Deregulation in the Electricity Sector:
Understanding Strategic and Regulatory Risk

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Abstract

This paper is motivated by our experiences since 1990 with developing system simulation models to help UK companies in the restructured electricity industry understand the radically different market within which they must become competitive. When public utilities such as electricity have been restructured, deregulated and/or privatized, the process has often been associated with a major change in the competitive environment. As a consequence, the strategic and regulatory uncertainties ahead for these companies are unprecedented. In such a market there has been no historical evolution and all the participants including the regulatory institutions have very little understanding of how it will operate in the short term and evolve in the future. In this situation, the use of systems dynamic models appears to offer an attractive way of gaining insights into how aspects of the competitive market might evolve. In the absence of real experience and relevant analogies, learning from models assumes a key role. Such models cannot not be validated empirically, but can be developed to represent how the system is designed to operate. From such a prototypical basis, sensitivity analysis can generate insights on the strategic opportunities created by failings in the market design, or its potential instability to shocks and market imperfections.

Introduction

Electricity, like many other activities within the public sector, has been subject to a wave of structural changes throughout the world, during the last decade of the twentieth century. Restructuring, privatization and deregulation of electricity started as a political ideology in Chile, New Zealand and the UK, but has spread to the European Union, the US, and most of the rest of the world, with various expectations of lower prices, greater efficiency and new investment, according to each country's most pressing needs. There are now many versions of how to (a) restructure, (b) create market mechanisms, and (c) regulate, and each country, or state, has chosen its own style and pace of change. As a result, the basic fact is that much of the world's electricity infrastructure has been transformed into progressively competitive electricity industries, and for the most part, each of these endeavours has been a huge act of faith. As a consequence, the strategic and regulatory uncertainties are unprecedented. In such a market, there has been no historical evolution and all the participants including the regulatory institutions have very little understanding of how it will operate in the short term and evolve in the future. In the absence of experience and analogies, analysis and learning from models assumes a key role.

One stream of research has been the economic analysis of structure, including market power [1,2] competitiveness[3], market mechanisms[4], transmission access pricing[5] and trading[6]. Another main theme of analysis has been more political, addressing questions such the underlying rationale[7], institutional regulation[8], and the interaction with energy policy[9]. In comparison, there has been relatively little analytical research focused at the corporate level, concerning issues of how companies in these newly deregulated industries can formulate and implement strategy, how traditional methods of strategic analysis work in these new environments and what new methods are needed. In later

sections we do, however, show some successes for the use of system dynamics in this context, and suggest that these major industry restructuring episodes provide scope for simulation to show its true advantages over traditional economic analysis.

System dynamics has, in fact, a long tradition for energy applications dating back, at least, to the seventies, when Coal2 was created for the US Department of Energy[10], to be followed by Fossil2, which is still in use by the US Department of Energy[11,12]. Another stream of models have looked at policy evaluation[13] , investment under uncertainty[14] and conservation[15]. Other studies have included broader aspects of the energy system[16,17]. Ford[18] provides an overview of the use of system dynamics in the electricity area and a several different types of systems approaches to energy policy were included in Bunn and Larsen[19], including some on deregulation and restructuring.

More generally, system dynamics has been used as a tool for solving a wide range of strategic problems and developing strategy in numerous organisational contexts. Examples can be found in many different industries, e.g. insurance industry[20] biotechnology[21], media[22], pulp and paper[23]. We will, in this paper, argue for a combination of these two areas of use, i.e. using system dynamics for strategy development in connection with electricity deregulation.

This paper is organised in the following way. In the next section we discuss the inherent characteristics of the traditional electricity sector, with its monopolistic features, and compare it with the requirements of a new competitive industry, essentially identifying the areas of rapid adaptation that are needed. This leads on to a discussion of how system dynamic models can be of use in meeting these challenges.

Change in the Electricity Sector

Hunt and Shuttleworth[6], have provided a good survey of the alternative structures which a competitive electricity industry can take, and so our emphasis here is to summarise some general corporate implications of change.

Table 1 about here

Table 1 compares some of the main characteristics, "before and after", at the industry level. The move from monopoly to competition is as fundamental as one can imagine and the differences are substantial. Whereas beforehand, the environment was stable, with a relatively predictable evolution, it now changes dramatically as new players and owners are introduced. Not only can a company no longer take prices and its own customer base for granted, it is also subject to the forces of the capital markets and cannot even be sure who its owners may be from year to year.

Furthermore, all of these risks have to be faced with greater uncertainty. In the less competitive days of public ownership, much of the information needed for debate was freely available and openly discussed. In the new competitive industry, information is valuable and confers commercial advantage. No company will disclose investment plans, maintenance schedules, upgrading, capacity retirements, unless mandated by regulatory or government inquiries. The information base that existed at the moment of deregulation slowly decays, and analysts who have been used to developing quite detailed deterministic models, are now inclined, by necessity, to use more subjective behavioural assumptions, and investigate the risks through multiple scenarios.

Another major problem is regulation. Regulating a private monopoly has always been adversarial game, as we have seen in the US for many years[24], but at least the objective of

balancing the costs to the customer with the revenue needs of the company was a clear one. In competitive markets, the ideal is one of deregulation, with the wholesale electricity market for generation and the retail markets for supply becoming self-regulating through competitive forces, leaving only the "wires" business (transmission and distribution) to be regulated as traditional natural monopolies. The problem is with trying to regulate the transition, as in the UK, from the initially inefficient to the ideally efficient wholesale and retail markets. This poses a delicate balance for the regulator: it is hard enough to regulate a monopoly in the consumer interest, but to maintain the markets' attractiveness for new entrants at the same time, in order to maintain competitiveness, requires a major compromise between accounting controls and strategic incentives. Furthermore, the history of the UK, in terms of restructuring with too much market power being granted to too few generators, continues to be repeated elsewhere, eg Sweden, Spain and the Netherlands. Governments are risk averse when it comes to the security of the electricity system, and want financially strong generators; thus the temptation to restructure with market power is easy to understand. Furthermore, if privatisations are involved, higher prices can be obtained for companies created with stronger market positions. This does pose a problem thereafter, however. Again, it means that pricing models cannot be based upon marginal cost outcomes but must embed strategic behaviour, and the regulatory risks that will follow from the difficulties of balancing new incentives for entry with cost controls for the benefit of customers must again be analysed through behavioural scenarios.

Table 2 about here

Distinct from changes at the industry level, Table 2 list a number of "before and after" corporate issues. The focus of organisations becomes more expedient, with a move from

"we want the best possible technological solutions" (i.e. money is not a major concern) to "we want the most cost efficient solution". Moving from an technical / political orientation towards a much more commercial way of thinking and acting is a difficult process, involving a major re-organization towards a customer and competitor focus. This is especially true in the cases where full retail competition is being encouraged.

Thus, to sum up the changes that take place at the company level in connection with industry restructuring, we can observe that in a regulated monopolistic market, regulators can aim at a social optimum, as approved costs associated with this can be passed on to the final users, whereas in a deregulated industry, a company can not be certain to get costs associated with "social" initiatives covered in the price that the final users. This is a major shift in how a number of external issues, such as Conservation, Demand Side Management, and the Environment can be incentivized. Nevertheless, politicians seek to achieve various goals in these areas, and in doing so induce another area of regulatory risk (eg the "temporary" moratorium by the UK government in 1998 on all investment in gas-fired generation to help the coal industry).

All of these changes lead to a new way of looking at the economic behaviour of the industry and one that emphasises new risks, corporate inexperience, imperfect competition and markets in evolutionary transition. The dynamic, uncertain and subjective nature of assumptions which need to be incorporated into strategic analyses are all more conducive to the use of systems thinking and simulation models than the more traditional ways of analysing the industry, eg through large-scale optimisation models. Prior to 1990, most of the modelling debate concerned with energy planning was about appropriate algorithms for the large scale, long-term, nonlinear, mixed integer capacity investment formulations which were set up, and Benders decomposition became widely used[25]. Uncertainty was mainly concerned with fuel costs and demand growth, and

handled by means of sensitivity analysis. Since then, fuel costs and demand have become of much less concern than market share, levels of contracting, regulatory policies, and spot market prices, for which the role of deterministic optimisation modelling is quite limited.

Taxonomy of Company Problems in Connection with Deregulation.

We can identify three broad areas of concern for companies in restructured industries, and the common theme is the understanding of risk and what level of risk to live with. This is the type of risk that did not exist when the company was a monopoly. The three types are corporate risk, market risk and regulatory risk. We will separately describe these below and show how system simulation can be used to help companies in each of these. At the same time will we provide examples of models already developed in these areas.

Corporate Risk and Simulation.

Most companies facing deregulation have not evolved the same commercial and entrepreneurial culture that fully competitive companies exhibit. In the public sector, more senior management may have more in common with government administrators than their corporate counterparts and middle management may have a strong technical or engineering orientation, rather than market-focused objectives. Thus, in the formulation of strategy and the raising of finance, these companies were agents of government policy, and were relatively inexperienced in risk-taking. These companies have been used to government subsides, which together with monopoly power, encouraged them to increase assets and manpower instead of becoming leaner and more productive, e.g. witness the up to 60% reduction in manpower in some UK electricity companies 3 years after de-regulation[26]. After deregulation, the culture of the companies changed suddenly. This is

by no means an easy and comfortable process. Inexperienced, cash–rich utilities have often made poor diversification decisions and fallen to predatory takeovers.

Simulations can indirectly help in this process of organisational development. The use of simulation here is mainly in two areas: communication and management development / training. In both cases the simulation models are normally combined with an user-friendly interface to create what is known as a microworld, which is essentially a computer game developed and designed for use with management teams[27,28]. This type of game can be used both as a tool for communicating why certain actions needs to be taken[20] as well as a general tool for management development[29]. There has been some documentation of the use of these tools in general [30,31, 32] but little as a tool within companies facing the challenges of restructuring and deregulation.

Market Risk and Simulation

An independent recently deregulated company faces new levels of financial risk in terms of potential insolvency and business risk in terms of failure in the market place. Furthermore, the business risk may be a type for which relevant experience cannot be bought-in. When deregulation has been associated with a novel market structure, which is almost always the case in the utility sector, there has been neither an evolutionary history of such a system from which to learn, nor reasonable analogies elsewhere. In other words this is new markets with no history to learn from., i.e. there is no way of using the past to understand the present and predict the future. This market "inexperience" is common to all companies, the regulator and the political framework in which everybody operates. The challenge for the company is thus to understand how the system works and the nature of its weakness, thereby to develop strategies either for competitive exploration or for political lobbying to influence future change.

Simulation can in this case help in two ways firstly by making up for the lack of history and secondly in evaluating strategies. There is a need for companies to understand the possibilities and threats that they face in a deregulated industry and to create long term strategies and visions of were the company is heading. However, to be able to do this, a structured way of understanding the future is needed without having access to the past (that does not exists). There is also a need to capture the dynamic elements and unintended consequence in the artificial market, i.e. a market made up of partly free and partly regulated market, confronting these companies. Deregulated industries can be seen as complex systems with many unanticipated consequences that the conventional economic and financial analysis will have difficulties in anticipating or discovering. An approach based on feedback, with explicit recognition of delays and representation of (bounded rational) decision rules as well as soft variables has the necessary ingredients to be useful in an analysis of a situation such as this. Furthermore, simulation models at an early state in a deregulation cannot be validated empirically (as no data exists), but they can be developed to represent how the system is designed to operate and therefore, from such a prototypical basis, generate insights on the strategic opportunities created by the market's potential instability to shocks, parameter uncertainties, and market imperfections. Such models can thereby identify the sorts of business risks that might follow a variety of scenarios for market structure and behaviour.

One example of such a model is by Bunn and Larsen[33,34] which analysed the investment behaviour in the recently restructured electricity market of England and Wales. The model and analysis was done when the market was still in a very early stage of development, focusing on the special aspects of the pricing mechanism and its long term incentives as well as on the effect of information exchange in the deregulated industry. The model differentiated the strategic objectives of the two main players. National Power and Powergen, with National Power seeking to maintain market share, and Powergen

focusing upon its rate of return. Figure 1 show the results obtained from the model in 1991 and published in 1992 with regards to how the market shares of these two main players might evolve. As we can observe, the scenario suggested a decline in National Power's market share over time, with Powergen more or less keeping its share. The independent power producers gain ground substantially, mainly at the expense of market share. Whilst this was not intended to be a forecast as such, more a revelation of model-based insight that National Power would be unable to maintain a strategy of market-share preservation, given a variety of strategic assumptions in the model, it is interesting to compare it with what did happen in the subsequent years (Figure 2). Our original model embedded functions which related the amount of debt and capacity under construction to the cost of capital for National Power. This relationship essentially induced the simulation results that an objective of maintaining its dominant market share would be unsustainable in the face of aggressive new capacity from independents, which in itself would be induced by the strategic needs of the distribution companies to redress the balance of power in the wholesale generation market. In actuality, it seems that National Power realised this quite quickly and sought to manage a decline in its UK market share, not least to reduce its exposure to UK regulatory risk.

(Figures 1 and 2 about here)

The other issue which this early system dynamics model sought to address was the potential which existed within the spot pricing mechanism to induce cycles of capacity and thereby threaten the security of supply in periods of inadequate reserve margins.. Figure 3 is illustrative of the sort of cycles which the model postulated would evolve if just the information in the spot market ("zero information exchange" and "zero foresight" in the Figure) were used as a basic for investment. Variants where greater information exchange, such as on building permits for competitive plant, or more accurate forecasts,

became common in the market were investigated. Apart from helping to understand how prices might evolve, one of the intentionshere was to give some regulatory insights into how the operation of the market could be improved. Our main conclusion was that the so-called capacity payments element of the pricing mechanism, being a nonlinear function of the reserve margin, did not provide a stable and efficient signal for new capacity, and it is interesting to observe that indeed that is now one aspect of the mechanism which the regulator suggests should be dropped[35]. For comparison, Figure 4, shows the cycle in reserve margin which has occurred during the period until 1998.

(Figures 3 and 4 about here)

Regulatory Risk and Simulation

The above example brings us to the third category of issues is caused by the difficulties of regulation. Regulators must choose to balance controls on prices, investment, divestment or institutional policies to limit anti-competitive behaviour. This can, in the extreme, take the form of instructions to divest assets, which happened for British Gas, National Power and PowerGen in 1994. Ideally, regulation is only seen as a temporary instrument to manage the transition to fully competitive markets, where this is possible, and so, it is essentially an adaptive process, and thereby one likely be well modeled by feedback systems

The use of simulation in this area has many similarities with the use in the market risk area. Again the reason for using simulation is this case is that it might alert thinking to various unintended consequences which might trigger the regulator, or government into reaction. An example of a simulation model used to explore the regulatory problems is Bunn, Dyner and Larsen[36,37]. Here a simulation model was used to explore the

consequences of arbitrage across the short-term electricity and gas markets. The model showed how a dominant generator could influence prices in both markets and how the regulators in gas and electricity will have difficulties in dealing with it as long as they are separate institutions. The dominant regulator can gain by creating increasing volatility in the electricity pool thereby increase the amount of contracts that the customers are willing to sign at a premium to the otherwise "fair" price. If the generator owns any retail business, they will they not suffer so much by this and will be in a better competitive position. New entrants might have second thoughts if there are large fluctuations in the price. All of this depends upon the opportunity to exercise the real option to convert gas into electricity or to sell it on the gas market. Again, it is interesting to observe, that in 1998, three years after this study, the merger of the gas and electricity regulators has been proposed by the UK government. Whilst no causal link is implied, the example does illustrate the ability of system dynamics models to provide useful scenario insights into the behaviour of evolving markets

Conclusion and Discussion

The experience from using simulation models in the UK electricity context helped to understand the dynamics of the new markets at the time and in reterospect appears to have been vindicated by events. The paper by Bunn and Larsen[33] indicated a fall in the market share of National Power, and a more or less constant market share for PowerGen. This insight was consistent across a number of different scenarios. It did in fact happen much faster than was expected, but insofar as the qualitative insights from the analysis were mainly concerned with the directions of change, it is the dynamic pattern of the model's results that are most significant. The same is true for the cyclical behaviour of the reserve margin. It is important to remember that these kind of models are not forecasting models, but rather should be used for creating a new understanding of a

complex situation. In a similar way, the gas arbitrage example illustrated that the market had the potential for gaming and that inevitably something would be done about it.

In seeking to address the issues of corporate, market and regulatory risk in a recently deregulated market, it seems that a simulation method which has its original source in system dynamics provides a balance of behavioural, dynamic and prototypical state representation which is conducive to creating new insights of the sort which more classical economic optimisation based models could not achieve. However, it is important to be aware of the new ways in which simulation models are now being applied. Traditionally simulation models have been used in predicting the future evolution of a variety of complicated systems from national economies to company cash-flows. While these generally large models are still common. i.e. from 500 to several thousand equations, we have also seen a growing interest in the applications of comparatively small models, i.e. from 100 to 300 equations, to help the users gain a better understanding of specific issues[38]. The predictive powers of these models are limited but they help the user to focus their learning on particular aspects of a complex situation and the likely implication of future change. Such strategic models concentrate on getting the main interconnections and the boundaries right, without trying to capture all the minor interconnections that might have limit influence on the behaviour of the situation. There should be only sufficient detail to give a broad understanding of the development of the scenarios overtime. We have followed this approach in developing the models of deregulation described in this paper[33,34,37]. Other examples of this type of simulation can be found in the modelling of growth in a small technology company[21], the evolution of the OPEC oil cartel[30] and the introduction of electric cars[39].

Generally speaking we see that one of the major challenges in the next millenium may be to design new "artificial markets", to create competition in what have previously been

seen as natural monopolies. This trend has been driven in the Western world by a popular demand for more efficient utilities, and in the developing world to attract more privately financed independent power producers. These markets are significant different from country to country, based on natural resources, generation technology, industry structure etc.[40] so there is little change of finding the right model which will fit all or a majority of countries. This means that there will be a need for each country to adapt, combine and invent a model that is suited for itself, and for each electricity company in each country to understand, learn and develop efficient strategies tailormade to that country. Simulation models should play a major role in this development, and in particular they can benefit from the behavioural, high-level and feedback characteristics of system dynamics to deal with the special modelling challenges of restructured industries.

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TABLE 1

Changes taking place at industry level when an industry is restructured

Industry Changes		
Attribute	**Monopolistic Market**	**Competitive Market**
Business environment	Stable with only gradual adjustment, technically driven changes. Uncertainties in demand and costs.	Unstable, volatile prices, new stakeholders, with diverse objectives. Market, corporate and regulatory
Information	Open and public domain information. Planned future.	Information becomes secret. Future signals misleading.
Regulatory Environment	Concerned with social welfare	Awkward balance between interests of customers and new entrants.
Market power	Not an issue as there was a regulated monopoly	Now crucial for regulators and companies
Conservation and Environment	Easily incorporated into energy policy.	Adds one more layer to regulatory risk
Public R&D	Public R&D was seen as an important part of long-term obligation	Companies cannot justify public domain R&D

TABLE 2
Changes taking place at company level when an industry is restructured

Internal Company Changes		
Attribute	**Monopolistic Market**	**Competitive Market**
Focus	Best technical solution	Best cost efficient solution
Management focus	Technical	Commercial
Customer focus	The customer has no choice	Retail competition forces a customer focus
Planning methods	Classic OR planning methods used successfully	New methods linking strategic thinking, uncertainty and limited information
Outsourcing	Little or none	Increasing interest,
Business Rationale	Social optimum	Shareholder value

Figure 1: Central 1992 Scenario for Market Shares

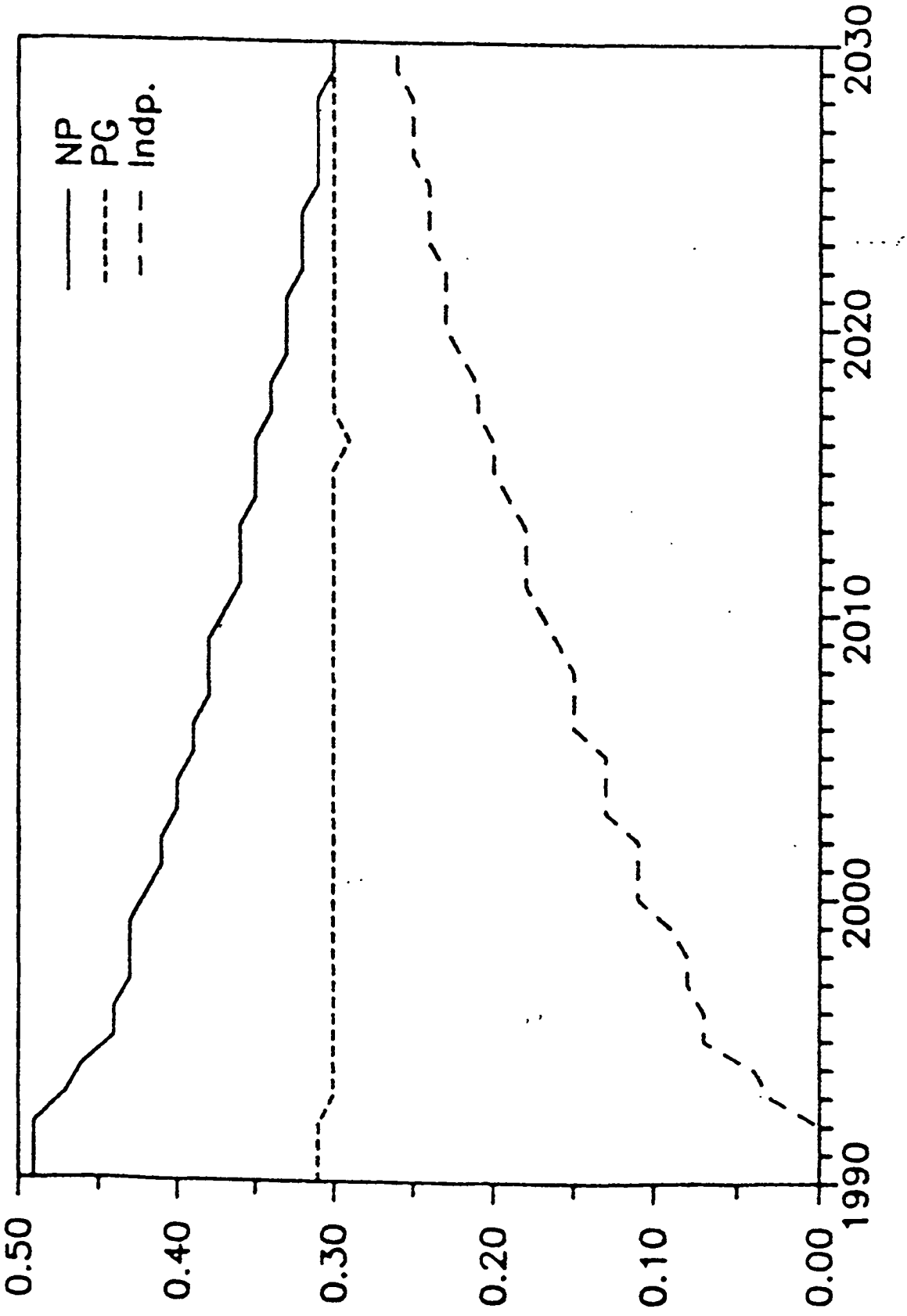
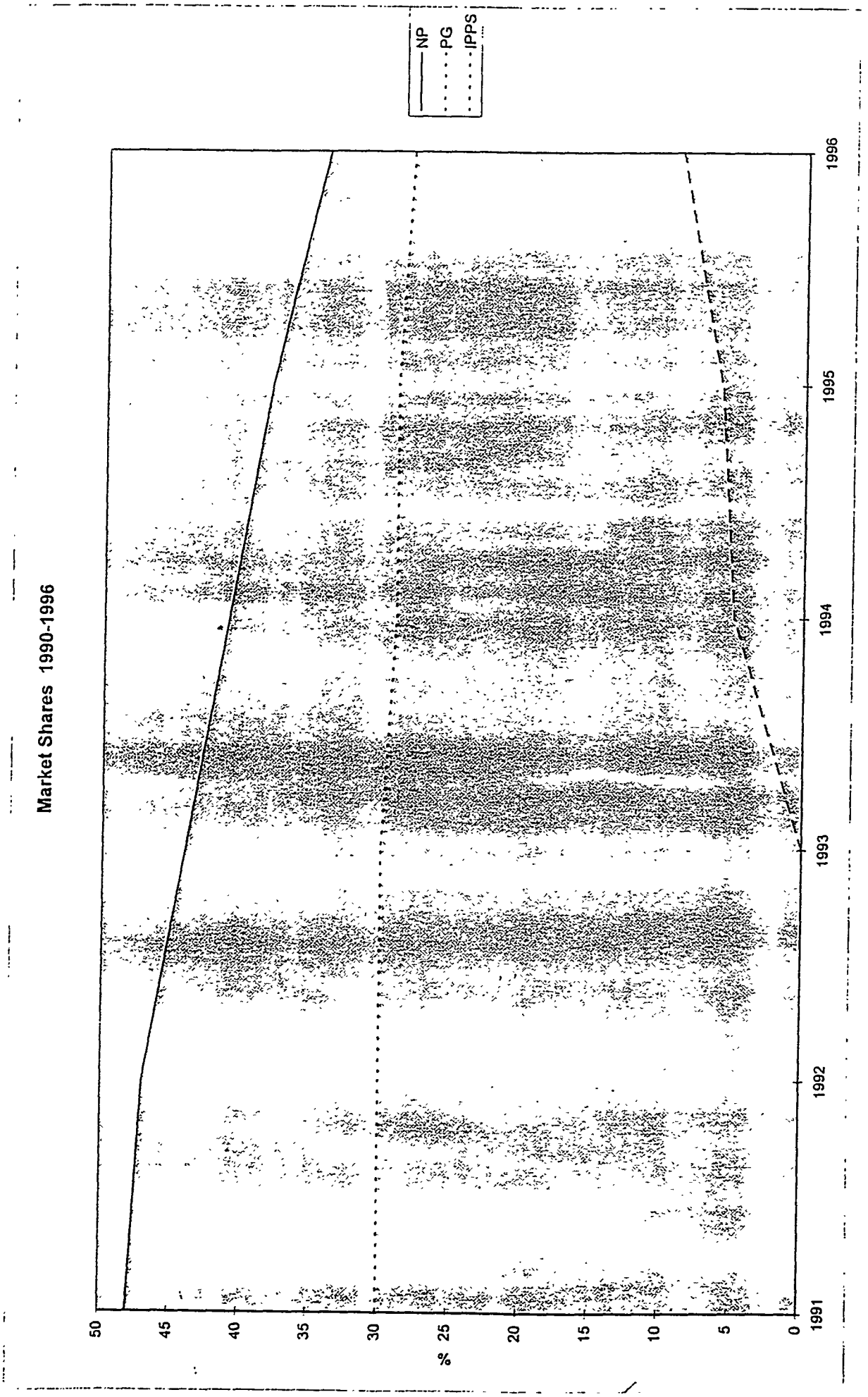


Figure 2: Actual Market Shares 1991-1996



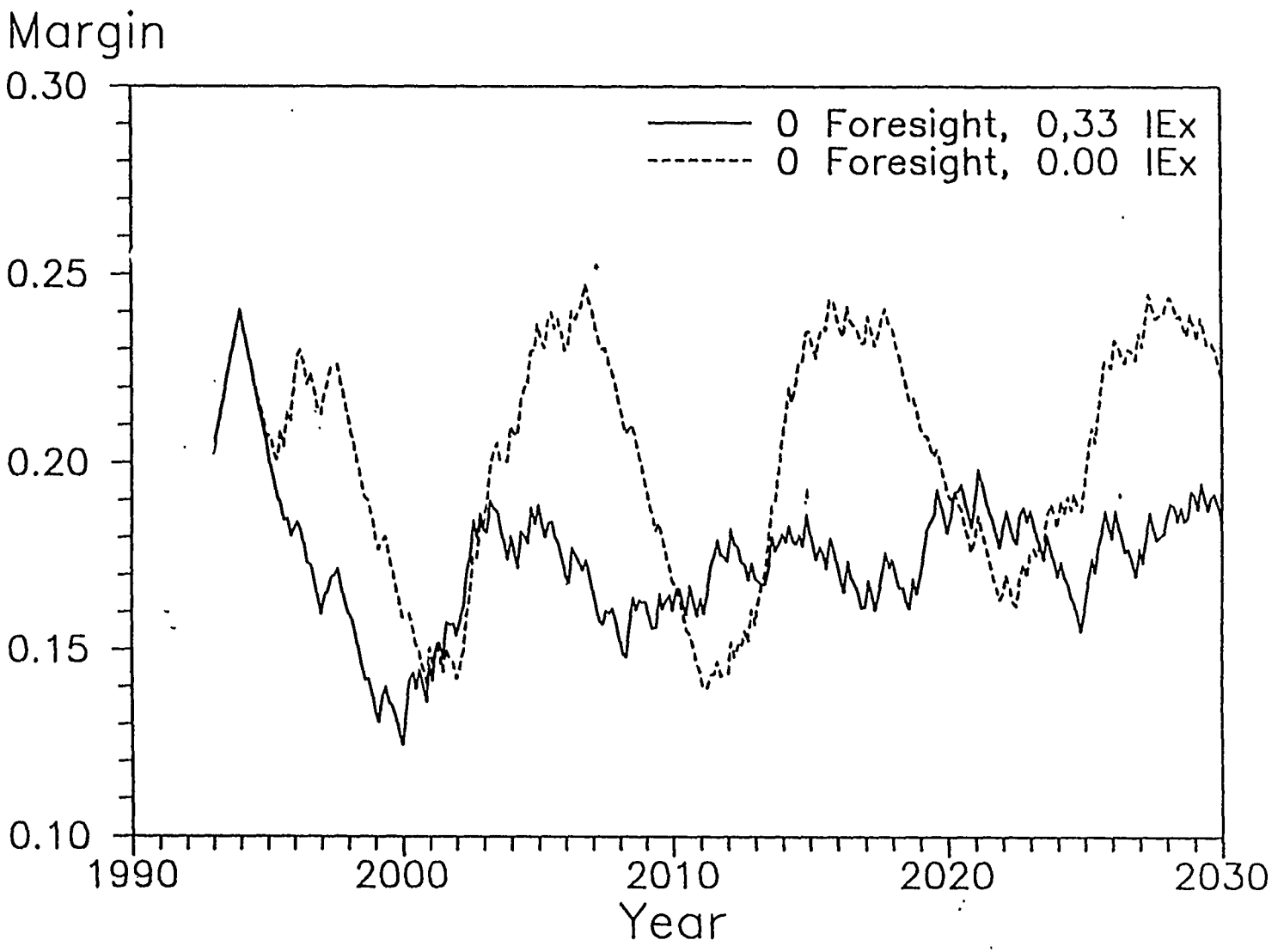


Figure 3: Simulations of Reserve Margin

Figure 4: Actual Average Winter Reserve Margins