Title

Investment under Regulatory Uncertainty: U.S. Electricity Generation Investment Since 1996

Authors

Ishii, Jun
Yan, Jingming

Publication Date

2004-03-01

CSEM WP 127

Investment under Regulatory Uncertainty: U.S. Electricity Generation Investment Since 1996

Jun Ishii and Jingming Yan

March 2004

2547 Channing Way
Berkeley, California 94720-5180
www.ucei.org

Investment under Regulatory Uncertainty:
U.S. Electricity Generation Investment Since 1996

Jun Ishii
University of California, Irvine

Jingming Yan*
Cornerstone Research

March 2004

Abstract

We investigate how uncertainty surrounding possible comprehensive regulatory restructuring affect the investment behavior of firms operating in the industry. We argue that such regulatory uncertainty can create a substantial option value that leads to firms delaying their investment decision in order to gather more information and assurances regarding future regulatory changes. We empirically examine this claim using data on U.S. electricity generation investment from 1996 to 2000. Using state-level, aggregate investment data, we find evidence that is consistent with the presence of substantial option value: a strong link between lesser aggregate generation investment and greater restructuring enactment uncertainty. Using data on firm-level generation investment decisions for a sample of major U.S. independent power producers (IPPs) from 1996 to 2000, we estimate a more structural model of generation investment that incorporates the option value effect. Comparing estimates from this "real options" based model with the corresponding estimates from two alternative models, expected Net Present Value (NPV) and Forward-Looking (FWL), we show that accounting for the option value can lead to different inferences regarding the impact of regulatory restructuring on IPP generation investment.

---

*3151 Social Science Plaza, Irvine, CA 92697-5100, E-mail: jishii@uci.edu; 1000 El Camino Real, Menlo Park, CA 94025, E-mail: myan@cornerstone.com. We are grateful for comments (on this and earlier drafts) from seminar participants at Berkeley, Davis, and the IDEI/CEPR Conference on "Competition and Coordination in the Electricity Industry," especially Farid Gasmi. Part of this draft was written while Jun Ishii was a visiting researcher at the U.C. Energy Institute (UCEI) Center for the Study of Energy Markets (CSEM). The paper borrows from two earlier drafts by the authors, Ishii (2001) and Yan (2001).

Introduction

In the United States and abroad, many state and national governments have implemented regulatory restructuring (and in some case broad liberalization) of their respective electricity industries. A key policy motivation underlying these efforts has been the desire to attract nonutility investments in new generation capacity. Perhaps ironically, however, many industry observers and experts have attributed this very movement toward greater regulatory restructuring as a main factor explaining the dramatic slowdown in new generation investments by U.S. electric utilities over the past two decades and by nonutility independent power producers in recent years, despite significant growth in electricity demand.

The returns that a firm expects to earn from its investment in a regulated industry can differ substantially depending on the implemented regulatory policies. In the case of comprehensive, market-based regulatory restructuring, electric generators assumes a larger share of the risk associated with an unanticipated market downturn: electricity consumers no longer necessarily bear the entire financial loss associated with a power plant that has, *ex post*, become less economically useful. Consequently, one might expect electric utilities, under the "threat" of electricity restructuring, to decrease their generation investment. This argument is complementary to the "overcapitalization" argument central to the literature on the Averch-Johnson (AJ) effect.[1] However, an investment slowdown motivated by such concerns may be socially desirable and is, in fact, one of the main hopes of electricity restructuring — an electricity supply that more closely follows electricity demand.

Furthermore, while a regulated electric utility may wish to reduce its investment, electricity restructuring creates new opportunities for nonutility independent power producers (IPPs) to challenge incumbent electric utilities. Depending on market conditions, aggregate investment levels need not decline with electricity restructuring; merchant power plant investments may make up (and possibly exceed) the reduction in utility power plant investments. But an examination of nonutility investments reveal that IPPs have not taken up the apparent slack in generation investment during the early stage of electricity restructuring. Until the arrival of sky-rocketing wholesale electricity prices,[2] only a small number of merchant power plants were being developed. Moreover, some researchers blame the lack of generation investment in recent years, by utilities and nonutilities alike, as a major impetus of such price spikes in restructured wholesale electricity markets. A major culprit attributed to this lack of nonutility generation investment is regulatory uncertainty.

---

[1] Averch & Johnson (1962)

[2] At times orders of magnitude larger than recent norms.

Although (prior to the California Energy Crisis) many industry participants believed that electricity restructuring was inevitable, there was a large amount of uncertainty surrounding when and how states would implement their electricity industry restructuring. It is argued that this "regulatory uncertainty" concerning electricity restructuring led many IPPs to delay their investment decisions. In the language of the "real options" literature on investment, IPPs, due to the substantial sunk costs associated with power plant projects, faced an "option value" that could be earned by delaying their investment decision and acquiring valuable information/assurances next period. More concretely, IPPs may delay their investment in order to minimize their risk of investing in an uneconomical power plant due to unanticipated regulatory developments (or, rather, development failures). A prominent realization of this regulatory concern is the New Smyrna Beach project in unrestructured Florida, initiated by the IPP subsidiary of Duke Energy with the blessing of local regulatory authorities.[3]

This paper seeks to explore empirically this issue of regulatory uncertainty and firm investment behavior. Specifically, we examine how uncertainty surrounding the timing and nature of state-level electricity industry restructuring seems to have influenced observed nonutility generation investment decisions since 1996. We take several approaches in investigating the presence and magnitude of this option value from regulatory uncertainty. First, we take a "reduced form" approach where we examine across-state and across-year variation in aggregate investment on new generation capacity. We find suggestive evidence that is consistent with electricity generators' delaying their investment activity in anticipation of future regulatory information and assurances. Second, we make explicit our idea of option value from regulatory uncertainty, following the theoretical lead of Cukierman (1980) and Bernanke (1983), and take a more "structural" approach. In this second approach, we consider three investment decision rules, the difference across which highlight the different inter-temporal aspects of generation investment. Estimates from the corresponding structural models show that, depending on which decision rule is adopted, different policy implications can be drawn, especially with respect to the impact of state restructuring legislation on nonutility investment costs.

While our analysis is applied to the specific case of recent state-level electricity restructuring, we believe that the empirical approach can be applied to the study of investment behavior in other industries under the shadow of "imminent" drastic regulatory changes. Moreover, we believe

---

[3] The project was begun in 1998 in response to favorable market conditions and the belief that Florida would welcome much needed new generation capacity from a "low cost" merchant power plant. However, the necessary "determination of need" certificate was revoked by the Florida Supreme Court in 2000 after the project was challenged by three major Florida electric utilities, resulting in a sizable financial setback for Duke Energy.

the results in this paper provide a *caveat* to empirical studies of the impact of regulatory change on firm investment behavior using data taken from a transition period: failure to account for the option value stemming from regulatory uncertainty can introduce significant biases. The rest of the paper is organized as follows. In section 1, we examine the observed generation investment slowdown prior to and during the early stage of electricity restructuring. We then discuss in section 2 the idea of an option value earned by delaying investment when there is regulatory uncertainty. Section 3 describes our "reduced form" investigation of possible investment delays due to regulatory uncertainty since 1996. In section 4, we propose and estimate a more structural, "real options" based empirical model of IPP investment. In the section, we also compare the estimates with those of two other models: the standard net present value (NPV) model and a "forward-looking" (FWL) model. Finally, section 5 summarizes our results and offers some concluding remarks.

1 Investment Slowdown

Although risk is a consideration in investment decisions made by all private firms, investments made by regulated firms, especially in the electricity industry, have traditionally been insulated from the full financial consequences of a market downturn. A prominent explicit example of regulator-provided "insurance" for electric utilities is the fuel adjustment mechanism (FAM) adopted during the 1970s: FAMs allowed utilities to pass through increased fuel costs to retail consumers, automatically.[4] But more importantly, electric utilities under the familiar price-regulated regime usually only had to defend their projects on an *ex ante* basis. As Paul Joskow writes:

> "Once regulators approve the construction costs of a generating plant or terms of an energy supply contract, these costs (amortized in the case of capital investments) continue to be included in regulated prices over the life of the investment or contract, independent of whether the market values of these commitments rise or fall over time as energy prices, technology, and supply and demand conditions change." Joskow (1997) p.125

Consequently, retail consumers (and not electric utilities) ultimately borned the financial consequences of an unexpected market downturn on power plant investments.

Recent regulatory changes, beginning with the greater use of *ex post* prudence reviews during the 1980s and continuing to the current state-level "experiments" with comprehensive electricity

---

[4] See Gollop & Karlson (1978), Clarke (1980), Isaac (1982) for more details on FAMs

restructuring, have been motivated in large part by a desire to shift much of this *ex post* responsibility for a power plant investment back to the investing electricity firm. These changes have presumably increased the risk faced by electricity firms. Earlier studies of U.S. electric utilities have found significant effects of regulatory policies on the cost of debt.[5] More recently, empirical studies of the electricity restructuring experience in the United Kingdom, which predates that of the United States, find some evidence that recent regulatory shifts in the U.K. has increased the systematic risk faced by electricity firms, as perceived by investors.[6] Theoretically, Brennan & Schwartz (1982) provides a formalization of the role regulatory risk can play in firm investment behavior in a price-regulated industry. More specific to the electricity industry, Teisberg (1993, 1994) extends Brennan & Schwartz to an option pricing model of electric utility investment that considers the regulatory uncertainty introduced by *ex post* prudence reviews during the 1980s.

An examination of utility investment behavior during this greater prudence review period demonstrates a significant generation investment slowdown. **Figure 1** shows the U.S. reserve margin falling from 1.4 to 1.2 from 1989 to 2000.[7] Other analyses comparing generation investment and demand (or expected demand) during the post 1980 period yield similar results. Of course, these stylized facts, in of themselves, do not necessarily implicate regulatory uncertainty. A major alternative that could explain the investment slowdown is over-capacity. In fact, Lyon & Mayo (2000), one of the few empirical studies that examine the impact of regulatory disallowances on utility investment behavior, argues that over-capacity from excessive generation investment during the 1970s explains most of the utility non-nuclear investment behavior during the 1980s. However, there are reasons to believe that their result, while suggestive and likely appropriate for the example of regulatory uncertainty they study, does not necessarily indicate a limited role for electricity restructuring uncertainty in deterring IPP generation investment.

In the Lyon & Mayo model, firms strictly maximize expected net present value and do not have the option of information gathering. Thus, to the extent that information gathering is possible and valuable, as we will argue is the case for state-level electricity restructuring, the Lyon & Mayo model abstracts away from an important avenue through which regulatory uncertainty can matter. Second, and more importantly, the regulatory uncertainty stemming from possible electricity restructuring is arguably more substantial than that from prudence reviews. While prudence reviews make electric utilities partially liable for the *ex post* market valuation of a power plant investment, a delay in

---

[5] e.g. Prager (1989)

[6] See Buckland & Fraser (2001) and Robinson & Taylor (1998)

[7] The quoted reserve margin is the ratio between the non-coincidental NERC summer peak load and total NERC summer generation capability. 1989 is the earliest available year. http://www.nerc.com

state restructuring implementation or an unexpected development in the restructuring design can completely alter the value of a merchant power plant (even make worthless) to an IPP.[8] Moreover, utilities reasonably had more influence in regulatory hearings than IPPs in debates concerning electricity restructuring. Lastly, an examination of the utilization rate of power plants suggests that the generation over-capacity from the 1970s was "used up" by the restructuring transition period studied in this draft: **Figure 2** shows the average utilization rate of power plants in the U.S. falling during the 1970s and early 1980s but rising by 1986 and achieving pre-1970 level by 1997.[9]

An examination of power plant site filings by both electric utilities and IPPs before the California Energy Commission (CEC) also provides some suggestive evidence for the effect of regulatory uncertainty.[10] **Figure 3** shows the total megawatts (MWs) of power plant cases filed before the CEC from 1980 to July 30, 2002. It is important to keep in mind that many more power plant projects are filed than eventually built.[11] In 1995 and 1996, no new cases are filed. But the number of files jump and continue to increase beginning in 1997. This coincides with the enactment of restructuring legislation (AB 1890) in California in September 1996 and the actual implementation of the legislation in 1998. Even though California had made its intent to restructure known since the release of its "Blue Book" in 1994, power plant applications do not arrive until the actual enactment of restructuring legislation. This is suggestive of IPPs delaying their investment decision until the arrival of restructuring legislation. Moreover, the continued increase in power plant investments is also consistent with IPPs taking a market "wait and see" approach - delaying their entry until they learn more about the actual performance of the restructured market.

A similar trend shows up in other states as well. **Table 1** depicts the "entry" decisions of the sampled 20 major IPPs for selected states. Here, "entry" refers to the year in which the IPP sinks the most substantial amount of its initial post-1995 generation investment in the state.[12] As elaborated later, we consider the year before commercial operation as the year in which the IPP incurs the most amount of its sunk investment cost (and hence its investment/entry year). The post-1995 criterion is added to distinguish between investments made for the restructured wholesale

---

[8] Note that even during the 1980s, full *ex post* cost disallowances of utility power plant investments were rare.

[9] The quoted utilization rate is the ratio of total NERC net electricity generation (MWh) by total possible NERC electricity generation (total summer capability (MW) × 365 days × 24 hours)

[10] In California, the CEC grants power plant site approval while the California Public Utilities Commission (CPUC) designs and implements general state regulatory policies, including restructuring.

[11] This is largely due to industry practice where firms simultaneously do initial developments on multiple sites, with the intent of building at most one of the plants. The abandoned sites are referred to as "vapor" projects.

[12] This would correspond to 1-2 years after site filing.

electricity markets and investments in PURPA Qualifying Facilities (QFs).[13] While PURPA QFs are, in some sense, merchant power plants, the participation in and the returns from such investment are mostly regulator determined and represent a very different type of investment.[14] The table shows entry clumping just prior to and year of the enactment of restructuring legislation and the presence of lagged entry after restructuring legislation is suggestive of some market "wait and see." The table also points out a complication that must be dealt in the model: the presence of utility divestiture of power plants. Some of the entry observed in the data are purchases of divested utility power plants. Our structural model accounts for this by incorporating the influence of divestiture on the investment/entry cost.[15] The table shows an entry pattern that is consistent with but not conclusive of investment deferment due to restructuring uncertainty. For a more definitive analysis, we need to clarify what we mean by an option value stemming from regulatory uncertainty.

2 Option Value from Regulatory Uncertainty

We draw a key distinction between the decision *not to invest* and the decision to *delay* investment. The decision not to invest corresponds to the case where the firm perceives the investment as having a non-positive expected net present value (NPV). On the other hand, the decision to delay investment corresponds to the case where the firm perceives the investment as having a positive expected NPV but smaller than the expected NPV associated with deferring the investment decision.[16] This emphasizes a crucial point: it is the difference in the information set faced by the firm in time $t+1$ compared to time t – rather than the underlying value of the project – that induces the firm to delay investment. To the extent that waiting leads to the resolution of some of the relevant regulatory uncertainty, the firm may face an *option value* to delaying investment stemming from regulatory uncertainty. In this manner, we follow in the spirit of "information gathering" investment models proposed by Cukierman (1980) and Bernanke (1983): we postulate that the major reason why a firm may delay investment in light of regulatory uncertainty is to gather additional regulatory information.

More specifically, we believe that a firm delays investing in order to gain further assurances about a state's commitment to regulatory restructuring (**regulatory commitment**) and, in later

---

[13] PURPA refers to the Public Utility Regulatory Policy Act of 1978.

[14] For the 20 IPPs in the sample, there were no non-QF, non-cogeneration power plant investments prior to 1996.

[15] In a separate paper, Ishii & Yan (2002), we consider the impact of divestiture on IPP new generation investments. We find that divestiture influences IPP primarily by lowering the cost of participating in the market.

[16] Note: in both cases, the firm does not make an investment during the current period.

years, observe more details about the design and performance of the implemented restructured market (**market "wait and see"**). For this paper, we focus on the former as the extent of data appropriate for studying the latter is still limited at this time.[17] In some sense, the most pressing information that an IPP seeks to learn from state regulators and policy-makers is the state's level of commitment to restructuring the industry away from explicit price regulation and toward greater market orientation:

> "Significant Uncertainties that are unclear or unmanageable leads us to make decisions not to invest in projects affected by such Uncertainties. One Uncertainty that fits this description is the risk of adverse governmental laws or actions. In general, we choose to invest in markets where the regulator has made the commitment to develop rules that are transparent, stable, and fair. The rules do not have to be exactly what we want, so long as we can operate within their framework. Consequently, we look for markets where the rules of competition are clear, encouraged and relatively stable."
> Geoffry Roberts, President & CEO, Entergy Wholesale Operations, U.S. Senate Hearing on S.764, June 19, 2001

The primary show of commitment available to state policy-makers and regulators is the enactment of a comprehensive restructuring legislation that outlines both the time-line and general process by which restructuring will be implemented. Consequently, in a state that has not enacted restructuring legislation, a firm may be able to reduce the regulatory risk it faces by delaying its investment decision and observing whether the state has enacted such a legislation. But the informational benefit from waiting comes at a cost as the firm pushes off its revenue stream further into the future. Depending on the firm's discount rate, delaying the investment can reduce the net present value of the investment, especially when the near future offers an exceptional expected revenue stream. Thus, a natural way of measuring the option value of delaying investment is the difference between the expected return from investing in the current period and that from delaying the investment decision until the next period.

Moreover, the value of waiting will depend on the firm's prior belief concerning the probability with which the state will enact such a legislation (λ_g). With $\lambda_g = 0$ or 1, the firm does not believe that waiting will provide any new information about whether the enactment is going to occur (ψ_{gt+1}):[18] the firm is certain what the state will do tomorrow with respect to restructuring

---

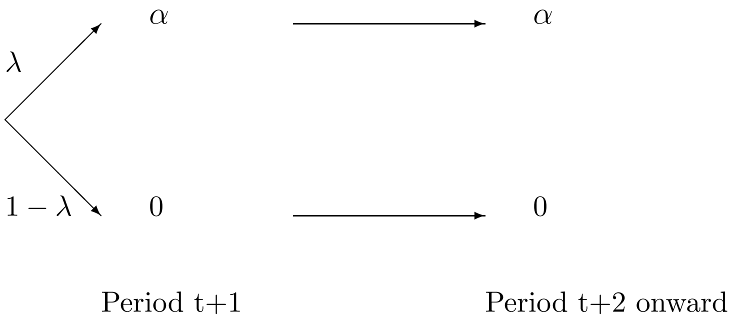
[17] The number of restructured wholesale electricity markets that have been fully implemented is few, limiting the variation that can be used to identify investment delays due to market "wait and see."

[18] $\psi_{gt+1} = 1$ if the enactment occurs next period, $= 0$ otherwise.

legislation. With values in-between, especially $\lambda_g = 0.5$, waiting has some value as the firm does not know with absolute confidence whether the state will enact restructuring.[19] However, it is essential to distinguish between the "option value" effect of restructuring (stemming from the revelation of new information) from the "real" effect that restructuring has on the expected revenues and costs facing an IPP power plant project. Although the option value effect of restructuring may be the same for $\lambda_g = 0$ and $\lambda_g = 1$ (waiting confers no new information in either case), the real effect on expected revenues and costs can differ – an IPP who find it profitable to build only if the state has enacted restructuring legislation may consider building when $\lambda_g = 1$ but not when $\lambda_g = 0$. Again, this harkens back to the distinction between delaying the investment decision and deciding not to invest.

To illustrate these points, consider the following simple algebraic example: an IPP has the opportunity to build a power plant, at cost $C > 0$, that yields a per period return of $\alpha > 0$ in a restructured market and 0 in a non-restructured market over the subsequent T periods. The plant has no other value and the cost C is otherwise irrecoverable. The state decides next period whether, once and for all, to restructure the relevant market. The IPP believes that the probability of restructuring is λ and uses a discount factor $\beta \in (0,1)$. Furthermore, assume that the project has a positive net present value if the market is restructured: $-C + \sum_{\tau=1}^{T} \beta^{\tau}\alpha > 0$

Figure 4: Restructuring Uncertainty



Under the traditional net present value (NPV) model of investment, an IPP would make the investment in period t as long as the NPV of making the investment is greater than the NPV of not making the investment:

$$-C + \lambda \sum_{\tau=1}^{T} \beta^{\tau}\alpha > 0$$

As long as $C < \frac{1-\beta^T}{1-\beta}\beta\ \lambda\ \alpha$ an IPP will make the investment. However, this is not necessarily the IPP's optimal decision rule as it does not take into consideration the fact that the IPP has additional

---

[19] Note that the variance of ψ_{gt+1} is $\lambda_g\ (1-\lambda_g)$, which is maximized at $\lambda_g = 0.5$

information at time $t+1$: the IPP knows whether the market is restructured. By waiting until $t+1$, the IPP can avoid sinking C toward a low value power plant in a non-restructured market. So the better decision is to invest today if the expected return from investing today is greater than 0 *and* the expected return (based on information today) from delaying the decision until tomorrow:

$$-C + \lambda \sum_{\tau=1}^{T} \beta^{\tau} \alpha > \max \{ \; 0 \; , \quad \underbrace{\beta \, \lambda \, (-C + \sum_{\tau=1}^{T} \beta^{\tau} \alpha)}_{\text{invest only if restructured}} \quad \}$$

Note that when λ is 0 or 1, the decision rule above that incorporates the "option value" collapses to the standard NPV decision rule. Certainty about restructuring in either direction reduces the option value of waiting to zero. If the market is not going to restructure with certainty, then the investment is a losing proposition today or tomorrow. If the market is going to restructure with certainty, then the IPP strictly prefers investing today over investing tomorrow due to discounting. However, the underlying value of the power plant differs greatly depending on whether λ is 0 or 1: an IPP would never invest if $\lambda = 0$ but would invest today if $\lambda = 1$.

With the above in mind, more insight can be drawn from **Table 1**. The table depicts Florida (FL) and Mississippi (MS) as having considerable IPP investment even though neither state has enacted restructuring legislation. This is consistent with the above option value idea as the two states are considered two of the least likely to enact restructuring legislation ($\lambda_g \approx 0$).[20] Hence, the value of waiting for regulatory commitment in those states is small. Similarly, the states in which we observe clumping of IPP investment around the enactment year are some of the states with the highest uncertainty concerning future enactment ($\lambda_g \approx 0.5$) and, thus, states with the highest value of waiting. While the results of the table are consistent with the presence of significant option value from regulatory uncertainty, they might also be explained by other, more traditional factors. In the next section, we further investigate the insights developed in this section by using a Tobit model to explore the link between observed investment decisions and the potential arrival of valuable regulatory information.

3 Reduced Form Analysis

The basic idea underlying the "information gathering" model of option value from regulatory uncertainty is that the firm can acquire valuable regulatory information by deferring its investment

---

[20] A more formal analysis of λ_g for each state is provided later.

decision. Consequently, we examine how observed generation investment decisions seem to correlate with the actual timing of the release key regulatory information. In particular, we look at the correlation between new generation investment and indicators of when a state actually enacted restructuring legislation and implemented utility divestiture programs. The intuition underlying this empirical exercise is that the actual timing of regulatory activities may serve as a proxy for the value that the firm places on the regulatory information it can acquire next period.

Utilities and independent power producers actively track and participate in the political restructuring debate. As a result, they probably have a good assessment as to whether a state will enact restructuring legislation in the immediate future. Thus, given that a state actually enacts restructuring legislation in year t, the firm in year $t-1$ was probably confident that the state would enact then. However, the firm would most likely be less confident in years $t-2$ and $t-3$. This would imply that the perceived value of waiting is smaller at time $t-1$ and greater for $t-2$ and $t-3$. Consequently, we would expect firms to have a stronger incentive to delay investment in years $t-2$ and $t-3$ than $t-1$. We look for such a relationship between observed investment and actual time until enactment by regressing for each state (s) and year (t) the observed aggregate new generation investment on market condition variables and variables indicating the actual timing of restructuring legislation. In order to help account for the observed large mass of zero investments (investments must, for the most part, be non-negative) we choose to run the regression using a Tobit setup rather than ordinary least squares (OLS).[21] We specify the underlying latent variable as below, with observed positive investment corresponding exactly to the positive value of the latent variable and observed zero investment with some non-positive value of the latent variable.[22]

$$\begin{aligned} Y^* \text{ (Latent Variable)} &= \alpha_0 + \alpha_1 \mathsf{LogLoad} + \alpha_2 \mathsf{LogRM} \\ &\quad + \alpha_3 \mathsf{LegPassFlag} + \alpha_4 \mathsf{LegPass1} + \alpha_5 \mathsf{LegPass2} + \alpha_6 \mathsf{LegPass3} \\ &\quad + \alpha_7 \mathsf{DivFlag} + \alpha_8 \mathsf{DivCurrent} + \alpha_9 \mathsf{DivFuture} + \epsilon \qquad (1) \\ \mathsf{LogNewInvestment} &= \begin{cases} Y^* & \text{if } Y^* > 0 \\ 0 & \text{if } Y^* \leq 0 \end{cases} \qquad (2) \end{aligned}$$

where, for each state s and year t

$\mathsf{LogNewInvestment}$: log(total new investment) if total new investment > 1 MW; 0 otherwise

$\mathsf{LogLoad}$: log of average load

LogRM : log of reserve margin (total capacity/peak load)

---

[21] See Maddala (1983) for more details on Tobit models

[22] A possible heuristic interpretation of the latent variable is as an index of the overall attractiveness of investment in the state in that year.

LegPassFlag : Dummy = 1 if restructuring legislation had been passed by the end of t

LegPass1 : Dummy = 1, if restructuring legislation was passed in $t + 1$, one year after t

LegPass2 : Dummy = 1, if restructuring legislation was passed in $t + 2$

LegPass3 : Dummy = 1, if restructuring legislation was passed in $t + 3$

DivFlag : Dummy = 1, if some utilities had divested by the end of t

DivCurrent : Dummy = 1 if some utility divestiture occurred in t

DivFuture : Dummy = 1 if some utility divestiture occurred in $t + 1$ through $t + 3$

We calculate the total new investment for state s in year t based on data from the Energy Information Administration (EIA).[23] Every year, the March issue of EIA's *Electric Power Monthly* reports the new electric generating units that came online during the previous year.[24] However, the publication only reports when the units came online and not when firms decided to sink a significant amount of investment cost toward the projects. For the purpose of our study, the latter is the timing of interest because investment on power plants is not instantaneous – even after a firm commits to investing, there is still a "lead time" (L) between when much of the investment cost is sunk and the completion of the project. The relevant information set is the information at the time (t) they made their decision and not the information when the plant comes online ($t+L$) since investments are, at least partially, irreversible; divestment is costly for firms that suffer a market downturn during the lead period.

If we observe the commercial start date of a new plant (t) and the plant's lead time (L), we can infer that the plant's investor made its decision to incur much of the investment cost for the plant at $t - L$. Unfortunately, we do not have comprehensive data on the lead times for the various power plant projects undertaken during our sample years. Instead, we choose to use rule of thumbs developed by examining both the lead times we do observe for a limited number of projects and more comprehensive information about California power plant projects available from the California Energy Commission (CEC).[25] The CEC California data shows that firms in recent years have, on average, been able to bring large plants (capacity > 300 MW) online within 18 months after acquiring the necessary siting permits; the corresponding time for small plants (capacity ≤ 300 MW) is 6 months. The information we do have about lead times for projects in

---

[23] *Electric Power Monthly* and Form 860B: "Annual Electric Generator Report - Nonutility."

[24] *Electric Power Monthly*, "Table 1. New Electric Generating Units by Operating Company, Plant, and State." The reports for 1996, 1997 and 1998 only include new units owned by utilities. We obtain 1996-1998 data for new units of nonutilities from EIA's Form 860B: "Annual Electric Generator Report - Nonutility."

[25] CEC website, http://www.energy.ca.gov/sitingcases/approved.html)

other states are largely consistent with California, perhaps a bit shorter. Consequently, it seems reasonable to assume that the appropriate lead time L for our analysis is about one to two years. The underlying assumption is that much of the investment cost is sunk after obtaining regulatory permission and before the actual construction of the plant.[26] We thus run our regression for three lead time scenarios: (1) $L = 1$ for all plants; (2) $L = 2$ for all plants; and (3) $L = 1$ for plants ≤ 300 MW and $L = 2$ for plants > 300 MW. Under each scenario, the decision year is assumed to be $t - L$ where t is the observed commercial start year.

In addition to the variables capturing the actual timing of the enactment of restructuring legislation, we include variables reflecting market condition and indicators of current and future divestment of utility power plants. The LogLoad and LogRM variables are meant to proxy for the market size and demand/supply condition firms face in state s in year t. We would expect new investments to be more attractive in a state and year where electricity demand (LogLoad) is larger and the reserve margin (LogRM), the ratio between peak electricity demand and existing supply, is smaller. While normally, investment would be modelled as a function of demand *growth* rather than level, we believe that both are important as new power plants can replace existing power plants, especially new power plants run by nonutility IPPs. The specification where we included both current and expected future demand values (and, hence, allowing for both a level and growth effect) yielded results that were qualitatively similar to the case where we included just the current values. Thus, we choose to focus on the results from therefore parsimonious specification. We obtain average load LogLoad from the EIA and reserve margin LogRM from the North American Electric Reliability Council (NERC)'s Electricity Supply and Demand (ES&D) Database.[27]

Indicators of current and future divestitures (DivFlag, DivCurrent, DivFuture) are also included as controls. We expect divestitures to have two types of effect on investments. First, we believe that divestiture is another method by which the state can show its commitment to restructuring: the more the supply of electricity is taken out of the hands of regulated utilities and into the hands of unregulated nonutilities, the more difficult it will be for the regulators to "undo" restructuring at a later date. Moreover, divestiture would lessen any concern entrant firms had about possible horizontal market power for the incumbent utility firms. Consequently, divestiture may encourage greater new investments. Second, divestiture offers an alternative channel by which firms can

---

[26] The industry-common practice of pursuing regulatory permits for multiple sites but only actually developing (at most) one site would suggest that much of the sunk investment cost is associated with construction.

[27] The NERC data are reported by NERC regions rather than states and some NERC regions cover multiple states. Given that the power grids for states within a NERC region are closely connected, the demand and supply in those states are closely related, with a shortage or surplus in one state affecting other states in the region. Therefore, we assume states in the same NERC region shares the same logRM.

participate in the market. Therefore, if firms anticipate that there might be some divestiture in the immediate future, they may choose to delay investment, retaining the option to divert the capital toward buying an existing plant instead. Thus, divestiture may discourage current investment. This suggests that the impact of current and anticipated future divestiture (DivCurrent, DivFuture) have an ambiguous net effect on investment. But note that we would expect *past* divestiture (DivFlag) to encourage investment as buying a divested utility plant is no longer an option. We further explore these issues in the next section and in much more details in a separate paper that explicitly models the "make or buy" investment decision, Ishii & Yan (2002). We construct the divestiture variables using information in EIA's Electric Power Monthly.[28]

The variables of main interest for us are the four dummies reflecting both the current and future status of electricity restructuring in a state (LegPassFlag, LegPass1-LegPass3). LegPassFlag reflects actual information available at time t: it indicates whether restructuring legislation has been enacted as of the end of year t. So for a state and year where LegPassFlag $= 1$, the firm faces no uncertainty regarding whether a state passes legislation and, hence, the option value stemming from such uncertainty would be zero. The other three variables represent future events that the firm might anticipate in differing degrees of confidence. LegPassX refers to whether a state will enact legislation by the end of year $t + X$. Consequently, we would expect the coefficient before LegPass2 and LegPass3 to be more negative than LegPass1 based on our earlier arguments, with firms being more uncertain and, therefore, facing a larger option value from waiting further away from the actual enactment date. Note that for a state that has not enacted as of the end of 2003, all four dummy variables would be equal to zero. So the dummy variables have an interpretation both individually and jointly. The individual dummies help capture the degree of uncertainty given that restructuring is perceived as a real possibility while, jointly, the dummies reflect whether restructuring is perceived as a real possibility at all.[29] The legislation dummies are constructed using data from EIA's "Status of State Electric Industry Restructuring Activity." [30]

We run the regression for years 1996 until 2000 for the 48 continental states. Table 2a lists the summary statistics of the variables used in those years for scenario 1 (Lead Time = 1). Table 2b

---

[28] "Electric Utility Plants That Have Been Sold and Reclassified as Nonutility Plants" in the section of "Industry Developments."

[29] One concern about using the Leg variables (and Div variables above) is that these variables may be endogenous, with current investments impacting future restructuring policy. It is unclear whether there was such an impact as available investment information was limited during the studied period; moreover, there is no clear indication in either the trade presses or government documents that actual generation investments influenced the timing of the enactment of restructuring legislation. Consequently, we choose not to address this endogeneity issue for now.

[30] http://www.eia.doe.gov/cneaf/electricy/chg_str/tab5rev.html.

shows the results of the Tobit regression for all three "lead time" scenarios.

The parameter estimates are similar across the three scenarios and are largely consistent with our *ex ante* expectations. We find that a market with larger electricity demand (LogLoad) is associated with greater propensity for new investments. Moreover, although the estimate is imprecise, the sign of the estimated coefficient for LogRM is negative, consistent with the belief that firms prefer markets where the supply of electricity is tight. The estimates for the divestiture dummies also follow our earlier developed intuition. When divestiture is a current option, DivCurrent = 1, the propensity for new investment is lower; firms that wish to participate in the market have a viable alternative to building a new plant. When divestiture has already happened, DivFlag = 1, the propensity for new investment is larger, perhaps due to the "commitment effect" of divestiture. Lastly, when there is prospect of future divestiture, DivFuture = 1, the propensity for new investment is a bit less; this suggests that firms may be holding off, anticipating the option of buying an existing plant from the local utilities.

But more importantly, the estimates for the four legislation dummies are suggestive of the presence of an option value from uncertainty surrounding whether and when a state will enact restructuring legislation. The propensity for new investment is slightly greater once legislation is enacted (LegPassFlag = 1) and the uncertainty is resolved.[31] But before legislation is actually enacted, the prospect of future enactment is associated with less propensity for new investment. Moreover, the further away the actual enactment year is, the lesser is the propensity. This matches the predictions of the option value model raised earlier. In (market, year) where one of the future LegPass dummies is equal to one, the firm places some non-trivial probability on the state enacting restructuring legislation. In the case where legislation is enacted the following year (LegPass1 = 1), the firm has strong belief that enactment is on the way ($\lambda \to 1$) and consequently does not earn much of an option value from waiting. However, in the case where legislation is three years away (LegPass3 = 1), the firm is more uncertain ($\lambda \gg 0$ but $\lambda \ll 1$) and faces a larger option value from waiting until the arrival of more information.

While, overall, the Tobit results seem largely consistent with our proposed option value from regulatory uncertainty, the analysis is complicated by the fact that the results may also be attributed to *real* effects from restructuring legislation. Consider the case where generation revenue

---

[31] Note that we are regressing aggregate investments that encompass both utility and nonutility investments. While restructuring may strongly encourage greater new investments from nonutilities, it arguably has the opposite effect for utilities. Consequently, there are no strong *a priori* predictions about the impact of restructuring on aggregate investment.

are greater under restructuring.[32] Even if a firm knows with certainty that the state will enact restructuring at some future date t, the firm may have an incentive to delay investment until a time closer to t. Although the firm faces a potential cost from delaying due to discounting, the cost is countered by the benefit of replacing some early pre-restructured revenue with later post-restructured revenue. Consequently, a firm would delay investment as long as the cost from discounting is outweighed by the benefit of replacing pre with post-restructuring revenue. Such a real effect from restructuring would manifest in the Tobit estimates much in the same way as the option value effect. Unfortunately, the Tobit analysis cannot distinguish between the real and option value effects associated with the arrival of restructuring legislation.

4 Structural Analysis

In an effort to separate the real effect of restructuring legislation from the option value effect from regulatory uncertainty, we consider a more structural empirical model of IPP investment; firm-level generation investment decisions are modelled as the outcomes of single-agent optimization problems that account for the option value from regulatory uncertainty. In addition to this "investment under regulatory uncertainty" model, we also estimate two other, complementary structural models: one based on the standard investment principle of expected net present value and another that extends the expected net present value model to allow for some intertemporal constraints. A central design of all three model, as well as the earlier Tobit analysis, is that investment is not simultaneous: firms first sink their investment cost and then subsequently earn revenue from its power plant.

4.1 Basic Set-up

Each of the three models share a basic unit of analysis: the net present value (NPV) a firm expects to earn from investing in a project today. The expected NPV of a project is disaggregated into the expected net profit stream and the investment cost that must be sunk *a priori.* For simplicity, we suppress the (firm, state) subscripts (f, g) that should accompany each time subscript (t).

$$E_t \text{ NPV} \quad = \quad -\underbrace{[\, C_t(K_t) + \eta_t \,]}_{\text{Inv Cost}} + \underbrace{\sum_{h=L}^{L+H} \beta^h (\pi_{t+h|t} + E_t \epsilon_{t+h}) \cdot K_t}_{\text{Expected Net Profit}} \tag{3}$$

---

[32] A, perhaps cynical, argument for this situation would be that the relaxation of price regulation allows for firms to exploit market power opportunities. A less cynical argument would be that restructuring creates incentives that better reward cost efficiencies.

The above formulation assumes that a firm investing in period t earns revenue from a project of size K_t for a duration of H periods, beginning with period $t + L$. Hence, the project has both a finite life (H) and a possible lag (L) before it becomes commercially operable. Moreover, the formulation assumes that the firm discounts future revenue with a constant discount rate, β. Both the investment cost and expected revenue stream are further disaggregated into an "average" $(C_t, \pi_{t+h|t})$ and "idiosyncratic" component (η_t, ϵ_{t+h}). The "average" components are estimated while the "idiosyncratic" components are modelled as unobserved random shocks (from the econometricians' perspective) from a known class of distribution. An interpretation of this set-up is that the "average" component is the industry average that can be estimated from a sample of firms and the "idiosyncratic" component is the deviation from the average for each specific firm. Alternatively, the "average" component can be thought of as reflecting common information shared by firms in the industry while the "idiosyncratic" component reflects private information.

The "average" component are functions of observed firm and market characteristics. The investment cost function, $C_t(K_t)$, is split into a fixed portion that largely captures the market-varying difficulty in getting new power plants approved and built while the capacity-varying portion reflects how certain types of firms have cost-advantages in managing larger, more complex projects: $C_t(K_t) = C_t^f + C_t^k(K_t)$. The fixed portion includes variables that indicate the attractiveness of a new power plant to a market.

$$\begin{aligned} \underbrace{C_t^f}_{\text{Fixed portion of } C_t} &= \theta_0^f + \theta_1^f \mathsf{P96} + \theta_2^f \mathsf{Age30} + \theta_3^f \mathsf{STNOX} \\ &\quad + \theta_4^f \mathsf{DivFlag} + \theta_5^f \mathsf{LegPassFlag} + \theta_6^f \mathsf{BondYield} \end{aligned} \tag{4}$$

A measure of the age of the existing generation portfolio Age30 is included with the idea that markets with older power plants would need (and hence be more amenable to) new power plants development. Similarly, a market with significant air pollution emission (NO_x) from existing plants may want to replace older generation technology with newer, cleaner technology.[33] We focus on NO_x as it is the primary pollutant associated with natural gas generation - the main technology adopted in recent power plant projects.[34] Two regulatory dummy variables are included to allow for both divestiture DivFlag and enactment of restructuring legislation LegPassFlag to have a real effect on the sunk investment cost. Much of the investment cost faced by a power producer is associated with the effort and financial costs that must be sunk in order for a power plant to be

---

[33] Alternatively, a particularly polluting market may oppose new plant construction if the new plats would only *add* to the total emission

[34] Using SO_x instead or jointly does no alter the results qualitatively, due in part to the collinearity between the two emission levels

approved. Restructuring legislation, at least nominally, reduces regulatory barriers to entry and investment by eliminating the need for non-utilities to justify to regulators the economic viability of their plants (replaced by the "market test"). We allow for divestiture of existing utility power plants to non-utility firms to have a similar effect as well. Lastly, we include the yield for Moody's corporate Baa bond index (beginning of year) to help account for changes in the cost of capital.

$$\underbrace{C_t^k(K_t)}_{\text{Variable portion of } C_t} = \exp\left\{ \theta_0^f + \theta_1^k \mathsf{IntCap96} + \theta_2^k \mathsf{USCap96} + \theta_3^k \mathsf{USIOU} \right\} \times (K_t)^2 \qquad (5)$$

The sunk investment cost that varies with capacity is modelled as a function of three observed firm characteristics that reflect the firm's experience with electricity generation. IntCap96 and USCap96 measure the amount of merchant power capacity operated by the firm in 1996 abroad and domestically. USIOU is a dummy variable that indicates whether the firm is affiliated (through a parent company) with a U.S. electric utility. The variables signify potential generation experience and skills a firm brings with it when it develops new power plants as an independent power producer.[35] By including these firm experience measures in the variable cost term, the model allows for the possibility that more experienced firms are more efficient in developing larger (more complex) plants.

The "average" component of expected net profit is denoted $\pi_{t+h|t}$ to note that it is the annual per-unit capacity net profit a firm *expects* to earn for period $t+h$ based on information available during period t. In order to capture this expectation, $\pi_{t+h|t}$ is formulated as a function of forecasted values of market characteristics, $X_{t+h|t}$, available to the firm in period t. Specifically, the Annual Energy Outlook (AEO) forecasts, published by the U.S. Energy Information Administration, are used. They are the most widely cited forecasts in the industry press and seem appropriate for capturing industry-wide expectations. $\pi_{t+h|t}$ is also a function of firm characteristics and regulatory variables for the market. With respect to the former, the firm characteristics used in this analysis are all time invariant.[36]. The forecasts of the regulatory variables is based on the estimated transition probability that the industry perceives as governing the evolution of the regulatory variable. For example, the forecast value for the regulatory dummy variable indicating whether a market has

---

[35] We believe that the three variables are largely exogenous as each measure activity in a distinct type of generation market. USCap96 reflects "qualifying facility" (QF) capacity built in response to the 1978 Public Utilities Regulatory Policy Act. Such QFs are built under conditions that differ greatly from plants built under restructuring; most notably, QFs have to adopt from a restrictive class of technology and are built largely with the implicit permission of local utilities. Similar arguments hold for international and utility power projects.

[36] Time-varying firm characteristics are subsumed in the firm-specific, idiosyncratic shock. The effect of the included firm characteristics can either be attributed as the constituting part of the "mean" of the firm-specific shock, given the linear specification of $\pi_{t+h|t}$

enacted restructuring legislation in $t+h$, ψ_{t+h}, given transition probability λ and $\psi_t = 0$ is calculated as follows:

$$
\begin{aligned}
E_t\ f(\psi_{t+h}) &= (1-\lambda)^h \times f(0) + \sum_{s=0}^{h-1} \lambda(1-\lambda)^s \times f(1) \\
&\text{where} \\
\psi_t &= \begin{cases} 1 & \text{if restructuring enacted by time } t \\ 0 & \text{otherwise} \end{cases} \\
\lambda &= \text{Probability}(\psi_t = 1 \mid \psi_{t-1} = 0)
\end{aligned}
$$

Here, as with rest of the paper, the transition is assumed to be one-way: λ is the probability that $\psi_{t+1} = 1$ given that $\psi_t = 0$. We assume that once $\psi_t = 1$, $\psi_{t+h} = 1$ for all $h > 0$. This is consistent with the prevalent belief during our study period: regulatory restructuring was "inevitable" with only the precise timing being uncertain.

We separate $\pi_{t+h|t}$ as the net profits the industry expects to earn in a non-restructured market ($\pi^N_{t+h|t}$) and the additional (or possibly deducting) net profits the industry expects to earn in a restructured market ($\pi^R_{t+h|t}$). An index for the level of "regulatory commitment" is introduced multiplicatively with $\pi^R_{t+h|t}$ to allow the difference in expected net profits to vary with degree to which a market is perceived to be restructured.

$$
\pi_{t+h|t} = \underbrace{\pi^N_{t+h|t}}_{\text{Non-restructured}} + \underbrace{\Gamma_{t+h|t}}_{\text{Commitment Index}} \times \underbrace{\pi^R_{t+h|t}}_{\text{Restructuring Difference}} \qquad (6)
$$

In non-restructured markets, non-utility firms participate largely at the behest of the local, incumbent utilities. Consequently, we model the net profits a firm expects to earn in such markets as largely functions of the observed firm characteristics. More experienced and efficient firms can underbid other firms while competing for the right to fulfill utility power procurement contracts. Additionally, we include two market characteristics to help account for the degree to which utilities in a market might outsource their power generation need: electricity peak demand (LogLoad) and the 1996 average retail electricity price (P96). The former indicates potential need for new electricity supply while the latter proxies the expensiveness of current electricity supply.[37]

$$
\pi^N_{t+h|t} = \theta^N_0 + \theta^N_1\ \mathsf{P96} + \theta^N_2\ \mathsf{LogLoad}_{t+h|t} + \theta^N_3\ \mathsf{IntCap96} + \theta^N_4\ \mathsf{USCap96} + \theta^N_5\ \mathsf{USIOU} \qquad (7)
$$

For restructured markets, non-utility firms participate depending on the signals they observe from the market. Consequently, in addition to firm characteristics, more detailed market demand char-

---

[37] Although levels are used for electricity demand, note that future values of the level are included in the calculation of the net profit stream. So the model implicitly accounts for demand growth.

acteristics are included in the "additional" net profits a non-utility firm expects to earn in a restructured market. Specifically, the log value of the reserve margin (LogRM) and load factor ($\mathsf{LogLDFact}$) are included. The reserve margin is the ratio of total generation supply and peak electricity demand; the load factor is the ratio of peak electricity demand and average electricity demand. We believe that non-utility firms would see greater profit opportunity in markets with tighter supply (low LogRM) and greater volatility (high $\mathsf{LogLDFact}$).[38]

$$\begin{aligned} \pi^R_{t+h|t} \;&=\; \theta^R_0 \;+\; \theta^R_1\, \mathsf{LogLoad} \;+\; \theta^R_2\, \mathsf{LogRM} \;+\; \theta^R_3\, \mathsf{LogLDFact} \\ &\quad +\; \theta^R_4\, \mathsf{IntCap96} \;+\; \theta^R_5\, \mathsf{USCap96} \;+\; \theta^R_6\, \mathsf{USIOU} \end{aligned} \qquad (8)$$

This difference in net profits between non-restructured and restructured markets are multiplied by an index that indicates the degree to which a market has committed to restructuring. The index incorporates whether the market has experienced divestiture of utility power plants ($\mathsf{DivFlag}$) and the number of years since restructuring legislation was enacted in the market ($\mathsf{LegYear}$).

$$\Gamma_{t+h|t} \;=\; \mathsf{LegYear}_{t+h|t} + \theta^R_7(\mathsf{LegYear}_{t+h|t})^2 + \theta^R_8\mathsf{DivFlag}_{t+h|t} \qquad (9)$$

We allow the number of years since enactment to enter non-linearly to account for the possibility of expected profits differing upon entry of non-utility firms. In this model, we explicitly model non-utility firms as being "small" with relation to the market. This is an assumption largely consistent with the current investment landscape: total new capacity account for a small share of the overall capacity in all U.S. restructured markets, with new power plants being largely inframarginal and older, utility power plants setting the market-clearing price. Consequently, the construction of any single power plant does not appear to have a substantial impact on the profitability of another, potential plant. Moreover, there is evidence that firms do not fully account for the individual investment decisions of their competitors and make decisions primarily based on more aggregate information – suggesting the appropriateness of modelling IPP investment as a single-agent optimization problem.[39] However, we allow for the possibility that there might be some early-mover advantages in the market by allowing $\mathsf{LegYear}$ to affect the index non-linearly: a market that just enacted restructuring would be one where the market has not fully committed to and implemented restructuring but one where there may be sizable early mover advantages.

---

[38] A high load factor might be perceived as being profit-enhancing as supply would most likely be tight during the "abnormal" peak periods, allowing for firms to earn significant scarcity rents during those periods.

[39] See Vaninetti (2002)

Lastly, for the idiosyncratic components, we make the following distributional assumptions

$$\begin{aligned} \eta_{fgt} &\overset{i.i.d.}{\sim} N(0,1) \\ \xi_{fg} &\overset{i.i.d.}{\sim} N(0,\sigma_\xi^2) \quad \text{where } \xi_{fg} \equiv \sum_{h=L}^{L+H} \beta^h \left(E_t \epsilon_{fgt+h}\right) = \sum_{h=L}^{L+H} \beta^h \mu_{fg} \\ \eta_{fgt} &\perp \xi_{fg} \end{aligned}$$

We normalize the means of the idiosyncratic components to be zero as the two means cannot be separately identified from the intercept in the "average" components of the investment and expected net profit function, respectively. Similarly, we normalize variance of η_{fgt} to be 1 as the variance of η_{fgt} cannot separately be identified from the variance of ξ_{fg} as neither the level of investment cost nor the level of expected net profits are ever explicitly observed in the data.[40] Therefore, σ_ξ^2 should be interpreted as the variance of ξ_{fg} relative to η_{fgt}. The decision to specify the distribution of ξ_{fg} (the discounted sum of the mean of ϵ_{fgt}) and not ϵ_{fgt}, itself, emphasizes the "random effects" role that ϵ plays - a point discussed more explicitly later.

Perhaps the most controversial aspect of the distributional assumptions above is the *i.i.d.* assumption. While we allow for some unobserved persistence in the idiosyncratic component of expected net profits (across firm/market through ξ_{fg}), we assume away other forms of unobserved persistence. In theory, we can allow for a more general stochastic relationship, either by modelling the errors as possibly correlated or introducing firm/market/time dummies. However, each of these solutions is very costly; both the limited data on IPP investment and computational complexity of the proposed models make such solutions theoretically possible but practically infeasible. Moreover, it is not clear that such "general" models yield a benefit commensurate to the cost: the model already allows for a rich *observed* persistence across firm, state, year.

4.2 A Short Note on Identification

From a statistics standpoint, the chosen functional forms ensure identification of the investment cost and expected net profit parameters. From an economics standpoint, identification stems from two sources. First, investment cost is sunk once, at period t, while expected net profits are earned repeatedly over a future horizon. Moreover, the expected net profits vary with the time-varying (future) market characteristics while investment cost vary with only the current value of those market characteristics. Consequently, this difference in timing contributes to the ability of the model to separate the effect on the investment cost function from the expected net profit

---

[40] This is analogous to the need to normalize the variance in standard discrete choice probit models

function for shared variables. Second, there are some variables that can naturally be excluded from each function. These excluded variables also help separately identify the investment cost from expected net profit function — in a manner similar to excluded variables in linear simultaneous equations models. We should also note that, ultimately, the main source of identification of the real effect of restructuring is the panel variation in the timing of restructuring enactment by the states. Therefore, identification depends on the extent to which the decision to enact restructuring legislation by a state is exogenous to the unobserved component(s) of the decision to invest by the IPP. For example, if firms lobbied much more effectively in states where they expected investment to be more profitable, due to factors not explicitly accounted for in the model, we would expect the model to over-estimate the real effects of restructuring. While we maintain this as a concern, there is no strong evidence to suggest that it is a major one. As explored in White (1996), the main impetus for restructuring appears to be consumer concerns, namely the high relative retail price for electricity. Moreover, subsequently observed investments by IPPs do not show any pattern that would suggest that IPPs perceived greater investment opportunity in states that adopted restructuring earlier rather than later.

4.3 Investment Decision

In all three models, the profit the firm expects to earn from investing in a project is the same. It is simply the expected net present value (NPV) described earlier. However, the three models differ in the *opportunity cost* associated with the project. The firm's objective can be written as follows for all three considered models:

$$V_t = \max_{\delta_t, K_t} U_t(\delta_t, K_t) = \begin{cases} \underbrace{-[\, C_t(K_t) + \eta_t \,] + \sum_{h=L}^{L+H} \beta^h (\pi_{t+h|t} + E_t \epsilon_{t+h}) \cdot K_t}_{E_t \ \mathrm{NPV}(\delta_t, K_t)} & \text{if } \delta_t = 1, K_t > 0 \\ \text{(Additional) Opportunity Cost} & \text{if } \delta_t = 0, K_t = 0 \end{cases}$$

$$\text{with} \quad \delta_t \in \{0,1\} \ , \ K_t \geq 0 \qquad (10)$$

$$\delta_t = \begin{cases} 1 & \text{if firm decides to invest in period } t \\ 0 & \text{if firm decides } \textit{not} \text{ to invest in period } t \end{cases}$$

$$K_t = \text{Capacity of the Generation Investment}$$

Note that the optimal capacity choice (conditional on investing) is independent of the manner in which the opportunity cost is calculated. The optimal capacity, K_t^* is defined by the optimization problem assuming $\delta_t = 1$ and imposing the non-negativity constraint: $K_t^* \geq 0$. Therefore, K_t^* is the larger of 0 and K_t^* defined implicitly in the first order condition given below [41]

$$-\frac{\partial C}{\partial K} + \sum_{h=L}^{L+H} \beta^h \left(\pi_{t+h|t} + E_t \epsilon_{t+h}\right) \ = \ 0 \tag{11}$$

For the chosen function forms, optimal capacity size, assuming investment, simplifies to

$$K_t^* \quad = \quad \max \left\{ 0 \ , \ \frac{\sum_{h=L}^{L+H} \ \beta^h \left(\pi_{t+h|t} + E_t \epsilon_{t+h}\right)}{2 \ \exp \ \{ \ \theta_0^f + \theta_1^k \mathsf{IntCap96} + \theta_2^k \mathsf{USCap96} + \theta_3^k \mathsf{USIOU} \ \}} \right\} \tag{12}$$

This independence makes sense; although, technically, the firm jointly chooses δ_t and K_t, the K_t choice is non-trivial (i.e. not zero) only if $\delta_t = 1$. Once a firm decides to invest, the foregone opportunity cost should have no bearing on the "subsequent" capacity choice. However, the opposite does not clearly hold: the decision whether to invest depends greatly on the optimal capacity choice. The relevant comparison for the firm is the opportunity cost versus the expected net present value from investing in the *optimal* capacity project. If the optimal capacity choice is at the corner solution ($K_t^* = 0$) then the firm never invests regardless of the (non-negative) opportunity cost. So the δ_t choice is non-trivial only when K_t^* (conditional on investment) is positive.

4.3.1 Model A: Expected Net Present Value (NPV)

For this traditional, baseline model of investment, the "opportunity cost" is simply zero: the firm invests as long as E_t NPV > 0. The traditional opportunity costs associated with investment – namely the sunk investment costs such as the cost of capital – are already subsumed in the calculation of E_t NPV. Therefore, what is meant by zero "opportunity cost" is that there are no *additional* opportunity costs beyond the traditional ones already incorporated in the sunk investment cost function. Therefore, the investment decision simplifies to

$$\delta_t \quad = \quad \begin{cases} 1 & \text{if } E_t \text{ NPV}(\delta_t = 1, K_t^*) \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{13}$$

If a firm is observed making an investment, then the model infers that the (*ex ante*) optimal capacity choice is the observed capacity, $K_t^* = K_t$, and that E_t NPV$(\delta_t = 1, K_t^*) \geq 0$. Similarly, if a firm is observing *not* making an investment, then $K_t^* \leq 0$ and/or E_t NPV$(\delta_t = 1, K_t^*) < 0$. Estimation is based on these revealed preference inferences.

---

[41] This assumes that the optimization problem is a properly concave - which it is for the chosen linear-quadratic function form

4.3.2 Model B: Forward-looking (FWL)

When a firm decides to invest in a project today, it forgoes the option of saving those resources and investing in the project later. This shifting of the timing of the project can affect the return from the project as investment cost might be lower in the near future and/or the expected revenue stream may be greater in later periods. If capital markets are perfect, our assumption of "small firms" would imply that there is no inter-temporal decision: each investment decision (today and tomorrow) is independent of the other and the firm can and should invest both today and tomorrow as long as each is individually profitable. However, there are indications in the industry press and conversations that non-utility firms face a real capital budget, at least during the studied transition period. Moreover, this budget seems to allow, realistically, each firm to consider, at most, one new power plant project for each market.[42] Taking this capital constraint seriously, a firm making its investment decision today would factor in the additional opportunity cost of losing the opportunity to invest tomorrow. Assuming that the firm "naively" calculates the expected value of investing tomorrow based on its *current* information set, the firm's decision becomes

$$\delta_t = \begin{cases} 1 & \text{if } E_t \text{ NPV}(\delta_t = 1, K_t^*) \geq \\ & \quad \underbrace{\max\{\, 0,\ \beta E_t \text{ NPV}(\delta_{t+1} = 1, K_{t+1}^*)\ ,\ \ldots\ ,\ \beta^T E_t \text{ NPV}(\delta_{t+T} = 1, K_{t+T}^*)\,\}}_{\text{Additional Opportunity Cost}} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{where} \qquad (14)$$

$$T = \text{Decision Horizon}$$

Note that the inference from observing a firm's investment decision (δ_t, K_t) differs between the NPV and FWL models. In the former, the decision to invest implies that the expected discounted net profit stream was greater than the investment cost (E_t NPV > 0). However, in the latter, investing today is not only expected to be profitable but also more profitable than investing sometime tomorrow. Consequently, the estimates for the investment cost and expected net profit function can differ between the two models, depending in large part on the expected time variance of investment cost and net profits. If, in expectation, there is no difference between today and tomorrow, then discounting would imply that investing today is, in expectation, always better than investing tomorrow: the forward-looking decision rule would reduce to the expected net present value rule.

---

[42] There may also be a budget constraint on the total number of projects; however, we believe this constraint is less binding as investing in two plants in two different markets is less risky than investing two in the same market. *Ceteris paribus*, we would expect the capital cost for a diversified portfolio to be less than a concentrated one.

4.3.3 Model C: Investment under Regulatory Uncertainty (IRU)

In the previous, forward-looking model, we asserted a capital constraint that forced firms to consider investing as an inter-temporal decision. However, when a firm decides not to invest today because it expects investing tomorrow to be more profitable, the firm does not have to commit to investing tomorrow. It can reconsider its decision tomorrow, based on updated information. Consequently, when a firm decides not to invest today, what it really does is delay its investment decision until tomorrow. Therefore, the additional opportunity cost for this model is simply the expected value of making the investment decision tomorrow using tomorrow's information set:

$$V_t = \max_{\delta_t, K_t} \; U_t(\delta_t, K_t) \quad = \quad \begin{cases} -[\; C_t(K_t) + \eta_t \;] + \sum\limits_{h=L}^{L+H} \beta^h (\pi_{t+h|t} + E_t \epsilon_{t+h}) \cdot K_t & \text{if } \delta_t = 1, K_t > 0 \\ \underbrace{\beta \; E_t \; V_{t+1}}_{\text{Expected Value of Deciding at } t+1} & \text{if } \delta_t = 0, K_t = 0 \end{cases} \tag{15}$$

$$\text{with} \;\; \delta_t \in \{0,1\} \; , \; K_t \geq 0 \; , \; E_{t+T}(V_{t+T+1}) = 0$$

The decision rule is the solution to a finite horizon Bellman Equation. Note that $E_t \; V_t$ includes both the value of investing sometime tomorrow and the value of future information sets. Accordingly,

$$E_t \; V_t \quad \geq \quad \max \; \{ \; 0, \; \beta E_t \; \text{NPV}(\delta_{t+1} = 1, K^*_{t+1}) \; , \; \ldots \; , \; \beta^T E_t \; \text{NPV}(\delta_{t+T} = 1, K^*_{t+T}) \; \}$$

Again, this suggests that estimates from this Investment under Regulatory Uncertainty model can differ from those obtained from the earlier two models. This difference will depend on the degree to which the updated information is valuable. If there is no updating – i.e. information set in the near future is the same as the information set today – then the decision rule for this model reduces to the decision rule for the forward-looking model.

Ideally, we would like to incorporate the value of all new information. However, in order to maintain tractability, we focus on the benefit from updating two parts of the overall information set: the firm-specific, idiosyncratic investment cost (η_{t+1}) and the dummy variable indicating whether a market has enacted restructuring legislation (ψ_{t+1}). We are, for now, assuming that firms do not consider the benefit of updating their information on market forecasts ($X_{t+h|t+1}$) and the firm-specific net profits (ϵ_{t+1}). The exclusion of market forecast updating would not seem to be a major omission as the market forecasts do not vary much from year-to-year: the difference between $X_{t+h|t}$ and $X_{t+h|t+1}$ tends to be fairly minimal. The exclusion of the firm-specific net profits is innocuous under our maintained distributional assumption: the ϵ's are drawn independently across time. Thus, the firm has as much information about ϵ_{t+2} at t as it does at $t+1$. Therefore, each firm makes its decision based on the mean of the distribution for ϵ which differs for each firm (f) in each market (g).

$$\sum_{h=L}^{L+H} \beta^h \left(E_t \epsilon_{fgt+h}\right) = \sum_{h=L}^{L+H} \beta^h \mu_{fg} = \xi_{fg}$$

Thus, ϵ – more specifically, ξ_{fg} – plays a role analogous to (time-invariant) random effects in a panel regression model.

4.3.4 The Three Models

Each of the three models is built on top of the subsequent model. This cumulative structure enables one to attribute differences in estimates across the three models to differences in the decision rule embodied within each model. The difference in estimates between the expected net present value (NPV) and the forward-looking model (FWL) can be attributed to the time varying value of the investment and net profit functions. For example, if we observe a firm not investing today in a market that has not enacted restructuring legislation, a possible explanation that is strictly ruled out in the NPV but not FWL model is that the firm expects for restructuring to be enacted soon and that the investment cost is much lower under restructuring. The project may be profitable, in expectations, today but may require a much lower sunk cost if invested tomorrow. This would suggest that the NPV model would infer a much larger investment cost (relative to net profits) than the FWL model as the NPV firm decides not to invest only if it expects the investment cost to be larger than the expected discounted net profit stream.

Similarly, the difference in estimates between the forward-looking (FWL) and "investment under regulatory uncertainty" (IRU) models can be attributed to the possible option value effect from regulatory uncertainty. A possible explanation for a firm not investing today in a market that has not enacted restructuring legislation that is ruled out in the FWL model but not the "investment under regulatory uncertainty" (IRU) model is that the firm places a substantial value on the information set tomorrow courtesy of sizable regulatory uncertainty that outweighs the expected NPV advantage of investing today – even if investing today is optimal given today's information set. This would suggest that the FWL model would infer a smaller difference between the return from investing in a restructured and non-restructured market than the IRU model; the prominence of the option value effect depends in large part on the degree to which the agent values differently the possible states of the world.[43]

---

[43] Consider the extreme case where firms perceive investment as equally (un)profitable in a restructured and non-restructured market. Then regulatory uncertainty has no impact on the firm's investment decision

4.4 Completing the Specification

To complete the specification, we pre-set the following parameters

$$\begin{array}{rcl} L = & \text{Lead Time} & = 1 \\ H = & \text{Revenue Horizon} & = 10 \\ T = & \text{Decision Horizon} & = 5 \\ \beta = & \text{Discount Factor} & = 0.95 \end{array}$$

We choose a revenue horizon of 10 years and an investment decision horizon of 5 years based on trade practice learned through the industry press, such as Vallen & Berlinger (1999), as well as some personal communication with IPPs. The much shorter revenue horizon for an IPP compared to the standard 20-30 years (reflecting physical life of the plant) for a regulated utility highlights one of the main differences between the traditional price-regulated and restructured electricity markets: in a restructured market, the relevant depreciation is economic and not physical.[44] Lastly, we set the discount factor (β) to be 0.95. Although β is nominally identified in the model, there are difficulties associated with estimating it.[45] So far, modest changes to any of these pre-set parameters do not appear to lead to qualitative changes in the result.

In addition to the discount factor, the transition probability (λ) perceived by the firms as governing the timing of the enactment of restructuring legislation is also difficult to estimate. Consequently, we choose a parsimonious structure for λ, motivated by White (1996), which has λ varying by state (g) according to the state's average 1996 retail electricity price ($P96_g$)

$$\lambda_g \quad = \quad \frac{1}{1 + \exp\{\theta_0^L + \theta_1^L P96_g\}} \tag{16}$$

Initial values for θ_0^L and θ_1^L are obtained by choosing the values that maximize the likelihood of the actual, realized pattern of restructuring enactment from 1996 to 2001. We have also tried other specifications of λ_g, such as one that includes a time trend – yielding little substantial change.

4.5 Estimation and Results

The estimation of the model is based on *revealed preference*. The endogenous variables we observe from each IPP (f) in our sample for a given market (g) and year (t) is [1] whether they invested (δ_{fgt}) and [2] if they invested, how much capacity (K_{fgt}). Furthermore, we examine the decision on

---

[44] For a more detailed discussion on this matter, see Ishii (2001) and Yan (2001).

[45] See Rust (1987) and Timmins (1996)

the *initial* investment: once an IPP has invested in the market, subsequent investment decisions are no longer considered. For example, suppose an IPP is observed making the following investment decisions over the sample period in a particular market:

$$\{\ (\delta_t, K_t)\ \}_{t=1996}^{2000} \quad = \quad \{\ (0,0),(0,0),(1,250),(0,0),(1,500)\ \}$$

In this example, the IPP is observed sinking investment cost toward a 250 MW power plant in 1998 and a 500 MW power plant in 2000. However, for the purposes of our analysis, we do not consider the investment decisions after the initial investment in 1998.

There are several reasons why we choose to do this. First, we believe that the initial investment decision is different from subsequent investment decisions due to entry considerations. A firm enters the wholesale electricity (generation) market in a state by investing in a power plant. As a result, the initial investment decision is confounded with the entry decision. More specifically, we believe that the estimated investment cost for the initial investment would also capture sunk *entry* costs. Second, we believe the investment decision differ due to potential (dis)economies of scale and scope in investing in and operating generation portfolios. These externalities across power plants complicate the underlying dynamic programming problem, making analytical representation of the firm's investment decision infeasible.[46] In order to avoid these distortions and complications, we focus on the initial investment decision; consequently, one might consider this model more a model of entry. However, to the extent that there are no sizable sunk entry costs nor generation (dis)economics of scale and scope, this model captures the investment decision as well. Estimation of this model is by maximum likelihood, where the likelihood is derived by inverting the solution to the above Bellman equation that characterizes each firm's investment decision for a given market and year. Details of the estimation procedure, as well as the data set, can be found in the Appendix.

Table 3 presents the estimated transition probabilities (λ_g) that characterize each firm's expectation about the evolution of restructuring legislation in a state. Although we eventually plan to estimate these transition probabilities jointly with the other parameters, for this draft, we fix the transition probabilities at their "initial" values (i.e. the values that maximize the likelihood of the actual, observed path of restructuring). Table 4 presents the estimates for the "average" component of expected net revenue from a new power plant and Table 5 the estimates for the "average" component of investment cost. For the purposes of this study, we focus on the differences in the estimates across the three models. We set aside a more comprehensive examination of the estimates for a later draft as the models are still under development/estimation. The preliminary estimates

---

[46] See Ishii (2001) for an empirical investment model that considers such externalities and is solved using simulation methods similar to Keane & Wolpin (1997)

presented in this draft are obtained with effort made to minimize the difference in estimates across the three models. The estimates for each model were started off with the same initial values and search was concentrated in the same parameter subspace. Moreover, once different estimates were obtained, the estimates from each model were used as initial values for estimating the other models – testing whether observed differences are robust.

Consider first the estimates of the investment cost parameters. We deviate from the specification described previously in one manner: for models where future investment costs are considered (namely, FWL and IRU), we allow the effect of restructuring legislation on fixed investment cost to differ between actual and anticipated. For the case where a firm is considering investment (today) in a currently restructured state ($\mathsf{LegYear}_{\mathsf{t}} = 1$), the *actual* effect of restructuring on fixed investment cost is θ_5^f. For the case where a firm at time t in a non-restructured state is considering the *potential* impact of *future* restructuring ($\mathsf{LegYear}_{\mathsf{t+h}} = 1$) on fixed investment cost, the *anticipated* effect is $\theta_5^f + \theta_{5b}^f$. We make this distinction as current investment cost, unlike revenue, is observed by the firms before they make their decision. Therefore, firms in our sample deal with both actual and anticipated investment costs.[47] Across the three models, the investment cost parameter estimates are qualitatively (sign) similar except for the constant and the actual/anticipated effect of restructuring (LegPassFlag).[48] The difference in the constant is misleading as the difference in the constant is roughly cancelled out by the difference in the BondYield effect – Moody's Baa corporate bond yield averaged between 7 to 9% during the sample period.

However, the difference in the estimated effect of restructuring on fixed investment cost is more robust. For both the NPV and FWL model, restructuring appears to have a positive actual impact on investment cost ($\theta_5^f > 0$), implying that firms incur greater investment cost in a restructured market, *ceteris paribus*. Only for the IRU model does the actual impact of restructuring have the expected negative estimate, consistent with idea of restructuring lowering regulatory barriers to entry/investment. Furthermore, for both FWL and IRU models, the estimates suggest that IPPs anticipate investment cost to be larger under restructuring ($\theta_{5b}^f > 0$). Taking the estimates at face value, this implies that the option value from regulatory uncertainty does not stem from the effect of restructuring on investment cost, but rather expected revenue (net profits). If firms anticipate investment cost being larger under restructuring, then firms, *ceteris paribus*, prefer investing today in a non-restructured state than tomorrow in a potentially restructured state. Therefore, the benefits of delaying investment must stem from the impact of restructuring on future revenue.

---

[47] On the other hand, firms always deal with expected net (variable) profits as revenue lags the investment decision

[48] Note: the parameter values are identified only relative to each other; consequently, it is difficult to compare *quantitatively* the estimates across the models

An examination of the results for the expected net profit (Table 4) is consistent with this view on the source of regulatory uncertainty option value. With the *caveat* that the estimate of σ_ξ indicates a strong, unobserved, idiosyncratic component of expected net profit, the estimates in Table 4 suggest that IPP power plant investments are largely unprofitable for non-restructured states but profitable for restructured states, with profits growing as restructuring further progresses. Consequently, while investments may be "cheaper" before restructuring, they yield much less fruit; a firm still prefers to invest in a restructured state overall.[49] We find that the expected net profits are similar between FWL and IRU models but drastically different from the NPV model. In the NPV model, investments are deemed rarely profitable, only if a state has been restructuring for many years. For $\mathsf{LegYear} > 2$, the commitment index $\Gamma_{t+h|t}$ is negative (and positive otherwise). Given that the restructuring difference $\pi^R_{t+h|t}$ is negative for most observations, this indicates that profits are higher under restructuring only if a state has been restructured for greater than 2 years. This is most likely a result of the key inference made by the NPV model: an observation of no investment implies that the firm perceives all investment in the market as being unprofitable. This is in contrast to the FWL and IRU models where the same observation indicates that investment *may* be profitable but not optimal.

The FWL/IRU estimates find restructuring immediately leading to higher perceived profits, with both $\Gamma_{t+h|t}$ and $\pi^R_{t+h|t}$ positive for most observations. The similarity in the estimates between the FWL and IRU models is not surprising given that these profit parameters are identified not only from observing whether a firm invested but also how much (capacity). The latter source of identification, as elaborated earlier, is largely unaffected by the difference in the two models (regulatory uncertainty option value). Moreover, while we do not want to stress individual parameter estimates at this time, it is important to note that the parameter estimates for the market and firm characteristics for the FWL/IRU models have the "opposite" sign of what was expected, *ex ante*. Under the standard market power story, we expect the reserve margin (logRM) to have a negative effect (less tight supply) and the load factor ($\mathsf{LogLDFact}$) to have a positive effect (greater volatility) on expected profits in restructured markets, as they are for the NPV model. The surprising estimates might be explained by two factors. First, the reserve margin used in the model is the *forecasted* value from the EIA AEO program, which incorporates anticipated future IPP investment. Consequently, the LogRM may simply be capturing the overall attractiveness of investment in the market.[50] Second, while we hypothesized that IPPs may associate greater demand volatility with

---

[49] For much of the common values of the observed variables, the discounted expected profit stream surpasses the investment cost only under restructuring

[50] There is an endogeneity concern only to the extent that LogRM reflects some aspect of the unobserved, idiosyncratic component of profit (ξ_{fg}). However, there is no reason to believe that the AEO forecasters have substantially

greater profits, this is mainly true for firms operating peak units. For baseload units, IPPs may prefer to sell more capacity steadily, albeit at a lower price.[51] The firm characteristics (IntCap96, USCap96, USIOU) also have a surprising negative impact on $\pi^R_{t+h|t}$. While we would like to interpret these estimates as the "returns" from skills inherent to each firm, precisely-speaking, the estimates reflect how different types of firm perceive expected profits. Therefore, the lower expected net profits for firms with greater merchant power experience does not necessarily indicate that they are less competitive, only that they have lower expectations concerning net profit in restructured markets (less "optimistic") than their less experienced counterparts.

Together, these estimates suggest that each of the models tell the following, respective story on how the enactment of restructuring legislation spurs IPP generation investment. For the NPV model, observed IPP investment is explained largely by the unobserved, idiosyncratic component of investment cost and expected net profit function. The NPV estimates find restructuring neither reducing the investment cost nor increasing the expected net profits substantially. This is arguably an artifact of the data largely consisting of "no investment" observations and the NPV rule necessarily inferring investments as being unprofitable (as opposed to just suboptimal) for "no investment" observations. In contrast, the FWL and IRU model find the enactment of restructuring playing an important role in explaining observed investment. For both models, expected net profits are substantially greater as states shift their electricity industry toward greater market-orientation. Consequently, firms might delay their investment and wait for restructuring legislation in order to ensure the largest possible revenue stream for their power plants. However, only the IRU model provides any evidence suggesting that restructuring legislation has lowered the perceived regulatory barriers to entry/investment ($\theta^f_5 > 0$) – with this lowering of investment cost being a *real* effect of restructuring and not an *option value* effect as the anticipated effect of restructuring on investment cost is positive ($\theta^f_5 + \theta^f_{5b} > 0$).

Lastly, in order to facilitate a more methodical comparison of the three models, Table 6 presents some standard model selection statistics. Given that the number of parameters is essentially the same across the three models, with NPV having only one less parameter than FWL/IRU, selecting a model based on one of the traditional information criteria (e.g. Akaike), is effectively equivalent to selecting the model with the largest log likelihood. Therefore, we find that the IRU (-1048.232) and FWL (-1058.387) models fit the data much better than the NPV model (-1440.705), with the IRU model nominally favored over the FWL model. Furthermore, the table also presents the Vuong (1989) likelihood ratio test statistic for each pair of models. While both the FWL and IRU

---

more information about idiosyncratic, firm-level expectations.

[51] See Ishii (2003) for more discussion.

models are found to be much closer to the true model than the NPV model, the Vuong statistic for IRU/NPV of 1.009 indicates that the null hypothesis that the IRU and NPV models are equally close to the true model cannot be rejected at conventional significance levels. This implies that accounting for the inter-temporal constraints has a stronger impact on the explanatory power of a model than accounting for regulatory uncertainty option value. A key *caveat* to this point is that the estimates were obtained using fixed restructuring transition probabilities (λ_g). The amount of option value facing a firm is a direct function of λ_g. Consequently, fixing λ_g constrains the ability of the IRU model to explain the data.

Conclusion

This paper reports on-going research that investigates the degree to which observed U.S. generation investment decisions since 1996 can be attributed to the impact of regulatory uncertainty. We believe that regulatory uncertainty can contribute to an apparent "investment slowdown" by creating an incentive for firms to delay their investment decision, allowing the firms to acquire more regulatory information that will enable them to make a better-informed decision. We provide a simple theoretical model, based on the intuition of earlier information-gathering models, that illustrate this "option value" from regulatory uncertainty that can be earned by delaying investment. We find suggestive evidence for the presence of such an option value in our Tobit regression analysis of aggregate state-level generation investments during the period 1996 to 2000. The estimates show that investments are lower in states that eventually enact restructuring legislation (as of 2003) in years further away from the actual enactment year. This is consistent with our intuition of regulatory uncertainty option value as we believe that option value is precisely the largest in states 2-3 years away from restructuring.

However, the Tobit analysis is complicated by the fact that we cannot separate the option value effect from the real effect of restructuring. The option value effect stems from uncertainty about restructuring and the value of updated regulatory information while the real effect are the more tangible impacts of restructuring on the revenue from and cost of new generation investment. Failure to separate these two effects can seriously bias the policy implications drawn from an empirical analysis of the impact of restructuring on investment. We find evidence of such a bias in our more structural analysis. We use data on firm-level, generation investment decisions for a sample of non-utility, independent power producers (IPPs). The data is applied to three different models of investment decision-making: the traditional expected net present value (NPV) model, a forward-looking (FWL) model, and our "investment under regulatory uncertainty" (IRU) model.

Differences in the (preliminary) estimates across the three models are attributed to differences in the decision-making rule underlying each of the models. While the NPV model is found to be largely inadequate to explain observed investment decision, the FWL and IRU models seem to fit the data similarly well, with the IRU model slightly favored. However, the interpretation of the impact if restructuring on IPP investment differ substantially, especially with respect to the impact of restructuring on fixed (sunk) investment cost.

We believe that this paper provides empirical evidence of regulatory uncertainty playing a substantial role in U.S. generation investment since 1996, lending some support to the uncertainty "rhetoric" surrounding current electricity restructuring debates. Both the descriptive analysis and the reduce form Tobit analysis are consistent with the presence of a sizable option value from regulatory uncertainty and our more structural analysis demonstrates how interpretation of the data can vary depending on whether the empirical model explicitly allows for such an option value. While we are currently working on refining our structural model to separate more precisely the real effects from the option value effects stemming from uncertainty surrounding restructuring legislation enactment, we are also considering manners in which this analysis might be extended to provide insight on the impacts of a second type of regulatory uncertainty – uncertainty regarding the actual design and performance of the restructured market. This is a regulatory uncertainty that exists *after* restructuring is enacted and one for which concern was amplified by the recent California Energy Crisis. The option value for this regulatory uncertainty would correspond to claims by IPPs operating in restructured wholesale markets that seemingly high generation prices include a necessary "risk premium." Moreover, this option value might also help explain the recent rash of cancelled non-utility power plant projects.

Bibliography

205 Independent Power Companies: Profiles of Industry Players and Projects (1999 Edition). McGraw-Hill Companies. New York, NY.

Electricity Supply & Demand. North American Electricity Reliability Council. Princeton, NJ. 1999.

Averch, H. & L. Johnson (1962). “Behavior of the Firm under Regulatory Constraint,” *American Economic Review.* 52(5). pp.1053-1069.

Bernanke, B.S. (1983). “Irreversibility, Uncertainty, and Cyclical Investment.” *Quarterly Journal of Economics.* February. 83(1). pp.85-106.

Brennan, M.J. & E.S. Schwartz (1982). “Consistent Regulatory Policy under Uncertainty.” *Bell Journal of Economics.* Autumn. 13(2). pp.506-521

Buckland, R. & P. Fraser (2001). “Political and Regulatory Risk in U.K. Electricity Distribution.” *Journal of Regulatory Economics.* 19(1). pp.5-25.

Clarke, R.G. (1980). “The Effect of Fuel Adjustment Clauses on the Systematic Risk and Market Values of Electric Utilities.” *Journal of Finance.* May. 35(2). pp.347-358.

Cukierman, A. (1980). “The Effects of Uncertainty on Investment under Risk Neutrality with Endogenous Information.” *Journal of Political Economy.* June. 88(3). pp. 462-475.

Gollop, F.M. & S.H. Karlson (1978). “The Impact of the Fuel Adjustment Mechanism on Economic Efficiency.” *Review of Economics & Statistics.* November. 60(4). pp.574-584.

Isaac, R.M. (1982). “Fuel Cost Adjusment Mechanisms and the Regulated Utility Facing Uncertain Fuel Prices.” *Bell Journal of Economics.* Spring. 13(1). pp.158-169.

Ishii, J. (2001). “An Empirical Model of Electricity Generation Investment under Regulatory Restructuring.” mimeo, Stanford University.

Ishii, J. (2003). “Technology Adoption and Regulatory Regime: Gas Turbine Electricity Generators from 1980 to 2001.” mimeo, University of California-Irvine.

Ishii, J. & J. Yan (2002). “The ‘Make or Buy’ Decision in U.S. Electricity Generation Investment.” UCEI CSEM Working Paper No. 107

Joskow, P.L. (1997). “Restructuring, Competition, and Regulatory Reform in the U.S. Electricity Sector.” *Journal of Economic Perspectives.* Summer.

Keane, M.P. & K.I. Wolpin (1997). "The Career Decisions of Young Men." *Journal of Political Economy.* 105(31). pp.473-522.

Lyon, T.P. & J.W. Mayo (2000). "Regulatory Opportunism and Investment Behavior: Evidence from the U.S. Electric Utility Industry." mimeo. June. Indiana University.

Maddala, G.S. (1983). *Limited Dependent and Qualitative Variables in Econometrics.* Econometric Society Monographs No.3, Cambridge University Press.

Prager, R.A. (1989). "The Effects of Regulatory Policies on the Cost of Debt for Electric Utilities: An Empirical Investigation." *Journal of Business.* January. 62(1). pp.33-53.

Robinson, T.A. & M.P. Taylor (1998). "The Effects of Regulation and Regulatory Risk in the U.K. Electricity Distribution Industry." *Annals of Public and Cooperative Economics.* 69(3). pp.331-346.

Rust, J.P. (1987). "Optimal Replacement of GMC Bus Engines: An Empirical Model of Harold Zurcher." *Econometrica.* September. 55(5). pp.999-1033.

Teisberg, E.O. (1993). "Capital Investment Strategies under Uncertain Regulation," *Rand Journal of Economics.* Winter. 24(4). pp.591-604.

Teisberg, E.O. (1994). "An Option Valuation Analysis of Investment Choices by a Regulated Firm," *Management Science.* April. 40(4). pp.535-548

Timmins, C.D. (1997). "Price as a Policy Tool for Dynamic Resource Allocation: The Case of the Municipally Owned Water Utility," Dissertation. Stanford University.

Vallen, M.A. & C.D. Bullinger (1999). "The Due Diligence Process for Acquiring and Building Power Plants." *The Electricity Journal* October. pp.28-37.

Vaninetti, B. (2002). "Overcapacity ... Just Part of the Growth Cycle." *Public Utilities Fortnightly.* Vol. 140. Issue 4. pp.12-14.

Vuong, Q. (1989). "Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses." *Econometrica.* 57(2). pp.307-334.

White, M. (1996). "Power Struggles: Explaining Deregulatory Reforms in Electric Power Markets." *Brookings Papers on Economic Activity: Microeconomics* pp.201-250.

Yan, J. (2001). "An Empirical Model of Entry for the U.S. Electricity Generation Industry Under Regulatory Restructuring." mimeo, Stanford University

Figures and Tables

- Figure 1-3: attached at end of the section
- Figure 4-5: in body of text

Table 1: Entry and Restructuring in Selected States

State	Variable	1996	1997	1998	1999	2000
AZ	ENTRY	0	0	1	0	4
	ψ_{gt}	0	0	1	1	1
	DIVMW	0	0	0	0	0
CA	ENTRY	3	6	1	0	1
	ψ_{gt}	1	1	1	1	1
	DIVMW	0	13564	6600	0	0
FL	ENTRY	1	1	1	0	1
	ψ_{gt}	0	0	0	0	0
	DIVMW	0	0	639	0	0
IL	ENTRY	0	1	3	2	2
	ψ_{gt}	0	0	1	1	1
	DIVMW	0	1319	15859	0	0
MA	ENTRY	1	5	4	0	1
	ψ_{gt}	0	0	1	1	1
	DIVMW	0	6408	1057	0	0
MS	ENTRY	0	0	1	1	3
	ψ_{gt}	0	0	0	0	0
	DIVMW	0	0	0	0	0
NH	ENTRY	0	1	0	0	0
	ψ_{gt}	1	1	1	1	1
	DIVMW	0	328	0	0	0
NY	ENTRY	2	2	5	2	1
	ψ_{gt}	0	1	1	1	1
	DIVMW	0	0	13363	0	0
PA	ENTRY	1	1	4	3	1
	ψ_{gt}	0	1	1	1	1
	DIVMW	0	0	8781	2489	0
TX	ENTRY	1	1	4	2	0
	ψ_{gt}	0	0	0	1	1
	DIVMW	0	0	0	0	0

$\psi_{gt} = 1$ if restructuring legislation has been enacted

DIVMW: Total utility divestiture available (MWs)

Table 2a: Summary Statistics for Tobit Variables*

Variable	Mean	Std	Min	Max
LogNewInvestment	3.45	2.95	0	8.84
LogLoad	8.39	0.98	6.24	10.14
LogRM	0.22	0.15	-0.10	0.73
LegPassFlag	0.29	0.45	0	1
LegPass1	0.08	0.28	0	1
LegPass2	0.06	0.23	0	1
LegPass3	0.04	0.20	0	1
DivFlag	0.29	0.45	0	1
DivCurrent	0.09	0.28	0	1
DivFuture	0.14	0.34	0	1

* Assuming majority of investment cost sunk one year before commercial operation ($L = 1$ scenario).

Table 2b: Estimates for Tobit Regression

Dependent Variable: Log of Total New Investment in a State/Year

Parameter	Lead Time=1*	Lead Time=2**	Lead Time=1 or 2***
	Estimate (Std Errors)	Estimate (Std Errors)	Estimate (Std Errors)
Constant	-3.56† (1.36)	-4.04† (1.31)	-4.37† (1.31)
LogLoad	0.97† (.16)	1.07† (.15)	1.09† (.15)
LogRM	-1.08 (.89)	-0.52 (.82)	-0.64 (.90)
LegPassFlag	0.26 (.39)	0.53 (.35)	0.79† (.37)
LegPass1	-0.06 (.65)	0.14 (.56)	0.30 (.55)
LegPass2	-0.84 (.68)	-0.51 (.69)	-0.63 (.66)
LegPass3	-1.39† (.68)	-1.52† (.72)	-1.79† (.67)
DivFlag	0.88† (.43)	0.64 (.35)	0.79† (.41)
DivCurrent	-1.72† (.62)	-1.14 †(.54)	-1.69† (.58)
DivFuture	-0.75 (.44)	-1.84† (.44)	-1.22† (.42)

* Assuming majority of investment cost sunk one year before commercial operation.

** Assuming majority of investment cost sunk two year before commercial operation.

*** Assuming majority of investment cost sunk one year before commercial operation for plant ≤ 300 MW and two years for plant > 300 MW.

† Estimates with P-Value ≤ 0.05

Table 3: Predicted Transition Probabilities (Starting Values)

State	$\hat{\lambda}_g$	State	$\hat{\lambda}_g$	State	$\hat{\lambda}_g$
AL	.057 (.254)	MA	.410 (.929)	OH	.092 (.383)
AR	.009 (.044)	MD	.143 (.538)	OK	.061 (.270)
AZ	.184 (.638)	ME	.350 (.884)	OR	.031 (.146)
CA	.390 (.916)	MI	.142 (.535)	PA	.209 (.690)
CO	.086 (.362)	MN	.061 (.270)	RI	.434 (.942)
CT	.446 (.948)	MO	.093 (.386)	SC	.066 (.289)
DE	.133 (.510)	MS	.079 (.337)	SD	.090 (.376)
FL	.139 (.527)	MT	.031 (.146)	TN	.047 (.214)
GA	.114 (.454)	NC	.112 (.448)	TX	.085 (.359)
IA	.082 (.348)	ND	.067 (.293)	UT	.051 (.230)
ID	.019 (.091)	NE	.054 (.242)	VA	.094 (.390)
IL	.189 (.649)	NH	.554 (.982)	VT	.347 (.881)
IN	.048 (.218)	NJ	.440 (.945)	WA	.019 (.091)
KS	.111 (.445)	NM	.123 (.481)	WI	.053 (.238)
KY	.018 (.087)	NV	.085 (.359)	WV	.052 (.234)
LA	.069 (.301)	NY	.497 (.968)	WY	.023 (.110)

Value in parentheses is the predicted probability for transition within 5 years: $1 - (1 - \hat{\lambda}_g)^5$

Table 4: Estimates for Expected Net (Variable) Profits

	Alternative		Main
Parameter	NPV	FWL	IRU
	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)
Non-Restructured ($\pi^N_{t+h\|t}$)			
θ^N_0 : Constant	-0.950 (0.433)	0.010 (0.002)	-0.160 (0.069)
θ^N_1 : P96	-0.140 (0.043)	-0.028 (0.001)	-0.007 (0.001)
θ^N_2 : LogLoad	0.135 (0.044)	0.037 (0.001)	0.034 (0.012)
θ^N_3 : IntCap96	-0.075 (0.083)	-0.063 (0.005)	-0.055 (0.011)
θ^N_4 : USCap96	0.093 (0.101)	-0.044 (0.001)	-0.042 (0.006)
θ^N_5 : USIOU	-0.162 (0.171)	-0.023 (0.003)	0.037 (0.003)
Commitment Index ($\Gamma_{t+h\|t}$)			
θ^R_7 : (LegYear)^2	-0.144 (0.005)	-0.034 (0.002)	-0.032 (0.002)
θ^R_8 : DivFlag	-0.625 (0.229)	3.333 (0.755)	3.684 (0.614)
Restructuring Difference ($\pi^R_{t+h\|t}$)			
θ^R_0 : Constant	-0.108 (0.269)	0.072 (0.001)	0.066 (0.001)
θ^R_1 : LogLoad	-0.226 (0.048)	-0.003 (0.000)	-0.004 (0.000)
θ^R_2 : LogRM	-0.276 (0.166)	0.010 (0.005)	0.009 (0.002)
θ^R_3 : LogLDFact	0.941 (0.518)	-0.033 (0.007)	-0.029 (0.005)
θ^R_4 : IntCap96	0.093 (0.092)	-0.006 (0.001)	-0.005 (0.001)
θ^R_5 : USCap96	0.145 (0.053)	-0.004 (0.001)	-0.005 (0.001)
θ^R_6 : USIOU	-0.094 (0.092)	-0.001 (0.002)	-0.001 (0.000)
σ_ξ	6.255 (1.154)	1.518 (0.224)	1.482 (0.129)

Table 5: Investment Cost Estimates

	Alternative		Main
Parameter	NPV	FWL	IRU
	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)
Fixed Investment Cost			
θ_0^f : Constant	1.659 (1.408)	-5.191 (6.683)	-5.230 (5.097)
θ_1^f : P96	-0.155 (0.073)	-0.742 (0.179)	-0.081 (0.074)
θ_2^f : Age30	0.937 (0.623)	3.055 (1.593)	2.357 (2.150)
θ_3^f : STNOX	0.003 (0.036)	0.391 (0.101)	0.104 (0.065)
θ_4^f : DivFlag	-0.504 (0.135)	-0.873 (0.158)	-0.840 (0.154)
θ_5^f : LegPassFlag	0.236 (0.128)	0.901 (0.907)	-3.321 (1.125)
θ_{5b}^f : Exp.LegPassFlag	N/A	0.405 (1.223)	6.872 (1.312)
θ_6^f : BondYield	0.151 (0.072)	0.889 (0.806)	0.657 (0.626)
Variable Investment Cost			
θ_0^k : Constant	-1.024 (0.179)	-1.822 (0.103)	-1.855 (0.068)
θ_1^k : IntCap96	-0.620 (0.061)	-0.382 (0.039)	-0.411 (0.044)
θ_2^k : USCap96	-0.517 (0.060)	-0.161 (0.024)	-0.218 (0.031)
θ_3^k : USIOU	-1.098 (0.130)	-0.215 (0.036)	-0.208 (0.035)

Table 6: Model Selection

	Alternative		Main
Log Likelihood	NPV	FWL	IRU
	-1440.705	-1058.387	-1048.232
Vuong Statistic	IRU/FWL	FWL/NPV	IRU/NPV
	1.009	10.364	11.108
$N = 48$ states $\times$ 20 firms $= 960$			

A Appendix: Estimating the Structural Model (IRU Model)

Given the focus on initial investment, an observation for our empirical model is defined as a series of entry/investment decisions made by an IPP in a market from 1996 until either the year it makes its initial investment or 2000, whichever arrives first. To derive the likelihood associated with such observations, we consider two scenarios. In the first scenario, firm f is observed making its initial investment of K_{fgt} capacity in year t ($1996 \leq t \leq 2000$). We assume that the observed capacity is the optimal capacity given information at time t, K^*_{fgt}

$$\delta_{fgt} = 1 \ , \ \delta_{fgt-1} = 0 \ , \ \ldots \ , \ \delta_{fg1996} = 0 \ , \ K^*_{fgt} = K_{fgt}$$

The optimal capacity can be derived by inverting the first order condition from the firm's expected NPV maximization problem.[52]

$$\begin{aligned}
\max_K \Pi &= -\underbrace{[C^f_{fgt} + C^k_{fgt}(K)]}_{C_{fgt}(K)} + \left(\sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} + \xi_{fg}\right) K \\
&= -[C^f_{fgt} + \omega_{fgt} K^2] + \left(\sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} + \xi_{fg}\right) K \\
0 &= -2 \ \omega_{fgt} \ K^*_{fgt} + \left(\sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} + \xi_{fg}\right) \\
K^*_{fgt} &= \frac{1}{2 \ \omega_{fgt}} \left(\sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} + \xi_{fg}\right)
\end{aligned}$$

Given the observed K_{fgt}, the above first order condition precisely determines the value of ξ_{fg}

$$\begin{aligned}
\xi_{fg} &= 2 \ \omega_{fgt} \ K_{fgt} - \sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} \\
&= 2 \ \exp(X^k_{fgt} \theta^k) \ K_{fgt} - \sum_{h=1}^{H} \beta^h (\ X^r_{fgt+h|t} \theta^r \ )
\end{aligned}$$

The revealed preference information obtained from the observed investment decisions (δ_{fgt}) constrains the values of η_{fgt}. Recall the firm's investment decision:

$$V_{fgt} = \max_{\delta_{fgt}, K_{fgt}} \ U_t(\delta_{fgt}, K_{fgt}) \ = \ \begin{cases} -[\ C_{fgt}(K_{fgt}) + \eta_{fgt} \ ] + (\sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} + \xi_{fg}) \cdot K_{fgt} \\ \beta \ E_t V_{fgt+1} \end{cases}$$

---

[52] Note that the net revenue function is linear in K and quadratic in cost, with a positive quadratic term, leading to a proper concave objective function. Furthermore, we know that the IPP made an investment; so we do not have to worry about a corner solution due to fixed costs. Thus, the F.O.C. is both necessary and sufficient.

Therefore, the value of η_{fgt} such that the firm is indifferent about investing now (η^*_{fgt}) can be defined as follows

$$\begin{aligned} \beta\ E_t V_{fgt+1} &= -[\ C_{fgt}(K_{fgt}) + \eta^*_{fgt}\ ] + (\sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} + \xi_{fg}) \cdot K_{fgt} \\ \eta^*_{fgt} &= -[C_{fgt}(K_{fgt}) + \beta\ E_t V_{fgt+1}] + (\sum_{h=1}^{H} \beta^h \pi_{fgt+h|t} + \xi_{fg}) \cdot K_{fgt} \end{aligned}$$

An observed investment decision ($\delta_{fgt} = 1$) implies that $\eta_{fgt} < \eta^*_{fgt}$. Similarly, an observed decision not to invest at time t ($\delta_{fgt} = 0$) implies that $\eta_{fgt} > \eta^*_{fgt}$. The key difficulty here is the calculation of η^*_{fgt} and, more specifically, $E_t V_{fgt+1}$. The Appendix explains how $E_t V_{fgt+1}$ is solved, analytically, using backward recursion.

Combining these results, we now present the likelihood for the observed history of investment decision for firm f who invests in market g in time t

$$\begin{aligned} L_{fg}(\text{entry}) &= Pr(\ \delta_{fg1996} = 0\ ,\ \ldots\ ,\ \delta_{fgt-1} = 0\ ,\ \delta_{fgt} = 1\ ,\ K^*_{fgt} = K_{fgt}\ ) \\ &= Pr(\ \delta_{fg1996} = 0\ ,\ \ldots\ ,\ \delta_{fgt-1} = 0\ ,\ \delta_{fgt} = 1 \mid K^*_{fgt} = K_{fgt}\ ) \cdot Pr(K^*_{fgt} = K_{fgt}) \\ &= Pr(\ \eta_{fg1996} > \eta^*_{fg1996}\ ,\ \ldots\ ,\ \eta_{fgt-1} > \eta^*_{fgt-1}\ ,\ \eta_{fgt} < \eta^*_{fgt} \mid \xi_{fg}\ ) \\ &\quad \times \left[Pr(\xi_{fg})\ \| \frac{\partial \xi_{fg}(K_{fgt})}{\partial K_{fgt}} \| \right] \\ &= \left[\prod_{\tau=1996}^{t-1} (1 - \Phi(\frac{\eta^*_{fg\tau}}{\sigma_\eta})) \cdot \Phi(\frac{\eta^*_{fgt}}{\sigma_\eta}) \right] \cdot \left[\frac{2\ \exp(X^k_{fgt}\theta^k)}{\sigma_\xi}\ \phi(\frac{\xi_{fg}}{\sigma_\xi}) \right] \end{aligned}$$

Now consider the second scenario where firm f has not made an investment in market g as of the end of the sample (year 2000). In this scenario, we do not observe any optimal capacity choice K^*_{fgt}. Therefore, we have no data to determine the exact value of ξ_{fg} and have to integrate ξ_{fg} out of the likelihood. There are two possible cases. First, given ξ_{fg}, the optimal capacity choice (without considering fixed cost) in period t is positive: $\sum_{h=1}^{H} \beta^h \pi_{t+h|t} + \xi_{fg} > 0$. In this case, η^*_{fgt} is well defined and the conditional likelihood is $(1 - \Phi(\eta^*_{fgt}))$. Second, if $\sum_{h=1}^{H} \beta^h \pi_{t+h|t} + \xi_{fg} \leq 0$ then the optimal capacity is zero ($K^*_{fgt} = 0$) and the conditional likelihood for η is 1 – any value of η in its the support would lead to a “zero capacity” investment. Therefore, the likelihood for the case of no entry/investment is:

$$
\begin{aligned}
L_{fg}(\text{no entry}) \quad &= \quad Pr(\ \delta_{fg1996} = 0\ ,\ \ldots\ ,\ \delta_{fg2000} = 0\ ) \\
&= \quad \int_{-\infty}^{+\infty} Pr(\ \delta_{fg1996} = 0\ ,\ \ldots\ ,\ \delta_{fg2000} = 0 \mid \xi_{fg} = u\ ) \cdot f_{\xi}(u)\ du \\
&= \quad \int_{-\infty}^{+\infty} \left[\prod_{\tau=1996}^{2000} \left\{ (1 - \Phi(\frac{\eta^{*}_{fg\tau}}{\sigma_{\eta}})) \cdot 1_{K^{*}_{fgt}>0} + (1 - 1_{K^{*}_{fgt}>0}) \right\} \right] \cdot \frac{1}{\sigma_{\xi}}\ \phi(u)\ du
\end{aligned}
$$

where

$$
1_{K^{*}_{fgt}>0} \quad = \quad \begin{cases} 1 & \text{if } K^{*}_{fgt} > 0 \\ 0 & \text{otherwise} \end{cases}
$$

Therefore, the maximum likelihood estimation procedure is

$$
\max_{\theta,\ \sigma_{\xi},\ \sigma_{\eta}} L \quad = \quad \prod_{f=1}^{F} \prod_{g=1}^{G} [\ L_{fg}(\text{Entry})\ ]^{\varphi_{fg}}\ [\ L_{fg}(\text{No Entry})\ ]^{1-\varphi_{fg}}
$$

where

$$
\theta \quad = \quad \{\ \theta^{r}\ ,\ \theta^{f}\ ,\ \theta^{k}\ ,\ \theta^{L}\ \}
$$

$$
\varphi_{fg} \quad = \quad \begin{cases} 1 & \text{if invested by 2000} \\ 0 & \text{otherwise} \end{cases}
$$

Unfortunately, we do not usually observe the exact *valuation* that an IPP places on its investment opportunity. We only observe whether the expected value of investing today was greater than the expected value of deferring investment. As a result, we need to normalize the unobserved and unidentified scale of valuation.[53] We choose to do so by normalizing the scale with respect to η, the firm-specific component of investment cost: we set $\sigma_{\eta} = 1$

Estimation of the other two models (NPV, FWL) is same as above except $\beta E_t(V_{t+1})$ is replaced with the appropriate alternative:

- NPV Model: Zero
- FWL Model: $\max\{\ 0,\ \beta\ E_t\text{NPV}_{t+1}(\delta_{t+1} = 1, K^{*}_{t+1}),\ \ldots\ ,\ \beta^{T}\ E_t\text{NPV}_{t+T}(\delta_{t+T} = 1, K^{*}_{t+T})\ \}$

---

[53] This is analogous to the need to normalize the variance in some Probit models.

B Appendix: Solving $E_t(V_{t+1})$

There are four basic cases for $U_t(\delta_t, K_t \mid \psi_t, \eta_t)$:

1. Enactment, Entry ($\psi_t = 1, \delta_t = 1$)
2. No Enactment Yet, Entry ($\psi_t = 0, \delta_t = 1$)
3. Enactment, No Entry ($\psi_t = 1, \delta_t = 0$)
4. No Enactment Yet, No Entry ($\psi_t = 0, \delta_t = 0$)

Case 1 and 3: Enactment

Given that the IPP has entered ($\delta_t = 1$), the state has enacted restructuring legislation ($\psi_t = 1$), and a value η_t

$$U_t(\delta_t = 1, K_t \mid \psi_t = 1, \eta_t) \quad = \quad -[\ C_t(K_t, \psi_t = 1) + \eta_t\ ] + \left(\sum_{h=1}^{H} \beta^h \pi_{t+h|t}(\psi_{t+h} = 1) + \xi \right) K_t$$

Moreover, if the firm does not enter ($\delta_t = 0$), it faces (ignoring initial discounting)

$$\begin{aligned}
E_t(V_{t+1} \mid \psi_{t+1} = 1) \quad &= \quad E_t[\max_{\delta_{t+1}, K_{t+1}} \{U_{t+1}(\delta_{t+1} = 1, K_{t+1} \mid \psi_{t+1} = 1, \eta_{t+1})\ ,\ \beta\ E_{t+1}[V_{t+2}]\}\ ] \\
&= \quad \int_{-\infty}^{\eta^*_{t+1}} U_{t+1}(\delta_{t+1} = 1, K_{t+1} \mid \psi_{t+1} = 1, \eta_{t+1} = u)\ f_\eta(u)\ du \\
&\quad\ + \int_{\eta^*_{t+1}}^{+\infty} \beta\ E_{t+1}[V_{t+2} \mid \psi_{t+1} = 1]\ f_\eta\ d\eta \\
&= \quad [\ U_{t+1}(1, K_{t+1} \mid \psi_{t+1} = 1, \eta_{t+1}) + \eta_{t+1}\ ]\ \Phi(\frac{\eta^*_{t+1}}{\sigma_\eta}) + \underbrace{\frac{1}{\sqrt{2\pi}}\ \sigma_\eta\ e^{-\frac{(\eta^*_{t+1})^2}{2\sigma^2_\eta}}}_{-E(\ \eta\ \mid\ \eta\ \leq\ \frac{\eta^*_t}{\sigma_\eta}\ )} \\
&\quad\ + \beta\ E_{t+1}[V_{t+2} \mid \psi_{t+2} = 1]\ \left(1 - \Phi(\frac{\eta^*_{t+1}}{\sigma_\eta})\right) \\
&\text{where} \\
\eta^*_{t+1} \quad &= \quad -C_{t+1}(K_{t+1}, 1) + \left(\sum_{h=1}^{H} \beta^h \pi_{t+1+h|t}(1) + \xi \right) K_{t+1} \\
&\quad\ - \beta\ E_{t+1}[V_{t+2} \mid \psi_{t+2} = 1]
\end{aligned}$$

But note that $E_{t+T}(V_{t+T+1}) = 0$. Therefore

$$\begin{aligned}
E_{t+T-1}(V_{t+T} \mid \psi_{t+T} = 1) &= E_{t+T-1}\Big[\max_{\delta_{t+T}, K_{t+T}} \ \{ \ U_{t+T}(1, K_{t+T} \mid \psi_{t+T} = 1, \eta_{t+T}) \ , \ 0 \ \} \ \Big] \\
&= \int_{-\infty}^{\eta^*_{t+T}} U_{t+T}(\delta_{t+T} = 1, K_{t+T} \mid \psi_{t+T} = 1, \eta_{t+T} = u) \ f_\eta(u) \ du \\
&\text{where} \\
\eta^*_{t+T} &= -C_{t+T}(K_{t+T}, 1) + \left(\sum_{h=1}^{H} \beta^h \pi_{t+T+h|t}(1) + \xi \right) K_{t+T}
\end{aligned}$$

The solution for $E_t(V_{t+1})$ can be obtained by means of backward recursion, starting with the above solution for $E_{t+T-1}(V_{t+T})$ and using the following solution for optimal capacity choice:

$$K_{t+1} = \max \left\{ 0 \ , \ \frac{1}{2\omega} \left[\ \sum_{h=1}^{H} \beta^h \pi_{t+h|t}(\psi_{t+h} = 1) + \xi \ \right] \right\}$$

Case 2 and 4: No Enactment Yet

Given that the IPP has entered ($\delta_t = 1$), the state has not yet enacted restructuring legislation ($\psi_t = 0$), and a value η_t

$$\begin{aligned}
U_t(\delta_t = 1, K_t \mid \psi_t = 0, \eta_t) &= -[\ C_t(K_t, \psi_t = 0) + \eta_t \ ] \\
&+ \underbrace{(1-\lambda)^H \ \left(\sum_{t=1}^{H} \beta^t \pi_{t+h|t}(\psi_{t+h} = 0) \ + \ \xi \right) \ K_{t+1}}_{\text{Scenario with no restructuring}} \\
&+ \underbrace{\sum_{s=1}^{H} \left[\ \lambda(1-\lambda)^{s-1} \left(\sum_{h=1}^{H} \beta^h \pi_{t+h|t}(\ \psi_{t+h} = I(h \le s) \ ) \ + \ \xi \right) \ K_{t+1} \right]}_{\text{Scenarios with restructuring}}
\end{aligned}$$

Moreover, if the firm does not enter ($\delta_t = 0$), it faces (ignoring initial discounting)

$$
\begin{aligned}
E_t(V_{t+1}) \quad &= \quad E_t[\max_{\delta_{t+1},K_{t+1}} \{\ U_{t+1}(\psi_{t+1}=1, K_{t+1} \mid \psi_{t+1}=0, \eta_{t+1})\ ,\ \beta\ E_{t+1}[V_{t+2}]\ \}\ ] \\
&= \quad \lambda\ \Bigg\{ \int_{-\infty}^{\eta^*_{t+1}(1)} U_{t+1}(\delta_{t+1}=1, K_{t+1} \mid \psi_{t+1}=1, \eta_{t+1}=u)\ f_\eta(u)\ du \\
&\qquad + \int_{\eta^*_{t+1}(1)}^{+\infty} \beta\ E_{t+1}[V_{t+2} \mid \psi_{t+2}=1]\ f_\eta(u)\ du \Bigg\} \\
&\qquad +(1-\lambda)\ \Bigg\{ \int_{-\infty}^{\eta^*_{t+1}(0)} U_{t+1}(\delta_{t+1}=1, K_{t+1} \mid \psi_{t+1}=0, \eta_{t+1}=u)\ f_\eta(u)\ du \\
&\qquad + \int_{\eta^*_{t+1}(0)}^{+\infty} \beta\,(\lambda\ E_{t+1}[V_{t+2} \mid \psi_{t+2}=1] + (1-\lambda)\ E_{t+1}[V_{t+2} \mid \psi_{t+2}=0])\, f_\eta(u)\ du \Bigg\} \\
&= \quad \lambda\ \Bigg\{ [\ U_{t+1}(1, K_{t+1} \mid 1, \eta_{t+1}) + \eta_{t+1}\ ]\Phi(\frac{\eta^*_{t+1}(1)}{\sigma_\eta}) + \frac{1}{\sqrt{2\pi}}\ \sigma_\eta\ e^{-\frac{(\eta^*_{t+1}(1))^2}{2\sigma^2_\eta}} \\
&\qquad + \beta\ E_{t+1}[V_{t+2} \mid \psi_{t+2}=1]\ \left(1 - \Phi(\frac{\eta^*_{t+1}(1)}{\sigma_\eta})\right)\ \Bigg\} \\
&\qquad +(1-\lambda)\ \Bigg\{ [\ U_{t+1}(1, K_{t+1} \mid 0, \eta_{t+1}) + \eta_{t+1}\ ]\Phi(\frac{\eta^*_{t+1}(0)}{\sigma_\eta}) + \frac{1}{\sqrt{2\pi}}\ \sigma_\eta\ e^{-\frac{(\eta^*_{t+1}(0))^2}{2\sigma^2_\eta}} \\
&\qquad + \beta\ \ (\lambda E_{t+1}[V_{t+2} \mid 1] + (1-\lambda)E_{t+1}[V_{t+2} \mid 0]\ )\left(1 - \Phi(\frac{\eta^*_{t+1}(1)}{\sigma_\eta})\right)\ \Bigg\}
\end{aligned}
$$

where

$$
\begin{aligned}
\eta^*_{t+1}(1) \quad &= \quad -C_{t+1}(K_{t+1}, 1) + \left(\sum_{h=1}^{H} \beta^h \pi_{t+1+h|t}(1) + \xi\right) K_{t+1} - \beta\ E_{t+1}[V_{t+2} \mid \psi_{t+2}=1] \\
\eta^*_{t+1}(0) \quad &= \quad -C_{t+1}(K_{t+1}, 0) \\
&\qquad +(1-\lambda)^H\ \left(\sum_{t=1}^{H} \beta^t \pi_{t+1+h|t}(\psi_{t+1+h}=0)\ +\ \xi\right)\ K_{t+1} \\
&\qquad +\sum_{s=1}^{H} \left[\ \lambda(1-\lambda)^{s-1} \left(\sum_{h=1}^{H} \beta^t \pi_{t+1+h|t}(\ \psi_{t+1+h} = I(h \le s)\ )\ +\ \xi\right)\ K_{t+1}\ \right] \\
&\qquad - \beta\ \{\ \lambda\ E_{t+1}[V_{t+2} \mid \psi_{t+2}=1] + (1-\lambda)\ E_{t+1}[V_{t+2} \mid \psi_{t+2}=0]\ \}
\end{aligned}
$$

But note that $E_{t+T}(V_{t+T+1}) = 0$. Therefore

$$\begin{aligned}
E_{t+T-1}(V_{t+T}) \quad &= \quad E_{t+T-1}[\ \max_{\delta_{t+T},K_{t+T}} \{\ U_{t+T}(\delta_{t+1}=1, K_{t+1} \mid \psi_{t+1}=0, \eta_{t+1})\ ,\ \beta\ E_{t+1}[V_{t+2}]\}\ ] \\
&= \quad \lambda\ \left\{ \int_{-\infty}^{\eta^*_{t+T}(1)} U_{t+T}(\delta_{t+T}=1, K_{t+T} \mid \psi_{t+T}=1, \eta_{t+T}=u)\ f_\eta(u)\ du \right\} \\
&\quad\quad +(1-\lambda)\ \left\{ \int_{-\infty}^{\eta^*_{t+T}(0)} U_{t+1}(\delta_{t+T}=1, K_{t+T} \mid \psi_{t+T}=0, \eta_{t+T}=u)\ f_\eta(u)\ du \right\}
\end{aligned}$$

where

$$\begin{aligned}
\eta^*_{t+T}(1) \quad &= \quad -C_{t+T}(K_{t+T},1) + \left(\sum_{h=1}^{H} \beta^h \pi_{t+T+h|t}(1) + \xi \right) K_{t+T} \\
\eta^*_{t+T}(0) \quad &= \quad -C_{t+T}(K_{t+T},0) \\
&\quad\quad +(1-\lambda)^H\ \left(\sum_{h=1}^{H} \beta^h \pi_{t+T+h|t}(\psi_{t+T+h}=0)\ +\ \xi \right)\ K_{t+1} \\
&\quad\quad + \sum_{s=1}^{H} \left[\ \lambda(1-\lambda)^{s-1} \left(\sum_{h=1}^{H} \beta^h \pi_{t+T+h|t}(\ \psi_{t+T+h} = I(h \le s)\ )\ +\ \xi \right)\ K_{t+T}\ \right]
\end{aligned}$$

The solution for $E_t(V_{t+1})$ can be obtained by means of backward recursion, starting with the above solution for $E_{t+T-1}(V_{t+T})$ and using the following solution for optimal capacity choice:

$$\begin{aligned}
K_{t+1} \quad = \quad \max\Bigg\{\ 0\ ,\ \frac{1}{2\omega} \Bigg[& (1-\lambda)^H\ \left(\sum_{t=1}^{H} \beta^t \pi_{t+1+h|t}(\psi_{t+1+h}=0)\ +\ \xi \right) \\
& + \sum_{s=1}^{H} \left(\ \lambda(1-\lambda)^{s-1} \sum_{h=1}^{H} \beta^h \pi_{t+1+h|t}(\ \psi_{t+1+h} = I(h \le s)\ )\ +\ \xi \right) \Bigg]\ \Bigg\}
\end{aligned}$$

C Appendix: Data

Variables in Structural Analysis

$\mathsf{Age30}_g$: Percentage of generation capacities more than 30 years old in g in 1996

$\mathsf{BondYield}_t$: Average bond yield for Moody's Baa Corporate Bond

$\mathsf{DivFlag}_{gt+h|t}$: Dummy for whether major divestitures have occurred in state g by $t+h$

$\mathsf{LegPassFlag}_{gt+h}$: Dummy for whether restructuring legislation has been enacted in g by $t+h$

$\mathsf{LegYear}_{gt+h}$: Number of years since state g enacted restructuring by $t+h$

$\mathsf{IntCap96}_i$: Index for generation capacity owned by firm i outside the U.S. in 1996

$\mathsf{LogLDFact}_{gt+h|t}$: Log of Forecasted load factor in the NERC subregion where state g is located

$\mathsf{LogLoad}_{gt+h|t}$: Log of the forecasted demand (billions Kwh) in NERC subregion for state g

$\mathsf{P96}_g$: Average retail electricity price (cents/Kwh) in state g in 1996

$\mathsf{LogRM}_{gt+h|t}$: Log of Forecasted reserve margin in the NERC subregion where state g is located

STNOX_g : Average NO_x emission (lbs/MMBtu) from electricity generation in g in 1996

USIOU_i : Dummy for whether firm i is affiliated with some major utilities

$\mathsf{USCap96}_i$: Index for nonutility generation capacity owned by firm i inside the U.S. in 1996

NERC Subregion

Table A1: NERC Subregions and Corresponding States

Region	States	Region	States
ECAR	IN, KY, MI, OH, WV	ERCOT	TX
FRCC	FL	MAAC	DE, MD, NJ, PA
MAIN	IL, WI	MAPP	IA, MN, ND, NE, SD
NPCC-NE	CT, MA, ME, NH, RI, VT	NPCC-NY	NY
SERC	AL, GA, MS, NC, SC, TN, VA	SPP	AR, KS, LA, MO, OK
WSCC-CNV	CA	WSCC-NWP	ID, MT, NV, OR, UT, WA
WSCC-RA	AZ, CO, NM, WY		

IPP Sample

Data on 41 IPPs were collected for the paper. The IPPs were slected based on the following qualifications: [1] the firm must be listed in either *UDI Who's Who at Electric Power Plants (Ninth Edition)* published by the Utility Data Institute or *205 Independent Power Producers (1999 Edition)* published by the Global Energy Report, McGraw-Hill Companies [2] the firm must have at least 750 Megawatts (MW) of net equity in merchant power plants as of January 1, 2001. These two conditions ensure that fairly comprehensive data will be available for the firms and that the firms will be nonutility generators whose main line of business is serving the general wholesale electricity market. The sample includes almost all of the major IPPs affiliated with large investor-owned electric utilities (e.g. Duke Energy North America), almsot all of the large U.S. based players in the international wholesale electricity markets (e.g. AES), and several of the major U.S. energy traders (e.g. Enron). Table A2.1 lists all 41 IPPs.

Table A2.1: The 41 Independent Power Producers in the Data

AES Corp	American National Power	Aquila Energy / UtilCo
Caithness Energy	CalEnergy	Calpine
CMS Generation	Coastal Power Corp	Cogentrix Energy
Columbia Electric	Constellation Power	Continental Energy Services
CSW Energy	Dominion Energy	Duke Energy North America
Dynegy	Edison Mission Energy	El Paso Energy
Enron International	EPG (Entergy Power Group)	FPL Energy
GE Global O&M Service	GPU International Inc	Illinova Generating
Indeck Energy Services	LG&E Energy Corp	LS Power
NRG Energy	Ogden Energy	Panda Energy International
PP&L Global	PSEG Global	Reliant Energy
Sempra Energy Resources	Sithe Energies	Southern Energy
Tenaska	Texaco Global Gas & Power	Tomen Power
Tractebel Power	U.S. (PG&E) Generating	Wheelabrator Technologies

We focus our analysis on the major IPPs: IPPs that have the capability to enter generation markets nationally. To determine whether an IPP is "major," we employ the following criteria: [1] the firm must own at least 500MW of capacity internationally or domestically or at least 100 MW both internationally and domestically before the first year of our sample period (1996); [2] if a firm does not satisfy [1], it can still be selected if it is affiliated with large investor-owned electric utilities and owned some capacity internationally or domestically before 1996; [3] There is no information in *205 Independent Power Producers (1999 Edition)* that indicates the firm's main goal is not to participate in generation markets nationally. [1] and [2] are meant to ensure that the firm has the experience and financial strength to enter generation markets nationally during our sample period. [3] is a criterion using more specific information availablke about an individual firm. Using [1] and [2], we exclude the following firms: Aquila Energy, Caithness Energy, Columbia Electric, Continental Energy, Indeck Energy Services, LS Power, Panda Energy Interational Inc, Sempra Energy Resources and Tenaska. Using [3], we further eliminate the following firms:

Table A2.2: IPPs Eliminated by Criterion [3]

Firm	Reason
CalEnergy	its core business is geothermal generation
CSW Energy	it has targeted the Texas and southeastern U.S. markets[54]
Dominion Energy	its business focus is on Midweset and Northeastern markets
GE Global O&M Services and Texaco Global Gas & Power	both are affiliates of firms that own significant generating technologies and use their plants as "displays"
GPU International	its business focus is on Australia and UK
Illinova Generating	merged with Dynegy during the sample period
Ogden Energy	its business focus is overseas markets. [55]
PSEG Global	its business focus is on overseas markets, e.g., Latin America
Sithe Energies	its business focus is on New England, New York and overseas [56]
Tomen Power	most of its activities are outside U.S. [57]
Tractebel	its focus is on the northeastern market
Wheelabrator Technologies	its core business is waste-to-energy facilities[58]

After these steps, we are left with 20 major IPPs for the purpose of our analysis. Table A3 shows some summary statistics for these IPPs.

Table A3: The 20 "major" Independent Power Producers in the Sample

Firm	USIOU	IntCap96	USCap96
AES Corp	0[a]	3	2
American National Power	0	3	2
CMS Generation	1	2	2
Calpine	0	0	3[b]
Coastal Power	0	1	1
Cogentrix Energy	0	0	2
Constellation Energy Services	1	1	1
Duke Energy North America	1	1	1
Dynegy	0	0	3
EPG	1	1	0
Edison Mission	1	3	3
El Paso Energy	0	1	1
Enron International	0	2	1
FPL Energy	1	1	1
LG&E Energy	1	1	1
NRG Energy	1	2	1
PP&L Global	1	1	0
Reliant Energy	1	1	0
Southern Energy	1	3	1
U.S. Generating	1	0	3

a. AES bought CILCORP, an U.S. utility in late 1998.

b. May include some capacity they built and operated but not owned

---

[54] *205 Independent Power Producers (1999 Edition)*, p. 90. Another factor for our exclusion of CSW Energy is that the firm had been in the process of being taken over by American Electric Power (AEP) during our sample period. AEP was an active player internationally but had no domestic IPP activities hence is not in our sample.

[55] "the company's first efforts were mostly mass-burn waste-to-energy plants, but more recently, it has focused on fossil-fueled projects in overseas markets" (*205 Independent Power Producers (1999 Edition)*, p. 227.). Ogden has also been acquiring renewable energy project in the U.S. But none of these is the focus on "major" IPPs, whose plant are mostly gas-based.

[56] Most of Sithe's capacities in the U.S. were bought before 1996. Most of its activities since 1996 have been internationally.

[57] Tomen Power is owned by a Japanese company, Tomen Corp. of Tokyo.

[58] "It no longer develops non-waste-to-energy projects in the U.S.", *205 Independent Power Producers (1999 Edition)*, p. 340.

It is reasonable to think that the difference in experience gained from operating power plants vary coarsely with the size of capacity. Consequently, based on the capacity distribution in the data, we choose to discretize the two "merchant power experience" variables in the following manner:

$$\mathsf{IntCap96} = \begin{cases} 0 & \text{if no intn'l projects in 1996} \\ 1 & \text{if less than 500 MW} \\ 2 & \text{if less than 1500 MW} \\ 3 & \text{if at least 1500 MW} \end{cases} \qquad \mathsf{USCap96} = \begin{cases} 0 & \text{if no US projects in 1996} \\ 1 & \text{if less than 500 MW} \\ 2 & \text{if less than 1000 MW} \\ 3 & \text{if at least 1000 MW} \end{cases}$$

The cut-off points are based on the data. Earlier experiments altering the cut-off values (e.g. choosing 1000 instead of 1500 MW and vice versa) did not appear to change the empirical results qualitatively.

Data Source

The investment and firm characteristic data for each of the independent power producers in the sample were collected over several years (1996-2001). The actual data set contains 41 IPPs. The sample used for estimation was whittled down to 20, as described in the last section. The main foundation of the IPP data comes from the firms themselves, either through postings on their web sites or through personal communication. Data was also augmented with information from popular trade presses. Many of the trade presses, such as the weekly *Global Report* published by the McGraw-Hill Companies, have a section that lists power plant transactions. Also of particular help was the online newsletter e-published by *Energyonline*.[59] The newsletter provides notification and summaries of the relevant press releases associated with the electricity industry. Lastly, data was also acquired from various releases of the McGraw-Hill publication *205 Independent Power Producers*. This data source was very useful in detailing the international operations of the IPPs. As much as possible, data acquired from third-party sources were later confirmed with sources closer to the firm.

Information on utility divestiture sales were gathered from various issues of the *Electric Power Monthly* published by the Energy Information Agency, the primary agency within the U.S. Department of Energy that collects and publishes data on energy industries. Information about the divested power plants themselves were obtained from the EIA annual publication *Inventory of Power Plants*. Information on state-level electricity restructuring programs was obtained from the EIA monthly update of the status of electricity restructuring.[60]

---

[59] http://www.energyonline.com

[60] http://www.eia.doe.gov/cneaf/electricity/chg_str/regmap.html

The market forecast data used in this analysis were obtained from the EIA. The forecasts are from the supplemental tables of the Annual Energy Outlook (AEO) forecast publication. Releases of the forecast from 1996 to 2000 were obtained. Although our copy came from correspondence with the very capable and helpful staff at the EIA, an archive of the forecasts have since been posted on the EIA website.[61] Market forecast data were also obtained from the North American Electric Reliability Council (NERC), the private governing association of electric transmission and distribution utilities in North America. Most of the data is similar to the AEO data as AEO bases much of their forecast on this NERC information. The NERC information can be found in their annual "Electricity Supply and Demand" (ES&D) publication. The AEO data is used for all market forecasts except load factor which is based on NERC data.

---

[61] Previously, they only posted the current forecasts. URL is http://www.eia.doe.gov/oiaf/aeo/index.html