Preliminary and Incomplete

Renegotiation, Adaptation, and Vertical Restraints in Electricity Marketing Contracts

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Abstract

What can parties achieve by long-term contract that they cannot achieve by a sequence of short-term contracts? The research points up 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-bearing schemes and financial structure (debt or equity financing) to channel investment incentives, and I provide evidence about how parties use contract duration and vertical restraints to address unprogrammable demands for contract adjustments. Previous theoretical and empirical research has established how long terms of contract can remedy problems relating to relationship-specific investment. This paper indicates complementary results pertaining to non-specific investment. Parties to contracts involving investments in non-specific, highly redeployable assets commit to a combination of longer terms and vertical restraints to facilitate project financing. The results lend themselves to a simple policy experiment: were the antitrust authorities to bar parties from instituting vertical restraints, 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, vertical restraints, project financing.

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, but that is just a second-order 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 on the part of 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 contract duration, vertical restraints, risk-bearing schemes, and 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 remedy problems relating to relationship-specific investment (the "Hold-up Problem."). (Masten and Crocker 1985, Joskow 1987, Crocker and Masten 1988) This paper indicates complementary results pertaining to non-specific investment. I maintain the hypothesis that debt financing requires fewer costly monitoring mechanisms than equity financing. (The discussion of Hansmann and

Kraakman [2000, pp. 399-401] on monitoring and "asset-partitioning" is apposite. See also Williamson 1988 and D.V. Williamson 2005.) With this hypothesis in hand, one can craft an organic explanation of (1) the role of vertical restraints in enabling parties to impose unprogrammed renegotiation, (2) the role of both programmed and unprogrammed renegotiation in enabling parties to adapt terms of contract over the course of long term exchange, (3) the role of adaptation in enabling parties to commit to investment and long-term exchange in the first place, (4) the prevalence of debt over equity in the financing of non-specific assets, (5) the role of two-part risk-sharing schemes in reducing monitoring costs, (6) the alignment of vertical restraints with long-term contracts and two-part risk-sharing, and (7) the absence of vertical restraints in short-term contracts. 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.[1] 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. Bringing new capacity online can complicate the efforts of the marketer to commercialize capacity that is already under contract. 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 bear all risk and to yield to the generator a stream of fixed payments. At the very least, 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 that enable one party or the other to impose renegotiation.

The principal theoretical and empirical results of the paper pertain to pair-wise patterns of substitution and complementarity between vertical restraints, contract duration, and risk-bearing. One can show how vertical restraints and contract duration are complements in that long terms of contract and vertical restraint tend to cluster together whereas short-term contracts tend not to feature vertical restraints. One can also show how risk-bearing and contract duration complement each other in that, other things equal, generators and marketers are more likely to share risk in long-term contracts and tend to impose the residual claim on marketers in short-term contracts. At the same time, however, one can show how vertical restraints and risk-sharing

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[1] 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.

are substitutes in that vertical restraints tend to show up in contracts in which the parties impose the residual claim on marketers.

The patterns of substitution and complementarity lend themselves to a simple narrative about how electricity marketing contracts work. Vertical restraints and contract duration complement each other in that long terms increase the prospect of unprogrammed demands for adaptation, and vertical restraints provide a way of enabling parties to impose renegotiation as a way of addressing unprogrammed demands. At the same time, short-term contracts tend not to feature vertical restraints, because short terms afford parties the option of renegotiating after a short term. Meanwhile, imposing the residual claim on marketers allows investors to focus 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. Taken all together, different combinations of contract duration, vertical restraints and risk-sharing feature tradeoffs. Posing the hypothesis that contracting parties choose efficient combinations yields a simple policy experiment: the theory presented here suggests that were the antitrust authorities to bar parties from instituting vertical restraints, 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.

The remainder of the paper proceeds in four parts. The first part situates the research in the intersection of literatures about financial structure and about problems of adaptation. The second part lays out a simple model of a contracting problem in which contract duration, vertical restraints and risk-sharing are endogenous. I simplify analysis by posing a simple taxonomy of four types of contracts and by characterizing the duration of each of the four types of contract. The results demonstrate patterns of complementarity and substitution between contract duration, vertical restraints, and risk-sharing. The results also yield stark predictions, one of which is that one of the four types of contracts is strictly dominated by other types and thus should never appear in equilibrium. The third part of the paper describes the structure of electricity marketing contracts and presents empirical results. The empirical results demonstrate, among other things, that the one dominated type of contract never appears. The results are also consistent with the predicted outcome of the policy experiment. The last part concludes.

1. Related Literature

Our starting points are the irrelevance theorems of Modigliani and Miller (MM [1958]) and Fudenberg, Holmstrom, and Milgrom (FHM [1990]). MM point out that without imposing a lot of structure, one cannot motivate why financial structure matters. FHM point out that only by imposing a lot of structure can one suggest that contract duration is irrelevant. It turns out that existing research that demonstrates how and why financial structure matters also illuminates considerations that are relevant for long-term contracting. At the same time, research on problems of adaptation in contractual relations also informs analysis of questions of financial structure.

FHM point out that one has to impose a lot of structure in order to suggest that contract duration is irrelevant. They characterize environments in which contracting parties can replicate an efficient long-term contract with a sequence of short-term contracts. They find that a sequence of short-term contracts may be efficient in environments in which (1) parties can identify any and all payoff-relevant contingencies, (2) parties can program adaptations at any and all payoff-relevant contingencies[2], (3) payoff-relevant information is common knowledge when programmed renegotiations arise, and (4) parties cannot impose unprogrammed renegotiations.[3] In the specific environment they consider, "[t]he distinction between long-term and short-term contracts [reduces to] one of commitment, not one of contingencies." (pg. 6) In such an environment, unprogrammed renegotiation serves no affirmative purpose but rather constitutes a nuisance. In the environment considered in this paper, however, it is not obvious that parties could program adaptations for all payoff-relevant contingencies that might arise, in which case unprogrammed renegotiation might serve a purpose of enabling unprogrammed adaptations. Thus, one of the distinctions considered here between long-term and short-term contracts turns on tradeoffs between the flexibility that unprogrammed renegotiation enables and the costs of implementing unprogrammed renegotiation.

MM also point out an important irrelevance result. MM demonstrate that, without imposing a lot of structure, it is not immediately obvious why there should be any tradeoffs between financing projects with debt or equity. Jensen and Meckling (1976) suggest how problems of hidden information and hidden action can motivate tradeoffs. Financial structure itself can make the private interests of parties within the firm (the "managers") deviate from those of outside stakeholders and bondholders. More generally, financial structure can induce insiders in some instances to forgo value-enhancing investment opportunities and in other instances to over-invest. If outsiders could costlessly identify and evaluate such instances, they might be in a place to intervene, and that would be that, but insiders' private information can frustrate easy remedies. The authors go on to suggest that the hazards attending debt financing can be qualitatively different than those attending equity. Different hazards can impose different costs, and different costs alone can motivate tradeoffs between debt and equity, but that is just a partial argument. The authors pose a familiar equilibrium argument that works out of what Williamson (1988) recognizes as "an efficient-contracting orientation to economic organization" (pg. 569): What matters are not the hazards alone but also the costs of mitigating the hazards. Thus, the costs of implementing remedies and the distortions that yet obtain after implementing remedies motivate the tradeoffs between debt and equity financing. Such tradeoffs allow one to pose the hypothesis that parties choose the capital structures and attending governance structures that maximize their rents.

Myers (1977) also appeals to problems of hidden information and hidden action to characterize tradeoffs between debt and equity financing, but his analysis makes explicit allowances for investment that unfolds over time. Again, the combination of financial structure with problems

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[2] "[T]he principal and agent can trade in a 'complete' set of contingencies, namely all contingencies that are relevant for determining future expected utilities." (pg. 4)

[3] Other conditions are featured in Theorem 3, pg. 21.

of hidden information and hidden action can distort insiders' investment decisions. The prospect of distortions invites outside investors to demand remedies. Adding time to the analysis of investment suggests that remedies can take the form of adaptations of investment plans. Demands for adaptation, in turn, motivate demands for renegotiation. Myers suggests that one way parties can meet demand for renegotiation is to program it by appealing to short-term debt financing.

In the environment examined in this paper, investing over time is also an important issue. The action depends on how contracting parties adapt production capacity over the course of long-term exchange to evolving demand and supply conditions. Williamson suggests that contracting parties might over the course of time find themselves knocked "off the contract curve." (Williamson 2000, pg. 34; 1985, pg. 21; See also Aoki 1983.) FHM examine an environment in which parties never get knocked off the contract curve, because they "can trade in a 'complete' set of contingencies" at the time of contracting, but even if one admits the prospect of getting knocked off the contract curve after contracting, the Second Theorem of Welfare Economics suggests that contracting parties may yet be able to trade their way back to the contract curve. Commercial realities in all of their glorious inconvenience, however, might impose themselves in at least four ways. First, organizing trade may not be a trivial exercise. Markets may not be complete in that nonconvexities, such as indivisibilities in production, may frustrate the appeal to decentralized means of organizing trade, thus forcing parties to appeal to (possibly messy) alternatives. (Banks, Ledyard and Porter 1989) The incompleteness of state-contingent markets alone says nothing about problems of hidden information or hidden action. Hence our second, third, and fourth considerations: (2) Discrete shocks to demand or supply might indicate obvious instances in which the contract curve may have shifted. These represent obvious demands for adaptation, but in less obvious cases parties might have to engage resources to determine whether or not they actually have meandered off the contract curve.[4] (3) Genuine disagreements or willful misrepresentations might complicate their efforts to identify rent-improving moves. (Williamson 1971) Thus (4), they might have to engage more resources to get back on the contract curve. At the very least, they might have to expend resources to withdraw, expand, or tune-up production capacity, and, again, they might have to expend resources simply to ascertain what might constitute rent-improving moves.

These complications suggest that parties might perceive tradeoffs in the way they identify and implement adaptations. That, in turn, leads to two interesting prospects: again, efficient adaptation can be an important economic problem, and efficiently achieving adaptation might impinge the design of the contract they use to govern exchange over the course of long term exchange. "The problem," as Crocker and Masten (1991) suggest, "is to devise a [governance] structure that encourages rent-increasing adjustments (flexibility) but discourages rent-dissipating efforts to redistribute existing surpluses (opportunism)." (pg. 72)

Williamson (1988) explicitly situates the question of financial structure in an efficient contracting framework. Williamson does this by characterizing an environment in which meandering off the contract curve is a realistic prospect and in which parties would have to incur costs to realign the terms of exchange with the contract curve (pg. 572). The economic problem involves not merely designing a governance structure that enables parties to efficiently realign

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[4] The discussion of Bajari and Tadelis (2000, pg. 396) on nonverifiable design failures is apposite.

terms of exchange but also involves folding the choice of financial structure into the design problem. They key point, however, is that Williamson goes beyond describing tradeoffs between the choice of debt or equity financing but also identifies an exogenous factor that drives the choice of financial structure. He ties the choice of financing (and the governance that the mode of financing implies) to "asset-specificity" – the extent to which surplus would be lost were parties to redeploy assets to purposes outside of their specific relationship.

The prospect that the contract curve might make unprogrammable shifts suggests why parties might find themselves contemplating the unprogrammed prospect of exercising their outside option to redeploy assets and bearing the losses (if any) that attend redeployment. Williamson suggests that the prospect of bearing unprogrammed losses induces demand for working things out. It might be efficient for parties to exercise their inside option to bear the costs of realigning the terms of exchange with the contract curve rather than bearing the losses that attends redeployment of assets to outside alternatives. Anticipating this, parties might put in place systems that facilitate efforts to both evaluate and implement the inside and outside options. Instituting and maintaining systems, however, entails some rent-dissipation of its own. Thus, if assets are redeployable with little or no dissipation of relationship-specific rents, then parties need not bear the costs of instituting and maintaining systems. In the event they find themselves knocked off the contract curve, they can just redeploy, and that is that.

Suppose now we add project finance to the analysis. Debt financing involves yielding to an outside party (e.g., the bank) some discretion over the decision to redeploy assets or to realign the terms of exchange. In the event parties fail to make payments, the lender might exercise its option to foreclose and demand liquidation. If assets are highly redeployable, then making allowances for an outside party to march in and demand liquidation entails little or no rent dissipation, because there is little or no relationship-specific rent to dissipate. Thus, it might not be efficient to bear the costs of instituting and maintaining a governance structure that facilitates unprogrammed efforts to "work things out." If, however, redeploying assets entails substantial dissipation, then parties might not want to yield rights to an outside party to impose unprogrammed demands to liquidate. Instead, parties may choose to institute costly systems that are more amenable to serving unprogrammed demands to adapt terms of exchange, and they may choose to line up a slate of equity investors who, by virtue of owning equity stakes, have greater interest in enabling unprogrammed adaptations. That is, in environments in which asset-specificity is high, the advantages of equity financing may dominate.

Since Williamson (1988), there has been little empirical or theoretical work in economics that explicitly joins problems of unprogrammable adaptation with financial structure. Riahi-Belkaoui and Bannister (1994) find empirical support for the proposition that equity financing tends to line up with asset-specificity and that debt lines up with highly redeployable assets. In related work, Bajari and Tadelis (2001) explore an environment in which problems of programmable adaptation and moral hazard dominate. They characterize a principal-agent problem that involves the procurement of a (possibly) complex output. They suggest how contracting parties use two types of instruments, risk-bearing schemes and the completeness of project design, to manage tradeoffs between three considerations: costly incentives to induce efforts to reduce procurement costs, rent-dissipation attending renegotiation, and the costs of avoiding the prospect of programmed renegotiation. More complete project designs allow parties to avoid costly renegotiation, but more complete designs are themselves more costly to assemble. Meanwhile, fixed price compensation may provide the highest-powered incentives to reduce procurement costs, but they induce more rent-dissipation when and if parties renegotiate. Cost-plus schemes provide no incentives to reduce project costs, but they relieve friction encountered during renegotiation. The authors go on to demonstrate that it can be efficient for parties to support complex projects by bearing a greater prospect of costly renegotiations and giving up on high-powered incentives in order to contain the rent-dissipation that attends renegotiation. In contrast, the combination of high-powered incentives (to induce lower procurement costs) and more complete design (to avoid renegotiation) constitutes the efficient match to simpler projects.

Bajari and Tadelis (2001) provide a number of instructive points of comparison and contrast with the research presented here. In the environment they explore, they elegantly demonstrate how it can be efficient for parties to leave contracts incomplete *even though* complete contracting is feasible. That is, even in environments in which all relevant contingencies lend themselves to programmable adaptations, it might be efficient for parties to not program adaptations for all contingencies. Thus, contractual incompleteness can be endogenous. (Saussier 2000 makes a parallel point.) In the environment explored here, the prospect of unprogrammable shifts of the contract curve renders complete contracting infeasible – that is, I allow the prospect that incompleteness can be at least partially exogenous. Even so, admitting some scope for exogenous incompleteness provides a way for implicitly endogenizing the complexity of a project. Bajari and Tadelis provide a crisp definition of complexity that precludes consideration of unprogrammed demands for adaptation but allows them to provide a crisp characterization of how contracting parties factor (exogenous) complexity into their contract design problem. In the environment explored here, I demonstrate how extending the duration of contracts increases the prospect of unprogrammed demands for adaptation. Choosing longer terms amounts to choosing projects of greater "complexity," because longer term projects are more susceptible to unprogrammed demands for adaptation. I demonstrate how implicitly endogenizing complexity allows one to characterize tradeoffs in contract duration.

One should probably ask whether or not endogenizing the completeness of contracts (and appealing to exogenous complexity) or endogenizing complexity (and appealing to exogenous incompleteness) amounts to nothing more than choosing one side or the other of the same coin. At this stage I am agnostic on this point and am willing to entertain the prospect that choosing one side or the other enables complementary research. One might be tempted to suggest that admitting the prospect of unprogrammed shifts merely introduces noise to the analysis and that, in turn, one should not admit exogenous incompleteness. It turns out, however, that admitting the prospect of unprogrammed shifts does enrich analysis: I am able to accommodate unprogrammed shifts in a simple model that yields simple, testable hypotheses and yields, moreover, hypotheses that affirmatively characterize the contract data. As the irrelevance result of FHM suggests, without admitting the prospect of unprogrammable shifts, it is not obvious why contract duration should matter. The results presented here suggest that there are tradeoffs between longer-term and shorter-term contracts. The results parallel those of Bajari and Tadelis in that containing instances of programmed renegotiation is an important consideration. The results complement those of Bajari and Tadelis in that they demonstrate tradeoffs involving unprogrammed instances of renegotiation.

2. Model and Hypotheses

Two risk-neutral parties, a marketer and a generator say, craft a contract that extends over an interval of duration $T \geq 0$. They join complementary assets for production in as many as two states. In the initial state, the parties anticipate a continuous, stochastic but 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 two binary choices. First, parties decide whether or not to impose the residual claim on the marketer, in which case the generator 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 the generator. Second, the parties decide whether or not to impose a vertical restraint in the contract. Specifically, they decide whether or not to impose a "veto provision" according to which either party might veto the proposal of the other to add, withdraw or tune up production capacity. Hence, a contract is a triple (T, m, v) with

$$T = \text{contract duration}$$

$$m = \begin{cases} 0 & \text{Parties share risk} \\ 1 & \text{Marketer bears all risk} \end{cases}$$

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

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 key point is that the adjustments the parties have to make are unprogrammable which renders them noncontractible. Thus, renegotiation may serve the purpose of enabling the parties to realize rent-maximizing adjustments. The tradeoff 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 instantaneous (expected) payoff Z. Meanwhile, imposing a risky stream of payoffs on the generator raises the auditing/monitoring costs of outside investors by increment *M*.

I justify this characterization of monitoring costs as follows: a marketer may have its hand in a broad portfolio of projects with any number of generators. 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. A generator, however, may separately incorporate each of its generating projects – which, it turns out, they uniformly do. In the language of Hansmann and Kraakman (2000), generators "partition 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 generators might cheat investors by misrepresenting their payoffs. However, relieving a generator's project-specific payoffs of risk relieves outside investors of having to bear incremental monitoring and auditing costs. Thus, imposing the residual claims on marketers still enables risk pooling, but it also enables parties to economize on auditing and monitoring costs; investors need only concentrate the lens of auditing and monitoring on marketers.

I indicate K as the up fixed cost of instituting a mechanism to monitor a generator's payoffs, and I indicate C as the instantaneous marginal cost of output. I indicate r as a discount rate and l as a hazard rate reflecting the instantaneous likelihood of the state reverting to the "salvage" state. Finally, I indicate a as the instantaneous rate at which the cost of producing output increases. Imposing $a > 0$ 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 of number of isomorphic ways to secure an interior solution. For example, the term a constitutes an indirect way of modeling depreciation of production capacity. Thus, imposing $a > 0$ constitutes little loss of generality and does not otherwise constitute an interesting, instructive assumption.

To recap, the parameters of the system are:

Z = Instantaneous expected payoff at time $t \in [0, T]$

M = Instantaneous monitoring costs

K = Fixed cost of instituting monitoring mechanism

C = Instantaneous cost of producing Z

R = Dissipation due to Renegotiation

D = Dissipation, proportional to expected income Z, that results from distorted investment incentives

S = Continuation payoff

r = Instantaneous discount rate

a = Instantaneous rate of cost appreciation

l = Instantaneous hazard rate reflecting the likelihood of switching from the stationary stream of payoffs to the continuation payoff

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

$$V(t^*;T) = \int_0^{t^*} \left(Z - Ce^{at} - (1-m)M\right)e^{-rt}dt + Se^{-rt^*} - v\,\mathrm{Re}^{-rt^*} - (1-v)mDZe^{r(T-t^*)}$$

The interpretation is that imposing vertical restraints $(v = 1)$ allows the parties to avoid the (discounted) rent dissipation *DZ* that occurs at time *t**, but setting $v = 1$ forces them to bear the (discounted) renegotiation tax *R.*[5] Parties secure the (discounted) salvage 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 the generator $(m = 0)$ forces the parties to bear incremental monitoring costs *M*, but imposing risk forces the generator to internalize the effects of inefficient investment at time *t**, thus enabling the parties to avoid the tax *DZ.* In contrast, relieving the generator of risk and imposing the residual claim on the generator enables the parties to avoid incremental monitoring costs but introduces the prospect of distorted investment at time *t**. Note, that either imposing the vertical or imposing risk on the generator allows the parties to avoid the tax *DZ.*

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

$$\begin{aligned} Ep &= EV - (1-m)K \\ &= \int_0^T V(t^*;T)\,f(t^*;\cdot)\,dt^* + \left(1 - F(T;\cdot)\right)V(T;T) - (1-m)K \end{aligned}$$

Note that imposing $m = 1$ (the marketer bears all risk) also allows the parties to avoid the up front fixed costs *K* of instituting a monitoring mechanism.

Now, if we let 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

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[5] Note that the rent dissipation that attends distorted investment at time *t** is diminishing with time. This is not an important assumption.

$$V(t^*) = \left[\frac{Z-(1-m)M}{r}\right]\left(1-e^{-rt^*}\right) + \left[\frac{C}{a-r}\right]\left(1-e^{(a-r)t^*}\right) + Se^{-rt^*} - v\,\mathrm{R}e^{-rt^*} - (1-v)mDZe^{r(T-t^*)}$$

and

$$\begin{aligned} Ep\,(m, v, T) = {} & \left[\frac{Z-(1-m)M}{r+l}\right]\left(1-e^{-(r+l)T}\right) + \left[\frac{C}{a-r-l}\right]\left(1-e^{(a-r-l)T}\right) - (1-m)K \\ & + \left[\frac{S}{r+l}\right]\left(l + re^{-(r+l)T}\right) - \left[\frac{vR}{r+l}\right]\left(l + re^{-(r+l)T}\right) - \left[\left(\frac{l}{r+l}\right)(1-v)mDZ\right]\left(e^{rT} - e^{-lT}\right) \end{aligned}$$

Thus, for each of the four pairs $(m, v) \in \{(0, 0), (0, 1), (1, 0), (1, 1)\}$ we have

$$\begin{aligned} Ep\,(0, 0, T) &= \left[\frac{Z-M}{r+l}\right]\left(1-e^{-(r+l)T}\right) + \left[\frac{S}{r+l}\right]\left(l + re^{-(r+l)T}\right) + \left[\frac{C}{a-r-l}\right]\left(1-e^{(a-r-l)T}\right) - K \\ Ep\,(0, 1, T) &= \left[\frac{Z-M}{r+l}\right]\left(1-e^{-(r+l)T}\right) + \left[\frac{S-R}{r+l}\right]\left(l + re^{-(r+l)T}\right) + \left[\frac{C}{a-r-l}\right]\left(1-e^{(a-r-l)T}\right) - K \\ Ep\,(1, 0, T) &= \left[\frac{Z}{r+l}\right]\left(1-e^{-(r+l)T}\right) + \left[\frac{S}{r+l}\right]\left(l + re^{-(r+l)T}\right) + \left[\frac{C}{a-r-l}\right]\left(1-e^{(a-r-l)T}\right) \\ &\quad - \left(\frac{l}{r+l}\right)DZ\left(e^{rT} - e^{-lT}\right) \\ Ep\,(1, 1, T) &= \left[\frac{Z}{r+l}\right]\left(1-e^{-(r+l)T}\right) + \left[\frac{S-R}{r+l}\right]\left(l + re^{-(r+l)T}\right) + \left[\frac{C}{a-r-l}\right]\left(1-e^{(a-r-l)T}\right) \end{aligned}$$

Inspection of these last four expressions yields $Ep\,(0, 0, T) > Ep\,(0, 1, T)$ for any T and $Ep\,(1, 1, T) > Ep\,(0, 1, T)$ for any T which, in turn, yields our first result.

Proposition 1: Given parties contract at all, any contract featuring $(m, v) = (0, 1)$ is never efficient.

Further inspection and some manipulation yields our second result.

Proposition 2: Any $(m, v) \in \{(0, 0), (1, 0), (1, 1)\}$ can be efficient.

Proof: Let $T(m, v) = \arg\max_{T} Ep\,(m, v, T)$ indicate the envelope of contract duration.

(a) $M = K = 0$ implies $(m, v) = (0, 0)$ is undominated. To see this, observe that

$$Ep\left(0, 0, T(m, v)\right) - Ep\left(1, 1, T(m, v)\right) = R\left(l + re^{-(r+l)T(m,v)}\right) \geq 0 .$$

Also, optimization implies $Ep\left(m, v, T(m, v)\right) \geq Ep\left(m, v, T(m', v')\right)$ for all (m, v) and $(m', v') \in \{(0, 0), (0, 1), (1, 0), (1, 1)\}$. Thus, along the contract duration envelope we have

$$Ep\left(0, 0, T(0, 0)\right) \quad \geq \quad Ep\left(0, 0, T(1, 1)\right) \quad \geq \quad Ep\left(1, 1, T(1, 1)\right) \quad \geq \quad Ep\left(1, 1, T(0, 0)\right).$$

The contract $\left(m, v, T(m, v)\right) = \left(1, 1, T(1, 1)\right)$ cannot dominate $\left(m, v, T(m, v)\right) = \left(0, 0, T(0, 0)\right)$.

Similarly, observe that
$Ep\left(0, 0, T(m, v)\right) - Ep\left(1, 0, T(m, v)\right) = \left(\dfrac{l}{r + l}\right) DZ\left(e^{rT(m,v)} - e^{-lT(m,v)}\right) \geq 0$. So, along the contract duration envelope we have

$$Ep\left(0, 0, T(0, 0)\right) \quad \geq \quad Ep\left(0, 0, T(1, 0)\right) \quad \geq \quad Ep\left(1, 0, T(1, 0)\right) \quad \geq \quad Ep\left(1, 0, T(0, 0)\right).$$

The contract $\left(m, v, T(m, v)\right) = \left(1, 0, T(1, 0)\right)$ cannot dominate $\left(0, 0, T(0, 0)\right)$.

Finally, from Proposition 1 we already know that the contract $\left(m, v, T(m, v)\right) = \left(0, 1, T(0, 1)\right)$ cannot dominate $\left(0, 0, T(0, 0)\right)$.

Similar calculations along the contract duration envelope yield:

(b) $D = 0$ implies $(m, v) = (1, 0)$ is undominated; and

(c) $R = 0$ implies $(m, v) = (1, 1)$ is undominated.

What we would like to be able to do, of course, is to characterize the optimal contract (T, m, v) and to characterize how the optimal contract varies across different parameter values. Unfortunately, we cannot appeal to monotone comparative statics. (See Appendix 1.) In what follows, I characterize the optimal contract duration $T(m, v)$ given (m, v), although (m, v) may itself not be optimal. I then demonstrate patterns of substitution and complementarity between *T*, *m*, and *v*.

Evaluating the first-order condition $\dfrac{\partial Ep}{\partial T} = 0$ for an interior solution at each $(m, v) \in \{(0, 0), (0, 1), (1, 0), (1, 1)\}$ yields

$$T(0,0)=\frac{1}{a}\ln\left[\frac{Z-rS-M}{C}\right]$$
$$T(0,1)=\frac{1}{a}\ln\left[\frac{Z-rS-M+rR)}{C}\right]$$
$$T(1,0)=\frac{1}{a}\ln\left[\frac{Z-rS}{C}-\left(\frac{DZe^{rT}}{C}\right)\left(\frac{l}{r+l}\right)\left(re^{(r+l)T}+l\right)\right]$$
$$T(1,1)=\frac{1}{a}\ln\left[\frac{Z-rS+rR)}{C}\right]$$

See Appendix 2.

The conditions $a>0$ and $r>l$ are sufficient for satisfying second-order conditions for each of the four interior maxima. See Appendix 3.

Inspection of the first-order conditions above indicates that no matter what type of contract (m, v) is optimal, the contract in which parties impose residual claimancy on the marketer $(m=1)$ and include a vertical restraint $(v=1)$ also features the longest duration. Thus:

Proposition 3: For any given feasible vector of parameters $\Gamma=(Z, M, K, C, R, D, S, r, a, l)$ and $T(1,1)>0$,

$$T(1,1)>\frac{1}{a}\ln\left[\frac{Z-rS}{C}\right]>T(0,0),$$
$$T(1,1)>\frac{1}{a}\ln\left[\frac{Z-rS}{C}\right]>T(1,0), \text{ and}$$
$$T(1,1)>T(0,1).$$

Remark 1: Proposition 3 implies that contract duration is increasing in v – that is, that vertical restraints and long terms of contract complement each other.

Remark 2: Propositions 2 and 3 yield a policy experiment. According to Proposition 2, we can pose the hypothesis that $(m, v)=(1,1)$ is optimal. Suppose, now, that the antitrust authorities block $v=1$. The contract parties then deviate to either $(m, v)=(1, 0)$, $(m, v)=(0, 0)$ or no contract. If the parties continue to contract, then Proposition 3 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.

Note that, in general, it is not possible to rank $T(0,0)$ and $T(1,0)$. However, if the dissipation that attends renegotiation is sufficiently high, we can yield $T(0,0)>T(1,0)$. This is interesting, because it suggests how risk-sharing $(m = 0)$ constitutes a substitute for short terms. That is, imposing some risk on the generator forces the generator to internalize at least some of the rent-dissipation that attends under or over-investment. Inducing the generator to invest more efficiently allows the parties to diminish the frequency of programmed renegotiation by establishing a longer term. Thus, we have our next proposition:

Proposition 4: Given $M < l\left(\frac{DZ}{C}\right)$ and $T(0, 0) > 0$, then $T(1, 1) > T(0, 0) > T(1, 0)$.

Inspection immediately yields the result. The immediate point is that as long as the instantaneous monitoring costs *M* are small relative to the one-time tax *DZ* that results from distorted investment at time *t**, then imposing some risk on generators can allow parties to commit to longer term contracts. The larger point is that the envelope of contract duration $T(m, v)$ is not monotonic in *m*, but if one controls for the prospect that parties exclude a vertical restraint in the contract – that is, if one holds *v* constant at zero – then one may observe that contract duration is decreasing in *m*.

The modeling suggests that one should interpret the optimal choice of contract duration (*T*), risk-bearing (*m*), and vertical restraints (*v*) as functions of each other. The model itself does not lend itself immediately to a simple econometric specification. In what follows, I pose the hypothesis that one can approximate the joint selection of *T*, *m*, and *v* by system of linear equations that also includes an equation characterizing the binary selection of debt financing $(Debt = 1)$ over other financing $(Debt = 0)$. Specifically, I interpret *m*, *v*, and *Debt* as continuous variables, and I pose contracting parties' payoff (the vertical rent) as

$$\begin{aligned} Ep &= k + r_T \ln T\left(a_T - \frac{\ln T}{2}\right) + r_m m\left(a_m - \frac{m}{2}\right) + r_v v\left(a_v - \frac{v}{2}\right) + r_d Debt\left(a_d - \frac{Debt}{2}\right) \\ &\quad + r_T g_T (\ln T) W_T + r_m g_m m W_m + r_v g_v v W_v + r_d g_d (Debt) W_d \\ &\quad + B^{Tm} m \ln T + B^{Tv} v \ln T + B^{mv} mv \end{aligned}$$

where W_T, W_m, W_v and W_d indicate vectors of predetermined variables with corresponding vectors of coefficients g_T, g_m, g_v and g_d, *k* is a constant, and r_T, r_m, r_v, and r_d indicate constants of proportionality, each greater than zero. If we let $B^{MT} = r_T b_{Tm} = r_m b_{mT}$, $B^{Tv} = r_T b_{Tv} = r_v b_{vT}$, and $B^{mv} = r_m b_{mv} = r_v b_{vm}$ indicate cross-equation restrictions, then optimization yields a system of four equations with the first three characterizing the first-order conditions for interior selections of *T*, *m*, and *v*:

$$\begin{aligned} \ln T &= a_T + b_{Tm} m + b_{Tv} v + g_T W_T \\ m &= a_m + b_{mT} \ln T + b_{mv} v + b_{md} Debt + g_m W_m \\ v &= a_v + b_{vT} \ln T + b_{vm} m + g_v W_v \\ Debt &= a_d + g_d W_d \end{aligned}$$

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

We thus have our last proposition:

Proposition 5: Within the context of the linear model, $b_{Tv} > 0$ and $b_{Tv} < 0$ imply the complementarity of contract duration *T* and vertical restraints *v*.

Remark: Proposition 5 says makes no contact with the cross-equation restrictions, and one might wonder whether or not one might be able to exploit these restrictions and impose more structure. These restrictions do yield the condition $b_{Tv} b_{vm} b_{mT} = b_{Tm} b_{mv} b_{vT}$, but this conditions is not amenable to obvious application.

Hypotheses

The Propositions suggest a number of qualitative patterns one might observe in the contract data:

H1: Contracts featuring $(m, v) = (0, 1)$ do not appear in the data. Instead, if parties use vertical restraints $(v = 1)$, they use them to support contracts in which marketers bear the residual claim $(m = 1)$.

H2: Contract duration *T* is increasing in *v*, and, absent vertical restraints, contract duration *T* is decreasing in *m*. That is, other things equal, $T(1,1) > T(0,0) > T(1,0)$. Within the context of the linear model, this amounts to $b_{Tv} > -b_{Tm} > 0$.

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; having neutralized the prospect of unprogrammed renegotiation parties increase the frequency of programmed renegotiation by imposing a shorter term.

Next, I pose the hypothesis that contract duration and vertical restraints are complements within the context of the linear model.

H3: Long terms of contract and vertical restraints cluster together. Specifically, $b_{Tv} > 0$.

Remark1: None of these hypotheses say anything about how the optimal contract (T, m, v) changes with innovations in the underlying parameters, but they do go some way toward characterizing patterns of complementarity and substitution between contract duration, the risk-bearing scheme, vertical restraints, and financial structure.

Remark 2: The formal model does not explicitly account for the role of financial structure but rather rests upon the hypothesis that parties are appealing to debt financing. I have two observations to make. First, I can indirectly distinguish differences in monitoring costs by distinguishing marginal generation from other types of generation. Marginal generation, by virtue of being marginal, is subject to uncertain dispatch demands and thus yields a stream of revenues that may be more difficult to track. Tracking revenues involves costly monitoring and auditing. Thus, if parties go through the trouble of instituting monitoring and auditing mechanisms, they might as well appeal to some portion of equity financing to support financing of their generation project.

H4: The appeal to debt financing is decreasing in monitoring costs. Thus, other things equal, marginal generation is more amenable to equity financing.

Second, I accommodate the prospect that contracting parties may not in all instances appeal strictly to (non-recourse) debt financing. I create an index of the degree to which underlying generation assets are amenable to debt financing, and I use the index to craft an informal hypothesis for which I have not provided a formal theoretical foundation. Note that estimating the linear system amounts to generating an index of predicted values $\overline{Debt}$ of Debt and regressing m on the index. I interpret $\overline{Debt}$ as an index of redeployability, and I pose the following hypothesis that greater redeployability makes it possible for parties to reduce monitoring costs by appealing to two-part compensation. Thus:

Informal hypothesis H5: The appeal to two-part compensation $(m = 1)$ is increasing in $\overline{Debt}$.

3. Data and Results

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").[6] (See Appendix 4.) 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.[7] 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 five types of generation: gas-fired generation ("Gas"), nuclear, coal-fired generation ("Coal"), wind-driven generation ("Wind"), and all other ("Other"). "Other" includes projects that burn waste from fiber products mills. Further, I distinguish gas-fired generation as "marginal" generation capacity, and I distinguish nuclear and coal-fired generation as "baseload" generation capacity. 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 might not cooperate.

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 pertaining to baseload capacity (nuclear and coal), tended to feature short terms whereas those pertaining to gas-fired generation averaged 12.22 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. By far, contracts pertaining to coal-fired generation covered, on average, the largest capacities (1,745.29 MW). Contracts pertaining to wind-driven generation or "Other" generation covered, on average, 81.75 MW and 71.58 MW respectively. Gas-fired generation averaged 551.64 MW per contract.

Eighty of the 101 contracts pertain to gas-fired generation. Twenty-one of these eighty contracts featured vertical restraints. (See Table 2.) Only two other contracts, both pertaining to Wind,

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[6] The FERC stopped requiring marketers to file contracts in 2002. The dataset features every contract I could identify in all available filings.

[7] 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.

featured vertical restraints. Of these 23 vertical restraints, eight are veto provisions. The two Wind contracts both feature veto provision, probably because wind-driven generation tends to rely on subsidies to be economical. Parties are not keen to invest heavily in long-lived assets only to find subsidies taken away in the future. The 15 other restraints 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. Examples: The marketer Williams Marketing Energy & Trading maintains rights of first-offer, but no veto rights, in its relationship with the generator Cleco Evangeline.[8] The marketer Coral Power, LLC maintains the right to veto "upgrades" of generating units that the generator Baconton Power, LLC might propose. "Equitable adjustments" to the two-part compensation scheme would attend such upgrades.[9] Williams and the generator AES Southland reserve the rights to veto proposals by the other to expand or withdraw capacity.[10]

Overall, 66 of the 101 contracts imposed the residual claim on marketers $(m=1)$. Sixty-two of the 66 contracts pertained to Gas. Of the 21 non-Gas contracts, only 4 imposed the residual claim on marketers. This is not surprising. Sometimes marketers share risk with generators $(m=0)$ 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 have constructed nineteen variables that I apply to a series of crosstabulations and to estimation of the linear model.

(1) LogTerm:	The logarithm of the duration of term of the contract, excluding options to extend.
(2) TwoPart:	The risk-bearing scheme assigns the residual claim to the marketer $(m=1)$ 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 $(m=0)$. (Binary)
(3) Restraint:	The contract features a vertical restraint $(v=1)$. (Binary)

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[8] See the FERC filing dated June 30, 2000 at docket # ER00-3058-001.

[9] See page 46 of the Baconton filing dated July10, 2000 at docket # ER00-3096.

[10] See page 2 of the Williams/AES agreement filed May 7, 2001 at docket # ER98-2184-006.

(4) Debt:	The contract indicates an underlying credit agreement $(d = 1)$. (Binary)
(5) Gas:	The contract features gas-fired generation capacity. (Binary)
(6) Nuclear:	The contract feature nuclear-powered generation capacity. (Binary)
(7) Coal:	The contract features coal-fired generation capacity. (Binary)
(8) Wind:	The contract features wind-driven generation capacity. (Binary)
(9) New:	The contract covers new generation capacity. (Binary)
(10) MW:	Generation capacity, indicated in megawatts (MW), covered by the contract.
(11) NewMW:	The interaction of New and MW.
(12) NewGas:	The interaction of New and Gas. (Binary)
(13) GasMW:	The interaction of Gas and MW. (Binary)
(14) NewWind:	The interaction of New and Wind. (Binary)
(15) Pops:	The population of the county in which the generation sites are located.
(16) PopsPerMW:	The ratio of Pops to MW. It constitutes a proxy for marginal generation since large, baseload generation plants are often located outside of populated areas and small, "peaking" units tend to be located within load pockets which themselves tend to be located within densely populated areas.
(17) Sites:	The number of distinct sites at which generation units are located.
(18) Retail:	An indicator that the "marketer" is a retail distributor of electricity. (Binary)
(19) FERC:	The contract was filed with the FERC, and the FERC opted to make the contract available to the public. (Binary)

Table 5 features correlation coefficients between LogTerm, TwoPart, Restraints, Debt, New, Gas, MW, and PopsPerMW. New is highly, positively correlated with all for endogenous variables LogTerm, TwoPart, Restraints, and Debt. Gas is highly correlated with all four but LogTerm. In contrast, MW is not highly correlated with any of the four endogenous variables, although it is negatively correlated with both New and Gas. New and Gas are highly correlated, which is no great surprise, in that much of the investment that came with market restructuring involved gas-fired generation.

I use the variables Gas, GasMW, and PopsPerMW as indications of marginal generation and, in turn, as proxies for monitoring costs. Gas-fired units themselves operate at higher marginal costs than other types of generation, but not all gas-fired generation may correspond to marginal generation. "Simple cycle" generation units constitute gas-fired generation with the highest marginal costs. Other types of "combined cycle" gas units feature heat recovery systems which allow them to be more fuel efficient but are less amenable to ramping up quickly to respond to spikes in demand. The important idea, however, 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.

Gas and PopsPerMW are virtually uncorrelated, and this reflects part of the appeal to including PopsPerMW in the regression analysis. It turns out that some gas-fired generation serves steady-state demands, especially in areas where regulatory restrictions, such as clean-air requirements, are in force. PopsPerMW, however, provides a way of identifying smaller, peaking units operating inside densely populated "load pockets" – the kinds of places at which peaking capacity should be situated.

I use three-stage least squares to estimate a linear version of the model that corresponds to

$$\begin{array}{lcl}
\text{LogTerm} & = & a_T + b_{Tm}\,\text{TwoPart} + b_{Tv}\,\text{Restraint} + g_T W_T \\
\text{TwoPart} & = & a_m + b_{mT}\,\text{LogTerm} + b_{mv}\,\text{Restraint} + b_{md}\,\text{Debt} + g_m W_m \\
\text{Restraint} & = & a_v + b_{vT}\,\text{LogTerm} + b_{vm}\,\text{TwoPart} + g_v W_v \\
\text{Debt} & = & a_d + g_d W_d
\end{array}$$

Note that estimation of the system involves generating the linear projection of Debt on the predetermined variables. The linear projection of Debt constitutes the index $\overline{Debt}$. Estimation also involves projecting TwoPart on the index $\overline{Debt}$.

Tables 6 and 7 feature results from estimation of the linear model. The specification in Table 7 is more general than the specification featured in Table 6 in that it unbundles a larger number of the elements from the index $\overline{Debt}$.

Results

The first seven results pertain directly to the hypotheses H1 – H5. I include nine other "empirical regularities," some of which are implications of the first five results and others of which are purely empirical observations about the data.

Result 1: Contracts featuring $(m, v) = (0, 1)$ do not appear in the contract data corresponding to marginal capacity and baseload capacity.

The results featured in Table 3 constitute affirmation of hypothesis H1 that contracts featuring $(m, v) = (0, 1)$ do not appear in the data. Table 3 features four cells corresponding to $(m, v) \in \{(0, 0), (0, 1), (1, 0), (1, 1)\}$. In Table 3 I limit analysis to the 91 contracts that correspond unambiguously to marginal capacity (Gas) or to baseload capacity (Nuclear and Coal). None of the 91 feature risk-sharing $(m = 0)$ and vertical restraints $(v = 1)$.

In Table 4 I expand analysis to all 101 contracts. Two of the contracts correspond to $(m, v) = (0, 1)$, 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: The results of the estimation are consistent with hypothesis H2 that $b_{Tv} > -b_{Tm} > 0$ and, other things equal, $T(1,1) > T(0, 0) > T(1, 0)$.

Estimation in Table 6 yields $b_{Tv} = 2.3105$ and $b_{Tm} = \text{-}1.1617$. The estimates of both coefficients are statistically significant at the 1% level. (Estimates of all of the coefficients are consistent with the cross-equation restriction $b_{Tv} b_{vm} b_{mT} = b_{Tm} b_{mv} b_{vT}$.) These coefficient estimates imply $T(1,1) - T(0, 0) = b_{Tv} + b_{Tm} = 1.1488 > 0$, which is statistically distinguishable from zero at the 1% level. The estimates also imply $T(0, 0) - T(1, 0) = -b_{Tm} = 1.1617 > 0$, which is significant at the 1% level. The results in Table 7 are consistent, with the difference $T(1,1) - T(0, 0) = b_{Tv} + b_{Tm} = 0.8657 > 0$ statistically significant at the 10% level.

One might note that the results also imply $T(0,1) > T(1,1)$ whereas the prediction that proceeds from the formal model is that $T(1,1) > T(0,1)$. Indeed, another prediction that proceeds from the formal model is that one should not observe contacts of the form $(m, v) = (0,1)$, anyway. We do observe two such contracts, although both contracts pertain to wind-driven generation. Wind-driven generation constitutes something of a hybrid in that it does not fit into the baseload-marginal dichotomy and also has depended on subsidies to remain economically viable. I include Wind in the duration equation and find that contracts featuring wind-driven generation tend to feature shorter terms. (The result in Table 6 is consistent at the 10% level.) The result is consistent with prediction that contracts featuring $m = 0$ tend to feature shorter terms.

Result 3: Contract duration and vertical restraints are complements.

The result that $T(1,1) > T(0,0) > T(1,0)$ is consistent with vertical restraints lining up with longer term contracts. Also, the estimation reported in Table 6 yields $b_{Tv} = 2.3105$ and $b_{vT} = 0.1759$, both significant at the 1% level. Table 7 features consistent results.

Result 4: The appeal to debt financing is decreasing in monitoring costs.

The results suggest that Debt is not decreasing in Gas but is decreasing in GasMW – that is, parties are less likely to secure debt financing for larger, gas-fired generation projects. The coefficient on Gas is positive but not statistically distinguishable from zero whereas the coefficient on GasMW is significant at the 10% and 5% levels in the two specifications. Insofar as larger, gas-fired projects lend themselves to higher monitoring costs, then the conclusion is that, other things equal, it is harder to line up debt financing in the face of higher monitoring costs increase.

Meanwhile, Debt is decreasing in PopsPerMW. The coefficient on PopsPerMW in both specifications is negative and significant at the 5% and 1% levels. Insofar as PopsPerMW constitutes a proxy for monitoring costs, then the results suggest that the greater monitoring costs that attend marginal generation complicate the appeal to debt financing.

Result 5: The results do not support the prediction that that the appeal to two-part compensation is increasing in the index $\overline{Debt}$. Both estimates of the coefficient b_{md} are positive, but neither is significant.

Empirical Regularities

Empirical Regularity 1: Relieving generators of risk and vertical restraints are complements.

In both specifications of the linear model, the estimates of b_{mv} and b_{vm} are both positive and statistically significant at the 1% level. (In Table 6, $b_{mv} = 1.3632$ and $b_{vm} = 0.4879$.) That is, the prospect of including a vertical restraint is increasing in *m* and *m* is increasing in *v*. The results in Tables 6 and 7 are consistent with the hypothesis that $b_{mv} > 0$ and $b_{vm} > 0$, which, in turn, is consistent with the hypothesis that $\frac{\partial^2 Ep}{\partial v \partial m} > 0$. That is, relieving generators of risk and vertical restraints complement each other.

Empirical Regularity 2: Imposing risk on generators effectively constitutes a substitute for shorter terms, or, the same thing, relieving generators of risk and longer terms are substitutes.

In both specifications of the linear model, the estimates of b_{Tm} and b_{mT} are both negative and statistically significant. (In Table 6, $b_{Tm} = -1.1617$ and $b_{mT} = -0.2771$.) That is, contract duration is decreasing in *m*, and *m* is decreasing in contract duration. The results in Tables 6 and 7 are statistically consistent with the hypotheses that $b_{Tm} < 0$ and $b_{mT} < 0$, which, in turn, are consistent with the hypothesis that $\frac{\partial^2 Ep}{\partial T \partial m} < 0$. That is, risk-sharing and shorter terms are effectively substitutes.

Empirical Regularity 3: On average, even when "other things" are not equal, $T(1,1) > T(0,0) > T(1,0)$ although the last inequality is not statistically significant.

In Figure 1 I feature the empirical distribution of the contract duration pertaining to contracts of types $(m,v) \in \{(0,0),(1,0),(1,1)\}$. The distribution of $T(1,1)$ first-order stochastically dominates the distribution of $T(0,0)$ which, in turn, second-order stochastically dominates the distribution of $T(1,0)$. The average of $T(1,1)$ is 18.05 years with a (bootstrapped) 95% confidence interval ranging from 15.55 years to 20.49 years. The average of $T(0,0)$ is 10.29 years with a 95% confidence interval ranging from 7.86 years to 12.86 years. These two confidence intervals do not overlap. Meanwhile, the average of $T(1,0)$ is 9.02 years with a 95% confidence interval ranging from 7.03 years to 11.23 years. The confidence intervals of the estimated means of $T(0,0)$ and $T(1,0)$ include both estimated means, indicating that it is not possible to statistically distinguish one mean from the other with great confidence.

Empirical Regularity 4: Larger capacity projects induce greater demands for debt financing.

This result is intuitively appealing. I perform what amounts to a "kitchen sink" regression of Debt against 17 regressors, including a constant. The coefficient estimate on MW in both specifications is positive and significant at the 1% level.

Empirical Regularity 5: Other things equal, contract duration is decreasing in monitoring costs.

The results in Table 6 and 7 indicate that contract duration is decreasing in PopsPerMW. Both coefficient estimates are significant at the 1% level. This is consistent with the results of the formal model which suggests that, in the absence of two-part compensation, contract duration is decreasing in monitoring costs.

Empirical Regularity 6: Other things equal, contract duration is increasing in the life of generating assets.

In both specifications, contract duration is increasing in New. The results reported in both Tables 6 and 7 are significant at the 1% and 5% levels, respectively.

Empirical Regularity 7: Contracts featuring wind-driven generation are more likely to feature vertical restraints and less likely to feature two-part compensation.

This was already obvious from the results featured in Table 2, but they also bear out in the regression results featured in Tables 6 and 7. The results are consistent with wind-driven generation being less amenable to two-part compensation and to the fact that wind-driven generation has tended to rely on subsidies.

Empirical Regularity 8: There is some suggestion that contracts featuring risk-sharing or vertical restraints are less likely to show up in publicly available filings at the Federal Energy Regulatory Commission.

The results pertaining to the variable FERC suggest that the FERC is less likely to publicly post contracts that feature vertical restraints or risk-sharing. (The results in Table 7 are significant at the 10% level.) The suggestion is that the FERC is exerting a systematic bias on the posting of contracts and that, in turn, restricting analysis to publicly posted contracts might miss much of the action.

Empirical Regularity 9: The policy experiment indicates that were the antitrust authorities to bar contracting parties from imposing vertical restraints, that parties would adapt by appealing to shorter term contracts – and, indeed, they might even exit – and they might also impose risk-sharing on the generator.

The other results abundantly demonstrate that, whether or not other things are equal, that $T(1,1) > T(0,0) > T(1,0)$. Thus, if other things are equal and parties had determined that $(m, v) = (1,1)$ was optimal, then forcing them to set $v = 0$ necessarily entails reverting to an inferior contract that features a shorter duration and might also entail greater monitoring costs that would attend the imposition of risk on the generator.

4. 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. Some recent theoretical and empirical research (e.g., Bajari and Tadelis [2001] and Saussier [2000]) is consistent with the idea that it might be efficient for parties to forgo programming adaptations for all foreseeable shifts of the contract curve that might obtain. It becomes natural to ask, then, whether one should bother entertain the prospect that some shifts of the contract curve are not amenable to programming. The results presented here suggest that appealing to the prospect that some shifts are unprogrammable makes it possible to characterize tradeoffs parties perceive between longer-term and shorter-term contracts. As the irrelevance result of Fudenberg, Holmstrom, and Milgrom (1990) suggests, if all adaptations are programmable, then it is not obvious why contract duration should matter. The results presented here suggest that if one admits the prospect of unprogrammable adaptations, then tradeoffs between longer-term and shorter-term contracts manifest themselves.

The research presented here goes farther and draws financial structure (debt or equity), risk-bearing and vertical restraints into the mix. The research demonstrates in a specific environment how parties use two instruments, financial structure and the distribution of risk, to organize project financing and use to other instruments, contract duration and vertical restraints, to respond to both programmable and unprogrammable shifts of the contract curve. I demonstrate both as a matter of theory and empirical investigation patterns of complementarity and substitution between contract duration, vertical restraints, and risk-sharing. Moreover, one can achieve the results without having to appeal to risk-aversion. I go on to demonstrate a policy-relevant conclusion: antitrust authorities might view vertical restraints in long-term contracts with suspicion. The research suggests that vertical restraints can be efficiency-enhancing. The antitrust authorities should worry about situations in which a single marketer maintains vertical restraints such as veto provisions in contracts it has with *more than one competing* generator. Other than that, barring parties from using vertical restraints induces them to revert to inefficient contracts and frustrates their effort to invest in production capacity.

Figure 1

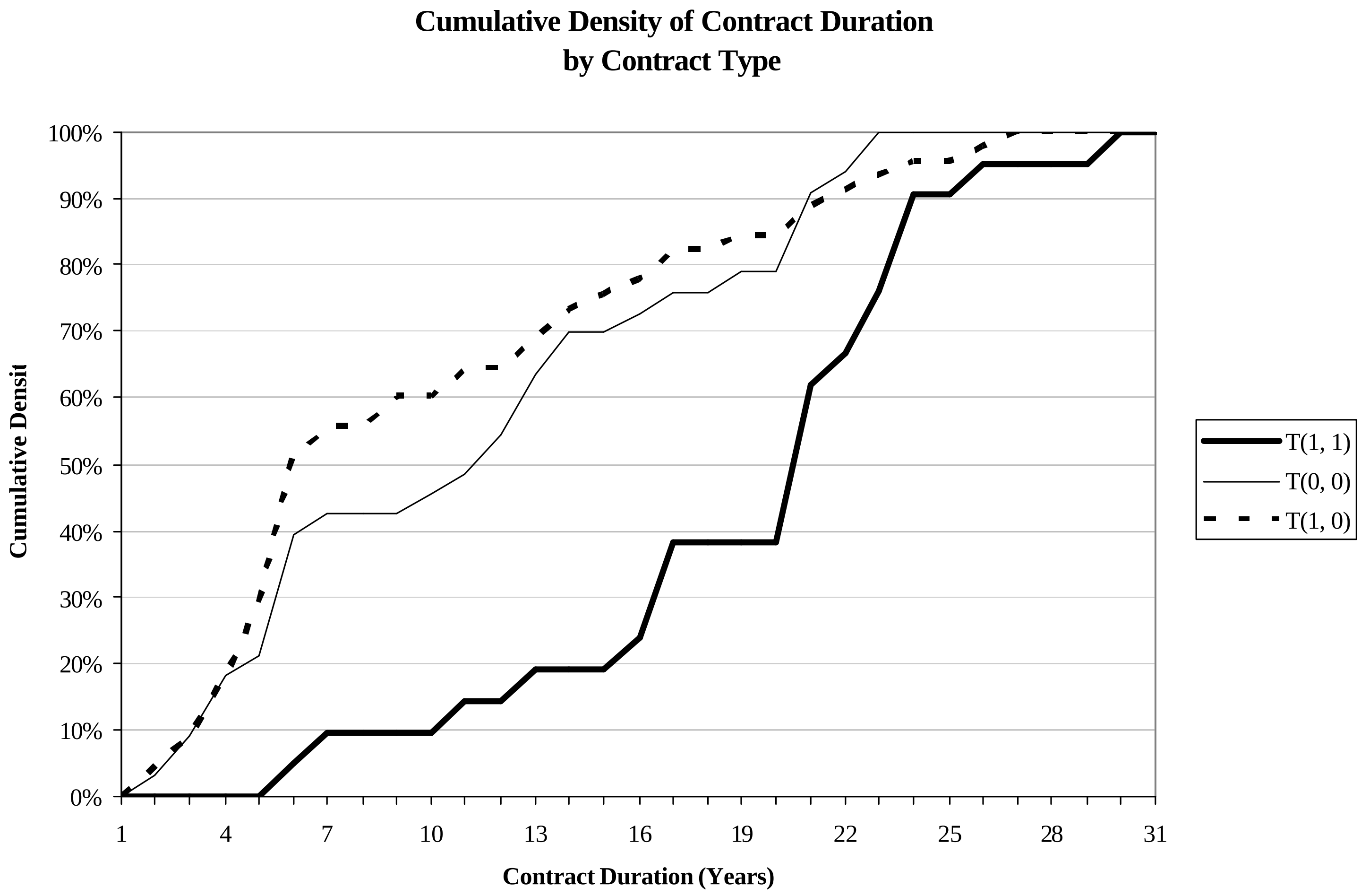
Cumulative Density of Contract Duration
by Contract Type
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative Densit
1
4
7
10
13
16
19
22
25
28
31
Contract Duration (Years)
T(1, 1)
T(0, 0)
T(1, 0)

Table 1

	Marginal Capacity	*Baseload Capacity*		*Other Capacity*		*All Capacity*
	Gas	**Nuclear**	**Coal***	**Other***	**Wind**	
Observations	80	4	7	6	6	101
Contract Duration (Years)						
Mean	12.22	9.18	6.69	5.06	14.87	11.59
Std. Deviation	8.06	4.49	2.92	2.70	8.19	1.79
Minimum	0.22	3.04	4.84	2.18	2.45	0.22
Maximum	28.19	13.00	11.81	10.00	26.08	28.19
Capacity (MW)						
Mean	551.64	909.30	1,745.29	71.58	81.75	599.61
Std. Deviation	636.48	559.55	2,484.13	109.04	109.89	909.57
Minimum	27.00	500.00	20.00	6.50	5.00	5.00
Maximum	3,956.00	1,730.00	5,645.00	292.00	300.00	5,645.00

* Two contracts feature both coal-fired generation and "other" generation.
Both contracts are counted in the columns labeled "Coal" and "Other"

Table 2

		Marginal Capacity	*Baseload Capacity*		*Other Capacity*		*All Capacity*
		Gas	**Nuclear**	**Coal***	**Other***	**Wind**	
Marketer bears risk	$(m = 1)$	**62**	**1**	**2**	**1**	**-**	**66**
Vertical Restraint	$(v = 1)$	21	-	-	-	-	21
Parties share risk	$(m = 0)$	**18**	**3**	**5**	**5**	**6**	**35**
Vertical Restraint	$(v = 1)$	-	-	-	-	2	2
Total Contracts		**80**	**4**	**7**	**6**	**6**	**101**

* Two contracts feature both coal-fired generation and "other" generation.
Both contracts are counted in the columns labeled "Coal" and "Other"

Table 3

Distribution of Vertical Restraints and Two-part Risk-sharing
over Marginal Capacity (gas-fired) and Baseload Capacity (coal-fired and nuclear)

		Vertical Restraint ($v = 1$)	**No Restraint** ($v = 0$)	
No Risk-sharing	($m = 1$)	21	44	**65**
Parties share risk	($m = 0$)	-	26	**26**
		21	**70**	**91**

Table 4

Distribution of Vertical Restraints and Two-part Risk-sharing
over All Contracts

		Vertical Restraint ($v = 1$)	**No Restraint** ($v = 0$)	
No Risk-sharing	($m = 1$)	21	45	**66**
Parties share risk	($m = 0$)	2	33	**35**
		23	**78**	**101**

Table 5

Correlation Coefficients

	LogTerm	TwoPart	Restraint	Debt	New	Gas	MW	GasMW	PopsPerMW
LogTerm	1								
TwoPart	0.0299	1							
Restraint	0.4037	0.2962	1						
Debt	0.5134	0.2721	0.3145	1					
New	0.4586	0.3462	0.2949	0.3026	1				
Gas	0.0519	0.4985	0.1619	0.3597	0.3334	1			
MW	0.0339	0.1911	0.0317	0.2040	-0.2671	-0.1035	1		
GasMW	0.1433	0.2288	0.1796	0.2566	-0.0834	0.3695	0.5397	1	
PopsPerMW	-0.5143	-0.0306	-0.1368	-0.2576	-0.2724	0.0403	-0.1582	-0.1648	1

Table 6

	Dependent Variables			
Explanatory Variables	**LogTerm**	**TwoPart**	**Restraint**	**Debt**
LogTerm		**-0.2771****	**0.1759*****	
		0.1158	0.0508	
TwoPart	**-1.1617*****		**0.4879*****	
	0.3489		0.1066	
Restraint	**2.3105*****	**1.3632*****		
	0.4336	0.3704		
Debt		**0.3082**		
		0.1972		
New	**0.4888*****			**0.2621**
	0.1798			0.3833
MW				**2.10E-04*****
				7.37E-05
Gas				**0.3742**
				0.3574
Nuclear				**-0.3614**
				0.3493
Coal				**-0.3375**
				0.2572
Other Fuel				**0.1397**
				0.3040
Wind	**-0.7579***	**-0.7049*****	**0.4023****	**0.1054**
	0.4358	0.2449	0.1697	0.4847
NewMW				**1.78E-04**
				1.66E-04
NewGas				**-0.0819**
				0.3993
GasMW				**-1.76E-04***
				9.51E-05
NewWind				**-0.0912**
				0.5193
Pops				**1.63E-08**
				1.94E-08
PopsPerMW	**-6.67E-06*****			**-2.86E-06****
	1.68E-06			1.19E-06
Sites				**-0.0194**
				0.0623
Retail		**0.1021**		**-0.1133**
		0.1344		0.1096
FERC			**-0.0712**	**0.0484**
			0.0585	0.0954
Constant	**2.1628*****	**0.7687*****	**-0.4353*****	**0.1314**
	0.2016	0.1785	0.1273	0.3618

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

Table 7

	Dependent Variables			
Explanatory Variables	**LogTerm**	**TwoPart**	**Restraint**	**Debt**
LogTerm		**-0.5580****	**0.2430*****	
		0.2369	0.0803	
TwoPart	**-0.8860****		**0.3694*****	
	0.3531		0.0838	
Restraint	**1.7517*****	**2.4926*****		
	0.4795	0.5618		
Debt		**0.1241**		
		0.2053		
New	**0.4953****			**0.1643**
	0.2035			0.3664
MW				**2.07E-04*****
				7.58E-05
Gas		**-0.0090**		**0.3601**
		0.1204		0.3461
Nuclear				**-0.3975**
				0.3302
Coal				**-0.3328**
				0.2448
Other Fuel				**0.0995**
				0.2893
Wind	**-0.5017**	**-1.0142****	**0.3724****	**0.0148**
	0.4426	0.3875	0.1724	0.4845
NewMW				**2.49E-04**
				1.63E-04
NewGas				**-0.0678**
				0.3834
GasMW			**8.09E-06**	**-2.19E-04****
			2.27E-05	9.99E-05
NewWind				**0.0468**
				0.5138
Pops				**2.90E-08**
				2.01E-08
PopsPerMW	**-8.43E-06*****	**-2.25E-06**	**1.34E-06**	**-3.64E-06*****
	1.96E-06	3.06E-06	1.31E-06	1.23E-06
Sites				**-0.0562**
				0.0655
Retail		**0.3313**	**-0.1083**	**-0.1136**
		0.2275	0.0777	0.1144
FERC		**0.3721***	**-0.1357***	**-0.0074**
		0.2078	0.0743	0.1019
Constant	**2.1125*****	**0.9689***	**-0.4546****	**0.2719**
	0.1927	0.4887	0.2046	0.3480

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

Appendix 1

The system is *not* amenable to Monotone Comparative Statics.

To see this, let

$$\begin{aligned}
&\Gamma = \left(Z,\, M,\, K,\, C,\, R,\, D,\, S,\, r,\, a,\, l\right)\\
&(m,\, v;\, \Gamma) = \underset{(\hat{m},\,\hat{v})}{\arg\max}\, Ep\left(\hat{m},\, \hat{v},\, T(\hat{m},\, \hat{v});\, \Gamma\right)\\
&\Gamma_0 = \left(Z_0,\, M,\, K,\, C,\, R_0,\, D_0,\, S,\, r,\, a,\, l\right)\\
&\Gamma_1 = \left(Z_1,\, M,\, K,\, C,\, R_0,\, D_1,\, S,\, r,\, a,\, l\right)\\
&\Gamma_2 = \left(Z_1,\, M,\, K,\, C,\, R_1,\, D_1,\, S,\, r,\, a,\, l\right)\\
&\text{with } Z_1 \geq Z_0,\ R_1 > R_0 = e > 0, \text{ and } D_1 > D_0 = 0
\end{aligned}$$

So $\Gamma_2 > \Gamma_1 > \Gamma_0$.

Suppose $(m, v) = (1, 0)$ is optimal for Γ_0 and Γ_2 – that is, $(m, v; \Gamma_0) = (m, v; \Gamma_2) = (1, 0)$ – and suppose $(m, v; \Gamma_1) = (1, 1)$. By inspection one can see that we can achieve this by (1) imposing high M or K to rule out $(m, v; \Gamma_i) = (0, 0)$; (2) imposing R_1 large enough; (3) imposing Z_1 and D_1 high enough.

Increasing differences requires

$$Ep(1,1;\Gamma_2) - Ep(1,0;\Gamma_2) \quad \geq \quad Ep(1,1;\Gamma_1) - Ep(1,0;\Gamma_1) \quad \geq \quad Ep(1,1;\Gamma_0) - Ep(1,0;\Gamma_0)$$

But the first difference is negative, the next difference is positive, and the last difference is negative. Thus, we have a non-monotonic pattern of hopping from one type of contract to another and back – a pattern that does not correspond to increasing differences. (See Amir 2005, pg. 654.)

Appendix 2

First-order conditions:

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

$$= \int_0^T V_2(t^*;T)\,f(t^*;\cdot)\,dt^* - \left(1 - F(T;\cdot)\right)\left(V_1(T;T) + V_2(T;T)\right)$$

$$\frac{\partial Ep}{\partial T} = \left[Z - (1-m)M\right]e^{-(r+l)T} - r\left[S - vR\right]e^{-(r+l)T} - Ce^{(a-r-l)T}$$

$$- (1-v)mDZ\left(\frac{l}{r+l}\right)\left(re^{rT} + l\,e^{-lT}\right)$$

$$\frac{\partial Ep(0,0,T)}{\partial T} = \left[Z - M\right]e^{-(r+l)T} - rSe^{-(r+l)T} - Ce^{(a-r-l)T} = 0 \text{ yields}$$

$$T(0,0) = \frac{1}{a}\ln\left[\frac{(Z-M) - rS}{C}\right]$$

$$\frac{\partial Ep(0,1)}{\partial T} = \left[Z - M\right]e^{-(r+l)T} - r\left[S - R\right]e^{-(r+l)T} - Ce^{(a-r-l)T} = 0 \text{ yields}$$

$$T(0,1) = \frac{1}{a}\ln\left[\frac{(Z-M) - r(S-R)}{C}\right]$$

$$\frac{\partial Ep(1,0)}{\partial T} = Ze^{-(r+l)T} - rSe^{-(r+l)T} - Ce^{(a-r-l)T} - DZ\left(\frac{l}{r+l}\right)\left(re^{rT} + l\,e^{-lT}\right) = 0 \text{ yields}$$

$$T(1,0) = \frac{1}{a}\ln\left[\frac{Z - rS}{C} - \left(\frac{DZe^{rT}}{C}\right)\left(\frac{l}{r+l}\right)\left(re^{(r+l)T} + l\right)\right]$$

Note: $T(1,0) < \frac{1}{a}\ln\left[\frac{Z - rS}{C}\right]$

$$\frac{\partial Ep(1,1)}{\partial T} = Ze^{-(r+l)T} - r\left[S - R\right]e^{-(r+l)T} - Ce^{(a-r-l)T} \text{ yields}$$

$$T(1,1) = \frac{1}{a}\ln\left[\frac{Z - r(S-R)}{C}\right]$$

Appendix 3

Second-order conditions:

$$\begin{aligned}\frac{\partial^2 Ep}{\partial T^2} &= V_2(T;T)\,f(T;\cdot) - f(T;\cdot)\left[V_1(T;T) + V_2(T;T)\right] \\ &\quad + \left(1 - F(T;\cdot)\right)\left[V_{11}(T;T) + V_{12}(T;T) + V_{21}(T;T) + V_{22}(T;T)\right] \\ &= \left(1 - F(T;\cdot)\right)\left[V_{11}(T;T) + V_{12}(T;T) + V_{21}(T;T) + V_{22}(T;T)\right] \quad - \quad f(T;\cdot)V_1(T;T)\end{aligned}$$

$$\begin{aligned}\frac{\partial^2 Ep}{\partial T^2} &= -(r + l)\left[Z - (1-m)M - rS + vrR)\right]e^{-(r+l)T} - (a - r - l)Ce^{(a-r-l)T} \\ &\quad + (1-v)mDZ\left(\frac{l}{r+l}\right)\left(l^2 e^{-lT} - r^2 e^{rT}\right)\end{aligned}$$

$$\begin{aligned}\frac{\partial^2 Ep\,(0,0)}{\partial T^2} \quad &= \quad -(r + l)\left[Z - M - rS\right]e^{-(r+l)T} - (a - r - l)Ce^{(a-r-l)T} \\ &= \quad -a \quad < \quad 0\end{aligned}$$

$$\begin{aligned}\frac{\partial^2 Ep\,(0,1)}{\partial T^2} \quad &= \quad -(r + l)\left[Z - M - rS + rR\right]e^{-(r+l)T} - (a - r - l)Ce^{(a-r-l)T} \\ &= \quad -a \quad < \quad 0\end{aligned}$$

$$\begin{aligned}\frac{\partial^2 Ep\,(1,0)}{\partial T^2} \quad &= \quad -(r + l)\left[Z - rS\right]e^{-(r+l)T} - (a - r - l)Ce^{(a-r-l)T} + DZ\left(\frac{l}{r+l}\right)\left(l^2 e^{-lT} - r^2 e^{rT}\right) \\ &= \quad -(r + l)\left[Z - rS - Ce^{aT}\right]e^{-(r+l)T} - aCe^{(a-r-l)T} + DZ\left(\frac{l}{r+l}\right)\left(l^2 e^{-lT} - r^2 e^{rT}\right)\end{aligned}$$

The FOC implies $\left[Z - rS - Ce^{aT}\right] > 0$

Thus $r > l$ implies $\dfrac{\partial^2 Ep\,(1,0)}{\partial T^2} \quad < \quad 0$

$$\begin{aligned}\frac{\partial^2 Ep\,(1,1)}{\partial T^2} \quad &= \quad -(r + l)\left[Z - rS + rR)\right]e^{-(r+l)T} - (a - r - l)Ce^{(a-r-l)T} \\ &= \quad -a \quad < \quad 0\end{aligned}$$

Appendix 4

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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