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REGULATORY EFFECTIVENESS AND THE EMPIRICAL IMPACT OF VARIATIONS IN REGULATORY GOVERNANCE

ELECTRICITY INDUSTRY CAPACITY AND EFFICIENCY IN DEVELOPING COUNTRIES

By

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ABSTRACT

This paper assesses for 28 developing countries over the period 1980-2001 whether the existence of a regulatory law and higher quality regulatory governance are significantly associated with superior electricity outcomes. The analysis draws on theoretical and empirical work on the impact of independent central banks and of developing country telecommunications regulators. The empirical analysis concludes that a regulatory law and higher quality governance are positively and significantly associated with higher per capita generation capacity levels. In addition, this positive impact continues to increase for at least three years and probably for over 10 years as experience develops and regulatory reputation grows. The results are robust to alternative dynamic specifications and show no sign of any significant endogeneity biases.

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1. Introduction

Over the last 10-15 years, a lot of attention has been given to the role of institutions in economic growth. This has, in large part, been driven by economic policy priorities such as how to develop effectively functioning market economies in Central and Eastern Europe and the former Soviet Union post-1989; and how to foster economic growth in lagging world regions such as Sub-Saharan Africa. In parallel, and partly in response, there have been major explorations of the role of institutions in the functioning of market economies both by economists (e.g. the literature arising out of Williamson's transaction cost economics approach) and by economic historians (e.g. North (1990) and others).

In recent years, there has also been a substantial empirical literature on the relative roles of institutions, policy, geography and trade openness on growth performance across countries. This literature currently indicates that *institutional quality* is the dominant determinant of variations in long-term growth performance[1]. Good institutions embody a heritage of past good policy decisions and themselves generate a flow of superior policy decisions that support sustained investment and productivity growth[2]. In his recent survey on growth strategies, Rodrik (2003) argues that, although it is quite possible to achieve short-term growth accelerations (e.g. of 10 years or more) with very limited institutional change; the main requirement to ensure sustained growth and convergence with the living standards in advanced countries "… is the acquisition of high quality institutions". In particular, he argues that there is a requirement for a "… cumulative process of institution building to ensure that growth does not run out of steam and that the economy remains resilient to shocks"[3].

Infrastructure industries are not just a microcosm of the aggregate economy. The arguments above on aggregate growth apply with extra force to utility service industries. This is because they are not only highly capital intensive, but also most of their assets are very long-lived and (in economic terms) sunk assets. Hence, an effective institutional framework is essential to sustain growth in output, efficiency and capacity for commercialized utility service industries such as electricity, telecommunications, water and others - particularly if these industries have significant amounts of private investment (physical and/or financial).

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1 See Rodrik , Subramanian and Trebbi (2002) for a recent survey of the literature on studies of cross-country growth performance.
2 Rodrik et al (2002), pp 20-21.
3 Rodrik (2003), p.25

The standard institutional solution is to introduce an *independent regulatory agency*, operating within a clearly defined legal framework[4]. The regulatory agency is intended to provide the "high quality institution" which permits and fosters sustained growth in capacity and efficiency in the utility service industries – particularly the network elements. Hence, whether country X has a high or a low quality institution is determined primarily by the *quality of governance of the regulatory agency* (conditional on the governance quality for the country as a whole). As with the aggregate economy, developing countries with high quality regulatory agencies (as measured by their regulatory governance) should attract more investment on a sustained basis into their utility service industries and at a lower cost of capital, as well as having higher efficiency levels and growth rates in the regulated utilties.

We would expect this outcome to arise because regulatory agencies with better governance should (a) make fewer mistakes and (b) have their mistakes identified and rectified better and more quickly so that (c) good regulatory practice is more readily established and maintained. It may well be possible to obtain a major short-to-medium term increase in investment without an effective regulatory framework, but the considerations outlined above suggest that this will not be sustained long-term. The collapse of the Asian IPP boom of the early 1990s and the difficulties with many of the Latin American infrastructure reforms and concession contracts in the late 1990s provide some evidence to support this conjecture.

The perspective outlined above is at the heart of the recent literature on regulatory governance for utility service industries, particularly the literature that focuses on developing and transition economies. This perspective is set out in Levy and Spiller (1994) – which draws explicitly on North (1990) – as well as in a number of subsequent papers[5]. However, until recently, there has been very little *systematic empirical testing* of the hypothesis that better regulatory governance (a) reduces unserved demand by encouraging investment or (b) increases efficiency. There have been many case studies – and these can be very illuminating but do not allow reliable generalizations – but, until the last 2-3 years, little formal econometric or other statistical testing.

This is now changing. More developing country utility regulators have been in place for 5 years or more and data are now becoming available on them that can be related to industry outcomes on a comparable basis, most obviously for telecoms. Hence, there have been a number of studies of the impact of a regulatory agency on capacity growth and efficiency in telecoms. All the major recent studies show that having a

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4 An independent regulatory agency is not the only way of providing the necessary institutional support either in theory or in practice. In addition, an independent regulator may be combined with a high or a low degree of reliance on contracts and courts.
There is a major issue of whether or not low income developing countries have the human and other resources to sustain independent regulatory agencies, particularly regulatory agencies with a significant degree of discretion. Nevertheless, an independent regulatory agency has become the standard solution to the private investment problem for utilities in the same way as an independent central bank has become the standard solution to handle commitment and time inconsistency problems in monetary policy. See Section 2 below as well as the literature discussed in Stern and Cubbin (2003).

5 See, inter alia, Smith (1997), Stern and Holder (1999), Noll (2001).

regulatory agency is significantly associated, either directly or indirectly, with higher mainline capacity per capita and higher labor productivity.

In this paper, we carry out a similar exercise for electricity supply industries in developing countries. Specifically, we provide an econometric analysis of the relationship between the quality of regulatory governance and (a) the level of generation capacity per capita and (b) some efficiency measures for a sample of 28 Latin American, Caribbean, Asian and African countries over the period 1980-2001.

The plan of the paper is as follows. In Section 2, we discuss the underlying economic issues and the main institutional design considerations. This includes a summary review of recent relevant literature and its relevance for our analysis. In Section 3, we set out our modelling approach, including the modelling objectives, our econometric approach, data issues and potential econometric concerns. Section 4 presents descriptive statistics. Section 5 presents the estimation results. Section 6 discusses the results and their implications and provides some short concluding comments.

2. Underlying Economic Issues, Institutional Design and Implications for Empirical Analysis

The main issue on which we focus is the inability of governments to make credible and binding commitments about utility pricing to sustain private investment while retaining decision-making powers over these issues.

The discussion of utility service regulation concentrates on *commercialized* utilities facing genuine budget constraints, particularly where private investment and/or private finance is important. The focus of the discussion (and of our empirical work) is on *regulatory governance* (e.g. autonomy, accountability, etc) rather than on *regulatory content* (e.g. methods of price, investment and related aspects of regulation)[6].

2.1 Time Inconsistency Problems and Utility Service Industry Investment

The underlying economic issue for utility regulation – as for monetary policy – is that governments, particularly at certain times, have a strong incentive to behave in a shortsighted and populist manner that reduces welfare summed over a medium to long-term period. Hence, both in general but particularly at times of pressure, they place a very high weight on retail electricity prices over the next year relative to the medium to long term. In consequence, in the utilities industry context, authoritarian governments facing serious protests (and democratic governments facing difficulties in imminent elections) have a strong incentive to hold down electricity prices below economic cost even if this jeopardizes future investment and consumption.

For utility service industries, long-term contracts without a regulatory agency may be sufficient in some circumstances to provide the necessary institutional surety (e.g. for toll roads, water and sewage and similar). However, a regulatory agency may well help improve the sustainability of contracts even in those industries[7]. For electricity, although contracts may play a large part, they do not seem to be able to substitute for regulation in providing a sound basis for private investment in generation, let alone in transmission and distribution[8].

In consequence, we assume in what follows that an independent regulatory agency is the first-best method of ensuring that private investment in the electricity and similar industries can be sustained and at the lowest possible cost of capital. Similarly, an independent regulatory agency seems to be the best way of providing effective but reasonable incentives for efficiency and high productivity – and strong growth in these. The question then is what are the appropriate measures of governance to ensure the effectiveness of the regulatory agency in terms of these objectives.

The answers to these are typically given as a combination of:

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6 We looked, in passing, at methods of price/profits regulation in our empirical work but this issue was a subsidiary concern for this paper. See Section 4 for the results.

7 See Guasch, J.L., Laffont, J.J. & Straub, S., (2003) for a discussion of renegotiation of water and transport concession contracts in Latin America.

8 See Stern (2003) for a discussion of these issues in the context of the development of the UK electricity industry pre-1940.

(i) some formal legal requirements both (a) to underpin the regulatory agency and (b) to set out the powers and duties of the regulatory agency; and

(ii) regulatory processes that promote consistent and reliable decision-making.[9]

In the empirical work that we discuss below, our measures of regulatory governance will, perforce, be limited to four indicators of the formal legal aspects of the regulatory agencies[10].

2.2 Output Measures for Utility Regulatory Agencies

For utility service industries, there is a major issue in defining appropriate output measures for utility regulation. For all countries, rich and poor, a relevant output is higher levels of (and faster growing) technical and efficiency as well as quality of service. However, whereas virtually all developing countries need significant *increases* in capacity to meet demand – at least in electricity supply, the same is by no means always true for rich countries. One of the main drivers of the liberalization plus privatization plus independent regulation OECD electricity reform model has been the desire to *reduce* unnecessarily high capacity reserve margins as well as to reduce investment costs.

This issue is important since *significantly higher investment (and private investment)* was the single most important reason cited over the last 15 years by the World Bank and similar policy institutions for the promotion of independent regulatory agencies in electricity and similar utility service industries[11]. This view goes back to the underlying time-inconsistency problem and the question of how, given limited tax resources, developing countries can increase capacity and reduced unserved demand – particularly for countries with poor reputations as regards their treatment of private investment. Hence, an independent regulatory agency has been advocated as the way in which private investors can be assured that they will be able to earn a reasonable rate of return.

In consequence, on this hypothesis, it is to be expected that sizeable increases in private investment flows (domestic and foreign) will arise in developing country electricity and similar industries following the establishment of an independent regulatory agency. It is, however, worth noting that the speed at which the regulatory credibility is established is very unclear. It is likely to take some time, so that one might well expect lags of some years between the establishment of the new regulatory agencies and any significant increase in investment.

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9 See among others Levy and Spiller (1994), Smith (1997), Stern and Holder (1999), Noll (2001). For a full discussion, see Stern and Cubbin (2003).

10 See Cubbin and Stern (2004) for a discussion of the implications of having only these as measures of governance.

11 The World Bank's 1994 World Development Report "Infrastructure for Development" is a good example. See Chapter 3.

The implications of the above are that, in estimating the impact of regulatory governance variables on outcomes, we concentrate on:

(i) Electricity capacity levels in developing countries, excluding transition economies as well as OECD countries; and

(ii) Efficiency measures in developing countries, insofar as they are available.

We discuss the precise statistical measures of these in the next section. However, the key point to note here is that we have chosen our sample so that it includes only countries where there is good reason to believe that there are significant amounts of unsatisfied electricity demand because of capacity constraints.

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2.3 Results from Studies of Regulation on Developing Country Telecommunications Outcomes

The approach outlined above is echoed in a rapidly growing literature on the impact of regulation on telecom outcomes.

The main empirical papers in this area (e.g. Fink, Mattoo and Rathindran (2003), Wallsten (2002) and Gutierrez (2003)) estimate the effects of regulation on

(i) mainline penetration rates (a standard measure of capacity) and

(b) efficiency (e.g. mainlines per employee).

They typically estimate panel data models (primarily fixed effects models) with one or other of the outcome measures as the dependent variable, and include regulatory variables as independent variables along with competition and privatisation variables, as well as standard control variables. We follow this approach in estimating the impact of regulation on electricity industry outcomes.

The standard model estimated in these papers (e.g. by Gutierrez) is

$$Y_{it} = X_{it}\beta + D_{it}\delta + \alpha_i + \varepsilon_{it}, \quad i = 1, \ldots, N; \; j = 1, \ldots, T \qquad \text{(Equ 1)}$$

where X is a vector of exogenous variables,
D is a vector of dummy variables,
α_i is a country specific fixed effect and
$\varepsilon_{it,}$ is an error model.

The X vector includes both regulatory variables and standard control variables

The approach of Gutierrez (2003) is particularly relevant to this paper. He constructs a *regulatory governance index* for his sample of 22 Latin American and Caribbean countries. This 7-element index (derived from the Stern-Holder typology) is calculated from examination of each country's telecom laws and changes in the laws. In our model for electricity outcomes, we adopt a similar approach and use a 'snapshot' 4-element index for 2000. (See Section 4 below for further details of our index and the data.)

Gutierrez (2003) finds statistically and positive direct effects of his regulatory index both on tele-density and on efficiency. This result occurs both in static and dynamic models and after testing for the endogeneity of regulation. The estimated effect of a 1-point increase in the index on mainlines per 100 inhabitants varies somewhat depending on the precise model specification but is, in general, of the order of 20%.

The Gutierrez study and its estimates provide a useful benchmark for our modelling of the effects of regulation on developing country electricity industry outcomes[12].

2.4. Results from Studies of Regulation on Developing Country Electricity Industry Outcomes

As yet, there are only a very few and very preliminary empirical studies e.g. Zhang, Kirkpatrick and Parker (2002) and a part of Pargal (2003). For data availability reasons, the capacity variable for these studies is *generation capacity only*. This is measured in physical units (ie in Gigawatts) Data on this is available on an annual basis from the US Department of Energy's EIA website for almost all countries from 1980. Unfortunately, there is nothing similar available for capacity in transmission or distribution[13].

These papers find only weak effects of regulation, if any, and there are major problems in disentangling the effects of regulation from those of liberalisation. However, the studies are much more preliminary than those for telecoms, particularly in data terms.

In this paper, we have had access to much better data on regulatory governance and its variation across countries. However, our estimation of models for capacity, like those of Zhang et al and Pargal, is also limited to generation capacity.

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12 See Stern and Cubbin op cit, p. 38-43 for further details of these studies

13 Pargal uses the Calderon –Serven infrastructure investment data set for 9 Latin American countries 1980-98. This divides electricity investment into public and private but appears, again, only to cover generation. See Calderon and Serven (2002) for a description of these data.

3. Model Specification and Modelling Issues

Our modelling work is primarily concerned with whether better regulatory governance in developing countries:

(i) increases rated generation capacity per capita; and

(ii) increases efficiency e.g. by increasing capacity utilisation in generation and/or reducing transmission and distribution losses.

3.1 Underlying Economic Rationale

On capacity, we start from the basis that developing countries have serious capacity constraints which lead to significant unserved demand arising, among other reasons. from many years of low levels of investment. In developing countries, it has typically been the case that electricity supplies were inadequate and intermittent. Supply was insufficient to cope with the level of demand as a result of a variety of interconnected factors.

Rectifying the issue of inadequate levels of capacity and investment has been a major policy objective and a justification for electricity sector reform shared by developing country governments and development agencies, national and international, including the World Bank and the international regional banks.

The World Bank and others have argued that the establishment of good regulatory governance (e.g. via the development of well-founded independent regulatory agencies) has been a key element in their reform strategy over the last 15 or more years. Hence, estimating whether regulatory agencies have significant impacts on electricity capacity levels over time is important for the effectiveness of the policy. This also provides a test of the theoretical case for the importance of time inconsistency arguments as a useful framework for considering investment in the electricity industry.

Of course, inadequate supply levels are not due just to inadequate investment. In many developing countries, rated capacity has been much higher than available capacity. However, the same factors (e.g. revenue shortages and inadequate returns) also lead to low levels of maintenance. This is a major reason for expecting that improvements in regulatory governance will increase efficiency and raise capacity utilisation rates.

3.1.1 Regulation and Capacity Levels

The effect of electricity reform and the introduction of explicit regulation is to focus the policy of the electricity industry on providing sufficient supplies.

In some cases, this has been done by harnessing the forces of private ownership and/or competition. In others, it has to provide a workable financial framework within which the electricity industry could develop by loosening the ties with government – for example, by enacting an electricity law giving various powers and duties to a Ministry regulator thereby requiring publicly owned electricity companies to operate in a more commercial way which would, among other things, allow state owned electricity companies to borrow from banks or debt markets on standard, commercial terms.

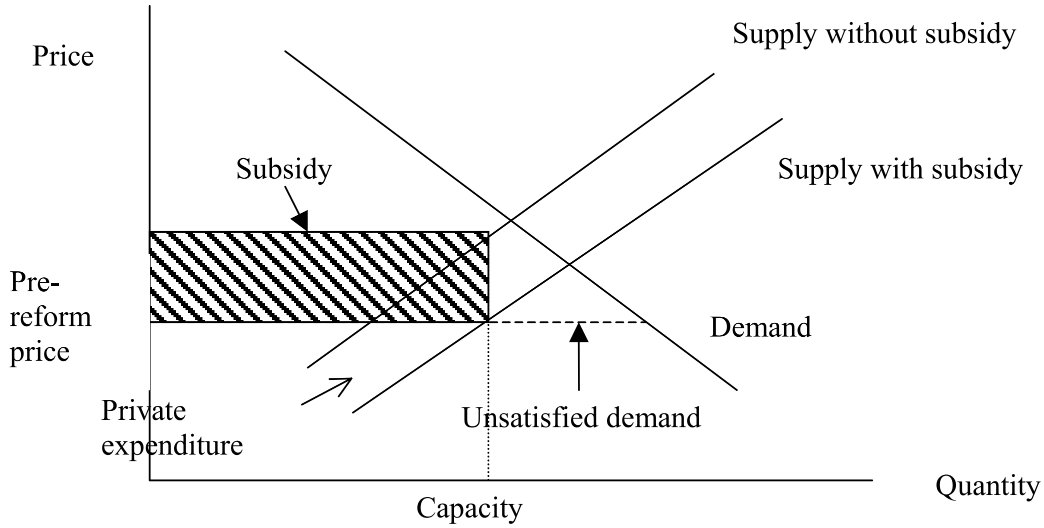
Investment is encouraged once effective regulation is available to support a workable financial framework. If the electricity industry is in private ownership the owners have the prospect of earning a reasonable return on their investment; if publicly owned, the industry can become independent of tax revenue or continually increasing loans. In addition, the existence of an effective regulatory framework can also encourage the growth of private investment and/or private finance within state systems, as has been happening in recent years in India and China.

These considerations suggest that the presence of an effective regulatory framework should, in general, lead to increased investment in the electricity sector, including the balanced development of generation, transmission, and distribution *ceteris paribus.* Unfortunately, comparable time-series capacity data across countries only exists for generation and it is on this aspect that the present study focuses.

In an unconstrained market economy, per capita generation capacity will adjust to the level of demand, which will depend upon the level of per capita income, the price of electricity, and environmental factors such as climate. The price of electricity will be determined in part by the efficiency of the sector. The latter may depend upon regulatory factors, but also availability of energy sources such as hydro, gas, oil, and coal. (This is most evident in cross-U.S. comparisons of prices.) However, many developing countries with a traditional, vertically integrated and state-owned electricity sector will be constrained not so much by market demand but by the availability of continuing subsidy.

The capacity constraints arise because of either inadequate government revenues for electricity investment or subsidy payments and/or insufficient revenue flow to support viable private investment. A simple diagrammatic version of such a model is shown in Figure 1 below

Figure 1 Chronic Supply Constrained Electricity Shortage (loss making public enterprise)



In this model, the level of capacity in the unreformed industry depends on the sum of private and public expenditure on investment in electricity which, in turn, will be determined primarily by the level of national income per capita. It is also well-established that the demand for electricity (and hence for electricity capacity) has an elasticity close to 1 with respect to GDP. Hence, we would expect equilibrium electricity demand and supply for electricity to be related to GDP growth.

For both these reasons, we include per capita GDP in our model, with an expected long-run elasticity not significantly different from 1. We also consider other control variables that have been found as statistically significant in previous studies eg the share of industry in value added, country debt levels and country economy-wide governance indicators.

The effect of an effective regulatory framework should be to reduce the constraint on the operation of the market, increasing supply and moving the outcome closer to the market equilibrium. The better the governance of the regulator, the greater the expected increase in capacity and increase in electricity supply.

We measure the quality of governance primarily by an *index of regulatory governance* which has 4 elements:

(i) Whether the country has an electricity or (energy) regulatory law;

(ii) Whether the country has an autonomous or a Ministry regulator for electricity;

(iii) Whether the country's electricity regulator is funded from licence fees (or equivalent) or out of the government budget; and

(iv) Whether the staff in the electricity regulator can be paid as appropriate given skill needs and labour markets or whether staff have to be paid on civil service pay scales.

These are all measured by 0/1 dummies. The highest governance ranking (a score of 4 on the index) is represented by having enacted an electricity regulatory law, plus an autonomous regulator, plus funding from licence fees and the staff not being confined to civil service pay scales. The dating of the switch from 0 to 1 on the appropriate variables (subsequently maintained at a constant level) is derived from the date of enactment of the law (except for cases where other information was available to provide a known, superior alternative). Hence, we can investigate the effect of *age* of the regulatory agency as well as its existence.

Given the economic arguments set out above and in Section 2, we would expect the coefficients on the index and on each of its components to be positive. We might also expect the effect of regulation to increase with the age of the regulator, particularly for the first few years.

In terms of the typology in Section 2.2, the regulatory variables in our index are all measures of *formal* attributes of regulation. Unfortunately, no comparable data is currently available on the *informal, practical* qualities of electricity regulation and the necessary omission of data on these characteristics must be borne in mind when considering the results, including potential biases to the estimates and to estimated standard errors. In addition, unlike Gutierrez (2003), we have no time dimension on changes in formal governance attributes subsequent to the enactment of the electricity/energy regulatory law.

These considerations suggest a capacity model of the following form:

$$\text{Log}(\text{ELCAPPC})_{it} = (a_0 + a_i) + a_1 \log(\text{GDPPC})_{it} + a_2\, \text{Industry}_{it} + a_3\, \text{Debt}_{it} + a_4\, \text{RegIndex}_{it} + a_5\, X_{it} + v_{it} \qquad (2)$$

Where Log ELCAPPC is the log of per capita electricity generation capacity in Gigawatts;

a_0 is a constant term;

a_i is a time-invariant country specific fixed effect

GDPPC is real per capita national income in $US 1995[14];

Industry is the log of industry value added as a percentage of GDP;

14 Hence, GDP is on an exchange rate rather than a PPP basis.

Debt is the share of government debt service as a percentage of gross national income;

RegIndex is our regulatory governance index (or individual components of it);

X is a vector of other potentially relevant variables (e.g. rule of law and corruption measures, age of regulatory agency, method of price regulation, etc); and

u_{it} is an error term

In all cases, the variables exist for i = 1, …, I countries over t = 1, …., T time periods.

The regulatory index takes the value of 0,1, 2, 3 or 4 where zero is ascribed to countries with a Ministry regulator, no electricity regulatory law, government budget funding and civil service pay scales.

The X vector for this equation might well include domestic fuel/hydro source availability and a variety of other country specific economic and/or institutional variables. However, these variables can be expected to stay fairly constant over the period of estimation - as do country governance rankings.

Following the literature on the impact of telecom reform in developing countries, we also explore the role of (i) privatisation and (ii) competition on generation capacity growth. We investigate both direct and indirect effects (e.g. interactions between these variables and the regulatory index).

Although we start by estimating an OLS version of the model above, most of the results reported in Section 4 are for a fixed effects model[15]. Differencing the equation above eliminates the constant term and the country-specific fixed effects. If fixed effects are significant, the error term the equation above will not be normally distributed with zero mean when estimated by OLS. (See Section 3.2.2 below for a fuller discussion of econometric issues.)

The fixed effects are likely to include country variables with little or no time variation over the sample period. This affects not just fuel source availability, but also many constant or slowly changing institutional variables. The estimated fixed effects may therefore capture key aspects of the rule of law and corruption as country rankings on these indicators tend to be relatively stable over 10-20 year periods.

The equation above is a *static* representation of the model, which provide evidence on long-run equilibrium effects. We also consider:

(i) *dynamic v*ariants e.g. incorporating a lagged dependent variable as in Gutierrez (2003); and

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15 See Section 3.3.2 .1 below for a fuller discussion of heterogeneity issues.

(ii) *error correction models* which allow for more explicit examination of long-run equilibrium effects as opposed to short-run adjustment effects

(iii) *IV (instrumental variable)models* that control for the potential endogeneity of our regulatory governance index.

3.1.2 Regulation and Efficiency

As regards efficiency, we concentrated on the impact of regulation on two readily measurable characteristics of electricity supply industries for which comparable time-series data existed:

(i) Utilisation of generation capacity; and

(ii) Technical losses in transmission and distribution.

The first was measured as:

(Total Annual Generation in TWh)/(Generation Capacity in TW/365 * 24).

This measure provides a good proxy for the *availability* of generation plant. Many developing countries have rated capacity levels that are considerably higher than available capacity and higher utilisation rates should closely reflect improvements in availability e.g. from the impact of better regulatory governance on maintenance expenditure.

Technical losses were measured as transmission and distribution losses as a percentage of total generation.

In both cases, we deliberately estimated a simple and parsimonious fixed effects model with the regulatory index as the main explanatory variable and real per capita GDP as a control variable. This was, not least, because there was no obvious well-defined theoretical model on which to base a more sophisticated approach.

We would very much have liked to estimate models for *quality of supply* (e.g. supply interruptions, coverage of system) and also for *commercial losses*. Empirical studies of electricity reform have shown that a major impact has been to improve quality and to reduce non-technical losses, particularly at the distribution level[16]. Unfortunately, no data currently exists for these variables that would allow the estimation of cross-country panel data models to test for the impact of improved regulation on quality.

[16] See, for instance, Bacon and Besant-Jones (2001)

3.2 Modelling Approach

The purpose of the investigation was:

a) to undertake a preliminary analysis for the electricity industry of the effect of independent regulators and aspects of their governance on improving the overall performance of the sector; and

b) to identify priority areas where enhanced data was required to allow a better analysis of these effects.

Under a), the key questions we have tried to answer are:

i) *Does the existence of an independent regulator appear to have any effects on measurable aspects of electricity industry performance (generation capacity, utilisation and technical losses)?*

ii) *If so, how big is the effect?*

iii) *By how much is the size of any effect influenced by measurable aspects of the governance of the regulatory institutions?*

iv) *What effects do private ownership and competition have in enhancing the aspects of performance we have measured, independently and in combination with regulation?*

Unfortunately, data limitations prevented us from seriously addressing the impacts of privatisation and competition[17].

On b), the quality and precision of the answers to these questions should help us to identify priorities for improvements on currently measured data. Consideration of the potential impact on the results of omitted variables and the resulting potential biases should help identify priorities for collecting data on variables for which data is not currently available.

3.2.1. Data

We have collected data on 28 developing countries over a 21 year period (1980-2001). Of the 28 countries in the sample, 15 were in Latin America, 6 in the Caribbean, 4 were in Asia and 5 were in Africa. The list of countries includes large countries (e.g. Brazil and India), small countries (e.g. Jamaica); middle income countries (e.g. Chile and Mexico) and poor countries (e.g. Ethiopia and Sudan). The full list of countries for which we have data is in the Appendix.

Although much of the regulatory activity took place in the last half of the data set, the earlier period is important in effectively establishing benchmark levels of the dependent variables, and also in reducing some of the biases that can potentially arise

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[17] See Section 5.1.2.2 below.

in the use of short panels. In fact, 20.7% of the total number of country-sample years were years with an autonomous regulator and 31% with an electricity or energy regulatory law.

The key data sources used are:

- US Energy Information Agency – for data on generation capacity by country (GW) 1980-2001 (Noted that the EIA series does not distinguish between publicly and privately owned generation capacity.)
- World Bank Development Indicators - for Per capita GDP in $US1995; electric power transmission and distribution losses and other control variables
- The Preetum Domah 2001 survey of electricity regulators for data on electricity regulatory governance, privatisation and competition (supplemented by the authors' own research).[18]

The Domah survey data (covering 50 developed, transition and developing countries) are the best data currently available to estimate the impact electricity regulators, not least because it allows the *dating* of regulatory reforms, primarily because it records the year in which key regulatory legislation was enacted.

The Domah data set is very suitable for a preliminary investigation of the impact of regulation but is far from ideal. In particular, it suffers from the following:

1) The data on electricity market structure is relatively weak and the data on privatisation very limited;
2) There is no data on the informal, practical aspects of regulation (e.g. security of tenure of regulatory agency heads or commissioners, etc);
3) The data on regulatory governance, competition and privatisation has no time dimension beyond a simple 0/1 dichotomy set at the year in which key regulatory legislation was enacted;
4) The data on the formal aspects of regulation only allows for a 4-element index rather than a larger index. These data weaknesses should be born in mind when considering the econometric results.

3.2.2. Econometric Issues

Panel data generally allow major opportunities for carrying out investigations that are not possible with single-year cross sections or single-country time series, but these give rise to a number of issues which need taking into account for estimation. In our case, with data on 28 countries for 21 years, we have a large and long panel. Because of missing observations, it is an unbalanced panel.

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18 See Domah, Pollitt, and Stern (2002) for full details. We are very grateful to Preetum Domah for permission to use the information from his survey in this paper.

The use of panel data may have many benefits but their use also raises a number of potential econometric problems including:

1) *Coefficient heterogeneity across countries*.

We have strong prior views that countries will differ consistently in their intercepts according to persisting, largely time invariant local factors. For this reason our maintained hypothesis is that a fixed effects model is more appropriate than a random effects approach. In addition, the fixed effects static model avoids the potential biases which could arise in the random effects model owing to correlation between the included exogenous variables and omitted country attributes.

2) *Dynamic structure*

Static models, which assume that all adjustment to disequilibrium occur within the period defined by observation frequency may be inappropriate. In particular, investment in electricity is not usually completed in a year so we would expect that scope for some adjustment process would need to be incorporated into our model. Such processes can be modelled generally by a combination of lags on the dependent variable (autoregressive) and on the explanatory variables (moving average).

However, the presence of a lagged dependent variable in a fixed-effects model can result in a biased estimates for the lagged dependent variable coefficient. The size of the bias will depend on the number of time series, *N,* the length of the time series, *T,* and the influence of other exogenous variables in the determination of the dependent variable.[19] The problem is mainly significant in short panels. For T=21 we have estimated the asymptotic bias (as N increases) to be of the order of 3%. This is an upper limit given the presence of other major influences on the dependent variable.

There is also the potential problem of spurious correlation eg if both electricity capacity and GDP per capita were both strongly trended across our countries. In fact, they are not in our data set, but we have considered carefully how the dynamics should be modelled and we report a selection of the key results.

3) *Endogeneity and Causality*

There has been much discussion of the need to take account of the endogeneity of regulatory agencies. This has been a major theme in the ICB literature where the introduction of an ICB (particularly the *early* introduction) may be interpreted as a signal of strong commitment to anti-inflation policies. Similarly, the early introduction of an autonomous regulator may also be a signal of a strong commitment to commercialisation and the enforcement of property rights[20].

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19 See Hsiao (1986)
20 See Gual and Trillas (2002)

Given the relatively time-invariant rankings of countries' governance (including rule of law, corruption, etc), it is not clear that there exists a particularly serious endogeneity problem – to the extent that there is an overall issue, it should be well-handled by country specific fixed effects. In addition, as noted by Fink et al (2002) and others, it is also extremely difficult to find appropriate instruments for regulatory governance variables. Nevertheless, we do in Section 5.2.4.1 explicitly consider endogeneity and report IV (instrumental variable) estimates that attempt to control for it within a fixed effects modelling framework.

Discussion of endogeneity issues in institutional models frequently reflects concerns over *causality* rather than endogeneity per se. With a long panel of 21 years, fixed effects should adequately control for country-specific institutional quality variations so that any bias in the estimates of regulatory governance impact from that source should be small. However, even if that were so, there remains the question of whether the estimated coefficients on regulatory governance can be taken as estimates of what would happen if countries were to improve or reduce the quality of governance of their existing regulatory institutions - or, more importantly, regulatory institutions of given quality were to be introduced into a country currently without such institutions. These, particularly the latter are the key policy questions.

We discuss both issues in Section 5.2.4[21].

[21] We are grateful to Richard Gilbert and Jean-Michel Glachant for helpful discussions on these issues.

4. Descriptive Statistics

In this section, we report some key descriptive statistics from the Domah survey.

4.1 Countries with Autonomous Electricity Regulators

Table 1 shows that by 1998 just under half the countries in our sample had an autonomous electricity regulator[22] – mainly in Latin America. However, in the following three years 3 African and 1 Caribbean country joined the set. Asia provides an exception to the spread of autonomous regulators with only 1 country (Philippines) having an autonomous regulator before 2001.

By 2001, a majority of countries had regulators classified (at least in legal terms) as autonomous.

Table 1: The Trend towards Autonomous Regulators (by Continent)

		1998		2001	
	Total	**Ministry**	**Autonomous**	**Ministry**	**Autonomous**
Africa	5	5	0	3	2
Asia	4	3	1	3	1
Carrib	6	3	3	2	4
Latin America	13	4	9	4	9
Total	28	15	13	11	17

Source: Domah 2001 survey, supplemented and updated by authors

4.2 Countries with Electricity Regulatory Laws

Even where there was no autonomous regulator, laws for the reform of the ESI Including regulatory reform were being passed. Table 2 shows the regional distribution of electricity reform laws for those states without autonomous regulation. According to the Domah data, all the countries with autonomous regulators had enacted an electricity regulatory law. By the end of our sample period only two countries in the sample (Barbados and Indonesia) did not have any electricity regulatory law in place.

These laws sometimes provided for IPPs or other elements of market reform, for commercialisation and sometimes for unbundling and competition in generation and supply[23]. If the laws covered regulation, they typically specified the powers and duties of the Ministry (or designated Ministry agency/department) in carrying out regulatory functions.

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22 The Domah questionnaire used the term "autonomous" rather than "independent", not least because it is more neutral. We treat the two terms as synonymous.

23 However, the actual introduction of competition and/or privatisation took place at some later date, typically with several events at different times. This is why we cannot within this data set obtain good indicators for privatisation and competition.

Table 2: Non-Autonomous Regulators: Existence of Law

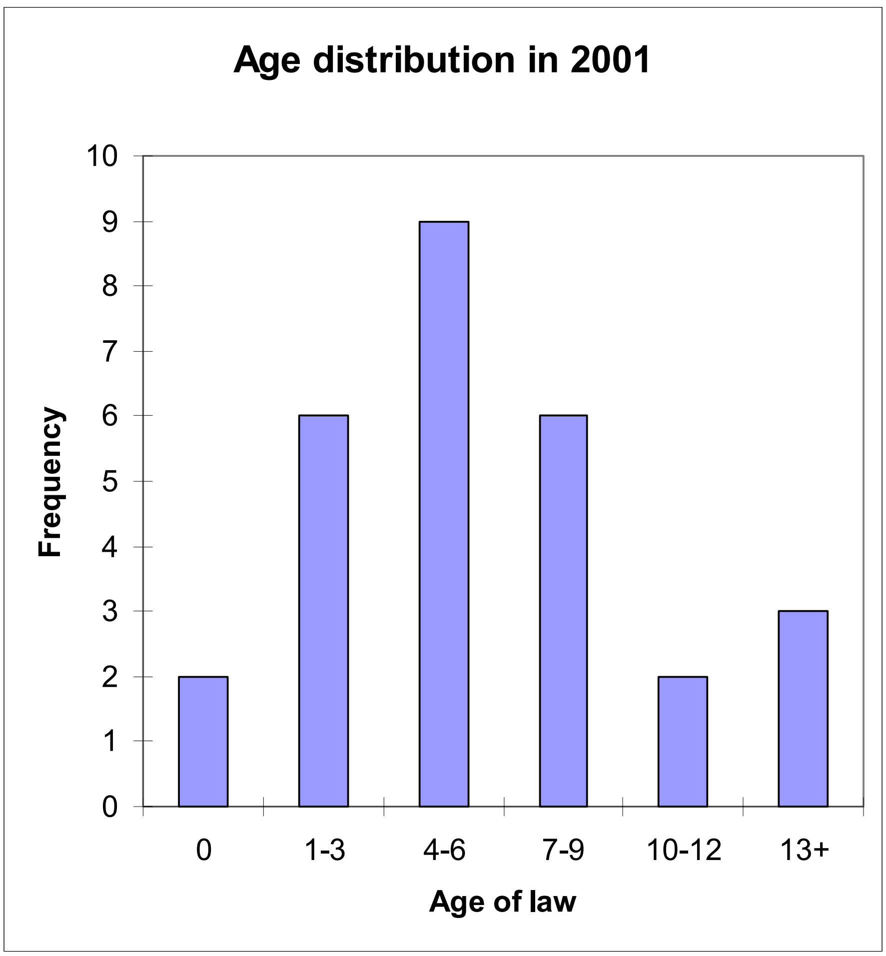
		1998		2001	
	Total	Law	No Law	Law	No Law
Africa	5	0	5	3	0
Asia	4	1	2	2	1
Carrib	6	1	2	1	1
Latin America	13	3	1	4	0
Total	28	5	9	10	2

Source: Domah 2001 survey, supplemented and updated by authors

4.3 Age Distribution of Autonomous Regulatory Agencies

Figure 2 shows the age distribution of energy regulatory agencies.

Figure 2: Age Distribution of Autonomous Electricity Regulators



Source: Domah 2001 survey, supplemented and updated by authors

Figure 2 shows clearly how many of the DTE regulatory agencies in our sample were very recently established. 8 (47%) were under 3-years old in 2001, including all the

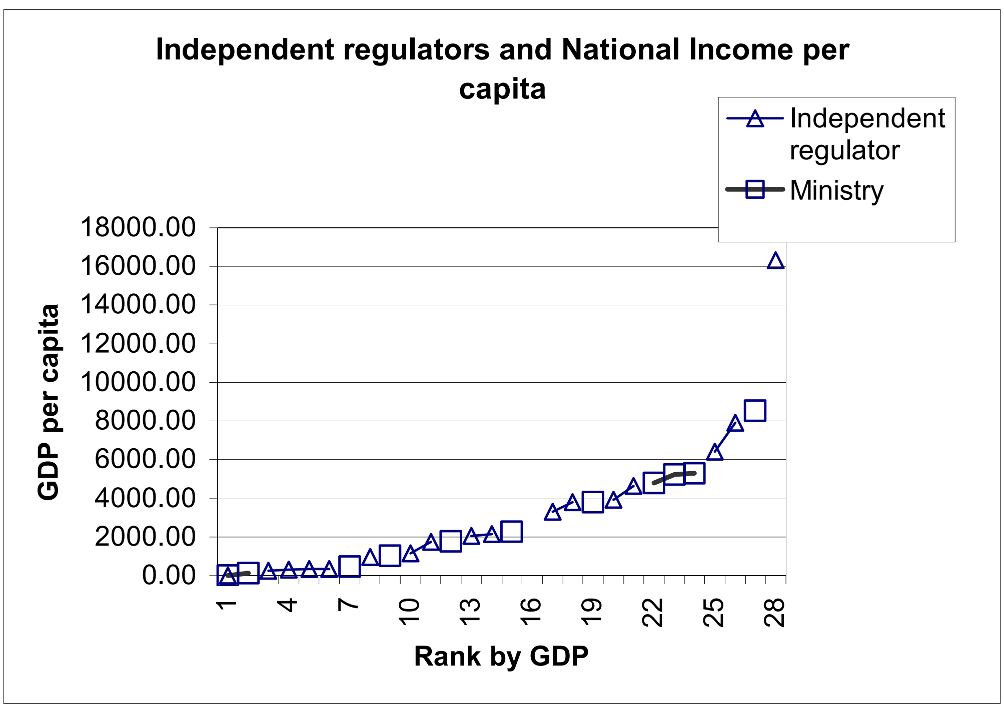
African electricity regulators. The median age was just under 5 years. However, 5 (29%) were 10 years old or more and accounts for 42% of the total number of sample years with an autonomous regulator. The over 13 year-old group of autonomous electricity regulatory agencies comprises Costa Rica, Philippines and Trinidad and Tobago.

4.4 Ministry or Autonomous Regulator and Per Capita GDP

Figure 3 shows, very interestingly, that – at least within this sample - there is little relationship between the existence of an autonomous regulator and per capita GDP. Both autonomous and Ministry regulators are scattered through the income range.

The mean income for countries with an autonomous electricity regulator was $3,500. For those with a ministry regulator it was $3,300. The difference was not significant. However, low income countries with an autonomous regulator have younger regulators e.g.. the two Sub-Saharan African regulators established since 1998 (Kenya and Uganda).

Figure 3: Type of Regulator and Per Capita Income (in Real $ 1995)

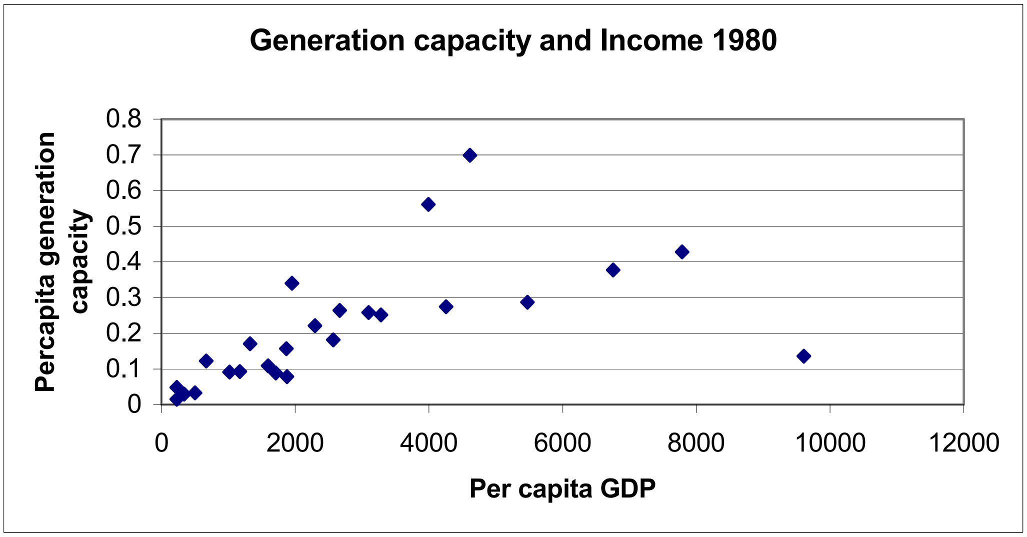


Source: Domah 2001 survey, supplemented and updated by authors

4.1.5 Generation Capacity and per Capita Income

Figures 4 and 5 plot generation capacity by real GDP for our 28 country panel at the start and end of the period. The plots show an upward sloping but by no means either uniform or linear relationship.

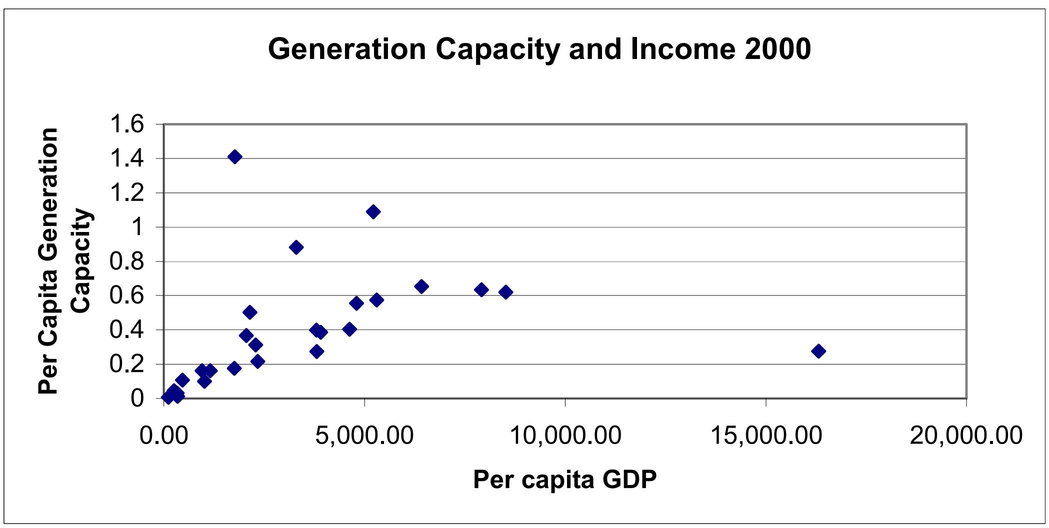
Figure 4: Generation Capacity and Income 1980



Source: US Energy Information Agency and World Bank Development Indicators

The outlier in the bottom right is Ecuador- as it was again in 2001. In 2001, only 55% of the population had access to mains electricity, even though the country is Latin America's largest oil exporter.

Figure 5: Generation Capacity and Income in 2000



Source: US Energy Information Agency and World Bank Development Indicators

The country at the top left of Figure 5 is Paraguay. It is a major exporter of hydro-power, and meets 25% and 40% respectively of Brazil and Argentina's electricity demands.[24] Interestingly, Ecuador has a (relatively young) autonomous regulator but Paraguay has a Ministry regulator.

For the pooled sample, the elasticity of generation capacity with respect to real per capita GDP was 0.89 (with a standard error of 0.02). The cross-section elasticities for selected years were as follows:

Table 3: Generation Capacity Real Income Elasticities

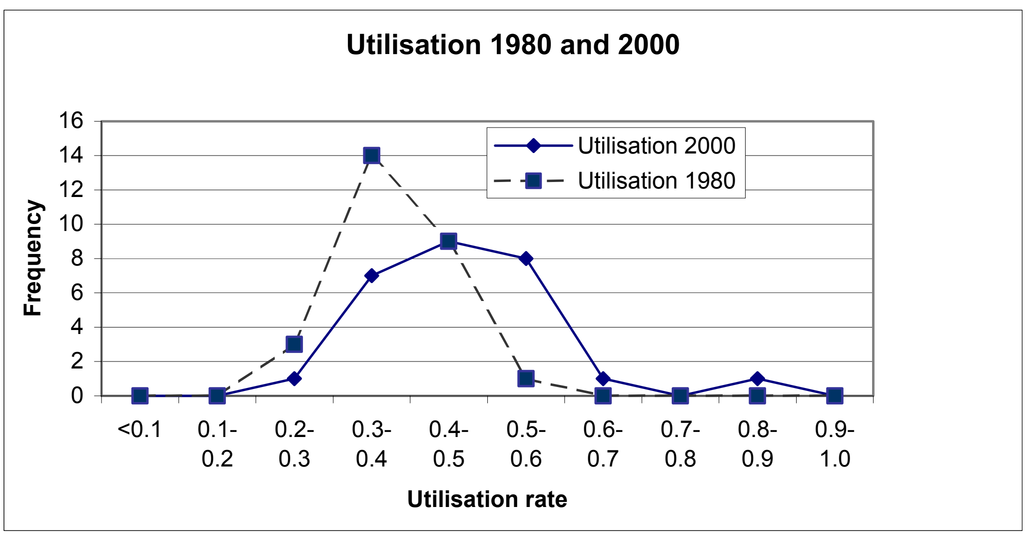
Year	Estimated Generation Capacity/ Real GDP Elasticities (Standard error in parentheses)
1980	0.78 (0.09)
1990	0.90 (0.11)
2000	0.94 (0.11)

Table 3 shows a trend towards the simple elasticity rising towards unity i.e. faster growth in generation capacity than in real income over the period. It remains to be seen whether this is in any way related to the spread of electricity regulatory reform.

4.1.6 Generation Capacity Utilisation 1980 and 2000

Beginning and end-of-period generation capacity utilisation rates are shown in Figure 6 below. In general, there has been a noticeable increase in capacity utilisation, but there are country exceptions (e.g. Colombia).

Figure 6: Utilisation of Generation Capacity 1980 and 2000



[24] See IEA country analysis brief :Paraguay at www.eia.doe.gov

4.5 Correlation between Indicators of Regulatory Governance

As discussed above, our regulatory index includes 4 indicators. These are classified positively for: (i) the enactment of an electricity regulatory law; (ii) the existence of an independent/autonomous regulator; (iii) funding from licence fees (or equivalent) and (v) staff salaries not necessarily confined to civil service pay scales.

Although the majority of our results are based on the index, we also try to estimate their separate effects. However, the degree to which we are able to do so depends on the levels to which they are correlated with one another. Not surprisingly, they are highly inter-correlated as shown in Table 4 below.

Table 4: Correlation Matrix between Regulatory Governance Variables

	ElAct	*Funding*	*Orgtype*	*Cserv*
ElAct	1			
Funding	0.848968	1		
Orgtype	0.783066	0.703489	1	
Cserv	0.783066	0.551221	0.442631	1

The correlations are highest within the law/funding/autonomy grouping.

For a visual depiction of the generation capacity and GDP data, see the Data Appendix in Cubbin and Stern (2004)

5 Econometric Results

In what follows, we report various results. In Table 5 below, we report the core results for our static model of per capita generation capacity. Tables 6 reports some results from simple LDV dynamic models of generation capacity. Table 7 reports the results from more sophisticated error correction dynamic models and Table 8 reports some results for generation capacity utilisation and technical losses.

5.1 Econometric Results for Models of Generation Capacity and Investment

We start by reporting the results of an OLS equation as a baseline. All subsequent equations are modelled using a fixed effects estimator.

Given the nature of the underlying model, we would expect a fixed effects model to be more appropriate than a random effects model. For some of the equations, we tested this assumption using the Hausman test and the random effects model was consistently rejected in favour of a fixed effects model.

5.1.1 Basic Static Generation Capacity Model Results

The key results are shown in Table 5:

- The fixed effects model clearly dominates the OLS model as shown in the standard error of estimate for the regressions.

- The estimated coefficient on the regulatory index is significantly different from zero at the 1% level in Equations 1 and 2.

- The implications of Equation 2 (our basic fixed effects model) is that, in the long-run, each unit increase in the regulatory governance index is associated with 4.3% higher per capita generation capacity. Hence, a country with best regulatory governance practice and an index score of 4 could expect to have 17.2% higher generation capacity per capita in the long run.

- The impact of regulation clearly increases with age of regulator. Equation 3 suggests a long-run effect of regulators (Ministry or autonomous) aged over 3 years of 35% on per capita generation capacity. Equation 4, which assumes a quadratic effect of age of regulator, implies that the impact of having a regulator peaks at 15 years.[25]

- The coefficient estimates for log(real GDP) are 0.7 - 0.8, with t-values of 8 or more.

- Neither the debt nor the industry value added variables were significant at the 5% level except in the OLS equation – a result consistently replicated.

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[25] The implicit decline in effectiveness after 15 years is not well-founded as only one of our regulatory agencies (Costa Rica) has a regulator in place for more than 15 years

- The equations all have very low Durbin-Watson statistics which suggest that t-values may be upward biased. (We explore this further in Section 5.2.2, where we report estimates from error correction models.)

Table 5: Static Models for Generation Capacity

Dependent Variable = Log(Electricity Generation capacity per capita)	**OLS model**	**Basic FE model**	**Age-of - regulator dummies**	**Quadratic in age of regulator**
Explanatory variables	**1**	**2**	**3**	**4**
Constant	-8.286			
	(-52.162)			
Real GDP per capita (log)	0.772	0.805	0.697	0.699
	(31.071)	(9.970)	(8.343)	(8.522)
Debt payments as a proportion of national income	4.14E-12	2.49E-12	-4.65E-13	1.07E-12
	(0.838)	(0.556)	(-0.104)	(0.244)
Industry value added as proportion of GDP	0.024	-0.002	0.000	0.001
	(7.981)	(-0.607)	(-0.003)	(0.232)
Index of regulatory governance 0-4	0.056	0.043	-0.026	-0.011
	(2.982)	(3.444)	(-1.067)	(-0.638)
Regulator under 1 year			0.090	
			(1.465)	
Regulator 1-3 years			0.187	
			(2.398)	
Regulator aged over 3 years			0.353	
			(4.370)	
Age of regulator				0.055
				(4.132)
$(\text{Age of regulator})^2$				-0.002
				(-2.635)
Estimation method	OLS	Fixed effects	Fixed effects	Fixed effects
Adjusted R-squared	0.764	0.952	0.954	0.954
S.E. of regression	0.605	0.272	0.267	0.266
F-statistic	465.943	372.079	352.169	365.770
Durbin-Watson	0.043	0.161	0.163	0.153
No of observations	577	577	577	

Note: t statistics in parentheses

5.1.2 Variants on the Fixed Effects Generation Capacity Model

A large number of variants, static and dynamic, are reported in full in Cubbin and Stern (2004). Here, we summarise the key results.

5.1.2.1 Static Model: Individual Governance Elements

The first set of variants was the estimation of the static model of per capita generation capacity, as in Table 5 above, but including in 4 separate equations each of the individual governance elements in our regulatory index. The main results were as follows:

- The largest estimated regulatory effect of the index components was, perhaps surprisingly, from having an electricity law (18% with a t-value of 5.1) rather than from having an autonomous regulator (10% with a t-value of 2.3). However, these must be interpreted in the light of the correlation between them of 0.78.

- Licence funding of the regulator also had a positive estimated effect (13.5% with a t-value of 3.4)

- The estimated sign on non-mandatory civil service pay scales was negative (and significant at the 1% level) ie the opposite of that predicted by regulatory governance theory.

The strong effect of a regulatory law – and of age of regulator variables derived from the date of the law – appears to reflect a signalling and commitment effect from having a legal framework which makes even Ministry regulators significantly more accountable for how they carry out their functions. It may be that the effect of an autonomous regulator would be higher in a sample where more autonomous regulators had been in operation for more than 5 years.

Given the high degree of collinearity between the regulatory variables, we used principal components to help better identify the effects of the individual governance elements. We first computed the principal components of the four governance element. We then included the first 2 principal components (accounting for over 90% of the total index variance) in a static fixed effects regression of per capita generation capacity with per capita GDP as the other explanatory variable. The estimated impact of each of the 2 principal components was positive but only the coefficient estimate of the first principal component was statistically significant at the 5% level, with a t-value of 3.8.[26]

Interestingly, the loadings of the individual components in the first principal component (accounting for 76% of the total index variance) were broadly similar. Nevertheless, the loading from the electricity law element was the highest, providing

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[26] Including the first 2 principal components in a dynamic equation with a lagged dependent variable produced very similar results.

some corroboration for the results and the associated conjectures above arising from the separate equations for the individual governance elements.

5.1.2.2. Static Model: Privatisation and Competition

The equations estimated showed no statistically significant effect of either of these on generation capacity. However, the privatisation dummy is deficient on dating and the competition dummy is a weak proxy as well as poor on dating.

- The coefficient on our competition proxy variable was consistently negative but not significantly different from zero.

- The coefficient on the privatisation variable was only significant at the 10% level or better when interacted with the regulatory dummy <u>and</u> the regulatory index was excluded[27].

5.1.2.2. Static Model: Country Governance Indicators

We included as explanatory variables the Kaufmann indexes for (i) rule of law and (ii) corruption by country for 1998. The key results were:

- The corruption index was never statistically significant in the fixed effect regressions at the 5% level or better, either as a separate variable or when interacted with the regulatory variables.

- The country rule of law index approached significance at the 5% level when interacted with the regulatory index and an age of regulator was also included as an explanatory variable.

- The Kaufman rule of law index was, however, highly significant in an OLS equation – and led to non-significance of the electricity regulatory variable.

The last result (and the pattern of residuals) is a major reason why we believe that the estimated fixed effects capture most of the country-specific institutional differences. We also found:

  - No statistically significant correlation between the fixed effects and the Kaufmann rule of law index; <u>but</u>

  - A sizeable and statistically significant interaction term between our regulatory index and the Kaufmann rule of law index in a *random effects* specification (a coefficient of 0.07 with a t-value of 2.3).

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27 Cubbin and Stern (2004), Table 7 and discussion for more details

These results provide interesting pointers that the estimated fixed effects capture wider country-specific institutional quality issues but are clearly far from conclusive.

5.2 Dynamic Models for Generation Capacity

In this section we discuss the results

(a) For a simple dynamic models for per capita generation capacity, adding a lagged dependent variable to the static, fixed effects model; and

(b) For more sophisticated error correction models.

Given the nature of the generation investment planning and construction process, we would expect quite long lags, which will be picked up from the simple formulation in (a). However, well-fitting simple LDV models may reflect spurious correlations rather than a systematic relationship so the more sophisticated models were estimated to test for spurious correlation as well as to improve our understanding of the dynamics and the lags, including the build-up of regulatory reputation effects

5.2.1 Simple Dynamic Models of Generation Capacity

These models were estimated by adding a lagged dependent variable (LDV). The estimated coefficient on the LDV was very high – over 0.85 implying, as one would expect, a slow rate of adjustment of generation capacity – and with very high estimated t-values, over 60.

The regression results are shown in Table 6 below. The key results are:

- The implicit long-run coefficient on the regulatory governance index was 6.1 per unit on the index, implying a long-run effect of 24% on per capita generation capacity for a maximum score on the index as compared to 17% in the static model. (However, the estimated coefficient was only significantly different from zero at the 10% level.)

- The implicit long-run effect in Equation 13 on per capita generation capacity from a regulatory agency (Ministry or autonomous) with at least 3 years of existence is 26% as compared to 35% in the static model. The estimated coefficient was significantly different from zero at the 5% level.

- The elasticity of per capita generation capacity wrt. real GDP was very close to 1 (0.998 and 1.03).

Table 6: Simple Dynamic LDV Models for per Capita Generation Capacity

Dependent Variable	Log(Electricity Generation capacity per capita)		Log(Electricity Generation capacity per capita)
Explanatory variables			
Lagged dependent variable	0.885		0.879
	(66.186)		(66.094)
Real GDP per capita (log)	0.119		0.121
	(4.558)		(4.610)
Index of regulatory governance 0-4	0.007		
	(1.835)		
Regulator aged 1-3 years			0.010
			(0.893)
Regulator aged over 3 years			0.032
			(2.247)
Implied long run multiplier $1/(1-\lambda)$	8.732		8.249
Estimation method	Fixed effects		Fixed effects
Adjusted R-squared	0.996		0.996
S.E. of regression	0.083		0.083
F-statistic	4366.527		4399.462
Durbin-Watson	1.850		1.834
No of observations	576		584
Note: t statistics in parentheses			

In all the main generation capacity equations reported above, the R^2 statistics are high – around 0.95 in the static fixed effects models and over 0.99 in the dynamic model. The latter in particular raises questions as to whether, given the fixed effects, the empirical results are dominated by the purely statistical relationship of one highly trended variable (per capita generation capacity) with another (real per capita GDP). In fact, neither of these series is dominated by an obvious trend[28] but the issue requires more formal investigation. See 5.2.2 below.

5.2.2 Error Correction Models and Lags

5.2.2.1 Time Trends and Lags

Our first test was to establish whether the coefficients on the regulatory governance variables remained positive and significant when we (a) included a time-trend and (b) lagged the index by 3 years.

The results were as follows:

28 See Data Annex in Cubbin and Stern (2004).

- The time trend was statistically significant at the 1% level in a static formulation but negative and far from significant in an LDV model. Its estimated value in the static model was only 1.7% p.a.

- The estimated coefficient on the lagged regulatory index was positive in both models. In the LDV model, it was statistically significant at the 1% level and the magnitude of the estimated long-run coefficient was very similar to that in the LDV model without a time-trend. However, the magnitude of the estimated regulatory coefficient in the static model was about half the magnitude of that in Table 1, Equation 2 and only significant at the 10% level[29].

(Note that lagging the regulatory variable by 3 years implies that all regulators established after 1997 are excluded from the sample.)

5.2.2.2 Error Correction Models

If we wish to be sure the fixed effects levels equations are not just spurious regressions, we can check to see whether there appears to be a plausible adjustment process.

The levels equation is: $$Y_{it} = \varphi_i + \beta G_{it} + \gamma R_{it} + \upsilon_{it} \qquad (3)$$

which can be estimated as: $$Y_{it} = f_i + bG_{it} + c\,R_{it} + u_{it} \qquad (4)$$

where Y_{it} = log(electricity generation capacity per capita)
G_{it} = log(GDP per capita)
R_{it} is a regulatory governance variable; and
f_i is the fixed effect for country i

From this, we can calculate the implied the steady state, equilibrium, or long term value, which can be written as:

$$Y^*_{it} = \varphi_i + \beta G_{it} + \gamma R_{it} \qquad (5)$$

We now postulate a partial adjustment error correction mechanism under which the actual value of capacity changes by a constant proportion of last year's deviation from the long term value ie

$$\Delta Y_{it} = Y_{it} - Y_{it-1} = -\lambda\,(Y_{it-1} - Y^*_{it-1}) \qquad (6)$$

where $(Y_{it-1} - Y^*_{it-1})$ is last year's deviation from equilibrium.

If we wish to estimate (6), we can take the residuals u_{it} from the levels equation in (4) and calculate the regression equation

29 See Cubbin & Stern op cit, Table 9 for more details.

$$\Delta Y_{it} = - \lambda u_{it-1} + e_{it} \quad (7)$$

Alternatively, we could estimate

$$\Delta Y_{it} = - \lambda (Y_{it-1} - \varphi_i - \beta G_{it-1} - \gamma R_{it-1}) + \varepsilon_{it} \quad (8a)$$
$$= \lambda\varphi - \lambda Y_{it-1} + \lambda \beta G_{it-1} + \lambda\gamma R_{i-1t} + \varepsilon_{it} \quad (8b)$$

More specifically, since we are particularly interested in the size and significance of the regulatory variable, R, we can impose the estimate of β from the long term levels relationship (2) and estimate

$$\Delta Y_{it} = \lambda\varphi - \lambda(Y_{it-1} - bG_{it-1}) + \lambda\gamma R_{it-1} + \varepsilon_{it} \quad (9a)$$

From this we derive the following which we estimate, including fixed effects:

.

$$\Delta Y_{it} = \lambda\varphi - \lambda(Y_{it-1} - 0.78\, G_{it-1}) + \lambda\gamma R_{it-1} + e_{it} \quad (9b)$$

We have alternative estimates of λ from equations (7) and (9b). These can be compared. In addition, we have alternative estimates of γ: firstly, from the *levels* equation (4); and, secondly, the *differences* equation 7(b) from which we can calculate the implied value of γ as λγ/λ from the estimated coefficients.

We tested for stationarity using the Pesharan-Shin W-statistic. Applying this test to the differenced equation 7(b), with the regulatory index as our measure of R_{it}, the test clearly rejects the presence of a unit root in the residuals with a t-statistic of –8.05. Even in the corresponding levels equation, the Pesharan-Shin W-statistic does not appear to suggest non-stationarity in the residuals, implying that our generation capacity variable, GDP and our regulatory variables are co-integrated[30].

The results are shown in Table 7 below. We report estimates for the levels equation (2), the partial adjustment equation (5) and the differenced model (9b). We report these (a) where the regulatory variable is the 4-element regulatory index and (b) where it is a dummy for all regulators over 3 years old. Equations estimated with alternative definitions of the regulatory variable yielded estimates with similar positive magnitude and statistically significant at the 5% level or better.

30 Very similar results on the unit root test applied when we took alternative definitions of the regulatory variables: regulator over 3 years old and a quadratic in the age of the regulator.

Table 7: Generation Capacity – Error Correction Models

Dependent Variable	Log (Per Cap Generation capacity) Levels 1	Log (Per Cap Generation capacity) Differences 2	Log (Per Cap Generation capacity) Differences 3	Log (Per Cap Generation capacity) Levels 1	Log (Per Cap Generation capacity) Differences 2	Log (Per Cap Generation capacity) Differences 3
Explanatory variables						
Real GDP per capita (log)	0.7913			0.7846		
	(10.787)			(10.830)		
Index of regulatory governance (0-4)	0.0490					
	(4.454)					
Index of regulatory governance (t-1)			0.0118			
			(3.230)			
Lagged Residuals from 1		0.1195			0.1188	
		(8.941)			(8.876)	
Error Correction Term			0.1181			0.1188
			(8.938)			(8.867)
Regulator aged over 3 years				0.2325		
				(5.673)		
Regulator aged over 3 years (t-1)						0.0286
						(2.000)

Long-run Coefficient on Index (per unit) ($\lambda\gamma/\lambda$)			0.099			
Long-run Coefficient on Regulator Aged over 3-years ($\lambda\gamma/\lambda$)						0.244

Estimation method	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects
Adjusted R-squared	0.955	0.156	0.159	0.955	0.150	0.149
S.E. of regression	0.265	0.084	0.084	0.266	0.084	0.084
F-statistic	448.7	4.676	4.784	450.3	4.676	4.51
Durbin-Watson	0.165	1.79	1.80	0.168	1.78	1.78
No of observations	608	582	582	610	583	583

Note: t statistics in parentheses

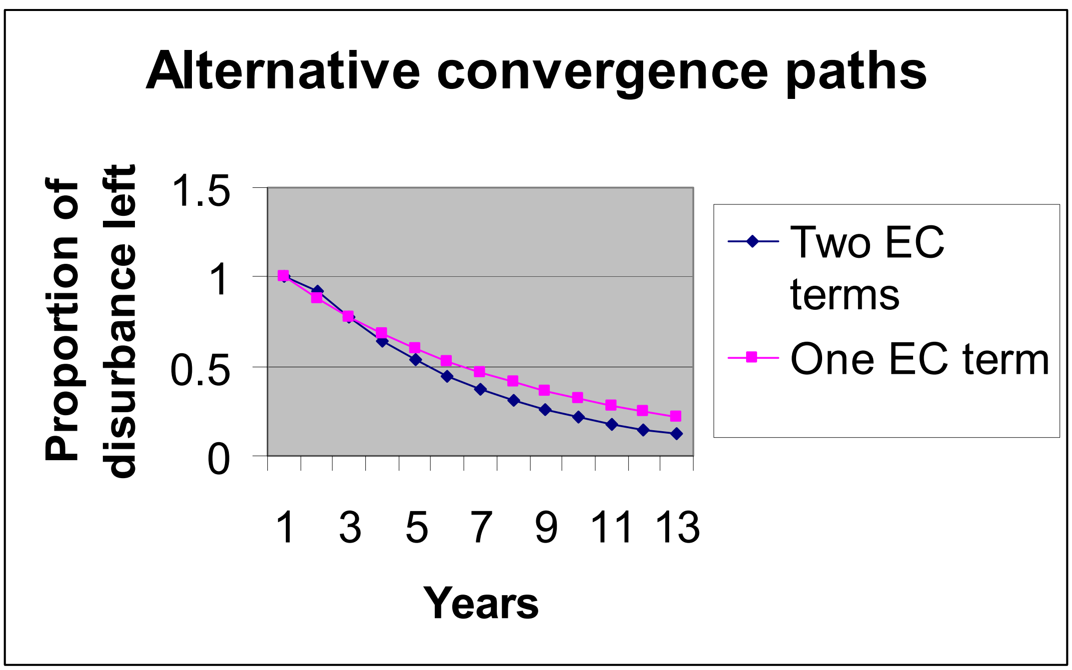
The key results are:

- The derived estimate of the long-run effect on generation capacity of having a regulator (Ministry or autonomous) aged 3 years or more in the differenced equation of column 6 is 24%. This is very similar to that in the LDV model but lower than in the static model.

- The derived estimate of the long-run effect of a unit increase in the regulatory governance index in the differenced equation of column 3 is almost 1%, implying that the maximum score on the index is associated with almost 40% higher generation capacity than under a Ministry regulator with no electricity law. This is a lot higher than in the LDV model (26%) and also above the level in the static model (35%)[31].

- The estimates of λ are similar to each other – and very similar to the implied adjustment speed in the LDV model. A more sophisticated two-term error correction model showed slightly faster adjustment, particularly after 5 years.

- The estimated response to changes in GDP and regulatory governance is slow. Only 12% of the difference between actual and equilibrium long-run per capita capacity levels is made up in the first year. The estimated adjustment processes with both one and with two-term error correction factors are shown below.



[31] Note that a simple multiplicative factor applied to a linear index is likely to exaggerate the maximum effect if there are diminishing returns to increases in regulatory governance quality.

These results provide strong support for the hypothesis that the regulatory governance impact on generation capacity in developing countries is positive and sizeable but takes time to build up.

5.2.3 Econometric Results for Models of Generating Capacity Utilisation and Technical Losses

Table 8 presents some results relating to the impact of regulatory governance on efficiency. For the reasons set out in Section 3.1.2, we deliberately estimated simple models. Unfortunately, we were unable to find any reliable time-series data for our countries on commercial losses, or quality of service or productivity.

The results were reasonably positive for capacity utilisation in generation but we never found any positive or significant effect of any regulatory variable for (technical) transmission and distribution losses.

Table 8: Utilisation and Technical Losses

Dependent Variable	**Utilisation of generation capacity***		**Technical losses in transmission and distribution (%)**
Explanatory variables	**17**		**18**
Real GDP per capita (log)	0.729		-0.841
	(2.279)		(-0.441)
Index of regulatory governance 0-4	0.079		0.219
	(2.330)		(1.016)
AR(1)	0.713		0.648
	(23.365)		(17.786)
Estimation method	FE + Prais – Winsten		FE + Prais – Winsten
Adjusted R-squared	0.743		0.840
S.E. of regression	0.449		2.697
F-statistic	56.196		92.624
Durbin-Watson	2.138		2.032
No of observations	574		472

Note: t statistics in parentheses

Utilisation = generation/(capacityx24x365)

The positive effect in the utilisation equation of the regulatory index (significantly different from zero at the 1% level) was found in some but not all other equations estimated.

In the equation reported, a 1 point increase in the regulatory index is associated with a 0.8% increase in utilisation so that utilisation with the maximum index score of 4 implies a 3.2% increase relative to countries with an index score of zero. Utilisation rates also appear to be positively (and significantly) associated with higher GDP within and between countries.

5.2.4 Endogeneity and Causality in Generation Capacity Models

5.2.4.1 Endogeneity

Much of the literature on regulatory effectiveness expresses concerns over the endogeneity of:

(a) countries choosing to have an independent/autonomous regulatory agency; and

(b) the quality of governance of that agency[32].

This discussion echoes similar debates about the endogeneity of independent central banks and how best to measure the impact of central bank independence eg on inflation and growth. The concern is essentially that countries with better (unobservable) governance have better functioning regulatory agencies eg because they have socio-economic characteristics that better support the rule of law, contracts and commercialisation. The problem is that it is very difficult to find good instruments ie instruments that are *both* correlated with the suspected endogenous variable *and* uncorrelated with the error term so that they can be treated as exogenous.

However, Edwards and Waverman (2004) have adopted a novel approach to this using a rank-based instrument for their (12 element) EU telecom regulatory governance index. This approach, taken from Evans and Kessides (1993), provides a simple procedure, firstly, for the testing of whether or not there is evidence of endogeneity; and, secondly, for deriving an IV estimator to control for the estimation.

The procedure is as follows. Firstly, we recalibrate our 4 element regulatory governance index, so that all countries where entries are 1 or 2 are reclassified as 1 and all entries of 3 or 4 are reclassified as 2. Zeroes remain zero. We denote this as the Rank Index. We then estimate the following equation:

$$\text{Index}_{(\text{Cubbin-Stern})} = a_0 + a_1 \text{RankIndex}_{it} + u_{it} \qquad (10)$$

32 See, for instance, Fink et al (2002), Gual and Trillas (2002) and Gutierrez (2004).

We then include the estimated residuals from (10) in the following equation for per capita generation capacity:

$$\text{Log(ELCAPPC)}_{it} = (a_0 + a_i) + a_1 \log(\text{GDPPC})_{it} + a2\, \hat{u}_{it} + v_{it} \qquad (11)$$

Whether or not a_2 is significantly different from zero provides a test as to whether or not there is a potential endogeneity problem associated with our regulatory governance measure. Similarly, including the *predicted* values of the Cubbin-Stern index derived from (10) in our basic, fixed effects, static model provides an effective instrument to estimate the effect of any endogeneity bias in practice.

As explained by Edwards and Waverman, the use of the Rank Index is, by construction correlated with the original index but orthogonal to the error term provided that a small change in the original index would not change the position in the Rank Index. This can be expected to hold except for observations near the thresholds between the close to the boundaries between the Ranks.

Adopting this procedure, we find that the coefficient on the residuals of (10) in the basic static equation for per capita generation capacity has a t-value of 1.7, implying that there is *marginal* evidence of endogeneity of the Cubbin-Stern regulatory index. However, instrumenting the Cubbin-Stern index by using its *predicted value* from (10) in place of the actual value produces virtually identical results – an estimated coefficient of 0.047 with a t-value of 4.3 in the instrumented case as opposed to an estimate of 0.049 and a t-value of 4.0 in the non-instrumented case.

Like Edwards and Waverman (2004) and Gutierrez (2003), we find some weak evidence of endogeneity of regulatory governance quality but very little change in coefficient estimates from correcting for it. The test in our case is not as strong as in Edwards and Waverman who have 12 rather than 4 initial governance levels. However, we can with some confidence reject the proposition that our results can be dismissed on the grounds of potential endogeneity of our indicator of regulatory governance.

5.2.4.2 Causality

The question remains as to whether, looking forward, our regulatory governance coefficient estimates have any *causal* interpretation. Even if, they are not statistical artefacts arising from failures adequately to address dynamics or endogeneity, they may still be merely descriptions of a past set of events that cannot be applied to future electricity regulatory governance changes in sample countries let alone to the introduction or development of electricity regulation in non-sample developing countries[33].

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33 For the reasons stated in Sections 2 and 3, we would not wish to claim that they are applicable to countries with an excess supply of generation capacity at any time during the period after 1980. This would exclude the Central and East European countries, the CIS and almost all OECD countries.

One reason why this question might be asked is that the regulatory literature derived from Levy and Spiller (1994) emphasises country-specific constitutional, legal, economic, and political differences as being crucial for the success or failure of utility regulation. Hence, a highly reduced form model that abstracts from all those issues may well fail to reflect these local issues that seem to be so important in practice.

The answer to both these concerns lies in the importance of the country-specific *fixed effects*. With 28 countries each having up to 21 years of data, we can obtain estimates of the fixed effects which should capture most if not all of the factors identified by Levy and Spiller and the subsequent literature. Hence, the estimated impact of eg enacting a regulatory law plus an autonomous regulator in Chile or Sudan (both countries in our sample) will be very different. That impact is the combination of (a) the predicted effect of the relevant regulatory variables ***plus*** (b) each country's predicted fixed effect. The Chilean fixed effect is strongly positive relative to the sample average whereas that for Sudan is strongly negative.

In other words, the coefficients that we report are 'highest common factor' estimates of the impact of regulatory governance indicators where the fixed effects not just control for but effectively "wash out" all the Levy and Spiller and similar factors. But, this means that the regulatory governance effects that we report are not just *average* cross-country sample effects but that they refer to a country with *average scores on country-specific fixed effects*. Moreover, they are the impacts that one might expect, looking forward, for a country:

- With an average country specific fixed effect
- Implementing an average quality law
- Establishing an average quality autonomous regulator, etc.

It is for such a country that one might expect that implementing a best quality electricity regulator would increase per capita generation capacity in the long run by 15-25%.

The policy implication of this is, firstly, that the quality of overall country governance matters considerably for the impact of regulation on outcomes (eg as in the rule of law); and secondly, that countries cannot expect to achieve the gains we have estimated by enacting low quality regulatory laws or introducing autonomous regulatory agencies with very low staffing levels. But, the corollary is that the potential gains from introducing an electricity regulator could be significantly higher than the average level for countries with good overall governance who deliberately try to introduce best practice regulatory agencies and practices.

The argument above follows not just from the logic of our fixed effect modelling but is supported by the suggestive implications of a potential interactive and/or independent impact of overall country governance (eg as measured by the Kaufmann index) on our regulatory governance measure. (See Section 5.1.2.2 above.)

These arguments do not, of course, apply just to this paper. They also apply to the similar models of Gutierrez, Edwards and Waverman, etc.

6. Discussion of Results and Concluding Comments

6.1 Discussion of Results

The results of this study seem to provide a broadly consistent picture that the existence of a regulatory agency with good governance characteristics not only can in principle improve regulatory outcomes *but seems actually to do so in practice*. For electricity supply industries in 28 developing countries in the 1980-2001 period, we find that an index of regulatory governance is a consistently positive and statistically significant determinant of per capita generation. Our results, using fixed effects estimation methods, are similar to those found in for telecoms in developing countries (e.g. Gutierrez, 2003).

The main positive findings are that, for developing countries:

1) Averaging over developing country regulatory agencies, the estimated long-run impact on per capita generation capacity of a maximum regulatory governance index score of 4 is of the order of 15-25% cet par – and, in particular, after controlling for country-specific fixed effects.

2) The estimated impact of regulation increases with experience – at least for the first 3-5 years or more. The cet par impact on per capita generation capacity of a regulator (autonomous and/or Ministry) established at least 3 years is of the order of 25-35%.

3) The effects on per generation capacity are robust not just to the inclusion of a lagged dependent variable but also to the inclusion of a time trend and 3-year lags on the regulatory variables. They are also robust to modelling via an error correction model and to IV modelling to allow for potential endogeneity biases.

4) The effects of the enactment of (a) a regulatory law, (b) of having an autonomous regulator and (c) licence fee funding of the regulatory agency were each positive and statistically significant at the 1% level.

5) There is some evidence, albeit weak, that better overall country regulatory governance is a statistically significant determinant of generation capacity utilization (a good proxy for availability).

6) There is some evidence, albeit weak, that the better the rule of law, the stronger the regulatory effect.

7) There is reasonable evidence that superior regulatory governance improves generation utilization rates.

There are, however, some negative findings. These include the following

1) There was no evidence of any significant, positive effect of any of our regulatory governance measures on transmission and distribution losses.

2) There was no reliable evidence in this data set that competition or privatization were significant determinants of generation capacity either individually or when interacted with regulatory governance. However, the data set we used was much stronger on regulatory variables than on competition and privatisation variables.

On the whole, we were surprised at the strength and robustness of the positive results. The data set we used has a number of major weaknesses in spite of being the best currently available. Among the main weaknesses of the data set are:

- The absence of any data on regulatory practice, including government (and/or electricity company) malpractice toward supposedly independent regulatory agencies (e.g. high within-term turnover rates of regulatory office heads/commissioners).

- The absence of any reliable cross-country data on ESI efficiency and productivity or on service quality and revenue collection.

- The limited time dimension to the regulatory data – and the extremely limited time dimension to data on privatization and competition.

- Potential omitted variable biases from the inability to test for the inclusion of many potentially significant variables.

- The limited and possibly unrepresentative sample of countries.

It is to be hoped that some of the major data weaknesses can be remedied e.g. by systematic data collection exercises of the sort that have been carried out for telecom reform.

5.2 Concluding Comments

In this paper we have presented evidence that suggests that good regulatory governance does have a positive and statistically significant effect on some electricity industry outcomes in developing countries – notably per capita generation capacity levels - but we have not examined *why* this is so.

To examine *why and how* regulation operates to improve outcomes is not a task that obviously recommends itself to econometric analysis. We suggest that, at least at this stage, it is better pursued by case studies with econometric work being concentrated on whether the results reported in this paper are confirmed in subsequent analyses e.g. with superior data, particularly on regulatory practice, privatization and competition variables.

Nevertheless, we are confident that the results reported here are entirely consistent with the literature on the role of institutions in economic growth. The key point is that regulatory agencies with better governance are:

- Less likely to make mistakes
- More likely to correct mistakes speedily
- Less likely to repeat mistakes
- More likely to develop procedures and methodologies that involve participants and develop good practice.

All of these reduce uncertainties for commercially operating companies – particularly private and foreign companies. This is especially important to sustain and encourage long-lived, sunk investments in highly capital-intensive industries at a reasonable cost of capital. As such, regulatory agencies, which have and maintain good governance, provide an effective underpinning for the operation of contracts as well as sound regulation of monopoly elements.

The utility service industries like electricity supply may be considered as a microcosm for considering the role of institutions in sustaining investment, efficiency and growth. But, in fact, they are a touchstone. Given their role in supporting growth as well as their technical characteristics, electricity and similar industries are among those most in need of strong and effective regulatory frameworks. Hence, we suggest that our positive results on the role of good governance support and enhance the lessons of similar studies for independent central banks and telecom reform as well as support the general arguments of North, Rodrik and others on the role of effective and evolving institutions for sustained growth.

It remains to be seen whether the results reported in this paper survive in the light of further analysis and can be replicated with better data.

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APPENDIX: LIST OF COUNTRIES IN SAMPLE

Argentina
Barbados
Bolivia
Brazil
Chile
Colombia
Costa Rica
Dominican Republic
Ecuador
El Salvador
Ethiopia
Grenada
India
Indonesia
Jamaica
Kenya
Malaysia
Mexico
Nicaragua
Nigeria
Paraguay
Peru
Philippines
Sudan
Trinidad
Uganda
Uruguay
Venezuela