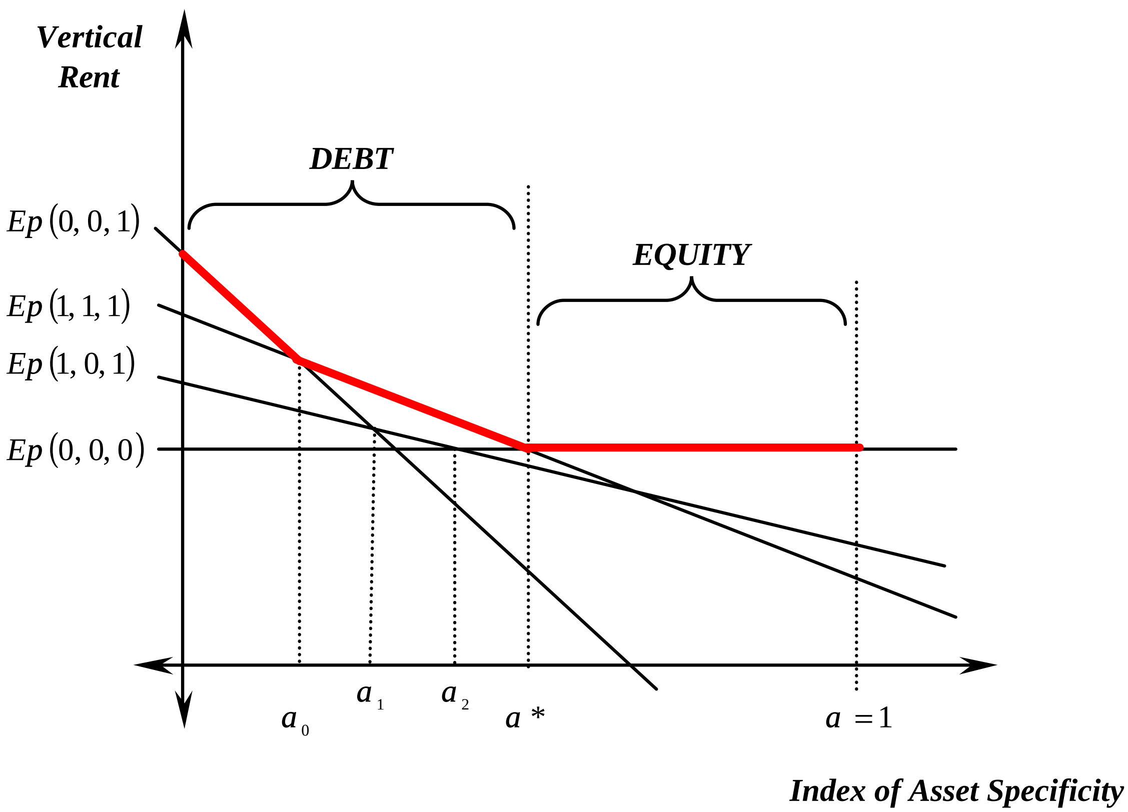
Vertical Rent
DEBT
EQUITY
Ep(0, 0, 1)
Ep(1, 1, 1)
Ep(1, 0, 1)
Ep(0, 0, 0)
a₀
a₁
a₂
a*
a = 1
Index of Asset Specificity

Figure 2

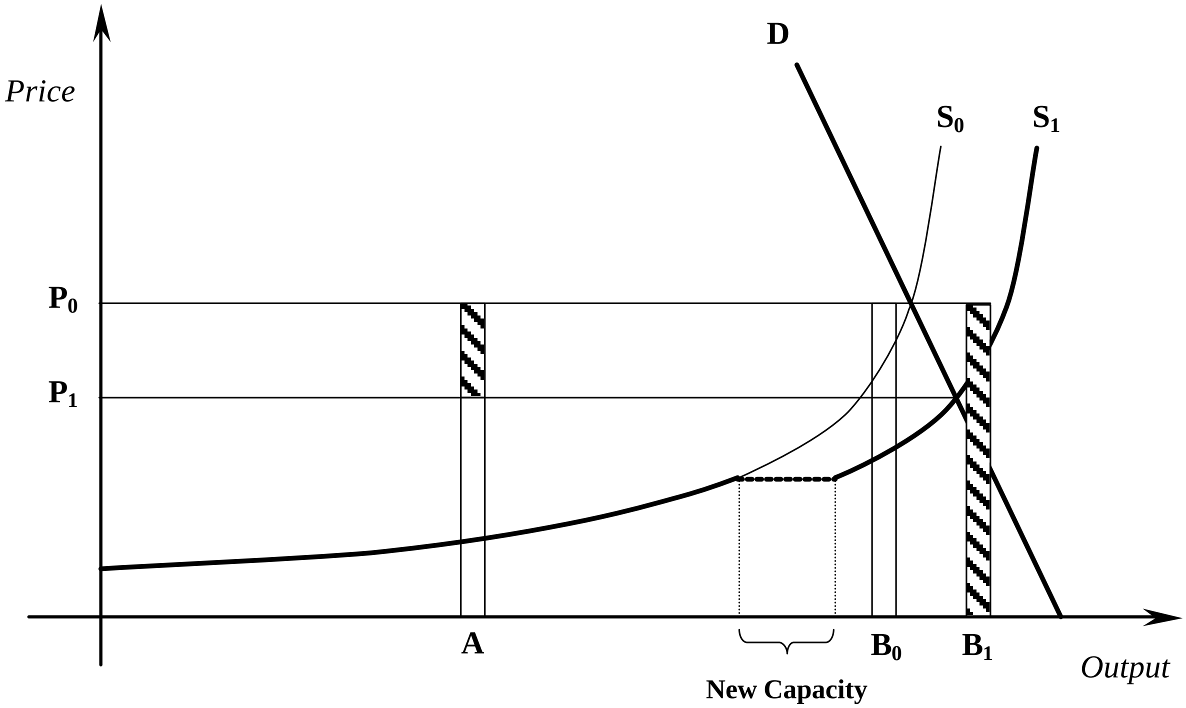

Table 1

	Gas*	Nuclear	Coal*	Oil*	Other Fuel	Wind	All Capacity
Observations	79	4	11	7	5	6	101
Contract Duration (Years)							
Mean	12.39	9.18	5.69	4.07	5.04	14.87	11.59
Std. Deviation	7.98	4.49	2.74	1.22	3.01	8.19	1.79
Minimum	0.22	30.40	2.92	2.50	2.18	2.45	0.22
Maximum	28.19	13.00	11.81	5.17	10.00	26.08	28.19
Generation Capacity (MW)							
Mean	635.62	909.30	1,592.60	2,350.71	27.50	81.75	599.61
Std. Deviation	961.51	559.55	2,012.08	2,177.80	16.93	109.89	909.57
Minimum	27.00	500.00	20.00	292.00	6.50	5.00	5.00
Maximum	5,645.00	1,730.00	5,645.00	5,645.00	52.00	300.00	5,645.00

* The columns do not partition the data set. Rather, some contracts feature distinct generating units fired by natural gas, coal, or oil. Such contracts are double or triple counted in the columns "Gas," "Coal," and "Oil."

Table 2

		Gas*	Nuclear	Coal*	Oil*	Other Fuel	Wind	All Capacity
Marketer bears risk	**(s = 1)**	**62**	**1**	**6**	**5**	**1**	**-**	**66**
Veto provision	(v = 1)	21	-	-	-	-	-	21
Parties share risk	**(s = 0)**	**17**	**3**	**5**	**2**	**4**	**6**	**35**
Veto provision	(v = 1)	-	-	-	-	-	2	2
								101
Total Contracts		**79**	**4**	**11**	**7**	**5**	**6**	

* The columns do not partition the data set. Rather, some contracts feature distinct generating units fired by natural gas, coal, or oil. Such contracts are double or triple counted in the columns "Gas," "Coal," and "Oil."

Table 3

Distribution of Veto Provisions and Two-part Risk-sharing
Absent Wind-driven Generation

		Veto Provision ($v = 1$)	**No Veto** ($v = 0$)	
Marketer bears risk	($s = 1$)	**21**	**45**	**66**
Parties share risk	($s = 0$)	**-**	**29**	**29**
		21	**74**	**95**

Table 4

Distribution of Veto Provisions and Two-part Risk-sharing
over All Contracts

		Veto Provision ($v = 1$)	**No Veto** ($v = 0$)	
Marketer bears risk	($s = 1$)	**21**	**45**	**66**
Parties share risk	($s = 0$)	**2**	**33**	**35**
		23	**78**	**101**

Table 5

Explanatory Variables	*Dependent Variables* LogTerm	TwoPart	Veto
LogTerm		**-0.0205** 0.1719	**0.1989**** 0.0801
TwoPart	**-0.5738** 0.3883		**0.3796**** 0.1524
Veto	**1.4187**** 0.6956	**0.8358**** 0.3677	
New	**0.5904**** 0.2285		
Capacity Factor	**0.3595** 0.4710		
County Capacity Factor	**0.0848** 0.4694		
Log PopsPerMW	**-0.1385**** 0.0623		
Log SubstationsPerArea	**0.1833*** 0.0975		
Generating Turbine		**0.1989*** 0.1059	
Combustion Turbine		**0.2137** 0.1818	
Combined Cycle		**0.1964*** 0.1027	
Steam Turbine		**-0.1249** 0.1225	
Wind		**-0.4172**** 0.1908	
Log Population Density		**6.05E-03** 2.88E-02	
Log Capacity (MW)		**-7.11E-04** 4.85E-02	
FERC			**-0.1006** 0.0756
Retail			**-0.0655** 0.0720
Log CountyMWPerArea			**-0.0425*** 0.0252
Constant	**3.3906***** 0.8451	**0.3425** 0.3473	**-0.3812**** 0.1877

The notations ***, **, and * respectively indicate 1%, 5% and 10% levels of significance.

Table 6

Explanatory Variables	*Dependent Variables* OLS **LogTerm**	Probit **TwoPart**	Probit **Veto**
LogTerm		**0.0926** 0.3744	**1.5061***** 0.5046
TwoPart	**-0.3655** 0.3622		**1.2303*** 0.6528
Veto	**1.1442**** 0.4908	**2.1456**** 1.0148	
New	**0.7126***** 0.2071		
Capacity Factor	**0.8127*** 0.4711		
County Capacity Factor	**0.1798** 0.4617		
Log PopsPerMW	**-0.1502***** 0.0490		
Log SubstationsPerArea	**0.2647**** 0.1025		

Explanatory Variables	*Dependent Variables* OLS **LogTerm**	Probit **TwoPart**	Probit **Veto**
LogTerm Residuals		**-0.3352** 0.4197	**-0.1239** 0.4492
TwoPart Residuals	**0.0272** 0.4362		**0.9140** 1.1135
Veto Residuals	**-0.2875** 0.5469	**-1.1074** 1.0689	
Generating Turbine		**1.0302***** 0.3778	
Combustion Turbine		**0.8952** 0.7282	
Combined Cycle		**1.0492***** 0.3886	
Steam Turbine		**-0.4118** 0.3875	
Log Population Density		**0.0342** 0.1023	
Log Capacity (MW)		**0.0716** 0.1379	
FERC			**-0.7007** 0.4599
Retail			**-1.3241*** 0.7604
Log CountyMWPerArea			**-0.4478***** 0.1616
Constant	**3.5238***** 0.7929	**-1.5848*** 0.9364	**-5.2121***** 1.4912

The notations ***, **, and * respectively indicate 1%, 5% and 10% levels of significance.

.Appendix 1

One can conclude that v and T are complements if the function $Ep(s, v, d, T)$ exhibits increasing differences in v and T. The function $Ep(s, v, d, T)$ exhibits increasing differences if , for all $T_1 > T_0$,

$$Ep(s, 1, d, T_1) - Ep(s, 0, d, T_1) \geq Ep(s, 1, d, T_0) - Ep(s, 0, d, T_0),$$

It is sufficient to show that $Ep(s, 1, d, T) - Ep(s, 0, d, T)$ is increasing in T or, the same thing, that $\frac{\partial}{\partial T}\{Ep(s, 1, d, T) - Ep(s, 0, d, T)\} \geq 0$.

This last expression yields $Rre^{-(r+l)T} + \left(\frac{lr}{r+l}\right) sdS\left(e^{rT} - e^{-lT}\right) \geq 0$, which holds for any R and r both greater than zero.

By similar calculations, one can show that s and T are not complements and may be substitutes. One can conclude that s and T are substitutes if the function $Ep(s, v, d, T)$ exhibits decreasing differences in s and T – that is, if $\frac{\partial}{\partial T}\{Ep(1, v, d, T) - Ep(0, v, d, T)\} \leq 0$. This last condition yields $da^d me^{-(r+l)T} - \left(\frac{lr}{r+l}\right)(1-v)dS\left(e^{rT} - e^{-lT}\right) \leq 0$, which fails if $d = v = 1$ and $m > 0$. This condition is satisfied if $am = 0$.

Appendix 2

First-order conditions:

Equity ($d = 0$):

$$T(0, 0, 0) = \frac{1}{g}\ln\left[\frac{(z-m)-rS}{c}\right]$$

$$T(0, 1, 0) = \frac{1}{g}\ln\left[\frac{(z-m)-r(S-R)}{c}\right]$$

$$T(1, 0, 0) = \frac{1}{g}\ln\left[\frac{(z-m)-rS}{c} - \left(\frac{lr}{r+l}\right)\left(\frac{dSe^{rT}}{c}\right)\left(e^{(r+l)T}-1\right)\right] \le \frac{1}{g}\ln\left[\frac{(z-m)-rS}{c}\right]$$

$$T(1, 1, 0) = \frac{1}{g}\ln\left[\frac{(z-m)-r(S-R)}{c}\right]$$

Debt ($d = 1$):

$$T(0, 0, 1) = \frac{1}{g}\ln\left[\frac{(z-am)-rS}{c} - \left(\frac{lr}{r+l}\right)\left(\frac{aSe^{rT}}{c}\right)\left(e^{(r+l)T}-1\right)\right] \le \frac{1}{g}\ln\left[\frac{(z-am)-rS}{c}\right]$$

$$T(0, 1, 1) = \frac{1}{g}\ln\left[\frac{(z-am)-r(S-R)}{c} - \left(\frac{lr}{r+l}\right)\left(\frac{aSe^{rT}}{c}\right)\left(e^{(r+l)T}-1\right)\right] \le \frac{1}{g}\ln\left[\frac{(z-am)-r(S-R)}{c}\right]$$

$$T(1, 0, 1) = \frac{1}{g}\ln\left[\frac{z-rS}{c} - \left(\frac{lr}{r+l}\right)\left(\frac{[a+d]Se^{rT}}{c}\right)\left(e^{(r+l)T}-1\right)\right] \le \frac{1}{g}\ln\left[\frac{z-rS}{c}\right]$$

$$T(1, 1, 1) = \frac{1}{g}\ln\left[\frac{z-r(S-R)}{c} - \left(\frac{lr}{r+l}\right)\left(\frac{aSe^{rT}}{c}\right)\left(e^{(r+l)T}-1\right)\right] \le \frac{1}{g}\ln\left[\frac{z-r(S-R)}{c}\right]$$

Appendix 3

I list here the vertical rents that obtain under each of the eight types of contracts for any one given parameterization.

Equity ($d = 0$):

$$Ep(0,0,0,T)=\left[\frac{z-m}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S}{r+l}\right]\left(l+re^{-(r+l)T}\right)-K$$

$$Ep(0,1,0,T)=\left[\frac{z-m}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S-R}{r+l}\right]\left(l+re^{-(r+l)T}\right)-K$$

$$Ep(1,0,0,T)=\left[\frac{z-m}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S}{r+l}\right]\left(l+re^{-(r+l)T}\right)-K$$
$$-\left[\frac{d}{r+l}\right]S\left[r\left(e^{-lT}-1\right)+l\left(e^{rT}-1\right)\right]$$

$$Ep(1,1,0,T)=\left[\frac{z-m}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S-R}{r+l}\right]\left(l+re^{-(r+l)T}\right)-K$$

Debt ($d = 1$):

$$Ep(0,0,1,T)=\left[\frac{z-am}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S}{r+l}\right]\left(l+re^{-(r+l)T}\right)-aK$$
$$-\left[\frac{a}{r+l}\right]S\left[r\left(e^{-lT}-1\right)+l\left(e^{rT}-1\right)\right]$$

$$Ep(0,1,1,T)=\left[\frac{z-am}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S-R}{r+l}\right]\left(l+re^{-(r+l)T}\right)-aK$$
$$-\left[\frac{a}{r+l}\right]S\left[r\left(e^{-lT}-1\right)+l\left(e^{rT}-1\right)\right]$$

$$Ep(1,0,1,T)=\left[\frac{z}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S}{r+l}\right]\left(l+re^{-(r+l)T}\right)$$
$$-\left[\frac{a+d}{r+l}\right]S\left[r\left(e^{-lT}-1\right)+l\left(e^{rT}-1\right)\right]$$

$$Ep(1,1,1,T)=\left[\frac{z}{r+l}\right]\left(1-e^{-(r+l)T}\right)+\left[\frac{c}{g-r-l}\right]\left(1-e^{(g-r-l)T}\right)+\left[\frac{S-R}{r+l}\right]\left(l+re^{-(r+l)T}\right)$$
$$-\left[\frac{a}{r+l}\right]S\left[r\left(e^{-lT}-1\right)+l\left(e^{rT}-1\right)\right]$$

Let $T(s, v, d) = \arg\max_{\hat{T}} Ep(s, v, d, \hat{T})$ indicate the envelope of contract duration. Inspection immediately yields for any given T $Ep(0, 0, 0, T) \geq Ep(0, 1, 0, T) = Ep(1, 1, 0, T)$. Given any $R > 0$, the inequality is strict. Thus, it is even the case that $Ep(0, 0, 0, T(0, 1, 0)) \geq Ep(0, 1, 0, T(0, 1, 0))$ with strict inequality given $R > 0$. That is, deviating from $(0, 1, 0, T)$ to $(0, 0, 0, T)$ given any T, including $T(0, 1, 0)$ is profitable. Accordingly, contracts conforming to $(s, v, d) = (0, 1, 0)$ can never dominate other contracts.

Further inspection yields $Ep(0, 0, 1, T) \geq Ep(0, 1, 1, T)$ with strict inequality given $R > 0$. We also have $Ep(1, 1, 1, T) \geq Ep(0, 1, 1, T)$ with strict inequality given $am > 0$. Similar reasoning indicates that $(0, 1, 1)$ can never dominate other contracts. This establishes lemma 1.

Finally, similar reasoning indicates that $(1, 0, 0)$ and $(1, 1, 0)$ never dominate. We already have $Ep(0, 0, 0, T) \geq Ep(0, 1, 0, T) = Ep(1, 1, 0, T)$ with strict inequality given $R > 0$. Further inspection yields $Ep(0, 0, 0, T) \geq Ep(1, 0, 0, T)$ with strict inequality given $d > 0$.

Appendix 4

The inequality $(1-a)m > aS\left(\frac{lr}{l+r}\right)\left(\frac{z-am-rS}{c}\right)^{\frac{r}{g}}\left\{\left(\frac{z-am-rS}{c}\right)^{\frac{r+l}{g}}-1\right\}$ implies

$T(0,0,1) > T(0,0,0)$. To see this, note that $T(0,0,1) \le T^* = \frac{1}{g}\ln\left[\frac{z-am-rS}{c}\right]$. Note also that

$$
\begin{aligned}
e^{gT(0,0,1)} &= \frac{(z-am)-rS}{c} - \left(\frac{lr}{r+l}\right)\left(\frac{aSe^{rT(0,0,1)}}{c}\right)\left(e^{(r+l)T(0,0,1)}-1\right) \\
&\ge \frac{(z-am)-rS}{c} - \left(\frac{lr}{r+l}\right)\left(\frac{aSe^{rT^*}}{c}\right)\left(e^{(r+l)T^*}-1\right) = e^{gT^*}
\end{aligned}
$$

Thus, imposing $e^{gT(0,0,0)} < e^{gT^*} \le e^{gT(0,0,1)}$ yields $T(0,0,1) > T(0,0,0)$. Evaluating

$e^{gT(0,0,0)} < e^{gT^*}$ yields the inequality in the premise of Proposition 3.

Appendix 5

I interpret *s*, *v*, and *d* as continuous variables, and I pose the joint payoff (the vertical rent) of representative contracting parties as

$$\begin{aligned} Ep &= k + r_T(\ln T)\left(a_T - \frac{\ln T}{2}\right) + r_s s\left(a_s - \frac{s}{2}\right) + r_v v\left(a_v - \frac{v}{2}\right) + r_d d\left(a_d - \frac{d}{2}\right) \\ &+ r_T(\ln T)g_T W_T + s r_s g_s W_s + v r_v g_v W_v + d r_d g_d W_d \\ &+ B^{Ts}(\ln T)s + B^{Tv}(\ln T)v + B^{Td}(\ln T)d \\ &+ B^{sv}sv + B^{sd}sd + B^{vd}vd \end{aligned}$$

where W_T, W_s, W_v and W_d indicate vectors of predetermined variables with corresponding vectors of coefficients g_T, g_s, g_v and g_d, k is a constant, and r_T, r_s, r_v, and r_d indicate constants each greater than zero. If one lets $B^{sT} = r_T b_{Ts} = r_s b_{sT}$, $B^{Tv} = r_T b_{Tv} = r_v b_{vT}$, $B^{Td} = r_T b_{Td} = r_d b_{dT}$, $B^{sv} = r_s b_{sv} = r_v b_{vs}$, $B^{sd} = r_s b_{sd} = r_d b_{ds}$, and $B^{vd} = r_v b_{vd} = r_d b_{dv}$ indicate cross-equation restrictions, then optimization yields a system of four equations:

$$\begin{aligned} \ln T &= a_T + b_{Ts}s + b_{Tv}v + b_{Td}d + g_T W_T \\ s &= a_s + b_{sT}\ln T + b_{sv}v + b_{sd}d + g_s W_s \\ v &= a_v + b_{vT}\ln T + b_{vs}s + b_{vd}d + g_v W_v \\ d &= a_d + b_{dT}\ln T + b_{ds}s + b_{dv}v + g_d W_d \end{aligned}$$

The cross-equation restrictions reduce to four restrictions $b_{Tv}b_{vs}b_{sT} = b_{Ts}b_{sv}b_{vT}$, $b_{Tv}b_{vd}b_{dT} = b_{Td}b_{dv}b_{vT}$, $b_{Td}b_{ds}b_{sT} = b_{Ts}b_{sd}b_{dT}$, and $b_{sv}b_{vd}b_{ds} = b_{sd}b_{dv}b_{vs}$.

Appendix 6

Contracts Derived from Filings to the FERC

Marketer	Generator	FERC Docket # or SEC filing
Alliant Energy	Minergy Neenah	ER00-89
Ameren Energy Marketing, Dynegy Power Marketing, LG&E Energy Marking	Midwest Electric Power Inc.	ER00-3353-001
Aquila Energy Marketing Corporation and UtiliCorp United Inc.	Elwood Energy II LLC	ER01-2270
Aquila Energy Marketing Corporation and UtiliCorp United Inc.	Elwood Energy III LLC	ER01-2681
Aquila Power Corporation and Utilicorp United Inc.	LSP Energy LP	ER00-3539
Attala Energy Company LLC	Attala Generating Company LLC	ER02-2165
Avista Energy	Rathdrum Power	ER02-216, ER01-2862
Central Illinois Light Company	AES Medina Valley Cogen	ER01-788
Central Illinois Light Company	Altorfer	ER01-1758
CinCap Duke Trenton	Duke Vermillion	ER01-2335
Commonwealth Edison Company (Coal Stations Agreement)	Midwest Generation LLC	ER00-1378
Commonwealth Edison Company (Collins Station Agreement)	Midwest Generation LLC	ER00-1378
Commonwealth Edison Company (Peaking Stations Agreement)	Midwest Generation LLC	ER00-1378
Commonwealth Edison Company	Midwest Generation LLC	ER02-289
Consolidated Edison Company of NY	Entergy Nuclear Indian Point 2 LLC	ER01-1721-001
Constellation Power Source Inc.	Calvert Cliffs Nuclear Power Plant Inc.	ER02-445
Constellation Power Source Inc.	Carr Street Generating Station	Orion Power Holdings 2000 10-K
Constellation Power Source Inc.	Deseret Generation & Transmission Cooperative	ER02-339
Coral Energy	Tenaska Gateway Partners	ER01-2903
Coral Power LLC	Baconton Power LLC	ER00-3096
Coral Power LLC	WFEC Genco LLC	ER01-1481
CPN Pleasant Hill LLC	MEP Pleasant Hill LLC & MEP Pleasant Hill Operating LLC	ER01-905
Dominion Nuclear Marketing I and Dominion Nuclear Marketing II	Pleasants Energy LLC	ER02-698
Duke Energy Corporation	Rockingham Power LLC	ER00-2984-001
Duke Energy Trading and Marketing LLC	Bridgeport Energy LLC	ER01-2352
Duke Energy Trading and Marketing LLC	Casco Bay	ER01-216
Duke Energy Trading and Marketing LLC	Duke Energy Moss Landing LLC	ER02-1662
Edison Mission Marketing and Trading Company	Harbor Cogeneration	ER99-4018
El Paso Energy Marketing Company	Berkshire Power Company LLC	ER00-498
El Paso Power Services Company	Cordova Energy Company LLC	ER01-2595
Engage US LP	Elwood Energy LLC	ER99-4100
Exelon	Kincaid Generation	ER01-2274
Exelon	University Park Energy	ER01-2725
Exelon Generation Company LLC	AmerGen Energy Company LLC	ER02-786
Exelon Generation Company LLC	Elwood Energy	ER01-1975
Exelon Generation Company LLC	Southeast Chicago Energy Project LLC	ER02-2017
Florida Power & Light Company	DeSoto County Generating Company LLC	ER02-1446
Florida Power & Light Company	DeSoto County Generating Company LLC	ER02-1446
Holy Cross Energy and Public Service Company of Colorado	Public Service Company of Colorado	ER02-8
LG&E Energy Marketing Inc.	LG&E Power Monroe LLC	ER02-902
MidAmerican	Cordova Energy Company	ER00-1967
Mirant Americas Energy Marketing LP	Commonwealth Chesapeake Company LLC	ER00-3703, ER02-1537
Mirant Americas Energy Marketing LP	Mirant Chalker Point LLC	ER01-2974
Mirant Americas Energy Marketing LP	Mirant Mid-Atlantic LLC	ER01-2981
Mirant Americas Energy Marketing LP	Mirant Peaker LLC	ER01-2975
Mirant Americas Energy Marketing LP	Mirant Zeeland LLC	ER01-2479
Morgan Stanley Capital Group Inc.	South Eastern Electric Development Corporation	ER99-3654
Municipal Energy Agency of Nebraska	Black Hills Power Inc.	ER01-2577
Niagara Mohawk Energy Marketing	Black River Power LLC	ER00-2044
Niagra Mohawk Power Corporation	Constellation Nuclear LLC	ER01-1654
NRG Power Marketing Inc.	NEO California Power LLC	ER02-1700
NRG Power Marketing Inc.	NRG Energy Center Dover	ER02-1698
Pacificorp	FPL Energy Vansycle	ER01-838
Pacificorp	Rock River I	ER01-2742
PECO Energy Company	AmerGen Energy Company LLC	ER00-1806
PG&E Energy Trading Power LP	DTE Georgetown	ER00-3054
PG&E Energy Trading Power LP	Lake Road Generating Company LP	ER02-2130
Public Service Company of Colorado	Indeck Colorado LLC (Arapahoe Station)	ER00-1952
Public Service Company of Colorado	Indeck Colorado LLC (Valmont Station)	ER00-1952
Public Service Company of New Mexico	Delta Person Limited LP	ER01-138
Public Service Electric & Gas	Cedar Brakes IV	ER01-2765
Select Energy Inc.	Northeast Generation Company	ER00-953
Sempra Energy Trading Corporation	Ogden Martin Systems of Union Inc.	ER00-1155
Sempra Energy Trading Corporation	Sunbury Generation	ER00-357
The California Department of Water Resources	Pacificorp Power Marketing	ER01-2685
Virginia Electric and Power Company	Doswell Limited Partnership	ER01-1182
Virginia Electric and Power Company	LSP Energy LP	ER00-3539
Williams Energy Marketing & Trading Company	AES Alamitos LLC AES Huntington Beach LLC AES Redondo Beach LLC	ER98-2184, ER98-2185, ER98-2186
Williams Energy Marketing and Trading Company	Cleco Evangeline LLC	ER00-3058-001
Wisconsin Electric Power Company	Badger Windpower LLC	ER01-1071
Wisconsin Power and Light Company	Northern Iowa Windpower	ER02-192
WPS Energy Services	Northeast Empire LP	ER01-2568
Yampa Valley Electric Association	Public Service Company of Colorado	ER01-1814

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