Comments on the use of computer models for merger analysis in the electricity industry FERC Docket No. PL98-6-000

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June, 1998

We applaud the Commission's efforts to both streamline the merger analysis process and to further incorporate the use of computer models into that process. Over the last few years, the University of California Energy Institute has been involved in several projects adapting computer models to the task of analyzing the potential for market power in electricity markets. These analyses have yielded several insights about the application of such models to merger analysis that we feel are relevant to the Commission's current initiatives.

The main point that we wish to make in this comment has to do with the use of computer models to define geographic markets and identify the potential suppliers to these markets. The simulation of an electricity market based upon an objective of least-cost production, as proposed in the attachment to the Commission's notice,[2] can sometimes dramatically overstate the geographic scope of a market and the number of potential suppliers to that market. More generally, there is a fundamental flaw in modeling approaches that simulate markets as if they were perfectly competitive, and then apply generic measures of the potential for exercise of market power, such as concentration indices. The flaw results from the fact a firm or set of firms, through the very act of exercising market power, will usually alter their production patterns in ways that violate the assumption of market-wide least-cost production. In addition, generic concentration measures fail to capture a number of factors that are critical in the exercise of market power, factors on which information in available in the electricity industry.

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[2] Federal Energy Regulatory Commission, Notice of Request for Written Comments and Intent to Convene a Technical Conference (notice). Inquiry Concerning the Commission's Policy on the Use of Computer Models in Merger Analysis. Docket No. PL98-6-000.

The notice describes three types of computer models that the commission is considering, electricity market models, production cost/optimal power flow models, and hybrids of those two. While such models can capture some of the physical and economic constraints of electricity markets in great detail, they do not explicitly represent the strategic behavior of firms. There is, however, another class of models that do attempt to explicitly model strategic behavior. Indeed, it is often far more important to represent the strategies of producers than to model their physical production characteristics in minute detail.

Researchers have begun to employ game-theoretic market analyses that attempt to capture the strategic aspects of competition in this industry. These models are imperfect, but they do offer several significant advantages over concentration analyses. This is because they are able to test for market outcomes that deviate substantially from the least-cost dispatch. In particular, they can model the market response to an attempt by a firm, or set of firms, to restrict output and raise price. The ability to profitably pursue such a strategy is the primary concern of market power analysis.

In this document, we discuss some of the strengths and weaknesses of the market power models that have been applied to the electricity industry. In doing so, we illustrate the main points of this comment: (1) that computer models designed to aid in analysis of market power must be able to incorporate strategic firm behavior into the analysis in order to correctly examine the geographic scope of electricity markets and the potential for exercise of market power within those markets and (2) that concentration measures, such as the HHI, are likely to yield misleading results and poor public policy, even when applied as simple guidelines. Firms in certain regions can find it profitable to reduce their output and induce significantly higher levels of congestion on transmission paths into their region than would occur under a non-strategic least-cost dispatch. Firms that face local competitors with limited generation capacity can find it profitable to pursue a similar strategy: reducing their output, exhausting the capacity of their competitors and exercising market power on any residual demand. Such strategies entail significantly altering production levels from those that would obtain in a least-cost dispatch. The examples that we present are taken from analyses we have performed on data from the California and eastern PJM electricity markets.

2.0 Market Power Analysis

Although industry concentration and individual firm market share are often correlated with market power, this is not always the case. There are many factors beyond the number and size of firms in a market that impact the degree of competition within an industry. Most of these factors are not represented in the production cost/optimal power flow models that focus on the physical characteristics of electricity systems. These factors include

- **The price-responsiveness (elasticity) of demand:** In markets where customers can easily choose not to consume a product, or to consume a substitute instead, producers cannot raise prices far above costs without significantly reducing sales. Conversely, a producer that knows that its product is absolutely needed can profitably raise prices to very high levels.

- **The price-responsiveness (elasticity) of supply:** In markets where many producers can easily increase their supply without suffering significantly increased marginal costs, it will be very difficult for any one producer to withhold output and profitably raise price, because an attempt to do so will be met by a nearly equal increase in output from competitors. In contrast, if competing producers face a binding capacity constraint, or a steeply increasing marginal cost of producing additional output, one producer that attempts to restrict output and raise price need not fear significant output increases from its rivals.

- **The incentives of producers**: In the near term, it is likely that electricity markets will feature a diverse set of firms, including publicly owned utilities, unregulated generation companies, and traditional vertically integrated regulated utilities. Each type of firm is likely to respond differently to a given competitive environment.

- **The short-run potential for entry into a market:** Just as a producer with very price responsive customers cannot exercise much market power, neither can a producer faced with many price-responsive competitors. Transmission capacity into a region and available competitive generation capacity are the main factors in determining the potential for short-run competitive entry. It is important to note that the existence of such capacity constraints can lead strategic producers to significantly alter their production levels from those that would obtain if these constraints did not exist.

In general, these factors are not captured by measures of the concentration of an industry, even if those measures are performed on data generated from a computer simulation of a perfectly competitive market. Such measures indicate the current or potential distribution of sales or capacity, but cannot indicate what will happen to prices when one firm reduces its output. This is a critical question in the electricity industry where the product is, with some exceptions, not storable and short-run demand is relatively inelasitic. Even though one firm may have a small market share at a given demand level, it may be the case that if that firm reduced output, no other firm would be able to replace that supply because of cost, capacity or transmission constraints. The Cournot-Nash algorithm, described below, helps to analyze and detect such situations.

2.1 Cournot-Nash Equilibrium Concept

The cornerstone of our analysis is the assumption that strategic players employ *quantity strategies*. That is to say that each strategic player, upon observing the output of its competitors, would select a production quantity that would maximize its profits. In an equilibrium, every producer has an output that maximizes its profits, given the output of every other producer. Therefore, no producer would find it profitable to unilaterally change its output. This is known as a *Cournot-Nash Equilibrium.*

In the context of an electricity market, the Cournot model seems an appropriate starting point. The other basic non-cooperative equilibrium concept, the Bertrand equilibrium, is supported by the assumption that any firm can capture the entire market by pricing below others and can expand output to meet such demand. Since generation capacities present significant constraints in electricity markets, this assumption is not tenable. Previous research suggests that if firms choose their capacities and then compete on price, within the restrictions of their capacity constraints, the outcome may be closely approximated by the Cournot model.[3]

Capacity constraints on generation are significant in both the medium-term – based upon investments in construction of new capacity – and the short-term, in which plants are rendered "unavailable" due to maintenance and other reliability considerations. This latter, short-term, constraint is most relevant to our work, because the capacity investments of the major players have already taken place.[4] In their study of the UK electricity market, Wolak and Patrick (1997)[5] argue that the market power of the dominant firms is manifested through those firms declaring certain plants unavailable to supply in certain periods. Thus, the centralized price mechanism and capacity-constrained suppliers in electricity markets (at least during peak periods) support the use of a Cournot model for a base case analysis.

Other oligopoly equilibrium concepts

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[3] See Kreps, D. M., and J. A. Scheinkman (1983), "Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes." *RAND Journal of Economics*, 14(2): 326-337. See Davidson, C., and R. Deneckere (1986), "Long-run Competition in Capacity, Short-run Competition in Price, and the Cournot Model." *RAND Journal of Economics*. 17(3): 404-415 for discussion of the limits of this finding.

[4] There is one other significant short-term capacity constraint, involving the commitment of generation units to a dispatch process. Since most generation units are constrained on how quickly they can begin producing output from a shut down state and how quickly they can increase output to higher levels, generators must commit to certain output capabilities before they actual provide output in a given hour. We discuss the qualitative implications of these constraints on our market power model later in this paper.

[5] Wolak, F. and R. Patrick (1997),"The Impact of Market Rules and Market Structure on the Price Determination Process in the England and Wales Electricity Market." University of California Energy Institute working paper PWP-047, April, 1997.

To date, we have primarily utilized the Cournot-Nash concept in our studies of electricity markets, and the examples we will draw on later come from Cournot analyses. There are however, other equilibrium concepts that can be considered. It is difficult to point to a single economic equilibrium concept as the "best" approach for all markets. Each has strengths and weaknesses that make such a choice very much case specific. It is often the case that different models may produce different insights into potentially profitable strategic behavior. However, all of these insights can be of value to policy makers. As with any economic model, it is important to remember the implications of the model choice itself when interpreting its results.

One game-theoretic concept that has been prominently applied to electricity markets is the modeling of equilibria when bidders specify full cost/quantity 'supply curves.'[6] One of the obvious attractions of a supply curve equilibrium model is that it seemingly represents the actual behavior of firms more accurately. The output of a supply-curve equilibrium model is an actual price-quantity bid curve, rather than the inflexible quantity bid given by the Cournot model. It is also important to note that supply-curve competition can produce results that are closer to the competitive outcome than those produced by the Cournot model.

However, the supply-curve model also has some weaknesses that may limit its usefulness when applied to certain electricity markets. In general, this approach produces multiple equilibria and the diversity of these equilibria grows as the uncertainty of demand is reduced. The supply curve approach also does not lend itself well to markets where there is a competitive fringe whose capacity may be limited due to either generation or transmission constraints.[7] In the United States, as we will argue below, this is often a key factor in determining the competitive outlook for a given market.

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[6] See Green, R., and Newbery, D. (1992), "Competition in the British Electricity Spot Market", *Journal of Political Economy*, 100 (5), 929-953 for examples of this approach.

[7] This is due in part to the fact that, to date, supply curve models have relied upon the assumption that the elasticity of demand does not vary across time periods (or demand levels).

Finally, neither the Cournot model nor the supply-curve approach addresses issues of collusion. In both of these models, it is assumed that any exercise of market power would be unilateral by each firm. The ability of a group of firms to collude will depend on many factors including the level of concentration, the ease of new entry or output expansion by fringe firms, the frequency with which prices are set, the likelihood that the firms will meet again in the future, the ability of firms to monitor the behavior of rivals or potential collusive partners, and the homogeneity of cost attributes across firms. Unfortunately, economic models of collusion generally offer little practical guidance about diagnosing collusive exercise of market power. Thus, our analysis does not directly capture the potential for collusive outcomes.

3.0 Results of Cournot–Nash Analysis of US Electricity Markets

In this section we provide examples of how an equilibrium analysis can yield insights into the competitive nature of markets beyond those provided by concentration indices. These examples are drawn from studies we have performed on electricity markets in the U.S. They make clear that the potential for market power depends heavily on the amount of demand in a given market. In almost every electricity market that we or others have examined there is little potential for market power in off-peak, low demand hours. In many markets, however, there is significant potential for market power during peak hours. This is due, in part, to the fact that when demand rises beyond a given level, both the transmission and generation capacity of potential competitors becomes exhausted, leaving the market to just a few dominant on the margin.

Because of this pervasive characteristic of competition in electricity markets, we examined a broad range of demand levels in the markets that we have studied. By a range of demand levels, we in effect mean a range of demand *curves*, since we assume that demand is at least somewhat price-responsive. Since most electricity customers today face a constant marginal price for electricity, we fix our demand curves to reference points that relate to currently observed or forecast price-quantity pairs. In other words, our demand curves are set so that the market demand, at current prices, would equal the current demand levels. To account for the fluctuations between peak and off-peak demand, we vary this "anchor quantity" of our demand curves, while keeping the reference price the same.

Production Capacity of Non-Strategic Producers

A brief examination of the California electricity market reveals a market with a diverse set of producers. California is home to a large amount of non-utility generation, using both fossil-based and renewable fuel technologies. Furthermore, there are several municipal utilities of various sizes, including the Los Angeles Department of Water and Power, the third largest producer in the state. When one also considers imports into the state from other regional markets, such as the Pacific northwest and the desert southwest, this market indeed appears quite *unconcentrated* by traditional standards. The HHI never exceeds 1200.

However, we found that under generation ownership that existed in 1997 there would be a significant potential for market power in hours with high demands.[8] This is due to the fact that, at higher demand levels, many producers reach their full output capacities. Thus, although many firms may have significant shares of the market, very few firms have the *additional* capacity to supply power at higher levels of demand. The disciplining effect of those limited capacity producers on the strategic behavior of the remaining firms is therefore severely reduced. The remaining producers can profitably reduce their output, knowing that most of their capacity-constrained competitors will be unable to respond with increased production. Ironically, when such behavior occurs, the concentration of the market appears to be reduced, since the strategic firms -- the largest producers -- are in fact withholding production, and therefore reducing their market share. We found many cases in which the price-cost margin increased as concentration declined.

[8] A detailed description of this study is provided in Borenstein, S. and J. Bushnell, "An Empirical Analysis of the Potential for Market Power in the California's Electricity Industry, University of California Energy Institute working paper PWP-044, January, 1997. This and other UCEI working papers are available for download at the Institute's website at www.ucei.berkeley.edu/ucei.

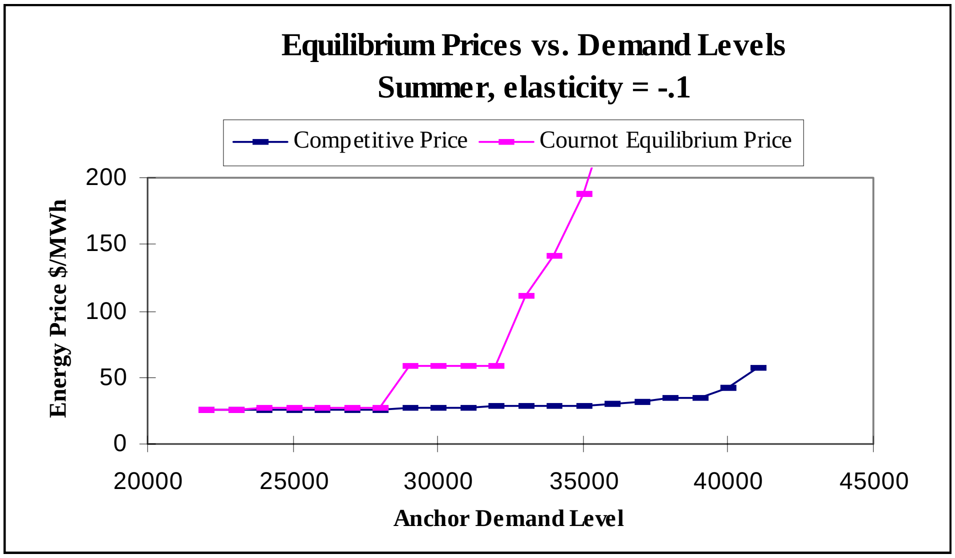

Figure 1

Figure 1 illustrates this point. On the horizontal axis we plot the "anchor quantity" of our demand curves. In other words, the demand in the market if prices were equal to those today.[9] The final market demand from our simulations varied from these levels as the Cournot equilibrium prices were sometimes far higher than current prices. In Figure 1 we plot the perfectly competitive price along with the Cournot equilibrium price for "anchor demands" ranging from 21,000 MW to 42,000. The Cournot price closely tracks the perfectly competitive price at low demand levels and then rises sharply beyond a certain threshold level, around 27000 MW. Prices at this point begin to rise because an increasing number of competitive firms reach their maximum capacity. The two largest firms, PG&E and SCE, then find it profitable to reduce their output and drive up prices. The resulting effect on concentration is that the market appears most concentrated at demand levels where these two firms are not trying to reduce output (see Figure 1). That is to say, the market is more concentrated when there is little or no price mark-up, as measured by the Lerner index.

[9] For our study of California, our reference price was based upon a forecast by the California Energy Commission of the State-wide average price in the year 2000. This price was 9.3 cents/kWh.

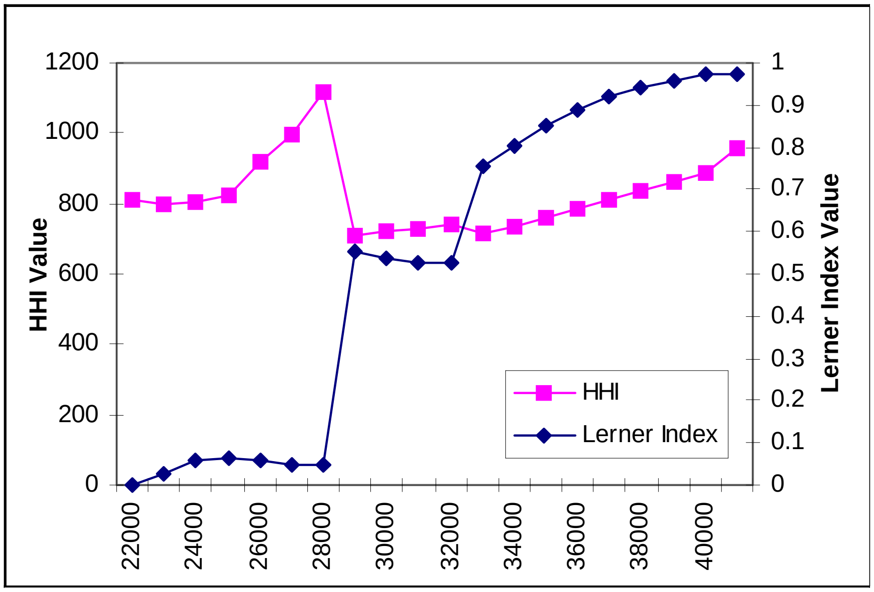

Figure 2

The Impact of Demand Elasticity

One of the reasons that extreme price mark-ups can be sustained at demand levels where fringe capacity is constrained is that demand for electricity currently is not very price responsive. When this is the case, a larger firm may be able to increase profit by unilaterally decreasing its output since output reductions have a substantial impact on price. Such reductions lead to higher retail rates and social losses. In contrast, if the amount of electricity demanded is responsive to changes in price, then reductions in output by a single firm lead to small price increases and therefore a loss of profit. Only if firms are able to effectively collude in joint output reductions will price be substantially above cost.

Indeed, our analyses of the California and New Jersey markets confirm the importance of the elasticity when exploring the likelihood of market power in a restructured electricity industry. The policy implications from these results are clear. Policies designed to make consumers more responsive to real time prices can have dramatic effects on equilibrium prices and may be more effective than more traditional policies designed to combat market power, such as increases in transmission limits and generation capacity. This point is highlighted in Figure 3, which illustrates the equilibrium prices found in a restructured California market under three alternative scenarios; a demand elasticity of .1, a demand elasticity of .4, and a balanced divestiture of PG&E and Southern California Edison gas units.[10] The results illustrate that increasing the elasticity of demand from .1 to a still relatively inelastic level of .4 produces substantial decreases in prices. At high demand levels, the price reductions are greater even than those under divestiture.

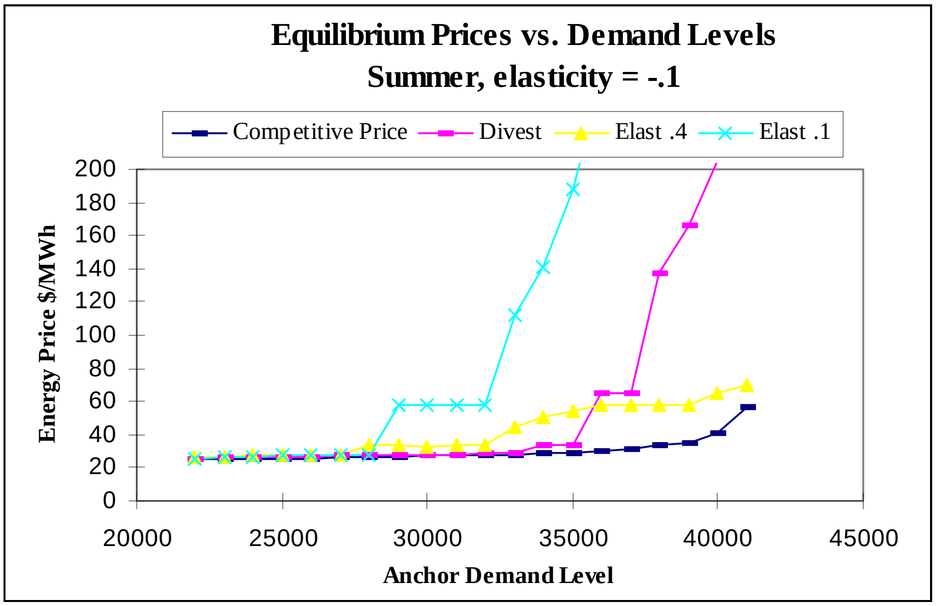

Figure 3 — The Impact of an Increase in the Responsiveness of Demand

The Potential for Strategic Use of Transmission Constraints

We have demonstrated that limits in transmission capacity can have important impacts on the level of competition in certain markets by restricting the potential short-term entry into a given market. It is important to note that this effect is likely to occur much more frequently in deregulated markets. Some strategic firms, knowing that the scope of imports is limited by transmission constraints can profitably restrict output, thereby increasing imports and congestion on transmission paths into the strategic firm's region.

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[10] In this case, "balanced" meant that of the units proposed for divestiture at that time, each set of units were divided into roughly equal lots. This created one additional northern Californian firm out of half of PG&E's gas generation and two additional southern Californian firms, each controlling roughly half of SCE's current gas generation capacity. These new firms were assumed to be Cournot players. Since this

Conversely, increasing transmission capacity into a region can have strikingly large impacts on the competitive health of that region.[11]

Some examples from a preliminary study we have made of the electricity market in New Jersey help illustrate this point. The eastern portion of the PJM (Pennsylvania, Maryland and New Jersey) pool at times constitutes a load pocket. An examination of historical congestion patterns[12] reveals that the transmission flows between the western and eastern portions of the pool have seldom reached the limits of that path. Flows along this path, however, have been within 500 MW of these limits far more often. This indicates that firms that own generation within the eastern portion of the pool might be able to profit from reducing output slightly and inducing congestion along this path.

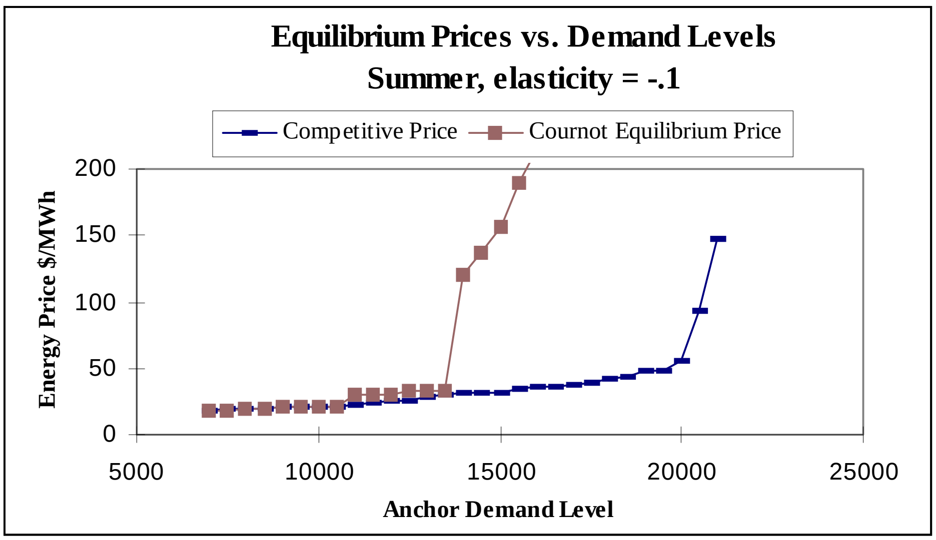

Figure 4: PJM-East Cournot and Competitive Prices, Summer Costs and Capacities

Our Cournot equilibrium analysis indicates that, at high demand levels, this is the case. We again examined a broad range of demand levels by varying the "anchor quantities" of

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study was completed, PG&E has announced a further divestiture of all its fossil fuel units and several sales aggreements for both PG&E and SCE generation units have been reached.

[11] A more general theory of the strategic impact of transmission capacity in a simple network can be found in Borenstein, S., Bushnell, J., and S. Stoft, "The Competitive Effects of Transmission Capacity in a Deregulated Electricity Industry," University of California Energy Institute working paper PWP-040, September, 1996. An analysis of the potential complications added by 'loop flow' considerations is given in Cardell, J., Hitt C., and W. Hogan, "Market Power and Strategic Interactions in Electricity Networks," *Resource and Energy Economics*, 19:109-138.

[12] See Joskow, P. and Frame, R. (1997), "Supporting Companies Report on Horizontal Market Power Analysis," Federal Energy Regulatory Commission Docket No. ER97-3729-000, July 14, 1997.

the demand curves used in our equilibrium calculations. As with the California market, we find that there is almost no market power at low demand levels, and that Cournot equilibrium prices rise steeply with demand above a certain threshold level. Figure 4 illustrates our results for a demand elasticity of 0.1.[13] The divergence of competitive and Cournot equilibrium price is closely related to the level of congestion along the PJM west-to-east interface. Indeed, a comparison of the west-to-east flows under the assumption of perfect competition with those that arise when firms in the east act as Cournot competitors (see Figure 5) reveals that the occurrence of congestion greatly increases when firms in the east act strategically. Under perfect competition (e.g. least-cost dispatch), there is congestion at only one level of demand. When firms act as Cournot producers, we find congestion on the east-west intertie in over 1000 additional hours. The assumption of least-cost dispatch therefore greatly overstates the potential suppliers to the PJM-east market for nearly 1/8 of the hours of a sample year.

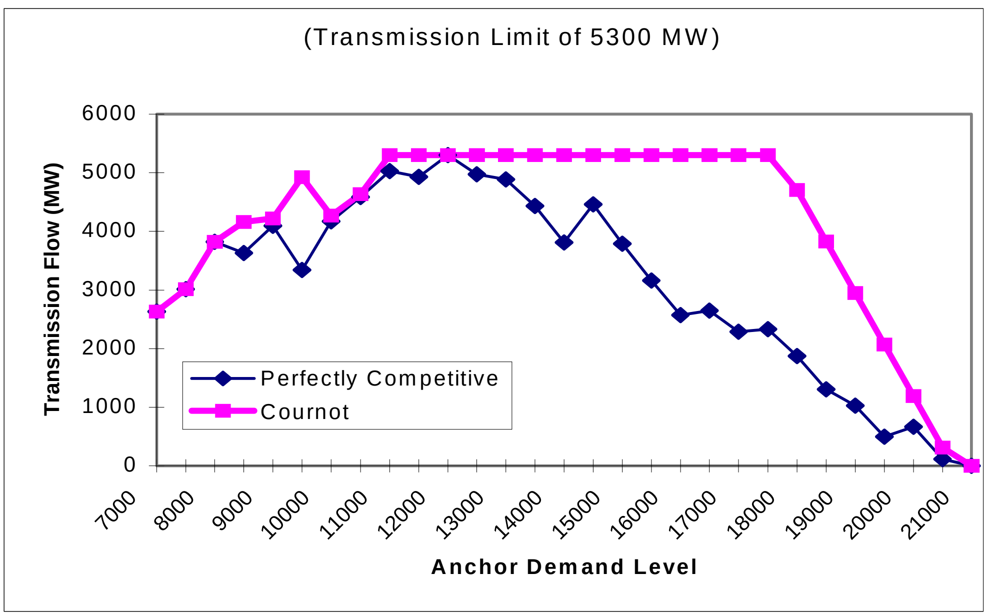

Figure 5— PJM West to East Transmission Flows

[13] In calculating these equilibria, we assumed that generation units located in the western portion of the PJM pool, including those owned by firms located primarily in the east, would be dispatched non-strategically. The study is described in detail in Borenstein, Bushnell, and Knittel (1997), "A Cournot-Nash Equilibrium Analysis of the New Jersey Electricity Market," Appendix A of Review of General Public Utilities' Restructuring Petition, Final Report. New Jersey Board of Public Utilities. Docket No. EA97060396. It is also available from the authors.

6.0 Summary

We have highlighted the results from our previous studies that analyze the potential for market power in an electricity market using an oligopoly framework. Our work has taken actual cost, demand, and transmission capacity data into account when employing a Cournot–Nash equilibrium model of the electricity market. In this filing, we have discussed some of the strengths and weaknesses of the market power models that have been applied to the electricity industry. While the Cournot-Nash model is far from perfect -- it ignores, for instance, the dynamic aspects of competition – it offers several significant advantages over models that represent the operation of an electricity system through an assumption of least-cost dispatch.

One significant advantage of a Cournot-Nash model is that it can detect when firms have the ability to profitably raise prices by reducing output. It is important to note that the market conditions under which such opportunities might arise are not well-identified by concentration indices such as the HHI. Furthermore, a Cournot-Nash model can detect when a firm can profitably induce additional congestion along certain transmission paths. When such opportunities exist, a 'delivered price' test using data from a simulation of the least-cost dispatch of an electricity system can dramatically overstate the geographic scope of an electricity market. This is because firms, through the very act of exercising their market power, are creating congestion that would not otherwise exist.