Incentive Regulation and Its Application to Electricity Networks

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Abstract

This paper examines developments since the publication of *The Economics of Regulation* in the theory of incentive regulation and its application to the regulation of unbundled electricity transmission and distribution networks. Conceptual mechanism design issues that arise when regulators are imperfectly informed and there is asymmetric information about costs, managerial effort, and quality of service are discussed. The design and application of price cap mechanisms and related quality of service incentives in the UK are explained. The limited literature that measures the effects of incentive regulation applied to electricity networks is reviewed.

1 Introduction

Alfred Kahn began to write what became *The Economics of Regulation* while I was an undergraduate at Cornell. He was my teacher and academic advisor at Cornell and is the one who stimulated my interest in both economics and the economics of regulation. Much has changed since *The Economics of Regulation* was published in 1970/71 (Volume 1 in 1970 and Volume 2 in 1971). Most of the industries that were thought to be "natural monopolies" and were subject to price, entry and service quality regulation at that time (for example, telecommunication, electricity, natural gas transportation, cable television, etc.) have been restructured and competition introduced into one or more of their horizontal segments.[1] Other industries, where the economic case for pervasive price and entry regulation was already increasingly being recognized as dubious by 1970, and where regulation and competition were often mixed together (for example, trucking, airlines, railroads, natural gas production), have been completely deregulated. The expanse of the economy in the U.S. and most other countries that is subject to price, entry and service quality regulation today has shrunk considerably since 1970.

There are many reasons for this trend, including changes in technology, poor performance exhibited by some regulated industries, changes in the political economy of regulation and associated changes in the power of different interest groups, and broader

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[1] Competition in Electricity remains a work in progress in the U.S. See Joskow (2006c).

ideological shifts favoring markets over regulation and state-owned enterprises. While the pendulum may be shifting back in some sectors (for example, financial market regulation, health and safety regulation, access of content providers to communications networks, etc.) the broad changes in the mix of regulated and competitive segments that we have observed in the last 30 years is unlikely to be reversed.

Even in countries that have gone the farthest in "liberalizing" previously regulated and state-owned enterprises, certain network segments of some of the historically regulated "natural monopoly" industries continue to be subject to price, entry and service quality regulation. These industries include electricity transmission and distribution networks, natural gas transmission and distribution networks, and water supply networks. In the case of electricity and natural gas transmission and distribution networks, the regulatory mechanisms applied to these networks have important implications for supporting wholesale competition (electricity generation, natural gas production, and associated wholesale marketing activities) and retail competition (competition to supply end-users) since they serve as platforms upon which competing wholesale and retail suppliers depend and also implement market and non-market mechanisms to maintain network reliability. Thus, good performance of the competitive segments depends on good performance of the remaining regulated network segments.

The application of sound regulatory mechanisms that affect the terms and conditions of network connections, network delivery prices, network investment, and network service quality have been important components of all successful electricity sector liberalization programs around the world. The benefits of a good regulatory framework include lower network service costs, improvements in service quality, investment to expand the network to support changes in supply and demand for network services, and the development of efficient network platforms to support robust competitive wholesale and retail markets. While many of the basic regulatory principles discussed in *The Economics of Regulation* still apply to these remaining regulated monopoly network segments, there have been important advances in both theory and application since those volumes were published as well.

Volume 1 of *The Economics of Regulation* focuses on the principles for pricing regulated services supplied by firms that are subject to budget or break-even constraints. While there have certainly been theoretical advances associated with the second-best pricing of services supplied by regulated monopoly firms since 1970, especially with regard to the design and welfare properties of non-linear prices to meet budget constraints, the application of these basic pricing principles at the retail level has not advanced very far. So, for example, except for large retail customers, time of day pricing and real time pricing for electricity and natural gas has not spread quickly at all, despite the fact that the information available from wholesale markets about generation and natural gas prices makes it even easier to apply these concepts today than in 1970. At the wholesale level, in those places where prices have been deregulated, the market naturally leads to the load varying prices whose basic economic principles are developed in detail in Volume 1.

The problem of designing rewards and incentives for efficient production by firms subject to cost-of-service or rate-of-return regulation is discussed briefly in Volume 1 (pages 53-54) and in (the more rarely read) Volume 2 (Chapters 2 and 3). The discussion in Volume II of *The Economics of Regulation* in particular raises the right issues:

> …the central institutional questions have to do with the nature and adequacy of the incentives and pressures that influence private management in making the critical economic decisions. (Volume II, page 47)

…[rate of return regulation] creates strong incentives to pad their expenses.” (Volume II, page 48)

It also has several insights into how incentives might be introduced into the regulatory process to improve performance:

> Freezing rates for the period of the [regulatory] lag imposes penalties for inefficiency, excessive conservatism, and wrong guesses, and offers rewards for the opposites …

From an overall economic efficiency perspective, these production cost and service quality inefficiencies are likely to be more important than are failures to adopt the most efficient (second best given budget constraints) pricing structures. This is the case because the efficiency losses from excessive costs lead to “first order” efficiency losses (“rectangles”) while the pricing inefficiencies are likely to be second order (Harberger “triangles”). The historical focus on efficient price structures, rather than cost control and service quality incentives, likely flows in part from the political concerns about monopoly power, excessive prices, and price discrimination that played an important political role leading to the creation of regulated legal monopolies and oligopolies in the first place. But we must recognize as well that in the last fifteen or twenty years there have been major advances in imperfect and asymmetric information theory, and in the theories of incentive mechanisms and associated contractual arrangements generally that have now made it possible to develop relevant theories and then to apply them.

At the time *The Economics of Regulation* was written, there was relatively little formal theoretical development of the properties of alternative incentive regulation mechanisms that provide incentives to regulated firms to control costs, to offer appropriate levels of service quality, and to find it in their interest to set efficient (second-best) price structures. Absent relevant theory, it was difficult to develop applications that could be applied in the real world, though experiments with incentive regulation go back to the 19th century (Joskow, 2007). At the time *The Economics of Regulation* was published, the primary theoretical analysis that focused on the incentive properties of rate of return regulation was the Averch-Johnson (or as Kahn refers to it in his book, the Averch, Johnson, and Wellisz or A-J-W effect, to recognize the less widely cited paper by Stanislaw Wellisz that identified similar potential distortions from rate of return regulation (Averch and Johnson, 1962; Wellisz, 1963)). The A-J-W effect turns on the incentives created by a characterization of rate of return regulation that effectively reduces the regulated firm’s effective cost of capital inputs (r) by creating a profit margin on increases in capital input while leaving fixed the price of other inputs (“labor” in the A-J model) since these input costs are assumed (that is, asymmetrically vis-à-vis capital costs) to be passed through dollar for dollar into regulated prices. This in turn leads a profit maximizing regulated firm subject to this type of regulation to make long run production decisions that use a higher capital/labor ratio than would be cost-minimizing given the firm’s production function and true input costs. This theory ignores many attributes of real regulatory institutions and it has little if any empirical support (Joskow, 1974, 2007; Joskow and Rose, 1989), but for many years it was “the” positive theory of regulation. However, in the last fifteen or twenty years there have been significant advances in the theory of “incentive regulation” or “performance-based regulation” and these concepts are beginning to be applied in the regulation of electricity and gas transmission and distribution networks in a number of countries (Joskow 2006a, 2006b, 2007).

The rest of this paper identifies the key elements associated with the development of modern incentive regulation theory and then examines the application of alternative types of “incentive” or “performance-based” regulation of electricity distribution and transmission network price levels, price structures and service quality. The discussion will assume that effective electricity sector restructuring and unbundling mechanisms have been put in place so that there are clearly defined distribution and transmission network entities offering unbundled delivery and network support services to market participants (as in the UK and portions of the U.S.). I will also assume that electricity networks are regulated monopolies[2] and that an independent regulator with adequate staff resources has been created to oversee the regulation of the distribution and transmission networks.

2 Theoretical considerations

The primary goal of regulation in the public interest is to stimulate the regulated firm to produce output efficiently from cost and quality (including reliability) perspectives, to price the associated services efficiently, and to achieve these goals consistent with satisfying a break-even or budget-balance constraint for the regulated firm that allows the firm to covered its costs of providing service while restraining its ability to exercise its market power to exploit consumers by charging excessive prices. Much of the older theoretical literature on optimal (first and second-best) pricing of services provided by regulated monopolies (for example, Boiteux, Steiner, Turvey) assumes implicitly that regulators are perfectly informed about the regulated firm's cost opportunities and demand patterns and can effectively enforce cost minimization on the regulated firm.[3] The literature then focuses on first and second-best pricing of the services provided by the regulated firm given defined cost functions, demand attributes and budget balance constraints (for example, Ramsey-Boiteux pricing, non-linear pricing, etc.).[4] The older literature did not focus on incentives to minimize costs or improve other dimensions of firm performance (for example, service quality attributes), aside from making the general observation that firms insulated from competition and subject to cost-based regulation were likely to be inefficient and the limited formal theoretical developments of the A-J-W effect discussed above.

In reality, regulators care (or at least should care) as well (or more) about the production efficiency and service quality implications of the regulatory mechanisms they choose. Regulators are neither completely informed nor completely uninformed about relevant cost, quality, and demand attributes faced by the regulated firm. Regulators have *imperfect* information about these firms and market attributes and the regulated firm generally has more information about these attributes than does the regulator. Furthermore, managers have discretion to make choices not only about input proportions (as in the A-J-W models) but on how hard they will work to minimize the firm's costs or in choosing the levels of service quality. Accordingly, the regulated firm may use its information advantage (*asymmetric information)* strategically to exploit the regulatory process to

[2] The economic attributes of unregulated "merchant" transmission network investment are discussed in Joskow and Tirole (2005).

[3] An exception is the extensive theoretical and limited empirical literature following Averch and Johnson (1962), and especially after Baumol and Klevorick (1970) that examines potential distortions in input proportions caused by rate-of-return constraints. The empirical foundations for these theories are discussed in Joskow and Rose (1989).

[4] Brauetigam (1989).

increase its profits or to pursue other managerial goals, to the disadvantage of consumers (Laffont and Tirole, 1993, Chapter 1).

This creates potential moral hazard (for example, too little managerial effort resulting in excessive costs) and adverse selection (for example, prices that are too high relative to production costs) problems that effective regulatory mechanism design must address. The recent theoretical literature on incentive regulation focuses on devising regulatory mechanisms to respond to these moral hazard and adverse selection problems (Laffont and Tirole, 1993; Armstrong and Sappington, 2007).

Consider a situation in which the regulator is uncertain about the firm's true underlying costs and its opportunities further to reduce costs, the regulator cannot observe the level of managerial effort expended by the firm, but the regulator can monitor accurately the firm's realized costs ex post in regulatory hearings and through audits. The regulated firm knows its true cost opportunities, its managerial effort, and the effects of managerial effort on costs. Following Laffont and Tirole (1993, pp.10-19), under these assumptions we can think of two polar case regulatory mechanisms that may be applied to a monopoly firm producing a single product with a fixed quality. The first regulatory mechanism involves setting a fixed price ex ante that the regulated firm will be permitted to charge going forward (that is, effectively forever). In a dynamic setting this is equivalent to a pricing formula that starts with a particular price and then adjusts this price for exogenous changes in input price indices and other exogenous indices of cost drivers (again, effectively forever). This type of regulatory mechanism can be characterized as a fixed price regulatory contract or, in a dynamic setting, a price cap regulatory mechanism.

Because prices are fixed with this mechanism (or vary based only on exogenous indices of cost drivers) and do not respond to changes in managerial effort or ex post cost realizations, the firm and its managers keep 100% of any cost reductions they realize by increasing effort. Accordingly, and ignoring service quality and investment considerations for now, this mechanism provides incentives to induce efficient levels of managerial effort and in turn cost reduction. This effect is a first order "rectangle" efficiency gain. However, because the regulator must ensure that any regulatory mechanism it imposes on the regulated firm meets a budget balance constraint, when the regulator is uncertain about the regulated firm's true cost opportunities she will have to set a relatively high fixed price (or dynamic price cap) to ensure that *if* the firm is indeed inherently high cost, the prices under the fixed price contract or price cap will be high enough to cover the firm's (efficient but high) realized costs. Accordingly, while a fixed price mechanism does well from the perspective of providing incentives to reduce costs it is potentially very poor at "rent extraction" for the benefit of consumers and society because prices may be too high relative to the firm's true cost opportunities. The social value of rent extraction depends upon the social welfare function applied to the distribution of these rents between consumers and producers (Armstrong and Sappington, 2007) or the cost of public funds in a public procurement theoretical framework (Laffont and Tirole, 1993).

At the other extreme, the regulator could implement a simplistic pure "cost of service" regulatory contract where the firm is assured that it will be compensated for all of the costs of production that it actually incurs and no more. After the firm produces, the regulator's uncertainty about whether the firm is a relatively high or a low cost opportunity firm will be resolved. And since the regulator compensates the firm only for its realized costs, there is no "rent" left to the firm or its managers in the form of excess profits. This solves the "rent extraction" or "adverse selection" problem that would arise under a fixed price contract. However, this kind of cost of service regulatory mechanism does not provide any incentives for the management to exert optimal (indeed any) effort. Even though there are no "excess profits" left to the firm, the actual costs incurred by the firm may be inefficiently high as a result of too little managerial effort. Managers now retain 0% of any cost savings they achieve and have no incentive to exert cost-reducing effort. Accordingly, consumers may now be paying higher prices than they would have to pay if the management could be induced to exert more effort to reduce costs. Indeed, it is this kind of managerial slack and associated x-inefficiencies that most policymakers have in mind when they discuss the "inefficiencies" associated with regulated firms.

Conceptually, fixed-price contracts (or price caps) are good at providing incentives for managerial efficiency and cost minimization, but bad at extracting the benefits of the lower costs for consumers. Cost of service contracts are good at aligning prices and costs but the costs will be excessive due to suboptimal managerial effort. Perhaps not surprisingly, the optimal regulatory mechanism in the presence of imperfect and asymmetric information will lie somewhere between these two extremes. It will have a form similar to a *profit sharing* contract or a *sliding scale* regulatory mechanism where the price that the regulated firm can charge is *partially* responsive to or contingent on changes in realized costs and *partially* fixed ex ante (Schmalensee, 1989; Lyon, 1996). (I should note that Volume II of *The Economics of Regulation* discusses some early profit sharing or sliding scale plans and performance benchmarking mechanisms (pp.61-63), but expresses some skepticism about the regulator's ability to apply these mechanisms effectively.) More generally, by offering the regulated firm a *menu* of cost-contingent regulatory contracts with different cost sharing provisions, the regulator can do even better than if it offers only a single profit sharing contract (Laffont and Tirole, 1993).

3 Price cap mechanisms in practice

While the theoretical literature on incentive regulation is quite rich, it still provides relatively little direct guidance for practical application in real-world circumstances. In practice, well-designed incentive regulation programs have adopted fairly simple mechanisms that reflect some of the basic theoretical principles discussed above.

A particular form of incentive regulation was introduced for the regulated segments of the privatized electric gas, telephone and water utilities in the UK, New Zealand, Australia, and portions of Latin American as well as in the regulated segments of the telecommunications industry in the U.S.[5] This mechanism chosen is the "price cap" (Beesley and Littlechild, 1989; Brennan, 1989; Armstrong, Cowan and Vickers, 1994; Isaac, 1991). Price cap regulation is a form of institutionalized regulatory lag. Under price cap regulation the regulator sets an initial price p_o (or a vector of prices for multiple products). This price (or a weighted average of the prices allowed for firms supplying multiple products or different types of customers) is then adjusted from one year to the next for changes in inflation (rate of input price increase or RPI) and a target productivity change factor "x."[6] Accordingly, the price p_1 in period 1 is given by:

[5] The U.S. is behind many other countries in the application of incentive regulation principles to electric distribution and transmission, though their use is slowly spreading in the U.S. beyond telecommunications.

[6] Many implementations of price cap regulation also have "z" factors. Z factors reflect cost elements that cannot be controlled by the regulated firm and are passed through in retail prices. For example, in the UK,

(1) $$p_1 = p_o (1 + RPI - x)$$

In theory, a “forever” price cap mechanism is a high-powered “fixed price” regulatory contract which provides powerful incentives for the firm to reduce costs. Moreover, if the price cap mechanism is applied to a (properly) weighted average of the revenues the firm earns from each product it supplies, the firm has an incentive to set the second-best prices for each service (Laffont and Tirole, 2000) given the level of the price cap. So to speak, it kills two birds with one stone. As already noted, however, when the regulator has imperfect information about the firm’s cost opportunities and must meet a budget balance constraint, pure “forever” price cap mechanisms are not optimal from the perspective of an appropriate tradeoff between efficiency incentives and rent extraction (Schmalensee, 1989) and would leave too much rent to the firm with “average” cost characteristics. Finally, any incentive regulation mechanism that provides incentives only for cost reduction also potentially creates incentives inefficiently to reduce service quality when service quality and costs are positively correlated with one another.

In practice, “forever” price caps are not typically used in the regulation of distribution and transmission network price levels. Some form of cost-based regulation is used to set an initial value for p_o. The price cap mechanism then operates for a pre-established time period (for example, five years). At the end of this period a new starting price p_o and a new x factor are established after another cost-of-service and prudence or efficiency review of the firm’s costs. That is, there is a pre-scheduled regulatory process to reset or “ratchet” prices based partially on costs realized during the previous period. In addition, price caps are often only one component of a larger portfolio of incentive mechanisms that include quality of service incentives, as discussed in the next section. Finally, regulated electric distribution and transmission network firms’ ability to determine the structure of prices for different types of customers or for services provided at different locations on the network under an overall revenue cap is typically limited. As a result, the applications of price caps in practice are properly thought of as cost and quality incentive mechanism not as a mechanism to induce optimal second-best pricing of various network services. So, in practice the incentive mechanisms are only targeted at one bird rather than two.

A natural question to ask about price cap mechanisms is where does “x’ (and perhaps p_o) come from or, more generally, how does one choose the correct starting value for p_o and the proper dynamic price trajectory? The difficulty of answering this question in practice is one of the sources of skepticism about formal incentive mechanisms expressed in Volume II of *The Economics of Regulation.* In England and Wales and some other countries, statistical benchmarking methods have come to be used to help to determine the relative efficiency of individual firms’ <u>operating</u> costs and service quality compared to their peers. This information can then be used as an input to setting values for both p_o and x (Jamasb and Pollitt, 2001, 2003; OFGEM, 2004a) to provide incentives for those far from the efficiency frontier to move toward it and to reward the most efficient firms in order to induce them to stay on the efficiency frontier, in a fashion that is effectively an application of yardstick regulation (Shleifer, 1985).

Although it is not discussed too much in the theoretical or empirical literature on price caps, capital-related cost are handled quite differently from operating costs in the

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the charges distribution companies pay for connections to the transmission network are treated as pass-throughs. Changes in property tax rates are also often treated as pass-throughs.

establishment and resetting of p_o and x. The limited attention paid to capital-related costs in the academic literature on price cap regulation provides a potentially misleading picture of the challenges associated with implementing a price-cap mechanism effectively. This is the case for several reasons. First, in practice, the p_o and x values must be developed based not only on a review of the relative efficiency of each firm's operating costs, but also based on the value of the firm's current capital stock or rate base, forecasts of future capital additions required to provide target levels of service quality, and the application of depreciation rates, estimates of the cost of the firm's debt and equity capital, assumptions about the firm's dept/equity ratio, tax allowances and other variables to turn capital stocks into prices for capital services over time. The capital cost related allowances represent a large fraction of the total price (p_o) of supplying unbundled electricity network services so the choices of these parameters for defining capital user charges are very important.

Second, allowances for capital-related costs are typically established by regulators using incentive regulation mechanisms through more traditional utility planning and cost-of-service regulatory accounting methods including the specification of a rate base (or regulatory asset value), depreciation rates, debt and equity costs, debt/equity ratios, tax allowances, etc. This is the case because the kinds of statistical benchmarking techniques that have been applied to operating costs have not been developed for capital-related costs, due to significant heterogeneity between firms in terms of the age of assets, geography, service quality, lumpiness of capital investments and other considerations. Third, the efficiency properties of a regulatory mechanism that mixes competitive benchmarking with more traditional forward-looking rate of return regulation are more complex than first meets the eye (Acemoglu and Finkelstein, 2006).

In principle, operating and capital costs could be integrated and associated benchmarks determined using total factor productivity measures. This is the approach taken by the initial price caps applied to telecom companies in the U.S. by the Federal Communications Commission. In electricity, this approach has been rejected largely because of the diversity in the capital stock, much of which is several decades old, and the associated difficulties of coming up with accurate total productivity measures. The application of price caps in England and Wales and other countries in Europe that have adopted this mechanism, benchmark a firm's performance against industry specific "best practice" (production frontier analysis using data for other firms in the industry).

Thus, the implementation of price cap mechanisms is more complicated and their efficiency properties more difficult to evaluate than is often implied and places a significant information collection, auditing and analysis burden on regulators. This is precisely the source of the skepticism about formal incentive mechanisms expressed in Volume II of *The Economics of Regulation*. In practice, modern applications of incentive regulation concepts involve the application of elements of traditional cost of service regulation, yardstick regulation, and high-powered "fixed price" incentives.

The challenge of forecasting future investment needs and costs for electricity network firms has historically been a rather contentious process, sometimes yielding significant differences between what the regulated firm's claim they need and what the regulator claims they need to meet their legal responsibilities to provide safe and reliable service efficiently. There is clearly a very serious asymmetric information problem here. In the 2004 review of electricity distribution prices in the UK, the regulator adopted an innovative "menu" of sliding scale mechanisms approach to resolve the asymmetric information problem faced by the regulator as she tries to deal with differences between the firms' claims and the regulator's consultants' claims (OFGEM, 2004b) about future capital investment requirements to meet reliability targets. The sliding scale menu allows firms to choose between getting a lower capital expenditure allowance but a higher powered incentive (and a higher expected return on investment) that allows them to retain more of the cost reduction if they can beat the target expenditure levels or a higher capital expenditure allowance combined with a lower powered sliding scale mechanism and lower expected return. (OFGEM, 2004b). This is an application of Laffont and Tirole's menu of cost-contingent contracts mechanism and provides a more effective way to deal with the imperfect and asymmetric information conditions and associated adverse selection problems than the traditional approach of offering a single regulatory contract.

An example of the use of a profit-sharing or cost-contingent form of incentive regulatory mechanism can be found in the incentive mechanism that has been applied to the costs of the transmission system operator (SO) in England and Wales (which is also the transmission owner (TO), though there are separate regulatory mechanisms for SO and TO functions). Each year forward targets are established for the costs of system balancing services and system losses (OFGEM, 2005). A sharing or sliding scale formula is specified which places the TO at risk for a fraction (for example 30%) of deviations from this benchmark (up or down) with caps on profits and losses. There is also a cap and a floor. In recent years the SO was given a menu of three alternative incentive arrangements with different sharing fractions and different caps and floors (with costs of service as a default) from which to choose. If the SO were to choose the cost-of-service default it would suggest that in constructing the menu, the regulator had underestimated the range of the SO's future cost realizations.

4 Service quality incentives

As noted earlier, any incentive regulation mechanism that provides incentives only for cost reduction also potentially creates incentives to reduce service quality when service quality and costs are positively related to one another. The higher powered are the incentives to reduce costs, the greater the incentive to reduce quality when cost and quality are correlated. Accordingly, price cap mechanisms are increasingly accompanied by a set performance standards and associated penalties and rewards for the regulated firm for falling above or below these performance norms. Similar mechanisms are used by several U.S. states and in other countries that have liberalized their electricity sectors (for example, New Zealand, Netherlands, and Argentina).

In the UK, the regulator (OFGEM) has developed several incentive mechanisms targeted at various dimensions of distribution network service quality (OFGEM, 2004b, 2004c). OFGEM uses statistical and engineering benchmarking studies and forecasts of planned maintenance outages to develop targets for the number of customer outages and the average number of minutes per outage for each distribution company.

Until recently in the UK, there was no formal incentive mechanism that applied to transmission system reliability – network failures that lead to administrative customer outages or "unsupplied energy". In 2005, a new incentive mechanism that focuses on the reliability of the transmission network as measured by the quantity of "unsupplied energy" resulting from transmission network outages went into effect (OFGEM, 2004d). NGC is assessed penalties or received rewards when outages fall outside of a "deadband" of +/- 5%

defined by the distribution of historical outage experience (and with potential adjustments for extreme weather events), using a sliding scale with a cap and a floor on the revenue impact.

5 Performance attributes

The information burden to implement incentive regulation mechanisms well is certainly no less than for traditional cost of service regulation. Incentive regulation in practice requires a good accounting system for capital and operating costs, cost reporting protocols, data collection and reporting requirements for dimensions of performance other than costs. Capital cost accounting rules are necessary, a rate base for capital must still be defined, depreciation rates specified, and an allowed rate of return on capital determined. Comprehensive "rate cases" or "price reviews" are still required to implement "simple" price cap mechanisms. Planning processes for determining needed capital additions are an important part of the process of setting total allowed revenues and associated prices going forward. Performance benchmarks must be defined and the power of the relevant incentive mechanisms determined. What distinguishes incentive regulation in practice from traditional cost of service regulation is that this information is used more effectively because it can rely on advances in incentive regulation theory to organize and apply it. Whether the extra effort is worth it depends on whether the performance improvements justify the additional effort.

Unfortunately, there are been relatively little systematic analysis of the effects of the application of incentive regulation mechanisms on the performance of electric distribution and transmission companies.[7] Improvements in labor productivity and service quality have been documented for electric distribution systems in England and Wales, Argentina, Chile, Brazil, Peru, New Zealand and other countries (Newbery and Pollitt, 1997; Rudnick and Zolezzi, 2001; Bacon and Besant-Jones, 2001; Estache and Rodriguez-Pardina, 1998; and Pollitt, 2004). However, most of these studies have focused on developing countries where the pre-reform levels of performance were especially poor prior to restructuring. Moreover, it is difficult to disentangle the effects of privatization, restructuring and incentive regulation from one another.

The most comprehensive study of the post reform performance of the regional electricity distribution companies in the UK (distribution and supply functions) has been done by Domah and Pollitt (2001). They find significant overall increases in productivity over the period 1990 to 2000 and lower real "controllable" distribution costs compared to a number of benchmarks. However, controllable costs and overall prices first rose in the early years of the reforms before falling dramatically after 1995. Moreover, the first application of price cap mechanisms to the distribution networks in 1990 was too generous (average of RPI+ 2.5%) and a lot of rent was initially left on the table for the RECs' initial owners (who cleverly soon sold out to foreign buyers). Distribution service quality in the UK, at least as measured by supply interruptions per 100 customers and average minutes of service lost per customer, has improved as well since the restructuring and privatization initiative in 1990. This suggests that incentive regulation has not led, as some had feared,

[7] There is a much more extensive body of empirical work that examines the effects of incentive regulation mechanisms, primarily price caps, on the performance of telecommunications firms. Examples are Ai and Sappington (2004), Sappington (2003), Ai, Martinez and Sappington (2005).

to deterioration in these dimensions of service quality. This is likely to have been the case because quality standards and associated mechanisms were included in the portfolio of incentive regulation mechanisms adopted in the UK.

The experience with the transmission system operator (SO) incentive mechanism in England and Wales also provides a good example of how incentive regulation can improve performance. During the first few years following the restructuring of the electricity sector in England and Wales in 1990, the SO recovered the costs of system balancing, including managing congestion and other network constraints, through a simple cost pass-through mechanism. The SO's costs escalated rapidly, growing from about $75 million per year in 1990/91 to almost $400 million per year in 1993/94. After the introduction of the SO incentive scheme in 1994, these costs fell to about $25 million in 1999/2000. OFGEM estimates that NGC's system operating costs fell by about £400 million ($600 million at current exchange rates) between 1994 and 2001. A new SO incentive scheme was introduced when NETA went into operation in early 2001. The SO's costs have fallen by nearly 20% over the three year period since the new scheme was introduced (OFGEM, 2003).

While the empirical evidence on the effects incentive regulation mechanisms applied to electric distribution and transmission system in practice is still limited, the experience so far is very encouraging.

6 Conclusion

As we look back at developments in the theory and practice of regulating firms that have been given de facto monopoly franchises since the publication of *The Economics of Regulation* in 1970 and 1971, we can come to a number of conclusions. First, the overall economic importance of getting the theory and application of "natural monopoly" regulation right has become less important over time since a smaller fraction of the economy is subject to these types of economic regulation as competition has replaced regulated monopoly in so many industries. Moreover, even in those industries where price, entry and service quality regulation continues, it is typically being applied to a smaller number of truly natural monopoly network segments of those industries as competition has been introduced into other horizontal segments that rely on the regulated network platform. The basic theory of efficient pricing (first and second best) under the assumption that the regulator is fully informed has not changed very much over the years, except perhaps for a better understanding of the properties of non-linear pricing for regulated firms subject to budget constraints. The major advances in the theory and practice of regulation have relied on formalizing the information structure that characterizes the real world. Regulators are imperfectly informed, regulated firms have better information about the cost and demand attributes they face, and regulated firms will use this information advantage to their benefit. This situation leads to adverse selection and moral hazard problems that have been incorporated into the modern theory of incentive regulation. While applying this theory in practice must confront numerous empirical challenges, the available evidence from their application to electricity distribution and transmission systems suggests that they can help to resolve what Kahn called "the central institutional question" that confronts economic regulation.

7 References

Acemoglu, D. and A. Finkelstein (2006) "Input Technology Choice in Regulated Industries: Evidence from the Health Care Sector," mimeo, MIT, Cambridge, February.

Ai, C. and D. Sappington (2005) "Reviewing the Impact of Incentive Regulation on U.S. Telephone Service Quality," *Utilities Policy*, 13: 201-210.

Ai, C., Martinez, S., and D. Sappington (2004) "Incentive Regulation and Telecommunications Service Quality," *The Journal of Regulatory Economics*, 26:263-285.

Armstrong, M., S. Cowan and J. Vickers (1994) *Regulatory Reform: Economic Analysis and British Experience*, MIT Press: Cambridge, MA.

Armstrong, M. and D. Sappington (2007) "Recent Developments in the Theory of Regulation," in M. Armstrong and R. Porter (ed.), *Handbook of Industrial Organization (Vol. III)*, Elsevier Science Publishers: Amsterdam.

Averch, H. and L.L. Johnson (1962) "Behavior of the Firm under Regulatory Constraint," *American Economic Review*, 52: 1059-69.

Bacon, R. W., and J. E. Besant-Jones (2001) "Global Electric Power Reform, Privatization and Liberalization of the Electric Power Industry in Developing Countries," *Annual Reviews of Energy and the Environment*, 26: 331–59.

Baumol, W. and A.K. Klevorick (1970) "Input Choices and Rate of Return Regulation: An Overview of the Discussion," *Bell Journal of Economics and Management Science*, 1: 169-190.

Beesley, M. and S. Littlechild (1989) "The Regulation of Privatized Monopolies in the United Kingdom," *Rand Journal of Economics*, 20: 454-472.

Braeutigam, R. (1989) "Optimal Prices for Natural Monopolies," in R. Schmalensee and R. Willig (ed.), *Handbook of Industrial Organization*, *Volume II*, Elsevier Science Publishers: Amsterdam.

Brennan, T. (1989) "Regulating By Capping Prices," *Journal of Regulatory Economics*, 1: 133-147.

Domah, P.D. and M.G. Pollitt (2001) "The Restructuring and Privatisation of the Regional Electricity Companies in England and Wales: A Social Cost Benefit Analysis," *Fiscal Studies*, 22:107-146.

Estache, A. and M. Rodriguez-Pardina (1998) "Light and Lightening at the End of the Public Tunnel: The Reform of the Electricity Sector in the Southern Cone," World Bank Working Paper, May.

Isaac, R.M. (1991) "Price Cap Regulation: A Case Study of Some Pitfalls of Implementation," *Journal of Regulatory Economics*, 3: 193-210.

Jasmsb, T. and M. Pollitt (2001) "Benchmarking and Regulation: International Electricity Experience, *Utilities Policy*, 9: 107-130.

Jamasb, T. and M. Pollitt (2003) "International Benchmarking and Regulation: An Application to European Electricity Distribution Utilities," *Energy Policy*, 31: 1609-1622.

Joskow, P.L. (1974) "Inflation and Environmental Concern: Change in the Process of Public Utility Price Regulation," *Journal of Law and Economics*, 17: 291-327.

Joskow, P.L. (2006a) "Incentive Regulation in Theory and Practice: Electric Distribution and Transmission," prepared for the National Bureau of Economic Research regulation project. http://econ-www.mit.edu/faculty/download_pdf.php?id=1220

Joskow, P.L. (2006b) "Incentive Regulation for Electricity Networks," *CESifo Dice Report*, 2/2006.

Joskow, P.L. (2006c) "Markets for Power in the United States: An Interim Assessment," *The Energy Journal*, 27: 1-36.

Joskow, P.L. (2007) "Regulation of Natural Monopolies," in A.M. Polinsky and S. Shavell (ed.), *Handbook of Law and Economics (Volume 2)*, Elsevier: Amsterdam.

Joskow, P.L. and N.L. Rose (1989) "The Effects of Economic Regulation," *Handbook of Industrial Organization (Volume II)*, R. Schmalensee and R Willig editors, North-Holland, Amsterdam.

Joskow, P.L. and J. Tirole (2005) "Merchant Transmission Investment," *Journal of Industrial Economics*, 53: 233-64.

Kahn, A.E. (1970, 1971) *The Economics of Regulation: Principles and Institutions*, Volume 1 (1970) and Volume 2 (1971), Wiley: NewYork.

Laffont, J-J and J. Tirole (1993) *A Theory of Incentives in Regulation and Procurement.* MIT Press: Cambridge, MA.

Laffont, J-J and J. Tirole (2000) *Competition in Telecommunication*. MIT Press: Cambridge, MA.

Lyon, T., (1996) "A Model of the Sliding Scale," *Journal of Regulatory Economics*, 9: 227-247.

Newbery, D., and M. Pollitt, (1997) "The Restructuring and Privatization of Britain's CEGB – Was it Worth It?" *Journal of Industrial Economics*, 45: 269-303.

Office of Gas and Electricity Markets (OFGEM) (2003) "NGC System Operator Incentive Scheme from April 2004, Initial Consultation Document," December 2003. London.

Office of Gas and Electricity Markets (OFGEM) (2004a) "Electricity Distribution Price Control Review," Initial Proposals, June 2004, 145/04. London.

Office of Gas and Electricity Markets (OFGEM) (2004b) "Electricity Distribution Price Control Review: Final Proposals," 265/04, November, London.

Office of Gas and Electricity Markets (OFGEM) (2004c) "Electricity Distribution Price Control Review: Appendix – The Losses Incentive and Quality of Service, June 2004 145e/04. London.

Office of Gas and Electricity Markets (OFGEM) (2004d) "Electricity Transmission Network Reliability Incentive Scheme: Final Proposals," December, London.

Office of Gas and Electricity Markets (OFGEM) (2005) "NGC System Operator Incentive Scheme from April 2005," Final Proposals and Statutory License Consultation, March 2005 65/05. London.

Pollitt, Michael, (2004) "Electricity Reforms in Argentina: Lessons for Developing Countries," CMI Working Paper 52, Cambridge Working Papers in Economics. http://www.econ.cam.ac.uk/electricity/publications/wp/ep52.pdf

Rudnick, H., and J. Zolezzi. (2001) "Electric Sector Deregulation and Restructuring in Latin America: Lessons to be Learnt and Possible Ways Forward," in *IEEE Proceedings Generation, Transmission and Distribution*, 148: 180-84.

Sappington, D. (2003) "The Effects of Incentive Regulation on Retail Telephone Service Quality in the United States," *Review of Network Economics*, 2: 355-375.

Schmalensee, R. (1989) "Good Regulatory Regimes," *Rand Journal of Economics*, 20: 417-436.

Schleifer, Andrei (1985) "A Theory of Yardstick Competition," *Rand Journal of Economics*, 16: 319-327.

Wellisz, S. (1963) "Regulation of Natural Gas Pipeline Companies: An Economic Analysis," *Journal of Political Economy*, 71: 30-43.