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NATURAL GAS AND ELECTRICITY MARKETS

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The natural gas and electric power industries—once the classic examples of natural monopoly—are increasingly being regulated by market forces instead of public service commissions. The emergence of markets in the North American natural gas industry in the mid-1980s resulted largely from the failure of regulation, and a consequence of this regulatory failure was the separation of the energy commodity from its transportation. This simple change in the organization—where the energy commodity was unbundled from its transmission—provides the basis for restructuring natural gas and electricity markets. The natural gas and electricity industries are being transformed so that they more closely resemble a commodity market than a public utility in the move toward market-oriented allocation mechanisms for production, transmission, and distribution.

1 The Emergence of Markets

Competitive markets for natural gas in the US emerged in the 1980s; since that time the natural gas and electric power industries in numerous countries around the globe have been transformed from a regulated structure to one based on markets, including those in Argentina, Australia, Canada, New Zealand, the US, and the United Kingdom and others. In the European Union, a directive on opening up markets was adopted in 1998; however, nearly ten years later, numerous countries—including France, Germany, Austria, Bulgaria, Cyprus, Greece, Luxembourg, Latvia and Slovakia—remain resistant to the full unbundling of energy production and transmission.[1] In contrast to the energy market reforms being imposed on EU member states, the initial emergence of markets in the US natural gas industry was not part of a conscious design to restructure an industry long held to be the classic example of a natural monopoly. Instead, it was an expedient way of correcting a long succession of regulatory mistakes.[2] Markets developed rapidly where permitted and within a few years dozens of spot markets for natural gas were in operation .[3] New market institutions were developed by industry participants for trading gas since there were no such institutions under the old system.[4] In North America, gas trading is decentralized in over-the-counter markets that span a large geography. Prices are now discovered in markets, not in regulatory proceedings.

Throughout most of the twentieth century the natural gas industry has adapted to an environment determined by government regulation. Markets were suppressed and were not part of the industry's basic institutions or ways of doing business. Everything turned on questions of regulatory approval and procedure. The industry functioned poorly, especially in the US (MacAvoy and Pindyck, 1975; Tussing and Barlow, 1984; De Vany and Walls, 1995). By the late 1970s natural gas was the worst regulated industry in the US. Shortages and curtailments there were common and disastrous. Industries were shut down or their gas use was rationed. Gas reserves reached a historic low relative to consumption. Regulation had not only lost control, it was causing the damage, and no hearing or resolution of a technical regulatory issue could restore the integrity of the gas supply system.

[1] "Breaking up is hard to do: Attempts to reform Europe's energy markets are losing out to protectionism." *The Economist*, 13th September 2007.

[2] See, for example, Tussing and Barlow (1984) and MacAvoy and Pindyck (1975) for historical and economic analysis of natural gas price regulation. Brief accounts are contained in Michaels (1993) and in De Vany and Walls (1995).

[3] Prior to this time nearly all gas was sold under long-term contracts that have been analyzed thoroughly in the economics literature. See, for example, Masten and Crocker (1985), Mulherin (1986a, 1986b), Masten (1988), Hubbard and Weiner (1986, 1991), and De Canio and Frech (1993)..

[4] The system of tradeable property rights proposed in Smith et al. (1988) is an example of the type of institutions that can be created by industry participants, in this case an association of natural gas suppliers.

The long-term contracts which had organized the natural gas industry were unsustainable. Price shocks and price regulation together caused the contractual relations to unravel. Regulators attempted to alleviate the shortages they caused, but this led to further problems. The slow collapse of the industry and the potential for very serious gas shortages forced Congress to increase the industry's reliance on markets and diminish the scope and harm of regulation. But changes in the patchwork of regulation that had been built up over the fifty to seventy year history of government control of industry structure and operation began to pull the whole fabric apart.[5] Once the existing contracts and regulation became unsustainable in 1983, some of the major pipelines were on the verge of bankruptcy from their contractual purchase obligations. They had to sell gas and to do that they had to transport it to the customer. That was the beginning of contract or what has become known as 'open access' transportation. The accumulated constraints of merchant carriage and onerous regulation became unsustainable and adjustments had to be made everywhere. This could not be accomplished by augmenting existing regulation. The industry reconstructed itself in the wake of the final crisis. What were the tools of this reconstruction? They were contesting markets, intermediaries and brokers, futures contracts and markets, storage programs, tariff discounting, interconnects, arbitrage, lower prices, well-behaved prices, prices that contain valuable information (not the mix of ancient and stale rate hearing history), prices that guide decisions, hubs, and the emergence of a strongly connected interstate pipeline grid.

In contrast to the natural gas industry, the emergence of comprehensive markets in the electricity industry was a more centrally designed process. Of course, decentralized markets isomorphic to those that emerged in the natural gas industry had existed in the US for many years. In these markets, electric utilities would trade wholesale power across their transmission networks, some-

[5] See U.S. Energy Information Administration (1989), Cramer (1991), and De Vany and Walls (1994a) for more details on the transition from merchant carriage to contract carriage.

times “wheeling” the power across their network from one utility to another (Joskow and Schmalensee, 1983). In the US, the Energy Policy Act of 1992 provided non-utility entities with access to the transmission network and this supported increased wholesale trade in power and this increased competition for wholesale power in an industry structured as vertically integrated monopolies (De Vany and Walls, 1999b). Like customers located behind the city gate of a gas distributor, customers located inside an electrical utility’s service area could not purchase power unless they could get access to wheel power through the local grid. Equally, the point applies to a power transaction that involves utilities located on opposite sides of an intervening utility’s territory. To transact, they must be able to wheel the power through the intervening utility’s grid. With pooling and wheeling, the US industry began to dissolve the territorial boundaries erected under the Public Utility Holding Company Act and subsequent regulation by federal and state authorities who carved territories into jurisdictional protectorates. As in the gas industry, access began to promote a more integrated power grid.

While natural gas markets emerged in a spontaneous way in the US, the first totally restructured electric power market—where the vertically integrated monopoly structure was dissolved—was located in England and Wales. While natural gas deregulation occurred in response to a series of regulatory crises in the industry, the motivation for electricity deregulation came from policy circles combined with the introduction of market rules that opened up the power transmission network. While the market rules opening up the transmission system were at a national level in the US, individual states have the authority to regulate the electric utilities within their geographic boundaries. As a result, individual states embarked on deregulation programs in the US and these programs typically included included the vertical disintegration of generation, transmission, and distribution. Restructured power markets did not begin to operate in the US until the end of the 1990s.[6] Power market restructuring is still under way in Europe, though opening up the power transmission system is a thorny issue (Serralles, 2006). Electricity markets are also being restructured in a number of other countries. For example, power markets are being restructured in Indonesia (Pintz and Korn, 2005), Taiwan (Hsu and Chen, 1997; Wang, 2006), Thailand (Chirarattananon and Nirukkanaporn, 2006; Mulugettaa et al., 2007; Nakawiro and Bhattacharyya, 2007), Japan (Asano, 2006), Singapore (Chang and Tay, 2006), Russia (Pittman, 2007), India (Singh, 2006; Balachandra, 2006), China (Xu and Chen, 2006), Israel (Tishler et al., 2006), and others.

2 Markets versus Regulation

The natural gas and electric power industries were considered to be natural monopolies and they were regulated as the theory prescribes (Scherer, 1980; Kahn, 1988). The conclusion that these industries were monopolies was based on economies of scale in firm size and output, that duplicating infrastructure would be wasteful, and that there was a need to plan the installation of infrastructure and coordinate its operation to achieve the economies that are inherent in a network. Proponents of regulation argued that decisions and actions were best made by a single organization and the regulated monopoly is the institutional embodiment of this argument. In this context, the state is the central coordinator and planner and the regulated monopoly is its agent; the hybrid organization combining state and monopoly is thought to provide the optimal span of control to solve the coordination problem and the right size of the production unit to realize economies of scale. The other half of the argument for regulation is that competition, with its decentralized and individualistic actors, could not effectively coordinate all the required decisions.

[6] Although comprehensive restructuring did not occur in practice until the late 1990s, economic models of spatial spot pricing that incorporated the physics of alternating current were developed much earlier. See, for example, Schweppe et al. (1988) and the numerous references to the work of Schweppe and associates referenced therein.

Decentralized competitive markets seem to provide no central place to collect the information required for coordination, and no mechanism for integrating it to plan and operate the system. It is said that there would be too much competition and wasteful duplication of facilities in the absence of an agent to serve as a central planner; as a result there would be inefficient coordination, excessive entry and exit, and volatile prices. Transmission was considered to be a natural monopoly because there are economies of scale in construction and operation up to a limit which is sufficient to serve the largest markets. Costs are subadditive and one firm is enough to serve the market at least cost if its average cost is declining at an output sufficient to fill demand at a price that exceeds average cost. Two or more firms having the same costs would raise total cost by duplicating facilities. They would also reduce each other's output, which would raise average cost. Increasing returns to scale is a justification for regulation on two grounds, according to the theory: to avoid or control monopoly power and to prevent duplication of capital and a loss of scale economies. To accomplish these ends, it is said that price must be regulated to prevent monopoly pricing and inefficient output. Moreover, entry must be prevented to prevent duplication and a division of output that loses economies of scale.

Regulation was also thought to improve coordination in an industry where there are externalities. A network industry, like gas and power transmission, could fail to realize the economies of coordination if each transmission link is independently owned and operated. Competition, the theory says, can not achieve the coordination needed to operate efficiently the network because each firm controls only a small part of it and cannot internalize the gains of coordination over the portion of the network where they occur. Full coordination might require that all the segments be owned and operated by a single firm, so that all the externalities are internalized inside the firm.[2] Since this would mean the firm would be a monopoly, the theory prescribes regulation to prevent inefficient monopoly pricing. The implication is that planning the network configuration is best accomplished by a single entity, be that a company or a regulator.

Commitment and opportunism are also important elements in the normative theory of regulation. A pipeline, for example, is a fixed asset; so is the collection system feeding gas to it from producing wells, and so is the distribution system that sends gas from the pipeline to users. No part of the system can operate without the other and the value of the assets in each part depends on what every part does. Since these assets are specialized and have little value independent of the other components, there is a potential for each to hold up the others. If, after all the assets are in the ground, one segment opportunistically seizes on an unanticipated event or an ambiguity in the agreements to hold up the others, they cannot move their assets to another use. It may not be possible to write a contract that prevents all the possibilities for opportunistic actions. To prevent opportunism, the components could be merged, but that would give the merged firm too much power, according to this theory.

By supplying a tribunal for adjudicating these disputes and specifying rules of behavior, regulation might avoid the opportunism to which private contracting is susceptible. The theory asserts that regulation can supply a more secure and broader form of contracting than markets. By reducing the scope for opportunistic behavior, regulation can lower the required rate of return for specialized assets and permit a socially valuable project to go ahead. However, since the regulator holds no equity in the regulated firm, it bears no cost for taking opportunistic actions against it. The constraint that would bind is if the firm goes out of business. The contract theory would make more sense if the regulator had something at stake to limit its own opportunism.

The simple theory of economies of scale neglects important features of the industry. Producers and users are diverse. Their uses vary by type of transmission, by time, by season, and by location. Supply sources also are diverse and variable. Uncertainty and diversity can alter the simple picture given by the theory of scale economies, where output, cost, and demand are assumed to be known and certain. In this case, a more dispersed pattern of transmission lines and energy sources can be more efficient than a single, large source of supply. A network of smaller lines can connect to more points of supply and use to pool their variations and load patterns. A network can provide more paths between points and make it possible to alter routes to avoid capacity bottlenecks.

Centralized control is not clearly more effective than decentralized control once the system becomes large and complex. There is a confusion in the natural monopoly argument between coordination and allocation. To grant the authority to coordinate transportation on a pipeline does not grant the authority to allocate transportation among users. The two functions are separable. A good example is the procedure pipelines and their customers use to coordinate the monthly transportation volumes. The pipeline customers—the shippers—nominate the volumes they intend to transport through the pipeline. They must inject and withdraw gas according to the rules of operation of the pipeline and in accordance with their nominations. This achieves coordination of shipments and pipeline operations.

The case for economic regulation rests on the particular organizational structure that the theory of natural monopoly assumes of the firm. Regulation encouraged or even required centralized ownership and control of the pipeline. It discouraged vertical integration of the pipeline with gas producers and distributors. In the US, Federal legislation, in the Public Utility Holding Company Act, barred holding companies. These companies integrated horizontal segments of the pipeline grid and spanned wide geographic areas. They also were effective competitors to locally franchised gas utilities. The same legislation balkanized the US electric power industry and may have caused a great deal of inefficiency in the process (Schrade and Walls, 2006).

The monopoly problem is an organizational problem, the consequence of combining and centralizing the authority to coordinate and allocate output in the hands of one agent. When the firm holds all of its transportation capacity, it considers the impact of each marginal unit of output on the price it receives for all units of output. It is this centralization of the output decision that causes the inefficiency usually attributed to monopoly. But, when units of capacity are owned by separate individuals, they compete with one another to supply transportation. The decentralized ownership structure that results from separate ownership eliminates the monopoly problem because each owner does not consider how his actions affect the prices received by other holders of capacity.

Another claim made for regulated natural monopoly is that, as an organization, it is a superior planner to competition. This would say that the natural monopoly is guided by the regulator, who approves all projects and pricing. Since the regulator looks over all projects, he or she may be able to plan the system in a way that is superior to unregulated monopoly or competition. Planning means that the impact on the entire network is considered and that the future plays a part in approving projects. This theory does not stand up to the facts. The pipeline network never took form until deregulation and the emerging gas market transformed it. Before that, pipelines were separate and segmented because regulation blocked the formation of a connected network. As to the superior foresight of regulators, one need only point to the chaos and crises that drove the move to deregulate well-head prices and which is moving through every segment of the industry from the well head to users.

Another claim made for regulation is that it prevents wasteful duplication. The ironic aspect of this argument is how far from realizing the supposed benefits of preventing duplication we are under the present system of regulation. Intrastate and interstate pipelines duplicate one another to a significant degree as do power lines. This is partly the fault of the artificial jurisdictional boundaries that carve regions into isolated protectorates. In nearly every local distribution area, there are private distribution systems operating in parallel with the public utility distribution company. One reason they do this is to get better terms and reliability than the local distributor can give them. Another is to cover parts of the region the distributor's system does not. Yet another is to augment the coverage where the distributor's coverage is inadequate.

Given a complex system and a dynamic world, regulation can build a system of prices and services that becomes un-sustainable. We have seen this several times in natural gas. Agreements and contracts had to be undone, price regulation went through five regimes, and regulation spread from the user all the way back to the producers and then came apart. As in any sustainable coalition that achieves political control of an industry, the combined claims of the members, which reflect what they can get outside the coalition, must not exceed the total value of resources available to the coalition. When they do, the system must collapse. It then can only be rebuilt on a new, and reduced, set of claims and, maybe, with different members. By blocking exit and altering constraints, the system can be made to work for a time, but the complexity of the interlocking constraints means that they must frequently be violated. Then a fix is required, as in the many changes of regulatory regime that have been made to natural gas. However, do regulators understand what they are doing? In this complex problem, regulation is just a blind search for a sustainable coalition and not for efficiency.

3 Markets in Operation

It will become evident in this section that the evidence on the performance of markets in natural gas and electric power is mixed. Where markets succeeded, it is largely because open access transportation gave them the scope to operate. Where markets failed, it is usually due to the imposition of an inflexible and centralized market design that misaligned incentives. The institutions separating the merchant and transportation functions allowed new kinds of traders into the market, and gave these traders the means to trade over wide areas. When the market design works, open access and transportation trading make it possible to create a more connected grid with flexible routings, and this more connected network topology expands the power of arbitrage to discipline prices across the locations of energy supply and use.

In the US the unbundling of gas transportation from the commodity completely changed the way the industry works. Pipelines coordinate their customers' transmission demands during what is called bidweek.[7] During the bidweek, usually the third week of each month, pipeline customers nominate the gas volumes they plan to ship during the following month. These nominations specify the injection point, the withdrawal point, and the volume of gas to be shipped. Customers may nominate volumes only up to the amount of their firm transmission rights. Those pipeline customers who transfer their transmission capacity to third parties are responsible for nominating and paying for it. The simultaneity of gas and interruptible transportation markets during the bidweek coordinates the purchase of gas and transportation. The spot contracts are for volumes to be delivered to specific injection points on the pipeline system. From the injection point, the gas flows through the interruptible transmission right that is purchased in the bulletin board market to the downstream destination.

Holders of firm transportation contracts may trade with one another or transfer their rights to brokers and other parties; however the federal regulator has not permitted transportation to become a fully transferable property right.[8] Unused firm transmission capacity reverts to the pipeline, which sells it as interruptible transportation. Brokers buy and sell gas throughout the pipeline network, even though they do not have uninterruptible transmission rights of their own. They aggregate the supplies of producers and the demands of gas users. By purchasing interruptible transmission from the pipeline, they

[7] The discussion of the market institutions follows closely De Vany and Walls (1994a).

[8] See Smith et al. (1988, 1990), Alger (1990) and De Vany and Walls (1994a) for a more detailed discussion of gas pipeline regulatory reform.

can ship gas from the producers to the users. Essentially, brokers hold a portfolio of gas market transactions which they match. Some brokers act as the purchasing agent for downstream local distribution companies. These brokers use the customer's transmission capacity to deliver the gas which they sell to the customer. Pipeline mergers have created extended networks. The technology for interconnecting pipelines quickly developed after 1985, so that it is now possible to interconnect lines with different pressures and to change the flow between them.[9] Markets quickly came forth as pipelines chose open access status. A few years after the initial institutionalization of open access by the federal regulator, the gas industry publication *Gas Daily* was reporting spot prices at over fifty market locations.

By 1989 almost all the major US pipelines had open access and by 1991 more than 65% of the regional markets had become integrated (De Vany and Walls, 1993). These findings have been echoed by other researchers who found an increasing in the geographical extent of the market after 1985 and concluded that open access created a national competitive natural gas market (Doane and Spulber, 1994). Kleit (1998), using an arbitrage cost approach, also found less strong evidence of market integration. Cuc and King (1996) also found an increasing degree of market integration in the North American natural gas market, but indicated thte presence of an east-west split in North American natural gas markets; however, Serletis (1997) finds on further examination, that markets are integrated and that there is no east-west split. The strong market integration at the field level was not completely reflected at the downstream city markets (Walls, 1994).

The benefits from open access may not be large when the pipeline network is not very dense since pipelines lack an incentive to price their interruptible capacity efficiently . In the absence of an established pipeline network, which is the case in many markets, pipelines may have little incentive to price their excess

[9] See *Oil and Gas Journal*, August 6, 1990, pp. 41–48.

capacity efficiently. In this case, attempts to promote an efficient allocative outcome through privatisation and open access are unlikely to be as successful as they have been in North America. This view is consistent with recent theoretical work that finds building excess transmission capacity leads to increased market integration through the mitigation of local market power (Cremer and Laffont, 2002).

In recent years, natural gas utilities have faced increasing demand, slower growth of production and pipeline capacity and, several episodes of sharp spot price increases, in the most two recent cases, lasting many months. Most of the gas sold to residential customers is done so under terms that simply pass-through the commodity costs of acquiring the gas. Further, there are few effective options for these consumers to observe changing gas spot prices in real time or to switch to alternative fuels in the short-to-mid term. Recent survey evidence indicates a great deal of disparity in the practices of regulated utilities with regard to hedging their purchases of natural gas. This disparity in utility purchasing practices appears to indicate a systemic problem, with the regulatory environment not conducive to regulators accepting the appropriate use of the hedging tools .

The restructuring of natural gas in the UK took shape with the privatization of of British Gas and the creation of a new regulator, Ofgas, in 1986. Due to the highly centralized structure of the industry and the dominance of British Gas, active spot markets did not evolve until the 1990s (Asche et al., 2006). The restructuring of the European natural gas industry, while centrally directed by the EU, has not been implemented with the same rapidity that characterized deregulation in the US and UK (Percebois, 1999; Radetzki, 1999; Heren, 1999). Lee et al. (1999) study the market performance of gas utilities across countries with different regulatory structures and conclude that the North American market, with its decentralized market structure and intense competition does not guarantee a more desirable market outcome than the European centralized and highly regulated structure. While different approaches to regulatory reform in natural gas markets have been applied, the price evidence indicates convergence toward a single market: Asche et al. (2002, 2006) and Silverstovs et al. (2005) find evidence of market integration in European natural gas markets.

In the US gas industry, the institutions and practices took some time to emerge and evolve to a level of refinement that let markets operate well. Several years were required to get smooth operation in gas markets even after open access was a completed property of the pipeline network. Unlike gas pipelines, the concept of shared transmission capacity has been used in electricity for some time.[10] Because power pools, wheeling, and energy trading have a long history in the electricity industry, the necessary institutions and practices were in place for increased wholesale trade once the transmission network began to open up. Before comprehensive introduction of market restructuring in electricity, decentralized wholesale power trading did lead to an increased integration of markets though the scope was trade was limited (De Vany and Walls, 1999a, 1999b). The advantages of an interconnected power grid are many. Generating resources could be pooled; load variations could be smoothed over the many markets and users on the grid; diverse customers could be combined into portfolios that balance loads by time and direction of flow; and power could flow from low-cost generators to replace high-cost generators. An active network of markets, which makes prices daily or by the hour, supplies the information needed to direct energy flows over the network of resources and users so as to minimize the total cost of electricity. As in the gas industry, access means that buyers and sellers could deal directly.[11] It also means that they can search over the network for the best price. This ability to search puts competitive pressure on the local utility to supply cheaper power.

The balancing of supply and demand for electricity is much more complex

[10] See, for example, the discussion in Joskow and Schmalensee (1983).

[11] Although the power market is typically an auction institution, this does not foreclose other transactions. See the many examples contained in Stoft (2002).

than for any other commodity. Due to the absence of much cost effective storage, and the fact that equipment that runs on electricity is quite sensitive to changes in voltage and frequency, the supply of and demand for electricity must at all times be maintained in almost precise and instantaneous balance. This is further complicated by the fact that consumers of electricity, by virtue of custom and the state of installed technology cannot effectively be excluded from consuming electricity, and therefore, there must always be enough power on the grid at all times to meet whatever demand is placed on it. Among other things, this requires some centralized control over the operation of the entire electricity grid. The grid operator must have enough control over the operation of generators to make instantaneous adjustments to the supply in response to unscheduled changes in demand. Superimposing competitive markets for wholesale electricity on this system has proven to be a challenge (Joskow and Tirole, 2005).

Results from an analysis of wholesale electricity spot prices on the western US electricity transmission system during 1994 to 1996 find a high degree of market integration (De Vany and Walls, 1999a; De Vany and Walls, 1999b); at this time electricity markets had not yet been comprehensively restructured but instead there was decentralized trade in wholesale power along the same lines in which open access transmission had been introduced to gas pipelines. The restructuring process in the electricity industry developed slowly, and wholesale trade in electric power was the logical way for the industry to evolve. But because there was no single national entity responsible for the power network in the US different states and regions have restructured their industries differently. However, in each jurisdiction a centralized market mechanism as been implemented to account for the complexity of balancing of supply and demand for electricity in a way that is consistent with the physics of the transmission network. Numerous different models have been employed, the main difference between gas and electricity markets being the decentralization of the former and the centralization of the latter. In power markets there is typically an auction institution for power in combination with centralized dispatch of power that accounts for the constraints of the transmission system.[12]

The performance of electricity markets that have been comprehensively restructured is mixed. Most markets are working in a sustainable way, though some markets that experienced problems—such as Ontario and California—have essentially halted their restructuring programs. The disaster in the California power market and the exercise of market power in that state's wholesale power market has been well documented and merits a short discussion here.[13] California restructured its electricity industry in the mid-1990s. The intention was to increase wholesale competition and then to gradually introduce retail competition. There were two principal flaws in the design of California's electricity markets that began operation in April 1998. The first was that the rate structure for the state's three investor owned utilities (IOUs) all but precluded the development of retail competition that might have introduced some measure of demand response to the market. Rates for the three utilities' customers were reduced by 10 percent and frozen, which simultaneously reduced the margin that might have encouraged retail competition and removed the option of increasing rates in the event that wholesale prices rose. Second, the same three IOUs were encouraged (some argue required) to divest themselves of their fossil-fuel generating facilities without signing any long-term contracts to buy back the power from these or other generators. As a result, the IOUs were in a position of buying a large proportion of the power to serve their load in the day-ahead and hour-ahead markets operated by the California Power Exchange. It is generally agreed that at the time the divestments were made, there was a surplus of power in the region and long-term contracts for power

[12] The different implemented architectures and discussed in depth in Stoft (2002). Wilson (2002) provides a more theoretical discussion of the incentive properties of various architectures for power market design.

[13] See, for example, the papers of Faruqui et al. (2001), Borenstein (2002), Joskow and Kahn (2002), Wolak (2003), the US General Accounting Office (2002a, 2002b), and many others. A discussion of the Ontario electricity market is contained in Trebilcock and Hrab (2005).

could have been purchased quite cheaply. In fact, for two years, the surplus capacity in the region kept wholesale market prices very low relative to the previous rate–regulated cost of electricity, and by design, the frozen rates of the IOU customers meant that the IOUs were recovering large amounts of their negotiated stranded costs.

The design of the California market implemented institutions and rules that were almost guaranteed to create market power in the event of tight supply conditions. The power exchange was set up to operate day-ahead and hour-ahead markets and the three investor-owned utilities were encouraged (required), after divesting much of their generating capacity, to buy all their power in these markets. Other suppliers of electricity were not similarly constrained. The root cause of the 2000–2001 crisis was a tight supply caused by static thermal generating capacity over a number of years coupled with rising demand and reduced hydro power as a result of a dry year. The resulting scarcity in the spring and early summer of 2000 caused prices to rise and allowed isolated exercise of market power by individual suppliers. However, the response by the system operator of (indirectly) capping prices in the day-ahead and hour-ahead markets had the effect of driving suppliers out of those markets. These suppliers either sold power out of state—exports and imports of power rose during this period—or waited to sell directly to the system operator closer to real time. In the latter case, the transmission system operator lacked the political will to credibly commit to shedding load if prices rose too high and so they were in a position of engaging in multiple bilateral negotiations under tremendous time pressure and where their bargaining opponents knew the system operator would have to blink first.[14] The problem worsened when the cap was lowered because it drove even more of the suppliers out of the day ahead and hour

[14] Under the design of California's electricity market, the system operator did not have broad authority to mitigate market power as did system operators in other restructured markets. On numerous occasions the system operator did request such authority from the Federal Energy Regulatory Commission (FERC) and also requested that FERC step in to mitigate prices that appeared to be far in excess of generation costs. FERC declined to act in the early stages of the crisis and the only tool CAISO had at its disposal was price caps.

ahead markets and closer to real time. As the system operator was forced to buy increasing amounts of energy close to real time, their ability to negotiate and to seek alternatives to high price offers became even more constrained. As the price caps were reduced, the imbalance between demand—the entire load of the three investor-owned utilities—and supply—the remaining capacity (nuclear and hydro) plus power from those suppliers who did not flee to real time—became greater. As a result, prices rose toward the cap in more and more hours as the cap was reduced, causing average prices in these markets to rise.

Another important and specific issue is the way in which power industry restructuring has changed the incentives to provide additional generation capacity. One key feature of restructuring has been a move away from centralized planning where utilities planned for development of new generating capacity and transmission upgrades in order to meet expected increases in future demand. In its place, a decentralized process of development and investment decisions—largely by non-utility companies—is evolving. Unlike the rate-regulated regime of the past, the development and investment plans of these companies are not subject to approval of public utilities commissions or centrally coordinated. Even under a market organization, government entities influence investments through licensing and permitting processes, through the terms of transmission interconnection agreements. There is considerable variation across locations in the administration of the development process and thereby in the costs developers must incur to gain approval governmental entities. In addition to the development costs associated with acquiring regulatory approval,new power plants must be interconnected with the transmission grid, frequently requiring costly upgrades to the system to maintain reliability.

A study of US power plant investment found that the addition of new power plants is much more prevalent in states that have either restructured their retail electricity markets or signaled an initial intent to do so than in states that have taken no restructuring actions . Such development is also more prevalent in areas of the country with a robust wholesale market infrastructure. Non-utility companies accounted for most new power plants in states taking restructuring actions, while utilities maintained a dominant role in states that have not restructured. States that implement retail competition have more investment in new power plants. These patterns indicate that regulatory actions are an important determinant of how well overall restructuring will ultimately work. The bulk of the potential benefits of restructuring the industry will come from improvements in efficiency of wholesale generation and sale of electricity and this depends critically on the ability of new companies to enter and exit. However, non-utility companies are far less likely to make the investments necessary to achieve these benefits in jurisdictions not committed to developing a competitive environment.

4 Moving Forward

Open access transportation has given us a glimpse of what market competition really looks like in natural gas, the first such view that can actually inform us as to how markets would work in this industry. What we have seen is very different from what the theory of regulated monopoly says should have happened. According to this theory, competition is unsuited to natural gas; it would lead to wasteful duplication, would not efficiently coordinate the use of the pipeline network, and would produce erratic price behavior. The evidence in North America—where open access transportation has been adopted—indicates that competition led to gas prices convergence over the network, eliminating pockets of non-responsive and possibly monopolistic prices, and integrating markets. The gas market is functionally competitive. The move toward market-based allocation in power has been more problematic.

What does functional competitiveness imply about the validity of the structural measures of monopoly and competition that market monitors and regulators apply? Interconnections and paths in the transmission network are the fundamental structural elements in the determination of prices. Open access and flexible transmission create the functional paths on this structure and they are assembled in response to prices and arbitrage opportunities. The market is functionally competitive if it produces competitive prices, whatever its physical structure. The market is competitive if the spatial distribution of prices over the network exhibits the right kind of convergence and dynamics.[15] Price evidence is functional and far more compelling than structural evidence., though there may be allowances for how easy it is to connect to a nearby, presently unconnected, transmission line and other such factors.

Any structural organization of the energy market that can deliver competitive prices is functionally competitive, no matter how it is structured. The ideal of perfect competition is wholly structural in content and not a model of function. The conditions that the model assumes are neither necessary nor sufficient for competitive pricing. North American gas markets show this clearly, since virtually none of these conditions are met and yet the gas market is functionally competitive, based on the price evidence. What is called perfect competition, and held up to be the ideal that regulation should strive to emulate, is a very poor market structure. It is maladaptive to changing circumstances. It does not deliver products with the kind of variety that is required to serve diverse customers. It is non-innovating; in fact, it just assumes that there is a product that customers want without ever telling how it is discovered. It does not capture the noise and chaos which any adaptive market must possess and which any real market exhibits.

Far from perfection, perfectly competitive markets do not function well because they share certain characteristics with planning. In planning, all the equations of the system are solved by the planning bureau who then calls out allocations or prices to managers whose behavioral rules tell them to set marginal

[15] Some electric power markets are even characterized as being informationally efficient; see, for example, Serletis and Bianchi's (2007) analysis of Alberta electricity spot prices.

cost equal to price. The model of perfect competition is similar in that in it markets solve the problem of computing a price vector, and profit-maximizing managers do the rest. Neither task is doable and the solutions they would obtain, if they could find them, are inept and narrow. It is time to stop apologizing for competition on the grounds that it is not perfect; perfect competition, like any homogeneous and noiseless process, is incapable of evolving and its structural perfection is its greatest weakness.

Prices that are made daily or hourly or even by ten-minute intervals in spot markets scattered over the grid can supply the information needed to guide the flow of electricity through the network, producing it at the lowest cost generators and sending it to the markets where its value is highest. With prices made continuously in a network of markets, the flow of energy can take place nearly in real time. Moreover, prices reflect the state of the network at each trading interval and they can supply state information to guide flows through the network. The signal that the process is working is the convergence of prices over the network, just as we have seen in the gas industry. Therefore, we should be looking at prices—spot, contract, and utility retail prices—over the power grid for evidence of competitiveness. Structural features like the number of lines into or out of a territory are important only if prices are out of line. Yet it is the price evidence that is decisive. Prices are likely to track the competitive arbitrage band, as we saw in US natural gas markets, if the power grid is open and competitive market institutions are in place.

5 Conclusion

In the move toward market-oriented allocation mechanisms, the natural gas and electric power industries are increasingly being regulated by market forces so that they more closely resemble a commodity market than a regulated public utility. The separation of the energy commodity from its transportation has provided the basis for restructuring natural gas and electricity markets. Competition in gas and power markets has been more like evolution than like solving a well-defined mathematical problem. Evolution is robust and opportunistic; it searches a broad landscape and promotes diversity. Selection eliminates weak solutions and random innovations present new alternatives for selection to affect. This is precisely what we have seen in the gas and electricity markets as they have evolved over the past two decades of relaxed regulation. Markets succeeded under open access to gas transmission because participants built effective institutions to govern their trade in gas and transportation. Under these institutions, markets have achieved a high degree of coordination between commodity trading and transportation. The transition from planned industry to markets in natural gas was easier in the US than one might have thought. A believer in what the theory of regulation claims would not have prepared for what happened. Market participants created the institutions that were required to support competitive exchange in gas across the transmission grid. Access to transmission opened paths in the network and let arbitrage force gas prices to converge to a spatial distribution that is competitive. None of the dire predictions of the theory of regulated natural monopoly about competition and markets came true. However, due to the complexity of balancing of supply and demand for electricity, the introduction of market-based allocation mechanisms have proven to be far more difficult for electric power than was the case for natural gas; in these cases, regulatory failures in design have resulted when the mandated rules and institutions did not appropriately reflect the constraints and incentives of the regulated. Nowhere has this been more evident than in restructured electricity markets.

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