The Market Response to Restructuring: A Behavioral Model*

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Abstract

In this paper, I model the behavior of producers, consumers, and regulators in deciding to restructure the electricity sector and estimate their equilibrium response to the newly restructured market. The empirical model consists of simultaneous price and restructuring equations with endogenous switching and cross-equation correlation in the errors. This approach allow me to account for the influence of special interest groups and potential selection bias in which countries choose to restructure. I estimate distinct shifts from restructuring in both industrial and residential prices, and for English speaking, Scandinavian, and South American countries. I find that in all countries, it is industrial consumers that experience the price effects of restructuring, while residential consumers remain largely unaffected. In English speaking and Scandinavian countries, industrial prices decrease while in South American countries they increase. This is consistent with the political-economic environment in which these countries have considered restructuring.

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1 Introduction

How do producers and consumers respond to restructuring in the electricity sector? In this paper, I estimate the market response to restructuring as measured by the change in end-user price. My approach is founded on the idea, developed in the regulation theory literature (Joskow and Noll (1981), Stigler (1971), Peltzman (1976), and Becker (1983)), that restructuring is the outcome of a political process in which price plays a role. Applied to the electricity supply industry, not only will restructuring induce a response by consumers and producers, but the interests of consumers and producers also enter regulators' utility functions. Here, I present a model of the joint determination of electricity price and restructuring to estimate the market response to restructuring in different countries and to identify the consumer groups that experience the benefits of restructuring.

I build on a small existing empirical literature on restructuring in the electricity supply industry that draws conclusions from variation across states in the U.S. or countries.[1] The existing literature has focused on predicting the probability of restructuring or alternatively the impact of restructuring on electricity prices. Building on insights from these descriptive models, I shift focus to estimation of a behavioral parameter that represents interactions of regulators, producers, and consumers that they themselves, but not the econometrician, observe. I estimate the market response to restructuring *per se* by controlling for selection bias that occurs if high regulated prices simultaneously increase the probability of restructuring, as well as for shifts in costs and interest group support. The estimated shift in equilibrium end user electricity prices is of interest to policy makers as they evaluate the efficacy and welfare effects of existing restructuring efforts and develop electricity policy for the future.

In the model, regulators, facing pressure from diverse interest groups,

[1] White (1996) compares the incidence of restructuring across states in the U.S. with electricity prices and production costs and concludes that it is the gap between the regulated price and the price that would prevail under competition that is critical to overcome regulatory inertia. Ando and Palmer (1998) estimate a reduced form duration model of the time to restructuring across states as a function of price and other factors. Wolak (1997) analyzes time-series data from restructured power markets in several countries and shows that ex ante market structure and the new market rules can lead alternatively to competition or market power in restructured markets. Steiner (2001) uses panel data in a random effects model to predict movement in prices and investment that results from different restructuring measures.

consider whether or not to restructure by subjectively weighing prospective producer profit and consumer surplus under regulated and potentially competitive regimes. At the same time, producers maximize profit given their information about the regulated or market price. The decision to restructure evolves from the interaction of self-interested individuals and is affirmative when there is sufficient net support for restructuring. I estimate simultaneous equations in which price and the decision to restructure are jointly determined and allow for cross-equation correlation in the errors.

I use the term "regulators" loosely here to refer to the legislators, executive, ministry, sectoral regulator, state-owned utility managers, or combination of institutions who are charged with oversight of the electricity supply industry prior to restructuring in each country. These institutions differ across countries and are often re-designed as a part of restructuring.[2] These institutional details and the constraints posed by the structure of the decision-making process influence the incentives of political actors and their preferences with respect to special interest groups. However, at this stage, I do not provide a model that reflects how a *particular* regulatory institution takes account of prices in deciding to restructure. Instead, I provide a macro model in which regulatory institutions *in general* make decisions based on their subjective valuation of prices.[3]

For the purposes of this analysis, I define restructuring as the unbundling of generation from transmission. This initial step in restructuring the electricity sector is an application of the "Bell Doctrine", in which natural monopoly functions (transmission) are isolated from potentially competitive functions (generation) in order to prevent market abuses by an integrated, dominant supplier.[4] To the extent that unbundling induces competition in generation, it could reduce pricing inefficiencies that arise under regulation. Because generation occupies a large portion of electricity costs, unbundling could result

[2] In some countries, (e.g. Argentina) cabinet ministers who controlled the electricity sector were replaced by independent sectoral regulators under restructuring, while in other countries (e.g. the United States), an independent sectoral regulator was well-established prior to restructuring. In deciding whether or not to restructure, the relevant government institutions will thus vary across countries, and may consist of a consensus or hybrid of institutions even within one country.

[3] The need to aggregate institutional and regulatory details and decisions in a way that is comparable across countries requires this broader model, where the "regulator" is a hybrid of political actors that may differ within and between countries, but where his objective function depends on the level and evolution of prices.

[4] Joskow and Noll (1999)

in a significant reduction in wholesale and end-user prices.[5]

In implementing the empirical model, I use a panel data set with average, annual, end-user electricity prices for a sample of OECD and South American countries. I estimate a distinct price response for different groups of countries because the impetus to restructure comes from the ex ante economic and political climate in a country, and thus defines the implementation, goals, and efficacy of restructuring. I find that prices to industrial consumers decrease in response to restructuring in English speaking and Scandinavian countries, and increase in South American countries. In addition, I estimate the model separately for industrial and residential consumers to identify who benefits from restructuring. I find that in English speaking and Scandinavian countries, industrial consumers capture all of the benefits of restructuring, while in South American countries, they face a larger increase in price than do residential consumers.

The paper is organized as follows: Section 2 summarizes the institutional development in electricity sectors of different countries and concludes with empirical predictions that differ according to cross-country heterogeneity in initial conditions. Section 3 develops the underlying theory and empirical model, Section 4 discusses the data, Section 5 provides results, and finally, Section 6 suggests directions for further research.

2 Historical Development of the Electricity Sector Across Countries

Across countries, different initial conditions have driven the decision to restructure and thus the evolution of electricity prices that has followed. In particular, heterogeneity in natural resource availability, generation technology, patterns of ownership and control, and macro-economic and political environment have lead to a different market response to restructuring in different countries.

Prior to restructuring, the dominant status quo tended toward two alternative models. In Europe and former European colonies, the sector was controlled by state owned, vertically integrated monopolies operated by cabinet ministries. In other countries, regulated private companies played a

[5] For example, in the UK generation occupies 65 percent of electricity costs, according to *Electricity Market Reform, An IEA Handbook* (1999).

larger role. In the U.S. and Japan, vertically integrated but decentralized investor-owned utilities were subject to rate-of-return regulation, while in Scandinavia, the state, municipalities, and private industry jointly owned and loosely regulated the electric utilities.

In a state owned enterprise (SOE), managers of integrated electric utilities lack autonomy from political figures who place the greatest value on their own (potentially short term) political prospects.[6] In general, the political vulnerability of utility managers leads to inefficient use of production inputs, uneconomic levels of investment, and prices that do not reflect the costs of production. The particular inefficiencies that have developed under state ownership in stable, financially solvent, developed countries have differed from the inefficiencies that have persisted in politically volatile, developing countries.

In Commonwealth countries such as England, Australia, and New Zealand, the inefficiencies that characterized the vertically integrated SOEs were most visible in their choice of production inputs and generation technologies. SOEs often employed inefficiently high levels of labor since managers would face (political) backlash if they tried to streamline employment.[7] Choices of fuel inputs and generation technology could also be driven by political expediency. In England, the state used electricity policy to support the dying coal industry by requiring the Central Electricity Generating Board (CEGB) to purchase domestic coal at above world-market prices and passing the premium on to consumers through the integrated electricity monopoly.[8]

In contrast, in South America, vertically integrated SOEs operated in a climate characterized by frequent changes of political regime and violent economic swings, with serious consequences for the electricity sector under state ownership.[9] Politicians facing pressures to balance budgets while satisfying constituents in the short term could re-direct cash flows from capital improvements in the electricity sector to other government projects with more immediate political payoffs. Capital starvation thus lead to exceptional rates

[6] Noll (2000)

[7] Noll (2000)

[8] Cross (1996) In fact, even under restructuring the English made special provision through sales to franchise customers to gradually phase out the mandatory use of domestic coal.

[9] In Argentina, for example, since the 1930's, political control oscillated between authoritarian and populist/corporatist regimes with great frequency, continuing even into the 1980's with army rebellions in 1987 and 1988.

of unavailability, power outages, and problems with quality and supply.[10] Moreover, politicians used electricity prices to redistribute income or accomplish other objectives rather than to communicate real, cost-based signals to producers and consumers. For years, electricity prices were kept inefficiently low to curry favor with constituents.[11]

In contrast, electricity was produced in Scandinavian countries by decentralized (though vertically integrated) private and public utilities, and political interference and uneconomic use of production inputs posed less of a problem. Even prior to restructuring, low end-user prices reflected use of abundant and inexpensive hydro resources in generation, as well as the success of informal regulation through the leadership of the dominant state-owned utilities and response of fringe producers.

The institutional, technological, and macro-economic histories of English speaking, South American, and Scandinavian countries thus suggest different prospects for restructuring. In English speaking countries, restructuring could improve efficiency by allowing economic use of production inputs (labor and fuel) and diversification of generation technology. If effective, restructuring could then lead to lower electricity prices.

In contrast, in South America, restructuring could improve efficiency if it helped to distance electric utility control and operation from political interests. With the creation of an independent sectoral regulator to oversee the electricity sector, electricity prices would no longer be subject to political manipulation, and would be expected to increase to cover production costs and to communicate the need to invest until capacity became sufficient to satisfy demand.

In Scandinavia, rather than a sweeping program to cure serious ailments, restructuring presented an opportunity to formalize and institutionalize mechanisms to encourage competition among already decentralized producers. As a group, the Scandinavian countries could realize economies of scale and scope from their technological complementarities and prospective opportunities to balance supply and demand at the regional level.[12] If effective, these

[10] Abdala and Bastos (1993)

[11] During the period of hyper-inflation in the late 1980's in Argentina, electricity pricing was used as a substitute for fiscal and monetary manipulation of the macro-economy according to EIA (1998).

[12] In Norway, hydro power generates more than 99 percent of electricity. In Sweden, hydro power (50 percent) and nuclear power (30 percent) dominate generation. In Finland, 35 percent of electricity is produced in combined heat and power plants while the remainder

efficiency gains could be reflected by lower electricity prices in Scandinavia.

In the remainder of this paper, these differences in the evolution of the electricity sector across countries guide the model which I use to estimate the market response to restructuring.

3 The Model

I begin with the empirical specification of the economic quantities that enter the theory and model and then discuss the measurable counterparts that I use to estimate the market response to restructuring.

3.1 The Economic Quantities

Here I describe the economic agents, their choices, and objectives; i.e., how regulators, producers, and consumers make decisions conditional on regime. This causes unconditional mean prices to diverge under regulation and restructuring, and it is the parametric representation of this shift that I seek to estimate.

3.1.1 The Regulator's Political Support Equation

In the model, the regulator decides whether to continue to regulate or to restructure the electricity sector by maximizing the utility that he derives from political support conferred by different interest groups.[13] In particular, support for restructuring from industrial groups, S_I, will depend on the difference in their expected profits under the regulated and prospective market prices, (P^R, P^D), while support from consumer groups, S_C will depend on differences in their consumer surplus under P^R and P^D.

is split between nuclear, hydro, and fossil fuels (31, 18, and 17 percent respectively). In Denmark, electricity is produced with fossil fuels, intensive use of combined heat and power plants, and a relatively large share of renewables. The Nordpool, the world's first international electricity market began operation in 1996. (IEA (1999))

[13]In the electricity sector, the relevant interest groups include incumbent producers who have made large investments in production capacity (e.g. nuclear generators), large consumers who may be able to purchase electricity directly from producers in a restructured market, potential entrants, and a diffuse group of residential and small industrial consumers.

The regulator cares about *total* political support but has idiosyncratic preferences over the distribution of support from different groups depending on his propensity to seek personal rents, his political ideology, and his effort to exercise state policy objectives. This gives rise to a utility function for restructuring:

$$S(P, D) = U(S^I(P^D, P^R), S^C(P^D, P^R); \lambda) \tag{1}$$

where λ parameterizes the regulator's subjective valuation of support from industry and consumers.

The regulator maximizes utility by choosing alternatively to continue with the regulated regime ($D = 0$) at his chosen P^R, or to restructure ($D = 1$) and relinquish direct control over prices. He will choose to restructure when his net political support from restructuring is positive.

Moving to the econometric specification, the econometrician does not observe the regulator's utility index but observes his actual decision to restructure, as well as the actual electricity prices under the regime in place:

$$\begin{array}{ll} \{(D = 1), P^D\} & \text{if} \quad S(P, D) > 0 \\ \{(D = 0), P^R\} & \text{if} \quad S(P, D) \leq 0 \end{array}$$

I specify political support, S (and thus D, its empirical realization) as a linear function of instruments X, which proxy for interest groups' expectations with respect to the difference between their surplus at the regulated versus the counterfactual competitive price. [14] Adding the random optimization error, V_2, the restructuring equation in the system is:[15]

$$S = X\lambda + V_2 \tag{2}$$

[14] In specifying the system of equations, since D appears in the price equation, the P from the price equation may not simultaneously enter the restructuring equation with a non-zero coefficient because the system would then fail to meet Heckman's (1976, 1978) logical consistency conditions.

[15] The stochastic errors are conceptualized as optimization errors since we cannot distinguish between this approach and direct inclusion of stochastic errors in agents' objective functions in estimation.

3.1.2 The Equilibrium Price Equation

The market then responds to the regulatory decision. On the demand side, aggregate demand for electricity is highly inelastic because there are few close substitutes for electricity in the short term.[16]

On the supply side, producers choose inputs to maximize profit. Their optimal choice of inputs differs across regimes because they face different constraints under regulation and restructuring. Producers know that under regulation, the regulator maximizes his measure of expected total surplus by setting regulated prices as a function of producers' costs, but that he cannot directly observe these costs.[17]

If regulators could perfectly observe producers' costs, then they could implement the first-best welfare-maximizing optimum and induce firms to produce at minimum cost. However, as Wolak (1994) shows, a moral hazard problem arises because regulated firms have hidden information about their production costs and thus may not choose inputs to minimize costs. In contrast, in a restructured competitive market, only the most efficient (cost-minimizing) firms will survive: profit maximization implies cost minimization. So production costs differ under regulation and restructuring because producers choose inputs and technology conditional on regime. The resulting equilibrium prices and quantities will thus differ across regulated and restructured regimes.[18]

I assume that electricity production entails constant marginal costs as well as fixed costs that shift with exogenous factors W_1 and W_2. Adding parameters and the random error, V_1, I specify equilibrium price as a linear function of exogenous shifts in costs and the endogenously chosen regime:

[16] Wolak and Patrick (1997) estimated own and cross-price elasticities for five classes of industrial consumers using half hourly price data from the England and Wales electricity market over a four year period. They found heterogeneity in elasticities across industries and times of day, but even the most price-responsive industry (water supply) had a maximum elasticity of under -0.30, while the steel tube, copper brass and other copper alloys, ceramic goods, and hand tools and finished metal goods industries had elasticities which ranged from 0.00 to -0.05.

[17] Typically, regulated prices are set to allow firms to recover average cost. (Joskow and Schmalensee (1986)).

[18] For example, using data from the water utility industry in California, Wolak (1994) estimates that asymmetric information in the regulated regime leads the average firm to produce twenty five percent less than it would in the first-best equilibrium.

$$P = \alpha W_2 + \delta_F D + \gamma W_1 + \delta_C W_1' D + V_1 \quad (3)$$

Then taking the difference in unconditional mean prices under restructuring and regulation returns the behavioral parameters I seek to estimate:

$$E[P^D] - E[P^R] = \delta_F + \delta_C W_1 \quad (4)$$

These are, respectively, the average and marginal (with respect to variable costs) shift in equilibrium electricity prices in response to restructuring.

3.2 Structural Assumptions

I estimate the reduced form equilibrium price equation jointly with the restructuring equation. Since the econometrician cannot perfectly observe how regulators, producers, and consumers take account of each other's actions when optimizing, I allow for correlation in the errors across equations.

In taking the model to the data, we must account for the fact that the unit of observation is a "country-year". The dynamic dimension allows us to estimate the probability of restructuring at time T, conditional on not having restructured at each time $t < T$.[19] I impose the restriction that once a country has restructured, it cannot revert to the regulated regime, i.e., the probability of restructuring is equal to one for all $t \geq T$, which is consistent with both the empirical facts and the institutional realities that make restructuring difficult to accomplish in the first place.

With respect to the cross-sectional dimension, as discussed in detail in Section 2, the shift in equilibrium prices under restructuring will differ across countries due to heterogeneity in initial conditions and objectives underlying restructuring. I account for this by introducing country indicators for English speaking, South American, and Scandinavian countries to estimate different equilibrium responses to restructuring, $[\delta_F + \delta_C W_1]_j$, for the different country types, j.

Assembling all of these elements, I estimate the following system of equations, where i indexes countries and t indexes years:

$$P_{it} = \alpha W_{2it} + [\delta_F]_j D_{it} + \gamma W_{1it} + [\delta_C]_j W_1' D + V_{1it}$$

[19] I assume that agents re-optimize at each t rather than optimizing intertemporally at $t = 0$.

$$
\begin{aligned}
S_{it} &= X_{it}\lambda + V_{2it} \\
D_{it} &= \begin{cases} 1 & \text{if } S_{it} > 0 \text{ and/or } D_{i(t-1)} = 1 \\ 0 & \text{otherwise} \end{cases}
\end{aligned} \tag{5}
$$

Since the observed D is discrete, the S equation is normalized by the standard deviation of V_2. I allow the variance of prices and therefore V_1 to differ under regulation and restructuring and assume that $V_{1it}^R, V_{1it}^D, V_{2it}$ follow a trivariate normal distribution, $h(V_1^R, V_1^D, V_2)$ with mean zero and covariance matrix Σ:

$$
\begin{bmatrix} \sigma_R^2 & \sigma_{RD} & \sigma_{R2} \\ & \sigma_D^2 & \sigma_{D2} \\ & & 1 \end{bmatrix}
$$

σ_R^2 and σ_D^2 are the variances of V_1 under regulation and restructuring, respectively. I restrict ρ, the correlation between the price and restructuring equations, to be the same across regulated and restructured regimes, so $\sigma_{R2} = \rho\sigma_R$ and $\sigma_{D2} = \rho\sigma_D$. Finally, applying conditional normal theory and performing the change of variables gives the individual contribution to the likelihood function:

$$
\begin{aligned}
&\forall\, t \leq T, \\
f(P_{it}, D_{it}) &= \frac{1}{\sqrt{\sigma_{r,d}^2}}\phi\left(\frac{V_{1it}}{\sqrt{\sigma_{r,d}^2}}\right)\left[1 - \Phi\left(\frac{-x_{it}\lambda - \rho V_{1it}/\sqrt{\sigma_{r,d}^2}}{\sqrt{1-\rho^2}}\right)\right]^{D_{it}} \times \\
&\quad \left[\Phi\left(\frac{-x_{it}\lambda_{it} - \rho V_{1it}/\sqrt{\sigma_{r,d}^2}}{\sqrt{1-\rho^2}}\right)\right]^{1-D_{it}} \\
&\forall\, t > T, \\
f(P_{it}, D_{it}) &= \frac{1}{\sqrt{\sigma_{r,d}^2}}\phi\left(\frac{V_{1it}}{\sqrt{\sigma_{r,d}^2}}\right)
\end{aligned} \tag{6}
$$

3.3 What Can Be Estimated

I now discuss the measured quantities, X, W_1, and W_2, that enter regulators', consumers', and producers' decision functions.

3.3.1 The Regulator

The X are proxies for the influence of different interest groups on regulators' choices. In general, the influence of an interest group will depend on its relative size and wealth, the magnitude of its potential gains and losses (profit and consumer surplus) under restructuring, and on the group's ability to communicate and push its agenda in the particular political and institutional environment that it faces.

I cannot measure directly the potential redistribution of total surplus among producers and consumers under restructuring. However, these economic quantities depend on both regulated electricity prices that precede restructuring and the counterfactual prices that would prevail in a restructured market.[20] Thus pre- and prospective post-restructuring prices could induce interest groups to alter their support for restructuring, and therefore change the regulator's decision.

To proxy for pre-restructuring prices, I include lagged, regulated prices.[21] While we would expect that high prices ex ante would induce greater support for restructuring by large consumers and Independent Power Producers (IPPs),they would also induce greater support for continued regulation by incumbent producers who risk facing competitive market prices under restructuring. A positive coefficient on the lagged price variable in the restructuring equation would thus reflect consumer and IPP hegemony, while a negative coefficient would be consistent with "regulatory capture".

To proxy for counterfactual prices that could prevail under restructuring, I also include the share of a country's neighbors that has restructured. Restructuring neighbors of a country could generate pressure for restructuring from its prospective large consumers and low-cost entrants who seek to participate in neighboring restructured markets.

I also use the nuclear share of production as a proxy for the influence of incumbent producers. Because nuclear production requires large investments that are typically undertaken by a single, large (often publicly owned) utility, incumbent nuclear producers are likely to seek to prevent restructuring in

[20] For an excellent discussion of how regulatory commissions in states in the U.S. evaluated the difference between regulated and prospective competitive prices in deciding whether or not to restructure their electricity sectors under the Energy Policy Act of 1992, see White (1996).

[21] In the model, electricity prices do not follow an autoregressive process, and therefore lagged prices are exogenous. Any inertia in prices over time will be captured by the input fuel price index included in the price equation.

order to avoid prospective competition from low cost Combined Cycle Gas Turbine (CCGT) producers that could cause their already sunk investment in nuclear plant to become stranded. Additionally, nuclear production tends to be concentrated, so following the logic in Stigler (1971) that concentrated lobbies tend to prevail over diffuse groups, the nuclear share is correlated with not only the incentives but also the influence of large incumbent producers.

Finally, as discussed in section 3.1, regulators facing the restructuring decision care about support from producers and consumers, but they also weigh support from different groups according to their own tastes for liberalization. In order to control for the facility that a precedent institutional setting might lend to liberalization as well as the general propensity of incumbent governments to restructure, I include an indicator for restructuring in the telecommunications sector. Experience in restructuring telecommunications may indicate a general preference for liberalization over tight regulation and control. Additionally, countries that have already restructured telecommunications may benefit from institutional economies of scale, reducing the prospective costs of restructuring electricity.

With the exception of the nuclear share, these X are included in the restructuring equation but not in the price equation.[22]

3.3.2 Equilibrium: Producers and Consumers

In the price equation, W_1 and W_2 are exogenous factors that respectively shift variable and fixed costs of producing electricity. W_1 consists of a fossil fuel (coal, gas, and oil) price index. Changes in fossil fuel prices shift the costs of fossil fuel-based production directly and the (opportunity) cost of nuclear and hydro production implicitly. The W_2 are hydro and nuclear production shares, technologies that are characterized by insignificant variable but high fixed costs.[23]

[22]Lagged electricity prices are excluded from the price equation because they do not follow an autoregressive process. Additionally, while the presence of low prices in restructured neighboring markets could shift support for restructuring within a country, i, electricity prices in i do not adjust until it has restructured internally and liberalized cross-border trade in electricity. Finally, restructuring in *telecommunications* may be correlated with *restructuring* in electricity but will not be correlated with *electricity prices*.

[23]The specification, allows marginal costs to differ across regimes so that not only may producers and consumers respond to restructuring with a *general* or *average* shift in their equilibrium behavior, but also they may incur different *marginal* costs if they alter their use of production inputs across regimes. For example, under restructuring, former SOEs

The W are included in the price equation but not in the restructuring equation because while generation technology varies contemporaneously with producers' choices, consumer demand, and thus equilibrium prices, it could influence the regulator's choice of policy and thus the probability of restructuring only with a lag that extends beyond the sample period.

4 Data

The data consist of a panel of 29 countries over the period 1986 - 1998. Sources include the International Energy Agency (IEA) Energy Prices and Taxes Data, the IEA Energy Information Data, the Organization for Economic Co-operation and Development (OECD) regulatory database for electricity, the Latin American Energy Organization (OLADE) Energy and Economic Statistics and Indicators of Latin America and the Caribbean, the Privatization International Database, the International Telecommunication Union (ITU) Privatization Survey, and regulator web sites. Countries included in the panel are OECD member countries as of 1998 (excluding Austria, Luxembourg, and Iceland), and three South American countries: Argentina, Chile, and Brazil. Data for former Eastern Block countries or countries that joined the OECD after 1986 are sometimes missing prior to the change in government or entry into the OECD. Appendix A provides details on the included countries and years.[24]

may no longer face constraints posed by state restrictions on the use of input fuels. In practice, we are unable to estimate distinct coefficients on the input price index in the two regimes because estimation of the three additional parameters (one additional marginal cost coefficient for each country type) causes an already small sample size to become insufficient. However, excluding the regime and country-specific marginal cost variables and thus implicitly assuming that marginal cost does not differ across restructured and regulated regimes is not a serious omission from the perspective of consistently estimating the average response to restructuring. In each attempted specification with regime-specific marginal cost coefficients, the estimated country type marginal cost increments were insignificant while the other estimates and in particular, $(\delta_F)_j$, remained significant and robust.

[24] In two cases, regressions were used to forecast missing data. First, a regression on residential end-use electricity prices was used to forecast the industrial end-use electricity price in Norway for five of the 12 sample years. Second, the input price index used in X_1 was available only for OECD countries, so a regression on coal and oil prices for electricity production was used to forecast equivalent observations for the three South American countries in the sample. The results are robust to exclusion of these observations.

The endogenous variables are price and the unbundling indicator. I use industrial, residential, and the ratio of industrial to residential electricity prices. The price data are the IEA annual pre-tax "average unit value" prices, calculated as average utility revenue per unit or average customer expenditure per unit, converted to U.S. dollars using Purchasing Power Parities (PPPs), and deflated to 1995 dollars using the Consumer Price Index (CPI). I use end-user prices rather than wholesale prices because these are the prices that directly reflect consumer welfare under regulation and restructuring.[25] The indicator of unbundling takes a value of one if generation is separated from transmission through either separate ownership or accounts.[26]

The control variables that compose W_1 and W_2 include an input fuel price index, the nuclear share of production, and the hydro share of production. The control variables that compose X include lagged price, the nuclear share of production, an indicator for whether a country has privatized telecommunications, and the share of neighboring countries having restructured. Finally, the indicators of country types take a value of one for countries where English is the dominant language, for South American countries, and for Scandinavian countries, respectively. Table 1 provides descriptive statistics.

Graphical inspection in Figure 1 illustrates the evolution of end-user electricity prices for industrial consumers in three very different restructuring countries: England (1990), Norway (1991), and Argentina (1992). In Argentina and to a lesser extent England, we see an initial spike in prices at the time of restructuring that is likely due to the privatization of SOEs that was synchronized with restructuring in these countries.[27] Facing the prospect of privatization, governments may maintain high electricity prices in order to appreciate share values and generate greater revenue from asset sales. Following the initial price spike at the time of restructuring in both countries, prices appear to remain relatively constant in England, while they settle into a higher, steady level in Argentina. This is consistent with the common cri-

[25]Moreover, wholesale prices that are comparable across countries and time are unavailable.

[26]It would be interesting to make the distinction between an accounting and legal separation through use of a multilevel dummy to illustrate not only the general impact of unbundling on prices, but also the incremental value to unbundling via separate accounts versus separate ownership. However, the data possess insufficient degrees of freedom to identify separately the effect of unbundling via separate ownership or accounts.

[27]The figure shows average prices for all industrial consumers and does not differentiate between the largest (e.g. more than 1 MW) and smaller industrial consumers.

Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Industrial Price	0.076	0.038	0.00	0.211
Residential Price	0.108	0.039	0.037	0.225
Industrial/Residential Ratio	0.711	0.287	0	2.500
Unbundling	0.205	0.404	0	1
Unbundling (English)	0.093	0.291	0	1
Unbundling (South America)	0.016	0.124	0	1
Unbundling (Scandinavia)	0.037	0.190	0	1
Input Prices	0.107	0.012	0.076	0.160
Hydro Share	0.026	0.027	0	0.100
Nuclear Share	0.019	0.021	0	0.078
Telecom Privatization	0.385	0.487	0	1
Neighbors Restructuring	0.138	0.318	0	1

Note: Variables Defined in Appendix A.

tique that in Argentina, pre-restructuring prices had long been excessively low to the detriment of electricity quality and supply. In contrast, in Norway, prices appear to spike down in the restructuring transition before settling at a lower, steady level. This provides heuristic evidence that the efficiency gains that motivated restructuring in Norway were achieved.

In order to evaluate whether the observed changes in prices are systematic with respect to restructuring or random, in Tables 2 and 3, I calculate the mean difference in mean prices post- and pre-restructuring for countries that have restructured. For the full set of restructuring countries, mean industrial prices and the mean industrial-residential price ratio each decrease significantly following restructuring, while mean residential prices show no significant change. In restructuring English speaking countries, mean prices decreased significantly for both industrial and residential consumers, while in South American restructuring countries, mean prices increased for both consumer types.

These comparisons suggest that prices *do* respond significantly to restructuring for at least some consumers and motivates further exploration with the system of structural equations. In the structural model, I can identify

Table 2: Average Difference in Average Performance Post- and Pre-Restructuring

Performance Measure	Mean	Standard Error
Industry Price [post - pre]∗	-0.011	0.022
Residential Price [post - pre]	-0.002	0.015
Price Ratio [post - pre]∗∗	-0.112	0.150

Note: Difference in means defined for fifteen countries that restructured in the 1986 - 1996 sample period.
∗ indicates significance (from zero) at the .1 level.
∗∗ indicates significance at the .01 level.

the shift in equilibrium market price that is associated with restructuring, while controlling for observable differences in costs and institutions as well as selection that may occur in the restructuring decision due to interactions between regulators and different political interest groups.

5 Results

I begin by estimating the model in (5), but with the restriction that ρ is equal to zero. With this restriction, maximum likelihood estimation returns least squares estimates of the price equation and probit estimates of the political support equation without accounting for their joint variation.[28] Table 4 provides the estimates from this model, and Table 5 summarizes the total effect of restructuring on equilibrium prices for each group of countries.

I then allow for selection bias that may occur if there is correlation in the price and restructuring disturbances that is unobserved by the econometrician. Table 6 provides the estimates of the full (unrestricted) model along with the LRT statistic for the null hypothesis that $\rho = 0$. Finally, Table 7 summarizes the estimated total response to restructuring for each country type using the unrestricted model.

In general, the estimates are robust to the inclusion or exclusion of the parameter ρ. However, likelihood ratio and Wald test statistics reject the

[28]The individual contribution to the likelihood in this case simplifies to $f(P_{it}, D_{it}) = \frac{1}{\sqrt{\sigma_{11}}}\phi\left(\frac{V_{1it}}{\sqrt{\sigma_{11}}}\right)[1-\Phi(a_{it})]^{D_{it}}[\Phi(a_{it})]^{1-D_{it}}$.

Table 3: Average Difference in Average Performance Post- and Pre-Restructuring by Country Type

Performance Measure	Mean	Standard Error
English speaking		
Industry Price [post - pre]∗	-0.010	0.003
Residential Price [post - pre]∗	-0.012	0.006
Price Ratio [post - pre]	-0.003	0.021
South American		
Industry Price [post - pre]∗	0.053	0.023
Residential Price [post - pre]∗	0.039	0.012
Price Ratio [post - pre]	0.188	0.214
Scandinavian		
Industry Price [post - pre]	-0.005	0.004
Residential Price [post - pre]	0.000	0.004
Price Ratio [post - pre]	-0.105	0.067

∗ indicates significance (from zero) at the .01 level.

null hypothesis that $\rho = 0$. In particular, for industrial prices and the ratio of industrial to residential prices, we reject the null hypothesis of no selection and ρ is estimated to be .936 and .973, respectively. While for residential prices, ρ, as well as most other parameters, are estimated to be insignificant.

The estimates of ρ suggest that regulators, producers, and consumers *do* take account of each other when making decisions, and that the observables do not fully explain the variation in prices and the decision to restructure. In particular, the positive estimate of ρ says that an unusually high realization of equilibrium market price tends to accompany an unusually high valuation of political support for restructuring from regulators. Additionally, while most of the coefficients of interest are similar across restricted and unrestricted models, the unrestricted model allows more precise estimation of the parameters in the restructuring equation and of the response to restructuring for the ratio of industrial to residential prices. In the unrestricted model, the response to restructuring is significant for all country types for both industrial and the ratio of industrial to residential prices.

We expect the sign of δ_j, the response to restructuring, to vary for different country types according to heterogeneity in local initial conditions that

Table 4: Least Squares and Probit Estimates: $\rho = 0$

Variable	Industrial Price	Residential Price	Price Ratio
	Price Equation		
Constant	.034	.0467*	.598*
	(.020)	(.022)	(.182)
Unbundling	.023**	.036**	.003
	(.007)	(.007)	(.070)
Unbundling (English Speaking)	-.045**	-.048	-.133
	(.011)	(.011)	(.099)
Unbundling (South America)	.021**	-.031**	.314
	(.010)	(.046)	(.078)
Unbundling (Scandinavia)	-.061**	-.083	-.097
	(.017)	(.043)	(.111)
Input fuel price	.562*	.677**	1.927
	(.171)	(.188)	(1.569)
Hydro share	-.211**	-.268**	-.566
	(.097)	(.094)	(.899)
Nuclear share	-.327**	-.059	-2.038
	(.139)	(.108)	(1.195)
Trend	-.001	-.0003	-.004
	(.001)	(.001)	(.006)
	Restructuring Equation		
Constant	-1.344**	-1.364**	-1.081
	(.366)	(.413)	(.655)
Nuclear share	-2.320	-1.245	-3.128
	(8.649)	(8.657)	(8.784)
Telecom privatization	.136	.158	.110
	(.304)	(.316)	(.291)
Lagged Price	-3.742	-2.758	-.655
	(4.097)	(3.227)	(.822)
Neighbor Restructuring	.453	.526	.386
	(.476)	(.474)	(.465)
Wald χ^2 (Ho: $\gamma_1 = \gamma_2 = \gamma_3 = 0$; $df = 3$)	42.330	2.795	27.711
Observations	309	309	303

Standard errors in parentheses.
* indicates significance (from zero) at the .05 level.
** indicates significance at the .01 level.

Table 5: Market Response to Restructuring By Country Type: $\rho = 0$

Country Type	Industrial Price	Residential Price	Price Ratio
English Speaking	-.022**	-.012	-.129
	(.010)	(.010)	(.097)
South America	.044**	.005	.316**
	(.009)	(.047)	(.070)
Scandinavia	-.038**	-.047	-.094
	(.017)	(.043)	(.096)

Standard errors in parentheses. The shift in price due to restructuring for a country i will be $\delta_i = \gamma_0 + \sum_{k=1}^{2} \gamma_k Z_{ki}$. t-statistics calculated accounting for the fact that δ_j is the sum of two estimates whose covariance must be included in the denominator.
** indicates significance at the .01 level.

has constrained the feasibility, timing, and consequences of restructuring. In general, the estimates are consistent with expectations: industrial prices change under restructuring, while residential consumers remain unaffected (outside South America). This is consistent with the fact that industrial consumers are likely to be better organized politically to move restructuring implementation in their favor and that in some restructuring countries (e.g. England, Argentina), lower voltage, lower volume (i.e. residential) consumers are excluded from participating in restructured markets in the short term.

The inference that industrial consumers capture greater benefits from restructuring than residential consumers is further substantiated by the estimates from the ratio of industrial to residential price equation. The ratio decreases significantly in English speaking and Scandinavian countries, widening the disparity between industrial and residential prices. In South American countries where prices to all consumers were unsustainably low prior to restructuring, industrial prices increase disproportionately relative to residential prices. In addition to the differential response to restructuring across countries, the estimates show interesting asymmetry in the capture of its benefits: where prices are expected to decrease, industrial consumers pay lower prices, whereas when prices are expected to increase, residential consumers experience a smaller increase in price. Since industrial demand is more elastic than residential demand, it may be less politically costly to

Table 6: Maximum Likelihood Estimates: $\rho \neq 0$

Variable	Industrial Price	Residential Price	Price Ratio
	Price Equation		
Constant	.039*	.048*	.602**
	(.019)	(.022)	(.166)
Unbundling	-.019**	.040**	-.205**
	(.007)	(.008)	(.052)
Unbundling (English Speaking)	-.019**	-.049**	-.055
	(.007)	(.011)	(.059)
Unbundling (South America)	.036**	-.032	.372**
	(.009)	(.062)	(.063)
Unbundling (Scandinavia)	-.032	-.084**	-.003
	(.021)	(.037)	(.097)
Input fuel price	.491**	.667**	1.444
	(.167)	(.188)	(1.422)
Hydro share	-.128	-.275**	-.534
	(.088)	(.093)	(.848)
Nuclear share	-.317**	-.0589	-2.122
	(.130)	(.108)	(1.132)
Trend	.00004	-.0005	.007
	(.001)	(.001)	(.006)
	Restructuring Equation		
Constant	.991**	-1.761**	2.164**
	(.280)	(.497)	(.740)
Nuclear share	-3.926	-1.248	-6.297
	(9.325)	(8.402)	(10.627)
Telecom privatization	.369	.092	-.010
	(.258)	(.332)	(.200)
Lagged Price	-23.390**	1.343	-3.431**
	(4.402)	(4.560)	(.817)
Neighbor Restructuring	.365	.538	.151
	(.432)	(.468)	(.859)
rho	.936**	-.178	.973**
	(.034)	(.173)	(.022)
LRT χ^2 (Ho: $\rho = 0$; $df = 1$	18.945**	0.162	61.923**
Wald χ^2 (Ho: $\gamma_1 = \gamma_2 = \gamma_3 = 0$; $df = 3$)	48.128**	2.202	47.139**
Observations	309	309	303

Standard errors in parentheses.
** indicates significance (from zero) at the .01 level.

Table 7: Market Response to Restructuring By Country Type: $\rho \neq 0$

Country Type	Industrial Price	Residential Price	Price Ratio
English Speaking	-.037**	-.009	-.260**
	(.007)	(.010)	(.051)
South America	.017*	.008	.167**
	(.009)	(.062)	(.067)
Scandinavia	-.051**	-.044	-.209**
	(.020)	(.037)	(.083)

Standard errors in parentheses. The shift in price due to restructuring for a country i will be $\delta_i = \gamma_0 + \sum_{k=1}^{2} \gamma_k Z_{ki}$. t-statistics calculated accounting for the fact that δ_j is the sum of two estimates whose covariance must be included in the denominator.
* indicates significance (from zero) at the .05 level.
** indicates significance at the .01 level.

increase prices for industrial consumers.

In English speaking and Scandinavian countries, industrial prices decrease by .04 and .05 USD/KWh respectively, while in South American countries, industrial prices increase by .02 USD/KWh.[29] In England, the average industrial price prior to restructuring was .08 USD/KWh, so restructuring led to a 50 percent average decrease in industrial prices. In Argentina, the average industrial price prior to restructuring was .06 USD/KWh, so prices increased by 30 percent on average for industrial consumers.

Based on the discussion in section 2 of the varied historical development of their electricity sectors, the signs of estimated responses to restructuring are consistent with our expectations, however, their magnitudes are surprising. In England, for example, the electricity sector was known to be highly inefficient prior to restructuring, especially due to the required use of British coal in generation. The effective subsidy to British coal was to be phased out gradually under restructuring, with franchise (small industrial and residential) consumers continuing to finance it initially. In Scandinavian countries, prices were low and competitive even prior to restructuring, so the estimated

[29] To put these magnitudes in perspective, the mean price paid by all industrial consumers in the sample is .06 USD/KWh, so the estimated responses to restructuring are quite substantial.

dramatic decrease in prices remains difficult to explain, even with improvements in regional efficiency.[30] In contrast, in South America, the magnitude of the estimated increase in prices is less surprising; electricity prices prior to restructuring were so divorced from production costs and unsustainably low that a large increase in prices had been long overdue.[31]

While from a policy perspective, the δ_j are the primary coefficients of interest, it is worth mentioning that the signs of the control variables in the price and restructuring equations are also generally significant and consistent with expectations. Prices increase with input prices and decrease when a large share of generation comes from hydropower. Variation in the probability of restructuring, however, is more difficult to explain, and only lagged price is consistently significant. The coefficient on lagged price is negative, so a high regulated price reduces the probability of restructuring. This is plausible if incumbent producers have dominant political influence and manage to dissuade regulators against restructuring.

6 Conclusion

In summary, I find that producers and consumers *do* change their behavior when regulators decide to restructure the electricity sector. The market response to restructuring, as measured by the shift in equilibrium price, differs in English speaking, South American, and Scandinavian countries, and the estimates for each country-type are consistent with expectations based on their pre-restructuring, initial conditions. In all country-types, it is the end-user *industrial* price that shifts most profoundly with the decision to restructure. In contrast, residential consumers do not generally see a shift in equilibrium price under restructuring, though relative prices for the two groups do change significantly.

While least squares estimates from a descriptive model in which prices depend on the restructuring indicator and exogenous cost shifters are generally consistent with the maximum likelihood estimates from the full system of equations, I find a large and significant correlation between prices and the

[30]In Scandinavia, however, all industrial and residential consumers were immediately allowed to participate in restructured markets.

[31]My "macro" data does not permit it, but it would be interesting to look at detailed country data to assess the extent to which the changes in prices reflect changes in efficiency versus monopoly rents.

decision to restructure. This underscores the importance of interest group politics in facilitating or impeding the implementation and efficacy of restructuring.

The joint modeling of producer, consumer, and regulator behavior provides a first step forward in understanding the market impact and political economy of restructuring, however, a great deal of work remains to be done. First, the analysis could usefully be extended forward in time to capitalize on recent decisions to restructure in many countries. A longer time-series would also afford opportunities to better assess the dynamic impact of restructuring on prices and to differentiate between the short and long term. Second, there are aspects of restructuring other than unbundling of generation from transmission that merit consideration. It would be interesting to apply a similar framework to the decision to privatize. It may well be that different motives underlie decisions to unbundle and to privatize, and thus induce a different response in equilibrium prices. A first empirical step would be to treat these decisions separately. However, if considered together, it could be that after controlling for the decision to privatize, the estimates of the market response to unbundling could even change sign. These decisions are endogenous and made in concert, and a definitive model of price determination in the electricity supply industry would account jointly for the endogeneity of all restructuring decisions.

A Appendix Tables

Table 1: Variables Description

Variable	Description
Price	Real industrial and residential end-user electricity prices USD/KWh, converted with PPP and the CPI, 1995 = 100. Prices are net of taxes and subsidies and are delivered prices, net of transport costs. Prices are calculated as average unit value (i.e. revenue per unit delivered).
Unbundling	Dummy: 1 if unbundled generation from transmission via separate accounts or ownership. 0 otherwise.
Unbundling (English)	Interaction: UnbundlingEnglish-Speaking.
Unbundling (South America)	Interaction: UnbundlingSouth America.
Unbundling (Scandinavia)	Interaction: UnbundlingScandinavia.
Input Prices	Index of Real Energy Prices: All Energy Products. (Oil, coal, and natural gas products) 1995 = 100.
Hydro Share	Proportion of generation using hydro power.
Nuclear Share	Proportion of generation using nuclear power.
Telecom Privatization	Dummy: 1 if privatize telecommunications. 0 otherwise.
Neighbors Restructuring	Total share of neighboring countries that have restructured

Note: Input prices and Production Shares divided by 1000 and 10 respectively to facilitate estimation.

Table 2: Panel Description

Country	Number of Years *
Australia	12
Belgium	12
Canada	9
Czech Republic	6
Denmark	13
Finland	13
France	13
Germany	13
Greece	13
Hungary	9
Ireland	13
Italy	13
Japan	12
Korea	5
Mexico	13
Netherlands	13
New Zealand	13
Norway	13
Poland	9
Portugal	13
Spain	13
Sweden	12
Switzerland	13
Turkey	13
United Kingdom	13
United States	13
Argentina	8
Brazil	9
Chile	8
Total	332

* Years with no missing data for any included variable.

B Figures