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REGULATION, INDUSTRY STRUCTURE AND PERFORMANCE IN THE ELECTRICITY SUPPLY INDUSTRY

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TABLE OF CONTENTS

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INTRODUCTION

Electricity is a vital service in the economy; it is an input in the production of nearly all other goods and services, and it is also an important final good, consumed by households. In the United States, for example, annual sales of electric power exceed $200 billion, and the electric power industry accounts for approximately 3.2 per cent of GDP and 5 per cent of gross capital stock (1994).[1] Moreover, the growth rate of the electricity sector has at least kept pace with GDP. In the 1960s, electricity generation grew at a rate of 7.6 per cent per year, followed by an annual growth rate of 4.4 per cent in the 1970s, 2.8 per cent in the 1980s, and a projected annual growth rate of 2-2.6 per cent until 2005. These rates have exceeded growth rates in total final energy consumption and total primary energy supplies, and have paralleled or exceeded the growth rate of GDP. While *energy* intensity has decreased since 1973, *electricity* intensity has increased: the share of electricity in final energy consumption more than doubled from 8.3 per cent in 1960 to 17.2 per cent in 1989.[2]

Over the past decade, the regulatory environment of the electricity supply industry has begun to change. A few OECD countries have implemented new regulations to stimulate competition by attempting to liberalise the industry, focusing reform efforts on functions that do not possess a natural monopoly component.[3] In particular, some OECD countries have passed legislation to introduce competition in electricity generation and retailing by unbundling these functions from the "wires" part of the business, providing mechanisms for new entrants to access existing networks, and creating markets where price is determined by supply and demand. Even in the case of these early reformers, implementation of reform has been a slow process, so that at most a handful of countries can point to actual progress toward competition.[4] Today, other OECD countries are on the cusp of liberalisation, particularly European Union countries, which face the implementation deadlines of the European Commission Electricity Directive to establish a single internal market for electricity in Europe.[5]

Most policy makers and economists agree that liberalisation of the electricity sector should enhance consumer welfare by reducing prices; however, there is no consensus on the specific regulatory reforms most likely to achieve the benefits of competition. Among countries that have initiated reforms, some have focused on liberalising their electricity supply industry, others have privatised segments of the industry, and still others have pursued both liberalisation and privatisation. The variation in country approaches to liberalisation and privatisation provides a platform for the empiricist to explore the benefits of reform. At a general level, one can examine whether the introduction of competition leads to real improvements in the efficiency and prices of electricity supply. Similarly, one can assess the impact of privatisation, itself, or in concert with liberalisation, on performance in the electricity supply industry. From a policy perspective, at a finer level, one may assess which reforms are most likely to result in increased competition, as well as which institutional and ownership patterns are correlated with improvements in performance.[6]

It is difficult to draw general policy conclusions from existing empirical work that focuses on far-reaching reforms in a single market[7] or other country-specific anecdotal discussion of regulatory changes[8] because neither type of study separates the effects of regulatory reform from country-specific features. This paper seeks to make this distinction by drawing on (comparable) cross-country data on regulation, industry structure, and performance. A "panel" data set is constructed from International Energy Agency (IEA) and other sources to compare empirically the experiences of 19 OECD countries over the period 1986-1996. Data collection and empirical work concentrated on the generation segment of the industry, the locus of most technological innovation and regulatory initiative. In particular, regulatory and industry structure indicators are constructed to summarise information about the timing and extent of liberalisation of entry into generation, the ownership structure and privatisation of incumbent utilities, vertical integration and functional unbundling of the industry, rules governing third party access to the national grid, and participation in electricity markets where they exist. On the other hand, indicators of horizontal unbundling, that is, market concentration, are not included in the analysis because for most countries, and for most of the time period, they vary insignificantly, reflecting (frequently legal) monopoly conditions. The regulatory and industry structure indicators are then used in panel regressions to assess their impact on measures of productive efficiency of generation plants (the utilisation of capacity and reserve margins, a measure of the ability of capacity to meet peak load), and retail electricity prices (both retail prices paid by industrial consumers and price differentials between industrial and residential consumers). In the panel regressions, the exploitation of both cross-country and time-series dimensions of the data allows for control of country-specific effects.

The paper is organised as follows. The second section describes the economic and technological features of the electricity supply industry which are most important for regulatory reform. The third section discusses the regulatory framework and regulatory reform process, underscoring the motivation for change and current patterns of regulation. In this section, the statistical methods of factor and cluster analysis are used to describe the constructed regulatory indicators. The final section discusses the empirical approach and challenges, presents results, and concludes.

THE ELECTRICITY SUPPLY INDUSTRY

Regulation of the electricity supply industry is primarily motivated by the existence of natural monopoly conditions, externalities, and public good characteristics.[9] These result from a number of unique economic characteristics: electricity cannot be stored. The non-storability of electricity reduces the size of markets according to the time dimension; the size of the market is determined by instantaneous demand rather than demand over a longer time period. As a consequence, it is more likely that a single firm can supply consumers in a given market at minimum efficient scale. Furthermore, the demand for electricity is subject to great cyclical, seasonal, and random variation in both the short and long term. At the same time, to satisfy customers' expectations, supply must be continuous, reliable, and supplied with sustained frequency and voltage.[10] As a consequence, electricity producers must maintain "spinning reserve" and "black start capacity".[11] The pairing of variable demand and continuous supply requires that suppliers maintain excess capacity to meet peaks in demand. As the number of customers supplied by a given utility increases, reserve margin requirements decrease because the grouping of heterogeneous consumers effectively pools risk faced by suppliers, and, as a consequence, operating and capital costs per customer decrease. In short, these conditions lead to increasing returns to scale and cost efficiencies to be realised by a monopoly market structure.

Additionally, externalities occur because the operation, function, and malfunction of each generator affects system conditions throughout the entire interconnected network. Moreover, investment in generating capacity involves difficult dynamic optimisation in the face of uncertainty, externalities in the sense that any addition or deletion of capacity affects the entire network, and public good characteristics in the sense that additions to a transmission network benefit all producers and consumers. The externality and public good aspects of electricity suggest the need for planning and co-ordination of the electricity supply network, roles that may also be most efficiently performed by a natural monopolist.

Functional decomposition of the electricity supply industry

While on the whole, electricity supply is characterised by conditions of natural monopoly, externalities, and public goods, some of its functional segments do not possess these economic features. The electricity supply industry can be functionally divided into generation, transmission, distribution, and supply. This functional division is particularly important for understanding recent regulatory developments. The different functions are differentiated technologically and economically, and regulatory reform has tended to proceed at this level of disaggregation.

Generation is the production of electricity. It involves the transformation of another form of energy into electrical energy. Electricity production may use oil, natural gas, coal, nuclear power, hydro power (falling water), renewable fuels, wind turbines, and photovoltaic technologies. The different generating technologies are differentiated according to cost structure. The main cost components of electricity generation are (delivered) fuel prices, capital costs, and operating and maintenance costs. Costs are also influenced by the performance of the generating technology (capacity factor, thermal efficiency, and operating life).[12] Nuclear generation has high capital costs which result in part from long construction lead times (interest charges) and decommissioning costs (costs of retiring a plant at the end of its design life). High fixed costs also result from public opposition to nuclear technology and waste disposal. On the other hand, nuclear technology has low fuel and operating costs (variable costs), and over the lifetime of a nuclear plant these costs remain relatively constant. Hydro generation costs depend largely on geography and climate. The variable costs to hydro generation are low. The costs of coal, oil, and natural gas fired generation consist largely of input fuel prices, so that the variable costs of fossil-fuel generation are higher than for nuclear generation.[13] However, fossil-fuel generation tends to have lower fixed costs than nuclear generation, particularly in the case of gas-fired plants, which have very short construction lead times.

The diversity of generating technology and cost structure results in a "least-cost merit order", in which different kinds of generators are operated according to variable costs: nuclear technology and often hydro technology and coal serve as base load, whereas other fossil fuel fired plants serve as intermediate or peak load. A diversified generation technology set improves efficiency by reducing reserve requirements and facilitating the balance of supply and demand for electricity in real time. The "least-cost merit order" and its associated efficiency gains should also lead to lower electricity prices.

Transmission and distribution comprise the "wires" functions. Transmission is the high-voltage transport of electricity. However, transmission is not merely transportation, but it also involves the management of dispersed generators in a grid to maintain suitable voltage and frequency and to prevent system breakdown. Transmission is a natural monopoly because competition in transmission would result in duplication of the existing network (duplicating high voltage AC networks and competing grid co-ordinators would increase transmission costs). Regulation of transmission typically involves rate-of-return regulation of prices, which has been shown in the classic study of Averch and Johnson (1962) to lead to over-investment in capital and, consequently, failure to cost-minimise.[14]

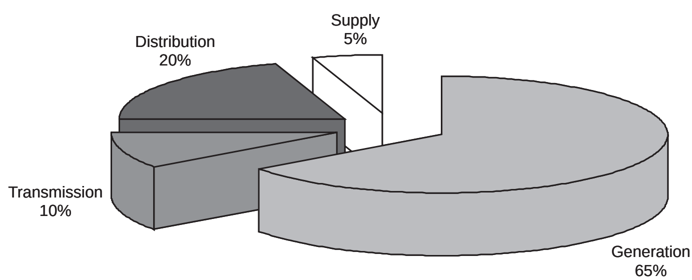
Co-ordination of generators in a merit-order lies between generation and transmission. From this perspective, integration of generation and transmission would lead to economies if it internalises externalities that result from dispersed generators who make investment and operating decisions that affect the entire network. On the contrary, if generation (itself not a natural monopoly) is integrated with transmission, then it will be subject to the same regulatory challenges and inefficiencies as transmission under rate-of-return regulation.

Distribution is the low-voltage transport of electricity. Like transmission, it is generally considered to be a natural monopoly; competition would similarly entail duplication of the existing set of "wires". Unlike transmission, there are no benefits to its integration with generation.

Finally, supply of electricity is the sale of electricity to end-users. This includes metering, billing, and marketing, and may be wholesale or retail. Supply is not considered to be a natural monopoly, nor are there significant advantages to its integration with the other functions.

Each of these functions contributes to the costs of providing electricity to final users. Using estimates from the United Kingdom, the share of each function in total cost are illustrated in Figure 1. One can see that generation makes up the largest proportion of the cost of electricity supply.

Figure 1. **Breakdown of electricity supply costs according to function for the United Kingdom**



Source: OECD.

Technological developments in the electricity supply industry

Technological advances have enhanced the potential for competition in generation by reducing the minimum efficient scale. The development of the combined cycle gas turbine (CCGT) greatly expanded thermal efficiency and reduced minimum efficient plant size from 1000 MW in the early 1980s to between

50 and 350 MW.[15] Furthermore, the low variable costs associated with CCGT technology makes it suitable for base load electricity generation. CCGT plants also require shorter construction and planning time horizons. At the same time, many countries have focused increasingly on renewable sources of electricity generation, projects that tend to be small and privately or locally owned. Some countries have also increased their use of combined heat and power facilities, which reduces optimal plant size.

In view of these technological developments, this paper focuses on the generation function. In the past decade, regulatory reforms have been concerned mainly with unbundling generation from other functions and introducing competition into generation. Consequently, empirical analysis focusing on the generation function will exploit the variation in generation regulation and industry structure across countries and time. In contrast, analysis of transmission and distribution may be less useful for drawing policy conclusions. Although these functions are also subject to regulation, as natural monopolies they are unlikely to be liberalised in the future. The analysis controls for the influence of regulatory arrangements in transmission and distribution; however, it does not seek to make policy inferences outside the generation segment.

REGULATORY FRAMEWORK AND REGULATORY REFORM

Motivation for change

The economic and technological features of the electricity supply industry have stimulated the evolution of its regulation, ownership, and market structure. Since transmission and distribution are natural monopolies, the industry as a whole was taken to be a natural monopoly, suggesting that an efficient regulatory framework would be a legal monopoly. On the other hand, monopoly also leads to dead-weight losses when a profit-maximising monopolist charges prices that exceed marginal cost. Historically, this led governments to adopt one of two approaches to the electricity sector: publicly owned, integrated monopoly, or privately owned regulated firms. Many countries (*e.g.* Ireland, France, Greece, and Italy) consolidated and nationalised their electricity supply industries into state-owned, legal monopolies under the assumption that a state-owned enterprise does not maximise profit, so public ownership should lead to greater consumer welfare. A variant on this approach is regional, legal monopolies, where public enterprise and monopoly occur at the regional level (*e.g.* Germany). In the case of private but regulated monopolies, firms are presumed to maximise profits, so regulation is used to reduce deleterious impacts on consumer welfare. Regulators of privately owned monopolies concentrate on pricing, often using rate-of-return regulation. The United States and Japan provide examples of investor-owned but regulated regional monopolies. Even in the case of the United States, however, regional government retains a large ownership and operative role in segments of the industry. Regardless of whether electric utilities are public or private, centralised or regional, in most countries, vertical unbundling has only recently begun.

Additionally, technological preferences have influenced ownership and market structure. Certain generating technologies such as hydropower have frequently resulted in state ownership; the state often had the property rights and financial resources needed for large-scale hydroelectric projects. Other shifts in preferences have changed the minimum efficient scale for production. For example, in the aftermath of oil shocks, preferences shifted toward large-scale nuclear projects, while with the advent of CCGT, preferences have shifted toward small-scale CCGT plants. Larger-scale technologies with high fixed costs often lead to state financing, whereas smaller scale technologies leave more room for private ownership.

Reform patterns

The current move toward liberalisation of the electricity supply industry has been characterised by substantial variation across countries in the timing and approach to reform. Generally, regulatory reform is focused on functional separation of generation and transmission, introduction of competition in generation, and expanded network access. More advanced stages of reform tend to include the formation of electricity spot markets for electricity price determination and trade, and unconstrained choice of supplier. The final stages of reform may also include a shift from (cost-based) rate of return regulation of transmission pricing to price caps.

The timing and scope of regulatory reforms, as well as the response of market participants varies considerably across countries. Tables 1-3 summarise the status as of 1998 of the regulatory environment and market structure in the OECD countries included in the sample.

As shown in Table 1, in 1998 many countries had liberalised access to transmission and distribution networks. In most cases, access liberalisation has taken the form of regulated TPA; that is, a legal obligation to provide network access under non-discriminatory conditions. Regulated TPA is necessary to allow entry of new generators into a competitive market, as well as to allow consumer choice of producer/supplier. Without regulated TPA, liberalisation of entry and termination of legal monopoly status is unlikely to lead to actual entry as potential entrants face "hold-up costs".[16] Incumbents who retain control of the transmission grid may either block potential entrants by refusing to wheel their electricity, or by charging price premia over the prices for their own wheeling or the wheeling of their affiliates. Similarly, without regulated TPA, legal provision for consumer choice of

Table 1. **Regulatory reform in the electricity supply industry as of 1998**

	Liberalisation	Third party access	Electricity market	Transmission price regulation	Consumer choice thresholds[1]
Australia	Electricity Industry Act for Victoria (1994)	Regulated TPA	National Electricity Market (1997), Vic Pool (1994)	Cost-based	Victoria: 1994 5 MW, 1995 1 MW, 1996 750 MWh/yr, 1998 160 MWh/yr, 2001 0 KW
Belgium	None	None	None	Cost-based	Distribution: 1 MW
Canada	None	None	Alberta Pool (1996)	Cost-based	No choice
Denmark	Amendment to Danish Electricity Supply Act (1996, implemented 1998)	Regulated TPA	None	Cost-based	No choice
Finland	Electricity Market Act (1995)	Regulated TPA	Finnish Electricity Exchange (1995)	Cost-based	1995 500 KW, 1997 0 KW
France	None	None	None	Cost-based	No choice
Germany	Act on the Supply of Electricity and Gas (1998)	Negotiated TPA	None	Cost-based	1998 0 KW
Greece	None	None	None	–	No choice
Ireland	None	None	None	–	No choice
Italy	None	None	None	Price cap	No choice
Japan	Amendments to Electric Utility Law (1995)	Negotiated TPA	None	Cost-based	1998 2 MW
Netherlands	The Electricity Act (1989)	None	None	None	No choice
New Zealand	Energy Act and Companies Act (1992)	Regulated TPA	Electricity Market Company (1996)	–	1993 500 KW, 1994 0 KW
Norway	Energy Act (1990)	Regulated TPA	Norwegian Power Pool (1991), Nordpool (1996)	Price cap	1991 0 KW
Portugal	None	None	None	Cost-based	1998 1 GW

Table 1. **Regulatory reform in the electricity supply industry as of 1998** (*cont.*)

	Liberalisation	Third party access	Electricity market	Transmission price regulation	Consumer choice thresholds[1]
Spain	Electricity Act (1994)	Negotiated TPA	None	Cost-based	1998 15 GWh, 2000 9 GWh, 2002 5 GWh, 2004 1 GWh
Sweden	Bill of 1992 passed in 1996.	Regulated TPA	Nordpool (1996)	None	1996 0 KW
United Kingdom	Electricity Supply Act (1990)	Regulated TPA	England and Wales Market (1990)	Price cap	1990 1 MW, 1994 100 KW, 1998 0 KW
United States	Energy Policy Act (1992)	Regulated TPA	None	Cost-based	New Hampshire, California: 1998 0 KW

1. Under the EC Directive on the Internal Electricity Market, EC Member States must open up their markets to customers above 40 GWh in 1999, 20 GWh in 2000, and 9 GWh in 2003.

Source: See main text.

supplier will not result in actual consumer choice; the lack of entry by new generators will not expand consumer options so that even legally unconstrained consumers will continue to contract with incumbent suppliers. Additionally, the largest consumers who most often qualify to choose suppliers may wish to contract directly with third-party generators, by-passing distribution utilities, but without TPA, they will be unable to do so. Under the 1996 European Commission Directive, which establishes common rules for the internal market in electricity, EC Member States will be required to introduce TPA. The types of TPA chosen by Member States are likely to have a significant impact on the development of competition in the industry.

Another regulatory effort to stimulate competition is the introduction of consumer choice of supplier. Some countries have introduced consumer choice for large consumers (*e.g.* England and Wales, New Zealand), phasing in full consumer choice gradually, while others introduced full consumer choice immediately upon adoption of electricity sector reform (*e.g.* Norway, Sweden). Even in countries with full consumer choice, it is primarily large customers that benefit from choice, as metering equipment remains prohibitively expensive for many small and residential consumers.[17] Under the EC Directive of 1996, all Member States will be required to offer choice to large consumers according to the following schedule: consumers above 40 GWh in 1999, consumers above 20 GWh in 2000, and consumers above 9 GWh in 2003. This corresponds to choice for (an estimated) 26.48 per cent, 28 per cent, and 33 per cent of national markets in 1999, 2000, and 2003, respectively.[18]

Very few countries have liberalised transmission pricing. The two dominant models of transmission pricing are cost-based (rate of return) pricing, such as in the United States, and loosely regulated prices as in the Netherlands and Sweden. The latter loose regulation is more prevalent in countries with a decentralised electricity supply industry and a tradition of regulation and control at a more localised level. In the United States, on the other hand, there is a long tradition of rate-of-return regulation. In this case, the "Takings Clause" in the United States Constitution serves as the operative barrier to adoption of potentially more efficient price-cap regulation.[19] At a more micro-level, there is still more variation in regulation of pricing: there are regulations about cross-subsidisation in end-user prices, about peak-load pricing, and there is variation in transmission pricing from nodal pricing (or locational spot pricing) to postage-stamp (zonal) pricing.[20] While the data set constructed for this study distinguishes between rate-of-return and price-cap regulation, it does not contain data on pricing regulations at a finer level.

Finally, a few countries have introduced markets for electricity, allowing for prices and quantities traded to be determined by the equivalence of supply and demand. The first electricity market in the OECD was established in England and

Wales in 1990. Many Nordic countries established electricity markets as well, and in particular, Sweden, Norway, Finland and Denmark participate in the first international electricity market, the Nord Pool, operational since 1996. New Zealand and some Australian states have also established electricity markets. In Australia, the state markets merged into a national market in 1997. Participation in electricity markets is mandatory in some countries (*e.g.* England and Wales, Australia), whereas it is optional in others (*e.g.* Nord Pool, New Zealand).

Regulatory reform, market and industry structure and ownership

The market structure of the electricity supply industry is closely related to the regulatory environment. At the present time, in most countries markets are extremely concentrated because competition has been expressly and legally forbidden (*e.g.* France, Belgium, Italy, Greece, Portugal), or because multiple firms exist but do not compete since each firm acts as a monopolist in its own market (*e.g.* Denmark, Japan, Netherlands, and Germany and Spain until 1998). New generators often enter liberalised generation markets slowly, and act as a competitive fringe with small market shares and little influence relative to the incumbent(s). For example, in the case of England and Wales, market participants were slow to respond to the Electricity Act of 1990, and evidence suggests that reforms merely shifted anti-competitive strategies from pricing to capacity decisions so that substantial market power remains.[21] On the other hand, as for many other goods, country borders do not necessarily define the markets that are relevant from a regulatory perspective: some countries, such as the United States, Canada, and Australia, are larger than a single market, whereas others, for example the Netherlands, are smaller. As a result, country-level concentration is not necessarily related to actual competitive pressures in the market.

The degree of vertical integration has an important bearing for competition in electricity supply. Table 2 summarises the current status of vertical integration for countries in the panel. It shows the degree of overall integration, from generation, through transmission and distribution, to supply, as well as the presence and type of separation of generation from transmission. Where generation and transmission have been unbundled, there may be either an accounting separation or a legal separation into different companies. The separation of generation and transmission, in concert with expanded TPA, is crucial to encourage competition. An incumbent generator with control of transmission holds an advantage over potential entrants to generation; the integrated generator-transmission firm may charge discriminatory prices for competitor use of the transmission grid, increasing their costs. An accounting separation, rather than a legal separation into distinct firms, may not quell this advantage, particularly as allocation of costs among different activities is difficult, even under the best efforts at transparency. In the panel under study, most countries that have separated generation and transmission

Table 2. **Vertical integration in the electricity supply industry, 1998**

	Degree of vertical integration (generation through supply)	Degree of integration between generation and transmission
Australia	Mixed	Separate companies
Belgium	Integrated	Integrated
Canada	Integrated	Integrated
Denmark	Integrated	Accounting separation
Finland	Unbundled	Separate companies
France	Integrated	Integrated
Germany	Unbundled	Accounting separation
Greece	Integrated	Integrated
Ireland	Mixed	Accounting separation
Italy	Integrated	Integrated
Japan	Mixed	Integrated
Netherlands	Mixed	Integrated
New Zealand	Mixed	Separate companies
Norway	Unbundled	Separate companies
Portugal	Mixed	Accounting separation
Spain	Mixed	Separate companies
Sweden	Mixed	Separate companies
United Kingdom	Unbundled	Separate companies
United States	Integrated	Accounting separation

Source: See main text.

have done so only recently as part of general regulatory reform of their electricity sectors [Victoria and Queensland in Australia (1993-4); United States (1996); New Zealand (1994); Portugal (1994); Spain (1994); Germany (1998); Denmark (1998); Sweden (1996); Finland (1995); Norway (1991); and England and Wales (1990)]. Countries that retain an integrated structure are generally countries with state-owned and operated, integrated monopolies that have not undertaken liberalisation of their electricity sectors.

Distinct from liberalisation, countries also vary in the degree of private ownership that has developed over time, as well as the decision regarding privatisation at the time of liberalisation. Table 3 summarises the current status of ownership in the generation segment of the electricity sector.[22] The decision to privatise is not necessarily correlated with the degree of liberalisation; some of the most liberal reformers have no plans to privatise (*e.g.* Norway), while others have made privatisation a central feature of reform (*e.g.* England and Wales). In some countries (United States, Japan), the electricity supply industry has had predominantly private ownership throughout its history. In countries which have chosen to include privatisation in their reform efforts, the sequence of privatisation and liberalisation has varied: in the United Kingdom, privatisation preceded

Table 3. **Ownership in the electricity supply industry, 1998**

	Ownership
Australia	Mixed
Belgium	Mostly private
Canada	Mixed
Denmark	Mostly public
Finland	Mostly public
France	Public
Germany	Mixed
Greece	Public
Ireland	Public
Italy	Public
Japan	Private
Netherlands	Public
New Zealand	Public
Norway	Mostly public
Portugal	Mostly public
Spain	Mostly private
Sweden	Mixed
United Kingdom	Private
United States	Mostly private

Source: See main text.

liberalisation, whereas in some Nordic countries, liberalisation has preceded partial privatisation, and in some Australian states, privatisation has both preceded and succeeded liberalisation.[23] In general, the industry trend is a move toward private ownership in generation, both from the active programme of privatisation that some countries have undertaken, and from the entry of privately-owned firms as generation opens to competition.

Summarising regulatory reform for empirical analysis

For the empirical analysis in this paper, the following regulatory indicators were constructed:[24]

– A dummy for liberalisation which indicates liberalisation of generation by legislation, decree, or other formal governmental measures.

– The expectation of liberalisation which is measured by the number of years remaining to liberalisation.[25]

– A dummy for privatisation that indicates any move to (partial or complete) privatisation of companies in the electricity generation segment.

– The expectation of privatisation which is measured by the number of years remaining to privatisation. Again, timing is based on the first private sales or public offer.[26]
– A multi-level indicator for ownership to reflect the range of ownership composition from public to private.
– A multi-level indicator for vertical integration to reflect the range of integration over all industry functions.
– An interaction effect which is an interaction of the ownership and vertical integration indicators.
– A multi-level indicator to indicate specifically the type of separation of generation from transmission, ranging from none to separate companies. In the panel regressions, this indicator is consolidated into a dummy variable reflecting the presence/absence of any form of unbundling in order to avoid imposing spurious monotonicity in the indicators.
– A multi-level indicator for network access rules to reflect the range of access from none to regulated TPA. Following a similar logic as in the unbundling of generation and transmission, the indicator is simplified to a dummy reflecting the presence/absence of TPA.
– A dummy for the existence of an electricity market.
– An indicator for the degree of consumer choice. This is the threshold above which customers are free to choose electricity producer/supplier, converted to the same units for all countries.[27]

Table 4 provides descriptive statistics on the regulatory and industry structure indicators. The indicator for price regulation was not included in the panel regressions due to a large number of missing observations. Similarly, consumer thresholds were excluded from the regressions due to insufficient variation.

To summarise these indicators and the information about regulation and industrial structure that they contain, factor and cluster analysis techniques were employed (for a summary description of these techniques see the Annex to R. Gönenç, M. Maher and G. Nicoletti in this issue). The time-period of the regulatory and industry structure analysis here spans 1991-1996 for cluster analysis, and 1986-1996 for factor analysis.[28]

Examination of country clusters over time reveals both the classification of countries along the dimension of overall liberalisation, as well as the shifts between groups of countries as they undertake regulatory reforms and change their relative positions. Table 5 indicates cluster membership for countries over 1991-1996. In 1991, there are seven clusters, from most liberal (the United Kingdom and Norway) to least liberal (New Zealand, Canada, Ireland, Greece and Italy). By 1996, however, the number of clusters is reduced to six. Reforms in New Zealand and the

Table 4. **Indicators of regulation and industry structure for empirical analysis**[1]

Indicator	Observations	Period	Mean	Stdev	Coefficient of variation	Minimum	Maximum
Time to liberalisation	209	86-96	–7.081	4.621	–0.653	–11	0
Time to privatisation	209	86-96	–7.053	4.897	–0.694	–11	0
Unbundling of generation from transmission	209	86-96	0.211	0.409	1.941	0	1
Private ownership	209	86-96	1.292	1.243	0.962	0	4
Third party access	205	86-96	0.220	0.415	1.887	0	1
Wholesale pool	209	86-96	0.096	0.295	3.081	0	1
Choice threshold	209	86-96	644 763	299 763	0.465	0	783 462
Price regulation	172	86-96	0.314	0.688	2.193	0	2

1. See variable definitions in main text. Price Regulation not used in estimation due to missing observations. Choice threshold not used in estimation due to insufficient variation.

Source: OECD.

Table 5. **Patterns of regulation and market structure (1991-1996)**[1]
Country clusters

	1991	1992	1993	1994	1995	1996
United Kingdom	7	7	6	6	6	6
Finland	3	3	1	1	5	5
New Zealand	1	1	5	5	5	5
Norway	6	6	5	5	5	5
Sweden	3	3	1	1	1	5
Germany	3	3	1	1	1	4
Japan	5	5	4	4	4	4
United States	5	5	4	4	4	4
Australia	4	4	3	3	3	3
Denmark	3	3	1	1	1	2
Belgium	2	2	2	2	2	1
Canada	1	1	1	1	1	1
France	3	3	1	1	1	1
Greece	1	1	1	1	1	1
Ireland	1	1	1	1	1	1
Italy	1	1	1	1	1	1
Netherlands	3	3	1	1	1	1
Portugal	3	3	1	1	1	1
Spain	3	3	1	1	1	1

1. Results of hierarchical cluster analysis. Total number of clusters is reduced from 7 to 6 in 1993. Countries ordered according to position in 1996.

Nordic countries have led to a change in positions: the United Kingdom remains alone in the most liberal cluster while Finland, New Zealand, and Sweden have moved from their initial positions to the next most liberal cluster, joining Norway. The separate cluster for Australia (as well as its robustness over time and model specification) is puzzling. The clustering of the United States with Japan reflects a common history of investor-owned, vertically integrated utilities, so neither country has a need for new privatisation. However, over the period of the sample, both have begun measures to liberalise access. Until 1996, Belgium forms an independent cluster that reflects its combination of integration and private ownership. Finally, the least liberal cluster reflects the presence of predominantly public, integrated electric utilities as well as late entry into liberalisation.

Three latent factors best describe the variance in regulatory and industry structure indicators across countries. Table 6 illustrates the assignment of indicators to factors. The first factor represents attempts to introduce competition in generation. The second factor represents ownership and privatisation, and the third factor represents regulation that is ancillary to generation (transmission pricing and preferred treatment of renewable technology).[29]

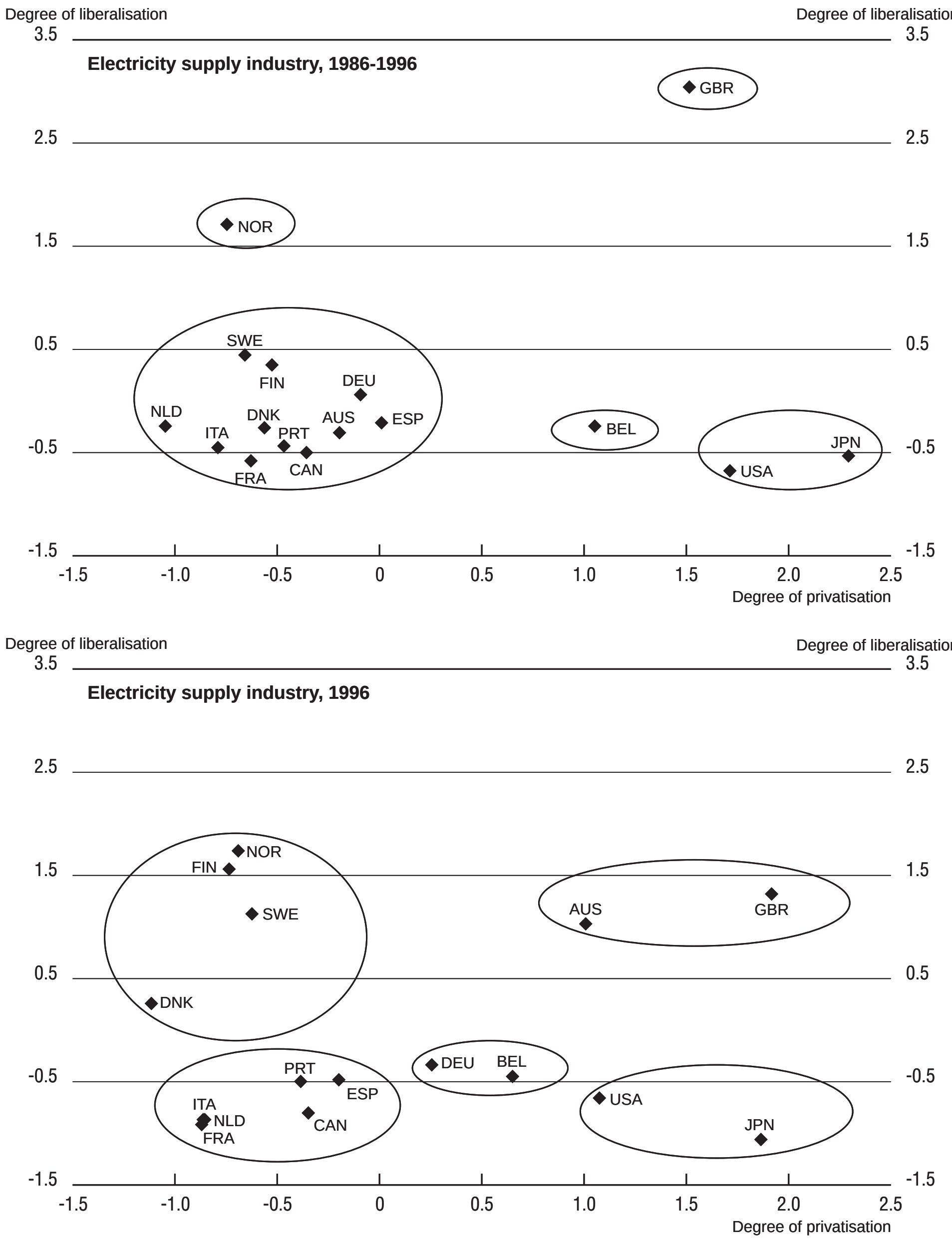
Table 6. **Regulation and industry structure: the discriminating factors (1986-1996)**
Results of factor analysis[1]
Rotated factor loadings[2]

	Liberalisation	Privatisation	Ancillary regulation
Liberalisation	0.928	0.052	–0.083
Time to liberalisation	0.744	–0.166	0.114
Third party access	0.827	0.122	0.152
Unbundling of generation and transmission	0.909	0.120	0.121
Vertical Integration	0.759	0.093	0.380
Interaction of integration and ownership	0.615	0.526	0.369
Wholesale pool	0.932	0.104	–0.081
Choice threshold	–0.711	–0.259	0.497
Privatisation	0.023	0.930	–0.157
Private ownership	0.126	0.900	0.011
Time to privatisation	0.093	0.836	0.197
Price regulation	0.207	–0.254	0.369
State preference for renewable technology	0.003	0.233	0.817

1. Extraction method: Principal component analysis. Rotation method: Varimax with Kaiser normalisation.
2. Factor loadings measure the correlation between the individual indicators and the latent factors. Indicators are assigned to the factor to which they are most correlated. The rotation of factor loadings is a transformation aimed at minimising the number of indicators that are highly correlated with more than one factor.

The estimated factors may also be used to "score" and group countries according to these three dimensions of liberalisation, privatisation, and ancillary regulation. Figure 2 plots averages of country scores in liberalisation against average scores in privatisation. Panel A positions countries according to data from the entire 1986–1996 period. Over the whole period, five groups of countries emerge: the United Kingdom has the highest liberalisation score and a high privatisation score; Norway scores high on liberalisation but low on privatisation; the United States and Japan form a group with a high degree of privatisation but a low degree of liberalisation; Belgium scores high on privatisation but low on liberalisation; and the remaining countries form a group with low scores on both liberalisation and privatisation. These groups reflect the different nature of regulatory reforms in the United Kingdom and Norway, the history of investor-owned, regional, integrated utilities in the United States and Japan, and the integrated but privately owned national monopoly in Belgium. Panel B positions countries according to scores for 1996, the final year in the sample. Comparison of the two panels illustrates the historical movement of countries along the two reform axes. In 1996, Australia joins the United Kingdom to form a group with a high degree of both liberalisation and privatisation. Sweden, Finland, and Denmark join Norway in the group characterised by a high degree of liberalisation, but a low degree of privatisation. The United States remains in a group with Japan, as before. The United States appears to have a lower liberalisation score than some countries in the remaining group which is characterised by both low liberalisation and

Figure 2. **Grouping countries according to estimated factors**



Source: OECD.

privatisation scores; this is because the variables associated with the liberalisation factor are predominantly measures of vertical integration, and the US utilities remain integrated in 1996.

EVALUATING THE EFFECTS OF REGULATORY REFORM ON PERFORMANCE IN THE ELECTRICITY SUPPLY INDUSTRY

The empirical approach

The empirical approach uses cross-country and time-series variation to examine the impact of indicators of regulation and industry structure on efficiency and prices. The performance measures are discussed in further detail below. The analysis also attempts to control for country-specific, economic and technological conditions. These are assumed to be exogenous and to exist independently of regulation, but may explain a portion of the variation in performance.

A reduced form model is defined to explain each performance measure, y_{it}, as a function of country-specific effects f_i, a set of controls which influence performance independently of regulation **Z** [i,t], and a set of regulatory and industry structure indicators **R** [i,t], for each country i and year t:

$$y_{is} = c + f_i + Z'\beta + R'\delta + \varepsilon_{it} \qquad (1)$$

The model is estimated using panel data techniques across countries and years (for a summary description of these techniques see the Annex to Boylaud and Nicoletti in this issue).

The control variables, **Z** [i,t], account for observed differences in economic and technological conditions that characterise countries over time, whereas the random effects, f_i, account for unobservable (and, therefore, unmeasurable), time-persistent differences across countries. The control variables include measures of cyclical economic conditions, geographical distribution of population, taxes and subsidies to specific generation technologies, and shares of different technologies employed in generation. Table 7 describes the economic and technology control variables used in the empirical analysis. These variables will not always fully control for variation in economic and technological conditions across countries. For example, insufficient time-series prevents inclusion of coal, oil, and gas prices for electricity generation. Similarly, the analysis does not control for weather and climate, important determinants of load shape, but these factors are partly captured by the country-specific effects.[30] Additionally, it is important to account for the choice of generation technology in empirical analysis. As discussed in the second section, different technologies will result in different prices and especially costs. An empirical difficulty results from the fact that the choice of technologies across countries is endogenous. Countries have idiosyncratic policy

Table 7. **Economic and technological control variables for empirical analysis**

Variable[1]	Observations	Period	Mean	Stdev	Coefficient of variation	Minimum	Maximum
GDP	204	86-96	766.616	1 362.075	1.777	27.003	7 661.575
Hydro share in generation	209	86-96	0.245	0.272	1.110	0.000	1.003
Nuclear share in generation	209	86-96	0.193	0.221	1.147	0.000	0.776
State preference against nuclear technology	209	86-96	0.206	0.405	1.970	0.000	1.000
State preference in favor of coal technology	209	86-96	0.244	0.431	1.764	0.000	1.000
Urbanisation	209	86-96	54.316	75.299	1.386	2.000	234.000

1. Urbanisation is the number of cities with a population greater than 100 000. Agricultural share of consumption excluded to avoid multicollinearity.
Sources: IEA Electricity Information, OECD *Analytical Database*, UN *World Population Estimates and Projections*.

objectives, resources, and preferences for technologies, which are observable to regulators and firms, but unobservable in the current context. The best empirical strategy would be joint estimation of a technological choice model along with the performance/regulation model. This approach is not pursued here, and, instead, production shares of different technologies are employed as controls in the performance regulation model.

Performance data

The performance indicators in this analysis are at best only proxies for efficiency and prices. An appropriate indicator for quality was unavailable, therefore, the empirical model was applied only to the price and efficiency dimensions of performance. The choice of indicators used was driven partially by data constraints and measurement difficulties. Table 8 describes the performance indicators.

Efficiency is difficult to measure in the electricity supply industry. One candidate proxy would be labour productivity (output per unit input); however, the appropriate data regarding employment in the electricity supply industry are not available, and a measure of labour productivity gives little indication about efficiency in a capital-intensive sector like electricity. Measures of capital or total factor productivity are difficult to construct, especially at the industry level, and would introduce additional error due to the difficulty in measuring capital. If efficiency is conceptualised as output per unit input, a possible indicator specific to the electricity supply industry would be thermal efficiency for nuclear and fossil-fuel based generation. However, this measure would preclude comparisons between the different technologies. Furthermore, even within a generation technology, there are significant differences across countries in the characteristics of input fuels that affect thermal efficiency but are not correlated with regulation.[31] Consequently, one indicator of efficiency used in this analysis is the capacity utilisation rate, calculated as energy production divided by total average capacity. Greater usage of capacity implies greater (productive) efficiency, though this indicator only proxies for the productive use of inputs to electricity generation.

A second indicator of efficiency employed here is the distance of actual reserve margins from "optimal" reserve margins, where the reserve margin is calculated as the difference between capacity and peak demand, divided by peak demand.[32] When introducing electricity sector reform, countries attempt to plan for their energy consumption needs to satisfy demand with a sufficient but not excessive buffer. As a result, a monotonic interpretation of a dependent variable such as the reserve margin itself (in which "more" is interpreted as "better") would be inappropriate because at some point, more is too much, based on the objectives of any country. Therefore, the distance of the reserve margin from a benchmark is employed, despite its crudeness as an indicator of efficiency.

Table 8. **Indicators of performance for empirical analysis**

Indicator[1]	Observations	Period	Mean	Stdev	Coefficient of variation	Minimum	Maximum
Industrial end-user price in PPPs	207	86-96	0.053	0.035	0.657	–0.005	0.163
Ratio of industrial to residential prices in PPPs	207	86-96	0.543	0.233	0.179	–0.125	0.857
Utilisation rate	209	86-96	0.000	0.000	0.127	2.408	5.286
Distance of actual from optimal reserve margin	193	86-96	0.324	0.184	0.567	0.008	0.842

1. Utilisation rate calculated as the ratio of electricity production to capacity. Actual Reserve margin is (capacity – peak)/peak, and optimal reserve margin is assumed to be 0.15. Distance is the absolute value of the deviation.

Sources: IEA *Electricity Information and Energy Prices and Taxes*.

Gilbert and Kahn (*op. cit.*) cite estimates by Southern Company Services which place optimal reserve margins in the range of 15 to 20 per cent for thermal power systems. The indicator in this paper uses 15 per cent as the optimal reserve margin benchmark, and does not attempt to distinguish between over and under capacity. The 15 per cent benchmark is chosen for practical purposes: the actual reserve margin may be country-specific, but more specific data are unavailable.[33] The interpretation of this efficiency measure is that greater deviations from "optimal" capacity result in lower efficiency of supply, though this is only an indirect indication. The reader should be aware, however, that the symmetric treatment of over and under capacity may not be fully satisfactory: while over capacity may be inefficient, it is a less serious problem than under capacity or the inability to meet peak demand.

Measurement of electricity prices also presents challenges. First, the analysis in this paper focuses on electricity generation, whereas price data exist only at the retail level. Particularly since the transmission and distribution components of prices are regulated, this introduces additional variation across countries which will be picked up by the end-user prices, but which would not occur in generation prices. In this analysis, the proportion of end-user prices explained by generation, relative to other functions, is assumed to be relatively constant across time; generation prices are assumed to be a mean-shifted version of retail prices. As seen in Figure 1, generation makes up the greatest proportion of electricity supply costs, so the majority of variation in end-user prices should be accounted for by generation prices. Generation prices make up proportionately more of industrial end-user prices than residential prices, hence the use of industrial prices in this analysis. Prices are also difficult to measure because their structure varies enormously both within and between countries with variation in fixed and or variable components, and they vary enormously across daily load cycles, seasons, and customer classes as well. Additionally, to be internationally comparable, prices must be converted into a common currency; volatility in exchange rates will introduce variation in prices that is independent of regulation. To counter this problem, GDP PPPs provided by the OECD were used to convert national currencies to US dollars. In general, while the price data are not free of measurement error for all of these reasons, measurement error in the dependent variable will not bias estimates, but only increase their variance. The price indicators employed in the analysis are industry, pre-tax electricity prices, and the ratio of industrial to residential pre-tax electricity prices.[34] The price for industrial consumers captures the effect of regulation on consumer welfare as a whole, whereas the industrial-residential differential may illuminate price discrimination across customer groups, a practice that could be partly symptomatic of market power, but also might reflect attempts at pursuing distributional objectives through regulatory interventions.[35]

In the electricity supply industry, quality is particularly important: customers pay not only for the physical product which they consume, but also for the security of uninterrupted power supply which they expect to receive. In this context, quality refers to frequency and voltage, continuity, and reliability.[36] For the electricity supply industry as a whole, the best indicator of quality would be the number of power outages per year, however, these data are not publicly available. Hence, cross-country comparisons of the quality dimension are severely constrained by data availability, and empirical examination of quality is left for future work.

Empirical difficulties

The results of the empirical analysis should be considered with caution. First, as discussed above, the performance measures are proxies that imperfectly represent efficiency and prices. Moreover, there are issues of cross-country comparability of the data. The IEA performance data are based on submissions from national administrations. Different countries have different classifications and reporting conventions, so that observations in a given performance data series may not have the same meaning across all countries. These errors in performance measurement are less serious than measurement error in the regulation and industry structure indicators, however, since errors in measuring dependent variables only reduce the efficiency of estimates.

Furthermore, the regulation and industry structure indicators are also measured with error. Construction of the quantitative indicators from qualitative information about regulation involved some subjectivity and judgement. In particular, some of these indicators serve only as crude proxies of the regulatory effects they are meant to measure. For example, the consumer choice threshold gives the thresholds above which consumers may choose electricity suppliers, however, this does not indicate the proportion of the market which is open to consumer choice. Similarly, the TPA indicator is based on the formal approach to network access rather than actual use of Third Party Access; there may be no formal barriers to TPA, but, simultaneously, a monopolist may be the only producer in a market, making TPA rules moot. In addition to measurement error, there may be an omitted variables problem if the regulatory indicators do not capture all of the variation in regulation that systematically impacts performance. Taken together, measurement error and omission of explanatory variables will bias estimates of all coefficients in the estimation. However, omitted variables should be captured at least in part by the country-specific effects, mitigating the potential for bias. These problems extend to the control variables, as well. For example, as discussed previously, technology shares may be endogenously determined. For the ten-year period of this analysis, however, it may be assumed that technological decisions are fixed, so that the use of technology shares should not bias estimates.[37]

Another possible source of bias is that the model does not control for market structure of the electricity supply industry. Complete time-series data on market shares are not available, prohibiting inclusion of a concentration proxy in the analysis. Omission of market *shares* is unlikely to result in empirical bias. For reasons explained above, in many countries the Herfindahl index (HHI) would be equal to one (indicating perfect concentration) over the entire time period. Moreover, since markets may be larger or smaller than single countries, country-level HHI or market share statistics would not necessarily reflect the actual degree of market concentration. However, the degree of market *power* is likely to have important effects on efficiency, quality, and especially prices. Therefore, it should be controlled for in empirical analysis. Regulatory reforms may not be met with synchronous performance improvements if residual market power remains, so an inability to control for market power may lead to an omitted variable problem.

Empirical results

The indicators of regulation, industry structure, and performance were used to estimate equation (1) for the electricity supply industry. Initially, each equation was estimated using two regression models: a random effects specification and a fixed effects specification. In each of these specifications, the country-specific effect was assumed to occur in the constant term, so that slope coefficients are identical across countries. The random or fixed effects account for country-specific effects not otherwise included in the regressions. The random effects specification assumes that the relevant units (in this case countries) are drawn at random from a larger population, while the fixed effects specification is more appropriate if the focus is restricted to a specific set of units. The relative merits of the two specifications for panel data are discussed in the Annex to Boylaud and Nicoletti in this issue. On the basis of Breusch-Pagan and Hausman tests, the random effects specification was chosen for the regressions in this analysis. Results for fixed effects estimation are, therefore, not provided, though the signs, magnitude, and significance of coefficients were robust to the use of either specification. The random effects specification makes sense in the context of this study if we consider that it consists of a sample of countries from a much larger population of OECD and non-OECD countries, so that country-specific constant terms are randomly distributed across cross-sectional units. Tables 9-10 summarise the estimated impact of regulation on industrial prices, industrial-residential price differentials, utilisation rates, and the gap between actual and optimal reserve margins, respectively.

Impact of regulation on prices

The model was estimated separately for industrial prices and for the ratio of industrial to residential prices, changing the model specification to account for different expectations as to the effect of regulation and industry structure on the two price indicators (Table 9). In the industry price regression, a number of control variables were included to account for cyclical economic variation and the impact of choice of generation technology. These controls were not included in the industrial-residential price differential regression, as the use of a price ratio should neutralise these effects, and the object of study is whether regulatory reform affects customer groups differentially. In both models, the explanatory

Table 9. **Results of random effects panel regressions for prices**[1]

Dependent variable	Industry price	Industrial/Residential price ratio
Constant	0.067	0.528
	7.104	**9.684**
Unbundling of generation from transmission	–0.001	–0.051
	–0.659	**–2.425**
Private ownership	0.003	0.035
	2.7	**2.786**
Third party access	–0.003	–0.035
	–1.357	**–1.755**
Wholesale pool	–0.005	–0.114
	–2.306	**–3.861**
Time to liberalisation	0.001	–
	2.814	–
Time to privatisation	0.001	–
	1.51	–
Hydro share in generation	–0.034	–
	–3.252	–
Nuclear share in generation	0.002	–
	0.132	–
GDP	0.000	–
	1.011	–
Number of periods	11	11
Number of countries	19	19
Number of observations	209	209
Tests		
Hausman Chi-squared statistic[2]	16.39	18.22
Breusch-Pagan Chi-squared statistic[3]	775.31	776.96
Ho: Regulation indicators = 0 (Wald test)	27.01	82.24

1. Z-statistics in **bold**.
2. For the Hausman test, the null hypothesis is that the random effects specification is correct.
3. For the Breusch-Pagan test, the null hypothesis is that the random effects equal zero.

variables are jointly significant in explaining the variation in prices, on the basis of the Chi-squared statistic, significant at the 0.01 level. Where they were included, the control variables had the correct sign but were generally insignificant. Only the share of hydro generation was significantly negative; a larger proportion of hydro-based generation results in lower industrial end-user prices, all else equal. This is consistent with expectations: the variable costs of hydropower are very low, except in drought years, so a large proportion of hydro generation should exert negative pressure on prices.

In the long run, liberalisation and privatisation may reduce electricity prices. Since there has been a gap between end-user prices and the cost of electricity supply (for example, in the United States),[38] this suggests potentially supra-competitive prices before deregulation and the possibility for downward movement of prices after. Unbundling of generation and transmission facilitates new entry into generation, so to the extent that entry intensifies competition, prices should decrease. Nevertheless, the estimated coefficient on unbundling of generation and transmission is statistically insignificant. While the negative sign of the estimated coefficient on the unbundling indicator was robust to different model specifications, its significance appeared to be affected by multicollinearity with the other indicators of liberalisation (TPA and the presence of an electricity market).

On the other hand, the positive and significant coefficient on ownership suggests that private ownership is not necessarily correlated with increased competition. This indicator reflects the influence of historic private ownership in addition to recent privatisation. The former could be correlated with higher prices due to a higher cost of capital, less tax advantages, and less access to low-cost hydro resources. In fact, in many countries in the panel, private ownership coincides with a highly concentrated market (*e.g.* Belgium). Furthermore, privatisation of historically public generators may still result in high prices in the short run. Governments may actually increase electricity prices in order to sell assets and generate revenue. Furthermore, while governments may use privatisation as a platform for horizontal unbundling, if horizontal unbundling does not reach far enough, post-privatisation prices may remain high. For example, in the United Kingdom, the former state-owned utility, the Central Electricity Generating Board (CEGB), was broken up into only three competing generators (National Power, PowerGen, and British Energy). As a result, private companies with market power replaced a public company with market power, so prices did not respond immediately to privatisation.

The model specification also permits assessment of the extent to which expanded legal rights to Third Party Access of networks and the establishment and operation of an electricity spot market are each effective in reducing prices. The estimated coefficients on these variables were negative, as expected.

However, the coefficient on TPA was not statistically significant. This may be because TPA will not make a difference in prices if *legal* TPA does not result in *actual* entry and if the incumbent retains practical control of the market. The coefficient on the spot market indicator was statistically significant. A real spot market should lower prices by inducing competition.

Indicators of the time remaining to liberalisation and privatisation were included to proxy for the impact of expectations of liberalisation and privatisation on prices. Both coefficients were positive, and time to liberalisation was statistically significant. This suggests that as liberalisation and privatisation dates approach, prices increase. In the case of privatisation, this is consistent with one potential policy goal underlying privatisation: to generate state revenue by selling assets, a goal that would be facilitated by higher prices. Also, to the extent that time to liberalisation and time to privatisation are correlated, this may help to explain the counterintuitive sign on time to liberalisation. Alternatively, this empirical finding may result from a problem of reverse causality if high prices act as an incentive for liberalisation.

The regulation and industry structure indicators were used to explain the differential between industrial and residential prices. To interpret the empirical results for this variable, it should be noticed that in all countries and time periods included in the sample industrial prices were lower than household prices (in US$ PPPs). Here, again, signs were largely consistent with expectations and statistically significant. The coefficient on private ownership was positive and significant. The coefficients on unbundling of generation and transmission, TPA, and the spot market were negative and significant, as expected.

The results underscore two important characteristics of reform in the electricity sector: first, the benefits of reform are disproportionately realised by industrial consumers, and second, price discrimination can persist and even intensify under reform if market power is not reduced by structural measures such as horizontal unbundling. The fact that unbundling of generation and transmission, TPA, and the existence of a spot market all have a greater impact on industrial prices than residential prices is consistent with expectations: industrial consumers are larger than residential consumers so they can benefit directly from third party access by arranging to have power wheeled by a generator, thereby avoiding other parts of the supply chain. Additionally, they have the resources to participate in spot markets. Furthermore, prices to industrial consumers should disproportionately reflect the effects of shifts in generation regulation because for these consumers, generation makes up a larger proportion of end-user electricity prices. In contrast, small residential consumers are less likely to be affected by these reforms because they continue to purchase electricity from local distribution companies so that they do not benefit directly from unbundling, expanded TPA, and spot markets. An additional factor that may explain why industrial prices tend to fall relative to residential prices in reforming countries is that industrial consumers (with the flexibility to time production with off-peak electricity hours, for example) have more elastic demand than residential consumers so that the price differential is consistent with Ramsey price discrimination (if the costs of supplying residential consumers do not exceed those of industrial consumers).[39] There is evidence, therefore, that reforms may not have generally succeeded in eliminating market power.[40]

Impact of regulation on efficiency

To estimate the impact of regulation on efficiency, the capacity utilisation rate was regressed on unbundling of generation and transmission, private ownership, and TPA (Table 10). Taken together, the explanatory variables are significant in explaining variation in utilisation of capacity, as evidenced by the Chi-squared

Table 10. **Results of random effects panel regressions for efficiency**[1]

Dependent variable	Utilisation rate	Reserve margin deviation
Constant	0.00045	0.38535
	29.00500	**7.62100**
Unbundling of generation from transmission	0.00003	–0.10447
	2.91200	**–3.52000**
Private ownership	0.00001	–0.03332
	1.80400	**–1.44200**
Third party access	–0.00001	0.03985
	–0.76900	**1.48400**
State preference against nuclear technology	–0.00002	–0.03986
	–1.03700	**–0.60500**
State preference in favour of coal technology	–0.00003	0.16975
	–1.19600	**2.24800**
Urbanisation	0.00000	–0.00071
	0.24500	**–1.41400**
Number of periods	11	11
Number of countries	19	19
Number of observations	209	209
Hausman Chi-squared statistic[2]	7.02	5.97
Breusch-Pagan Chi-squared statistic[3]	362.71	378.12
Ho: Regulation indicators = 0 (Wald test)	17.26	16.94

1. Z-statistics in **bold**.
2. For the Hausman test, the null is that the random effects specification is correct.
3. For the Breusch-Pagan test, the null hypothesis is that the random effects equal zero.

statistic, which is significant at the 0.01 level. The model includes control variables, state technology preferences and urbanisation, which were of the expected sign but were insignificant.

A number of regulation indicators used in the price regressions were excluded from the efficiency regression because they were not expected, *a priori*, to impact efficiency. In particular, the spot market indicator was not included; the existence of a spot market is likely to reduce prices, but not to impact the utilisation rate.[41]

The estimated impact of regulation and industry structure on efficiency was generally in line with expectations. The utilisation rate is positively and significantly affected by both private ownership and the unbundling of generation and transmission. This is consistent with both general theories that posit private firms as more efficient than publicly owned firms due to better management practices and increased efforts to minimise costs in the former contrasted with organisational slack in the latter, as well as existing electricity-specific empirical evidence.[42] There may be an additional efficiency advantage to privatisation if governments in countries with national state-owned monopolies use privatisation as an opportunity to horizontally unbundle the generation segment of the industry to reduce concentration and market power. Unbundling of generation and transmission can lead to more efficient investment (in capacity) and better production management (including scheduling of generators) if all responsibility for the transmission grid is allocated to one company that is autonomous of generation. Finally, the coefficient on TPA was insignificant. These results may derive from the fact that legal rights to TPA may not translate into actual TPA if an incumbent retains a dominant presence.

The same regulatory indicators and controls were employed in a regression to explain the absolute deviation of actual from optimal reserve margins. In this case, the expected impact of regulatory reforms is ambiguous. Countries might be expected to seek "optimal" reserve margins through reform measures. From an efficiency perspective, one would expect the industry to bring reserve margins closer to the optimum, avoiding both under and over investment. The narrowing of this gap would therefore be interpreted as an improvement in efficiency. However, some countries might start from a baseline of dramatically insufficient supply, or might anticipate large increases in demand, so that reform can be used to encourage investment in capacity over and above the assumed "optimal" level.

The results of the reserve margin regression confirm the linkages between regulatory changes and efficiency that were found for the rate of capacity utilisation. Jointly, the regulation and industry structure indicators are significant in explaining the reserve margin gap. The coefficient on the unbundling of generation and transmission is negative and statistically significant. Thus, unbundling is associated with reserve margins which are closer to the optimum, perhaps due to better capacity investment and grid management. Similarly, the coefficient on private ownership is negative and significant. On the other hand, the coefficient on TPA is positive but statistically insignificant. This mirrors the result in the efficiency equation where the sign of TPA is contrary to expectations, but insignificant and may illustrate a case where a change in legal rules is slow to stimulate a change in conduct.

A *further look at electricity supply performance in the* OECD *area*

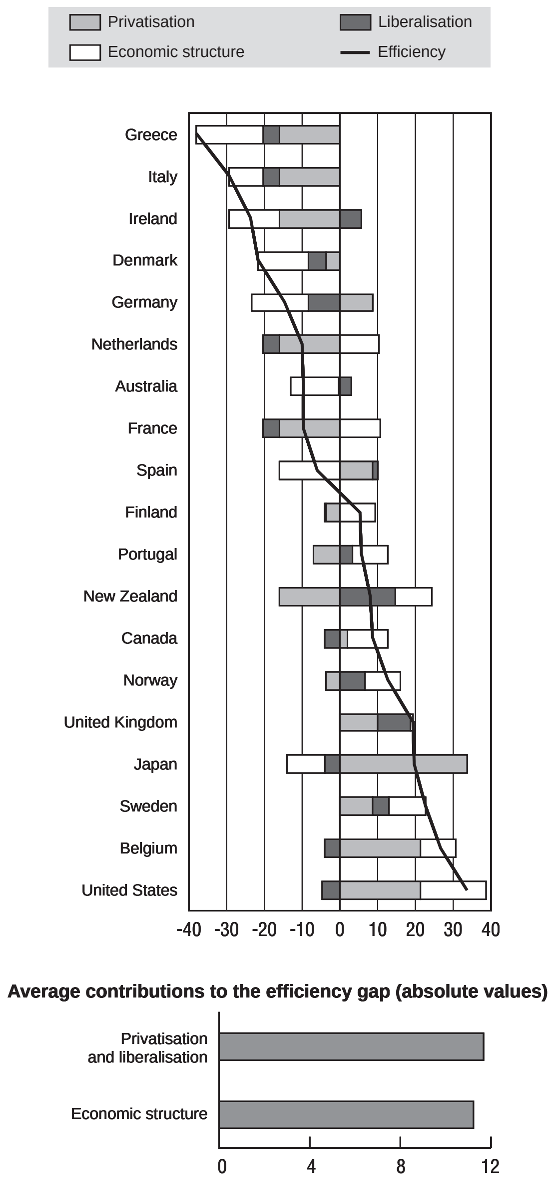
The results of regression analysis can be used to calculate the relative contributions of, on the one hand, country-specific and structural effects (economic structure and technology) and, on the other, regulatory effects to explaining differences in electricity supply performance across OECD countries. The discussion focuses on the effects of privatisation and liberalisation on efficiency (measured as utilisation of capacity). It should be reminded that structural and economic factors could be partly driven by regulatory reform. Therefore the contribution of privatisation and liberalisation to explaining efficiency may not be correctly identified.

Figure 3 shows the relative contributions of privatisation, liberalisation and other factors (pooling economic structure, technology and other country-specific unexplained factors) to explaining differences in the rate of capacity utilisation across OECD countries. Contributions to efficiency are positive (negative) when liberalisation, privatisation or other effects are broader (narrower) than in the average OECD country. The combined effects of privatisation and liberalisation are generally larger than other effects in explaining the relative efficiency position of countries. Given the limited degree of liberalisation in OECD countries, privatisation often has the largest effect. However, in countries that have reformed more extensively their regulatory framework (*e.g.* the United Kingdom, New Zealand and Norway), the positive impact of liberalisation is apparent.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The diffusion of new technologies is putting a strong demand pressure on the electricity sector. Moreover, the development of the emerging economies will require tremendous investments in electricity generation in future years. There are also key environmental dimensions related to the pollution externalities and the pressure on electricity demand from the adaptation to climate change. All these elements make it critical to achieve a high degree of economic efficiency in the production, distribution and supply of electricity.

Figure 3. **Explaining cross-country differences in electricity supply performance**[1]



1. Efficiency is defined as the rate of capacity utilisation. Percentage deviations from OECD average.

This paper has provided a first attempt to assess, on the basis of international evidence, to what extent regulatory reform in the electricity industry can contribute to improved efficiency and welfare outcomes. The comparative data on regulations presented in the paper show that most countries have just begun to consider and to implement regulatory reform in the electricity supply industry. Furthermore, early efforts at liberalisation and or privatisation, while creating legal access for competition in generation, are slow to meet with actual entry and competition in generation. The most common pattern of liberalisation begins with attempts to introduce competition in generation by unbundling generation from transmission and expanding legal access to the transmission network. The most far-reaching reforms also create spot markets for trade in electricity and allow consumer choice of supplier for some consumers. Preliminary exploration of the data using cluster analysis identified six groups of countries in 1996, with the United Kingdom as most liberal, followed by Finland, New Zealand, Norway, and Sweden. The least liberal group included Belgium, Canada, France, Greece, Ireland, Italy, Netherlands, Portugal, and Spain.

In summary, the primary empirical findings concerning the impact of these reforms on efficiency and prices are as follows:

– The ratio of industrial to residential end-user electricity prices is reduced by the unbundling of generation and transmission, expansion of Third Party Access (TPA), and introduction of electricity markets. The existence of these markets also tends to reduce the levels of industrial end-user prices. However, a high degree of private ownership and imminence of both privatisation and liberalisation tend to increase industrial end-user prices.

– Unbundling of generation and transmission and private ownership each serve to improve the utilisation of capacity in electricity generation.

– Unbundling of generation and transmission also brings reserve margins (the ability of capacity to handle peak load) closer to their optimal level.

Taken together, these findings suggest that regulatory reforms involving vertical separation of the industry, market price determination and privatisation impacted favourably on efficiency. There are also signs that this cost reduction translated into better opportunities for price discrimination between different categories of consumers and lower industrial end-user prices. However, the effects of regulatory reform on prices appear to depend crucially on the ability of regulatory policies to control market power after reforms have been implemented.

While this analysis serves as a first step in assessing the impact of regulation and industry structure on performance, much work remains to be done. The analysis could be enhanced by refining the regulatory indicators and finding a suitable proxy for quality and for market power. Additionally, the analysis could benefit from improved controls for the effect of regulation in the transmission and distribution functions, particularly in the case of prices which, as measured, are influenced by regulation outside of the generation segment. A more complicated model that controls for the endogeneity of generation technology choice across countries might also improve estimates by better controlling for factors that affect performance independently of regulation and industry structure. Finally, perhaps most useful, would be to extend the analysis through time to include the many reforms which have just begun, and the many more on the horizon.

NOTES

1. IEA (1999), *Electricity Market Reform*, Paris.
2. IEA (1992), *Electricity Supply in the OECD*.
3. While recent and forthcoming environmental regulations are likely to influence economic performance in the electricity supply industry, this paper does not discuss environmental regulations.
4. For example, England and Wales unbundled its electricity supply industry (ESI), privatised generation, introduced transmission price-caps, and introduced a spot market in electricity under implementation of the Electricity Supply Act of 1990. New Zealand also unbundled its ESI and introduced a spot market with the Energy Act and Company Act of 1992. Norway unbundled its ESI, introduced unconstrained choice of supplier, and extended its wholesale electricity pool to other Nordic countries with the Energy Act of 1990. Sweden reformed its ESI according to a similar pattern with a bill passed in 1996. Note additionally, that progress has been slow in some countries due to the issue of remunerating "stranded costs", that is costs of investments undertaken under regulation, but no more profitable in a competitive environment.
5. Directive 96/92/EC was adopted by the Council of Ministers on 19 December 1996 and entered into force on 19 February 1997. Member states have two years to implement changes necessary to comply with the Directive, except for Belgium, Ireland, and Greece, who have an additional year (two in the case of Greece) to implement the Directive.
6. Relevant institutional arrangements include the need to co-ordinate the activities of energy and environmental regulatory agencies, an issue that has received relatively little attention in many OECD countries.
7. See, for example, R.J. Green and D.M. Newbery (1992) "Competition and Regulation in the British Electricity Spot Market," *Journal of Political Economy*, 100(5) 929-953, and F.A. Wolak. and R.H. Patrick (1996*a*) "Industry Structure and Regulation in the England and Wales Electricity Market", in M.A. Crew, ed., *Pricing and Regulatory Innovations Under Increasing Competition*.
8. For example, E.D. Cross (1996), *Electric Utility Regulation in the European Union*, Wiley and Sons, New York, offers excellent and detailed accounts of legislation in EU countries. R.J. Gilbert and E.P. Kahn (1996) *International Comparisons of Electricity Regulation*, Cambridge University Press, offers good historical descriptions of regulatory environments in many OECD countries. F.A. Wolak (1997), "Market Design and Price Behaviour in Restructured Electricity Markets: An International Comparison", *mimeo*, offers detailed discussion of markets in England and Wales, Norway, New Zealand, and Victoria, Australia, including an empirical description of performance in each country, and underscoring reform weakness in eliminating market power. Also B. Bortolotti, M. Fantini and D. Siniscalco (1999),

"Regulation and Privatisation: The Case of Electricity", mimeo, presents empirical panel data analysis, however, the regulation and privatisation indicators are aggregated into indices, so that assessment of individual components of regulatory reforms remains impossible.

9. Natural monopoly is when a single firm can supply a good at lower total cost than two or more firms. An externality is when a consumer or firm is affected by the consumption or activity of other agents in the economy.

10. Following IEA definitions, continuity means consumer confidence in long-term supply, beyond the duration of a contract. Reliability means consumer confidence in day-to-day supply. Also, electricity supply must be characterised by a narrow range of frequency and voltage to be usable, otherwise appliances will malfunction and unsafe conditions may result. Avoiding black-outs (complete loss of power) or brown-outs (drops in system voltage due to insufficient generation) is also important.

11. Spinning reserve is a quantity of capacity able to provide energy instantly; a plant in spinning reserve incurs operating costs but does not provide electricity to the network. Black start capability is the ability of a generating unit to start up when system power has been lost.

12. Capacity factor is the utilisation of capacity. Thermal efficiency is the ability to generate electricity output per unit of fuel input. Operating life is the scheduled lifetime of a plant. IEA (1994) *Electricity Supply Industry*, Paris, p. 65.

13. Oil prices are perceived as volatile and risky, and coal prices may increase with environmental restrictions on coal.

14. H. Averch and L.L. Johnson (1962), "Behaviour of the Firm under Regulatory Constraint". *American Economic Review*, Vol. 52.

15. IEA (1999), *Electricity Market Reform*, Paris. To put these numbers in perspective, an aluminium producer, for example, has approximately constant demand throughout the year, on the order of 1500-1800 GWh per year, requiring a capacity of roughly 170-205 MW.

16. Hold-up costs may be discriminatory rates or contracting hurdles directed at entrants by incumbents.

17. However, technological advances are reducing the costs of metering equipment. Additionally, regulators are responding to these costs with the introduction of load profiling, an innovation to avoid the need to monitor customer electricity use at the individual level.

18. *europa.eu.int/en/comm/dg17/elec/memor.htm*.

19. The "Takings Clause" of the Constitution forbids the federal government from taking action which bankrupts a firm. This has led to the adoption of rate-of-return regulation, where the government sets electricity prices to effectively guarantee the firm a "fair" rate of return. In contrast, under price cap regulation, prices would be indexed to a moving indicator such as the Producer Price Index, less a portion which provides incentive for innovation and improved efficiency. Under this type of regulation, firms could realise negative returns in the short run if they were operating inefficiently.

20. Cross-subsidisation of electricity prices may occur between segments of the market, such as residential, industrial, and commercial consumers, or geographically between rural and urban consumers. Peak-load pricing is when prices increase at peak usage

times. Under nodal pricing, the price at each node (location) should reflect the marginal cost of production plus the marginal cost of transportation. Postage-stamp pricing is the most rudimentary pricing mechanism, under which rates are based on division of total network cost by total connected load, with no attempt to account for the spatial dimension of electricity transmission.

21. The largest electricity generation companies are seen to influence prices by restricting capacity in order to capitalise on price determination formulas used to match supply and demand on the electricity market. R.H. Patrick and F.A. Wolak (1997), "The Impact of Market Rules and Market Structure on the Price Determination Process in the England and Wales Electricity Market", mimeo.

22. Further details about privatisation in electricity generation at the firm level for countries in the panel are provided in Steiner (2000), OECD *Economics Department Working Paper*, No. 238.

23. IEA (1999) *Competition in Electricity Markets*, Paris.

24. These indicators were constructed using a number of sources: replies of Member countries to an *ad hoc* OECD questionnaire, as well as E.D. Cross (1996), *Electric Utility Regulation in the European Union*, Wiley and Sons, New York; Richard J. Gilbert and Edward P. Kahn (1996) *International Comparisons of Electricity Regulation*, Cambridge University Press; Frank A. Wolak (1997), "Market Design and Price Behaviour in Restructured Electricity Markets: An International Comparison", mimeo; B. Bortolotti, M. Fantini and D. Siniscalco (1999), "Regulation and Privatisation: The Case of Electricity", mimeo; and a number of IEA publications: *Electricity Supply Industry* (1994); Energy Policies of IEA Countries (*Japan 1999 Review*; *Finland 1999 Review*; *Spain 1998 Review*; *United States 1998 Review*, *Denmark 1998 Review*; *New Zealand 1997 Review*; *Norway 1997 Review*; *Australia 1997 Review*; *United Kingdom 1998 Review*; *Sweden 1996 Review*; *Portugal 1996 Review*). It should be emphasised that while it was attempted to construct indicators in the most objective way possible, some judgement was required in translating qualitative and historical information into quantitative indicators. The detailed numeric scale for each indicator is provided in Steiner (2000), OECD *Economics Department Working Paper*, No. 238.

25. In principle, for countries that have not liberalised and have no plans to do so, this indicator should take the value of infinity. However, since this indicator should proxy for expectations to the point of the end of the period under consideration, the value assigned to observations of no liberalisation plans is truncated at the maximum time to the end of the period plus one year. The time to liberalisation is additionally right censored: for all observations following the year of liberalisation, the time to liberalisation indicator continues to take a value of zero.

26. This indicator is left and right censored according to the same approach as in the expectation of liberalisation.

27. If all consumers in a country have free choice, then this variable takes the value 0. If no consumers have free choice, then in principle, the threshold is infinity, or more practically, larger than the largest market participant. This variable has been truncated by coding no choice as the theoretically largest consumer, that is, the largest capacity over countries and time, converted to KW. This is based on the idea that hypothetically, the largest consumer would be one that owns all of the capacity in the country with the greatest capacity. The number thus used comes from the capacity in the United States in 1996. It should be noted that from the perspective of comparability across countries, a better indicator would be the percentage of the market open to consumer choice under the country-specific thresholds. This is because the country

thresholds are not directly comparable, as there is variation in the size of consumers and their distribution across countries. However, data constraints made it impossible to construct this indicator for all countries and times in the panel.

28. Cluster analysis in previous years would yield excessive redundancy as there was little regulatory action prior to the early 1990s.

29. Preferences for renewable technology were included in the factor analysis because they are correlated with policies which encourage entry of private and independent producers. By contrast, the indicators for technological preferences against nuclear technology and for coal technology were omitted. Their omission is unimportant for the analysis because they are likely to influence prices of inputs to electricity production and, thus, end-user prices, but they are not a part of a liberalisation programme.

30. Inclusion of a measure of variability of average monthly temperatures was explored, however, temperature is measured at the weather station level, whereas the unit of observation for the analysis is a country. Aggregation of station-level data to the country level would not yield meaningful data.

31. For example, in the case of coal, data refer to the most common coal quality in a given country so that they are not necessarily comparable between countries.

32. The reserve margin is not likely to be meaningful for hydroelectric systems since variation in rainfall, rather than equipment failure, poses the greatest difficulty.

33. The use of 15 per cent as compared with any other constant number will not affect the estimates of the slope coefficients, however, if the optimal reserve margin differs by country or over time, this introduces measurement error in this efficiency indicator. As in the case of the other performance measures, this measurement error is not too serious because it will not bias estimates but just increase their variance.

34. These prices include transportation costs to consumers and are prices actually paid, net of rebates.

35. Industry prices are used instead of average prices because for industrial consumers, generation constitutes a larger proportion of costs and prices so the gap between generation and retail prices will be narrower.

36. Technically, quality depends on the following outputs: capacity, voltage support, frequency support, off-peak load, spinning reserve, load following capability, black start capability, dual fuel capability, and local load. However, data on these aspects of quality are not available at the country level.

37. There may be a more serious endogeneity problem if the regulation indicators are not exogenous to performance. If causality between performance and regulation indeed runs in both directions, then single equation panel regressions result in biased and inconsistent estimates. It is beyond the scope of this project to control for endogeneity of regulation. Instead, this paper assumes exogeneity of regulation by noting regulatory lag; it takes time for regulation and performance to respond to each other, so that at a given point in time, the two may be related recursively. In this study, it is assumed that the government cannot respond to changes in performance within the ten-year period of the analysis.

38. P.L. Joskow (1997) "Restructuring, Competition and Regulatory Reform in the US Electricity Sector", *Journal of Economic Perspectives*. Vol. 11, No. 3, p. 125.

39. Ramsey pricing is a form of price discrimination in which prices charged to customer segments are inversely related to elasticities of demand.

40. It is impossible, however, to assess the degree or change in cross-subsidisation across customer groups because prices have been regulated before liberalisation so that observed prices reflect the interaction of buyers, sellers, and regulators.

41. It is true that to the extent that regulatory reforms exert negative pressure on price, they may also act to improve efficiency, but these effects are indirect and unlikely to surface in the data.

42. For example, Pollitt (in M.G. Pollitt, 1995), *Ownership and Performance in Electric Utilities*, Oxford Institute for Energy Studies/Oxford University Press) uses a cross-country sample of 95 utilities in 9 countries and finds a statistically significant difference in cost efficiency across privately and publicly owned utilities. However, he finds no difference in technical efficiency. See also R.J. Gilbert and E.P. Kahn (1996) *International Comparisons of Electricity Regulation*, Cambridge University Press, p. 7. For more recent evidence on the impact of privatisation on electricity industry performance, see M.G. Pollitt (1997) "The Impact of Liberalisation on the Performance of the Electricity Supply Industry: An International Survey", *Journal of Energy Literature*. Vol. III, No. 2.