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Modelling the costs of energy regulation : Evidence of human resource constraints in developing countries

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Modelling the Costs of Electricity Regulation: Evidence of Human Resource Constraints in Developing Countries*

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Abstract

Successful electricity industry reform depends on the presence of an appropriately staffed regulatory agency for the liberalised sector. However developing countries can have resource constraints that make the establishment of an effective regulatory agency difficult. This paper attempts an econometric modelling of staff numbers in electricity regulatory institutions. We specify a model of the determinants of staff numbers that reflects electricity system complexity as well as national economic and regulatory environments. We empirically estimate a translog cost function specification of the model using data on 60 electricity regulators collected from an international questionnaire survey in 2000-01. We conclude that there are significant differences between the regulatory cost functions of developed and developing countries and that, in establishing independent regulatory agencies, developing countries face high fixed costs relative to market size.

JEL Classification: L30; N40; O15.
Keywords: Electricity Regulation; International Comparisons; Human Resources.

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1. Introduction

Governments in many countries, developing and developed alike, have begun to allow private initiatives in infrastructure investments and services, both to enhance efficiency and to ease the strain on public finances. As part of the reform process, restructuring has usually been accompanied by the introduction of new utility regulatory institutions. The economic regulation of decentralised and usually wholly or partially privatised electricity industries in most of the developed world, and in some large developing countries, appears to have *increased* both the numbers of people involved in regulation and certainly the complexity and skill levels of the staff involved in regulation. The situation in small and low-income developing countries is quite different in many respects. On the one hand, utility regulatory institutions are relatively new and small, covering several sectors; and, conversely, there is a common belief that they are understaffed, particularly with respect to the employment of experienced professionals. This paper uses econometric regression analysis to shed light on the extent to which institutional capability may be a problem in this area.

The paper is organised as follows. Section 2 discusses some theoretical issues relating to the design of a regulatory institution. Section 3 extends the analysis in section 2 to discuss the issues of scope and the choice of design in both developed and developing countries. Section 4 discusses the model used in this paper to evaluate human resource deficiencies. Section 5 details the data collection method and the actual dataset used. In section 6 the results are presented and discussed in the context of small developing countries. Section 7 provides a short conclusion.

2. The Importance of Human Resources in Effective Regulation

The design of “effective” regulatory institutions involves defining the regulatory scope and policies that should accompany ESI reforms. There is a growing literature on what constitutes an effective regulatory system. Stern and Holder (1999: 43), for instance, suggest that regulatory institutions should be characterised by *Clarity* of roles and objectives, *Autonomy* from political intervention, wide *Participation* by (or consultation with) relevant stakeholders, *Accountability* to outside agencies, *Transparency* of decision making process and *Predictability* of decisions.

In practice, the attainment of the six criteria above hinges on the availability and use of an adequate supply of economic resources, particularly the supply of trained staff involved in regulation. Estache and Mortimort (1999), Knack and Keefer (1995), Levy and Spiller (1996), Gray (1998) and Stern (2001) agree on the importance of adequate human capabilities to provide for effective regulation. It is not just the total numbers of staff but a sufficient pool of professionally qualified ones (lawyers, technicians, economists and accountants, among others) that will provide for the critical institutional continuity of regulation. Such an institutional base will in turn provide for the required quality and ability of regulatory systems. A strong professionally trained administration should also be better able to maintain policy stability in the face of political instabilities (Bergara et al., 1998).

Most of the empirical work on utility regulation such as Buckle (1999) and Spiller et al. (1997) consist of case studies on telecommunication regulation. Stern (2001) investigates whether or not there is a problem in the supply of resources for utility (electricity and telecommunications) regulation in small and low-income countries; to estimate its potential severity and, finally, to consider some potential options for how it might be tackled. None of these studies applied econometric analysis to the issue.

In many large developed countries, such as the UK and the USA, regulators do possess most if not all of the ‘desirable characteristics’ owing to their favourable endowment of human capital and legal institutions, but the economic and social structure of small developing countries may act as real obstacles in achieving them. Large developing, middle income nations such as Argentina, Brazil, Chile, Malaysia and the Philippines appear to have been able to cope with the staffing needs of their regulatory institutions, but for low income Asian and African countries and most of the small island states (such as Grenada or St. Lucia), the problem of the supply of adequate human capability is much more acute.

The problem in developing countries seems to be exacerbated by their prevailing poor governance structure. The recent 2002 World Development Report (WDR, 2001) stresses the importance of clear governance rules for developing countries. It reports that, in general, lower income countries tend to have more barriers to regulatory reforms and to the introduction of competition (see WDR,2001, Chapter 8). This also implies that poor governance rules not only affect the *number* of personnel that regulatory institutions can employ, but also the *ability* of such staff to function effectively.

A pervasive feature of many (but by no means all) developing countries is the high level of government corruption, which increases the need for uncorruptprofessionally trained staff in regulation, in order to counterbalance the more difficult governance structure. However, governments in countries with high levels of corruption may also wish to use utility regulators (particularly Ministry regulators) as a method of creating jobs – or jobs for favoured people. This is likely, *ceteris paribus*, to increase the numbers of *total* staff but its effect on the numbers of *professional* staff actually employed is ambiguous since poor governance structures may also be accompanied by a considerable lack of qualified manpower necessary to bring change and to support institutions. In such a situation the qualifications of the professional staff may be of doubtful quality and relevance. Also, there may be an unwillingness on the part of appropriately qualified professionals to work in the regulatory agencies where governance is poor and/or corruption is widespread. In these circumstances, the recruitment policies of the regulatory institutions are likely to be subject to political pressures of various kinds.

In consequence, we would suggest that, if there is a premium attached to good governance, countries with low levels of corruption are more likely to promote effective regulation, as Stern (2001) indicates in the case of Botswana. Less corrupt countries may (cet par) therefore prefer to have larger regulatory institutions with a higher proportion of appropriately qualified professional staff – resource constraints permitting.
evy and Spiller (1996) have developed a framework to analyse the interaction of the institutional endowment of a country, the nature of its regulatory institutions, and performance. They emphasise that the credibility and effectiveness of a regulatory framework can vary with a country's political and social institutions. Good governance is believed to be the key to improve institutions of regulation by more effective conflict

management and sophisticated contract enforcement regimes. Bergara et al. (1998), based on the framework developed by Levy and Spiller (1996), analysed the impact of political institutions and government commitment on electric utility performance. One of the main conclusions of the study is that even in the face of some political instability, the existence of independent institutions, and a professional and competent judiciary can insure better policy stability even in developing countries (ceteris paribus).

3. The Design of Regulatory Institutions

Regulation can be carried out by a variety of bodies, viz. Government ministries, independent regulators, or in courts of law. Hence, the nature of the regulating institutions can affect not merely the style of regulation and the strategies employed but also the success with which regulatory ends are achieved. There are some common elements that designers of regulatory agencies need to address. Note that the examples used in this section are derived from the survey results, unless otherwise stated. They all refer to data as at December 2000.

3.1. The Scope of Regulatory Activity

Governments must decide on the breadth of regulatory authority. In principle, regulatory authorities can be *industry-specific* with separate agencies for gas, water, electricity, and so on - as in Bolivia, Israel, Kenya and the Russian Federation. They can be *sector-specific* with separate agencies for groups of related industries, such as for gas and electricity combined - as in the UK, Sudan and Swaziland. Or they can be *multi-sectoral* with a single regulatory agency for all or most infrastructure sectors - as in state-level regulators in the United States and national regulators in The Bahamas, Eritrea, and Gambia.

In principle, a multi-sectoral agency offers advantages over the alternatives, especially for small and resource scarce developing countries. It can also be argued that they reduce the risks of regulatory capture by the industry. Sectoral or multi-sectoral regulators pool

1

regulatory resources (regulatory economists and lawyers, for example) and also save on high regulatory costs. However, multi-sectoral regulators also have some potential disadvantages, e.g. on reduced industry knowledge and understanding. In addition, the political undermining of a single multi-sectoral regulator may be easier. Indeed, political or company capture of a single multi-sectoral regulator is likely to be more damaging than for one of a number of separate regulators.

3.2. Independence and Accountability

Independence and professionalism imply a more secure framework for providing stable and predictable regulation. Many electricity/energy regulatory institutions in developing countries such as Gambia or Trinidad and Tobago have moved away from direct central government funding to licence fees or levies on regulated companies or consumers.

Another aspect of regulatory independence is over the choice of an independent remuneration scale, and the ability of the regulatory institution to recruit staff without any interference from the government. This may involve the freedom to move away from a civil service pay scale.

3.3. Regulatory Design in Developed Countries

The record of OECD economies in regulatory reform is mixed. Different economies have progressed at a different pace, with the United Kingdom and Norway probably the pathfinders. The United States has assumed a heterogeneous regulatory approach based on a Federal Regulatory Commissions for inter-state issues (based on legislation originating in the Federal Power Act of 1935) with multi-sector regulatory commissions in each state following a variety of approaches (for instance the California Public Utilities Commission largely originates from the state's Public Utilities Act of 1912).

The UK electricity and gas regulator, Ofgem, is likely to continue with high (but falling) staff levels as is evident from the recently published corporate plan (Ofgem, 2002).

Ofgem's total number of professional staff employed, of 197, as at year 2000 seems very large from a developing country perspective. However, there are some regulators in our sample with staff numbers far exceeding this level. For instance, the multi-sectoral Public Utilities Commission of California employs more than 600 professional staff, although it regulates only about half the number of customers as Ofgem (although it does regulate more sectors).

There is a considerable amount of variation in the design and scope of regulation in developed countries, and there is a tendency for regulation to become more complex involving network access and pricing issues. In contrast, in many small developing countries regulation is usually more basic and often limited to regulating final retail tariffs (e.g. Nigeria). For developing countries, the design and limited scope of regulation is, in practice, largely determined by the restricted supply of trained manpower and/or low budget allocations form the government.

3.4. The Case of Developing Countries

Developing countries have been late entrants in the move toward liberalisation, but are quickly catching up. Indeed, some countries in the Latin America and Caribbean region, such as Argentina, El Salvador, Peru and Mexico, have in recent years made attempts (or are currently trying) to implement major economic deregulation initiatives in electricity and other utility service industries, although many do not seem to have had an easy ride due, not least, to difficult macroeconomic conditions.

For developing countries and the countries of Central and Eastern Europe and the CIS, the issue of the supply of sufficient regulatory experts can be critical as to whether regulation can, in practice, effectively be separated from government policy and from company management (i.e. can avoid the twin dangers of ministerial interference and regulatory capture). If it cannot be so separated, the question then arises as to the sustainability of unbundled, commercialised and privatised provision of telecom, electricity and other infrastructure services (Stern, 2001).

Most small developing countries have very few professional staff to support an effective regulatory institution e.g. because of severe competition over scarce human resources. Hence, Kenya, Namibia and Uganda all have fewer than 10 professional staff each in their multi-sector regulatory institutions. Low income and small countries have less choice both on the structure and on the form of regulation as they are more likely to be resource-constrained, particularly in professional human capital. In consequence, low income and small developing countries are more likely – at least in principle – to benefit from multi-sectoral institutions for utility regulation.

4. Model Specification

4.1. General Issues in Modelling Human Resource Requirements

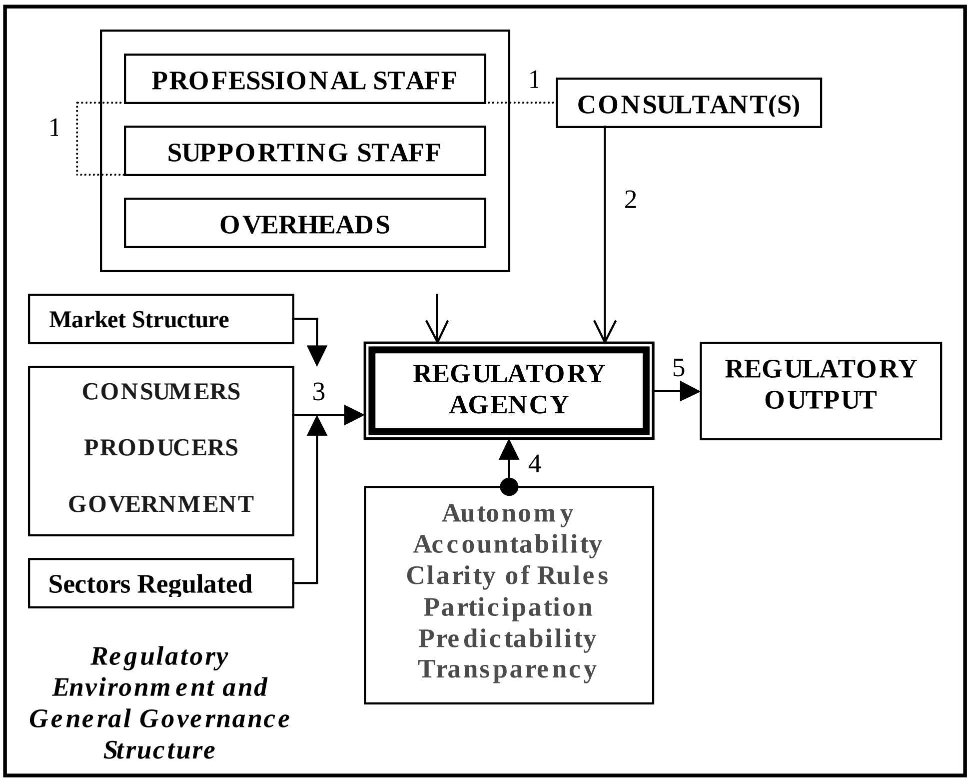
The core concept of our model is summarised in Figure 1. Here, we briefly explain the ‘links’ in the diagram.

Links numbers 1 and 2 represent the relationships between the number of locally available professional staff and foreign consultants and non-professional staff. In a number of countries, foreign professionals substitute for short-term scarce local capability (e.g. Botswana.). It may also happen that, in many developing countries, cheaper non-professionals are substituted for professionals (e.g. Sudan). (Note that substitution possibilities are limited, particularly for decision-making regulatory bodies, which have to follow defined legal processes).

Link number 3 represents the major cost drivers of the regulatory agency. The agency is accountable to the consumers, and has to balance their interest against the two other groups, viz., producers and the government.

The size of the regulatory agency in terms of total staff numbers is primarily a function of the size of the two main groups (customers and regulated companies), via their basic characteristics (such as the actual amount of product or services sold, or the degree of market power held by the regulated companies). For instance, it is clear that the larger the number of consumers, the larger will be the number of staff needed by the regulatory institution. This is explained by the very nature of regulatory activity e.g. in handling consumer concerns and complaints.

Figure 1: Schematic Presentation of Regulatory Activity



The size of the regulatory agency *may* be inversely related to the number of companies (due to competition in networks, or probably due to more viable use of incentive regulation). However, more regulated companies also usually imply that the regulator has more licences to deal with, more analyses of companies' performance and accounts, and greater effort is likely to be required to implement incentive regulation. In addition, greater regulatory complexity (e.g. arising from regulation of competitive companies using monopoly networks or more interconnected regional franchise companies) is also likely to increase the expected number of staff, particularly professional staff. The cross-section analysis in this paper provides only tentative conclusions on this issue. (See Section 6 below.)

Our paper also focuses on number of electricity companies regulated; unfortunately we do not have information regarding non-electricity businesses that are also regulated (by the multi-sectoral regulators in our cross-section of countries) and which also use scarce professional resources.

Link number 4 in Figure 1 relates to the perceived essential characteristics of the regulatory agency as explained in section 2.1 above. We have deliberately excluded a detailed description of the quantity and quality of the output of the regulatory agency since we only aim at estimating the human input requirement of the regulatory institution relative to the complexity and size of the system being regulated.

The operation of regulation lies within the country's broad economic, social and regulatory environment. The operating (economic and regulatory) environment influences the extent to which the six 'essential characteristics' (discussed in section 2) are taken into consideration at the design stage. The operating environment also impacts on the whole process of regulation, from the way that staff recruitment is conducted to the manner in which customer complaints are actually addressed.

4.2. The Model

The schematic presentation in section 4.1 above allows us to write a model of staff as follows:

(1) ***$Staff_i$ = f (System Complexity, Economic Environment, Regulatory Environment,***

where, *$Staff_i$, = total number of staff (or professional staff) employed in the electricity regulator in Country i and*

(2) *System Complexity = g_i (Number of Customers, Number and Size of Companies, Number of Sectors Regulated)*

(3) *Economic Environment = h_i (Per Capita GDP, Supply of highly educated labour)*

(4) *Regulatory Environment = i_i (Corruption level, Governance, Age of agency, Funding Source)*

In Table 1, we provide a list of variables derived from equations 1-4 above. In the next section we explain each group of variables and provide some explanation on the expected sign of each coefficient in the list of variables used in our regression analyses.

Table 1: Variable List

VARIABLE	DESCRIPTION	SOURCE	Expected Sign of STAFF	Expected sign of PROF

Dependent Variables				
STAFF	Total number of staff employed in regulatory institution	Survey		
PROF	Number of professional staff in regulatory institution	Survey		
System Complexity				
NCUSMN	Number of customers (in million)	Survey	+	+
NCOMP	Number of regulated companies	Survey follow-up	+	+ or ?
GCAP	Generating capacity (MW)	Survey	+ or ?	+ or ?
SECTORS	Number of sectors regulated by the agency	Survey	+	+
SSMN	Units supplied (million) MWh (units sold in case supplied not reported)	Survey	+	+
Economic Environment				
PCGDP	GDP per capita at 2000 constant dollars	WDI[2]	+	+
POP	Population Size (Million)	WDI	+	+
POSTSEC	Percentage attaining tertiary level qualifications[3](TERTED) *times* population size	UNESCO	?	+
Regulatory Environment				
CORRUPT	Corruption index (10 = highly clean, 0 = highly corrupt)	Transparency International	?	?
REGENV	Index of regulatory environment	Kauffman (1999)	?	?
CSERV	Dummy variable (civil service pay=1, otherwise=0)	Survey	+	– or ?
FUNDING	Source of finance of the regulatory institution: dummy (government or central budget funding=0, otherwise = 1)	Survey	+ or ?	+
ORGTYPE	Organisation type dummy (autonomous=1, otherwise=0)	Survey	–	+ or ?
REGTYPE	Dummy (performance-based=1 ; otherwise=0)	Survey	?	?
JURISD	Dummy variable (national jurisdiction = 1, provincial=0)	Survey	+	+
YRS	No. of years (to survey date) since electricity/regulatory Act was passed DummyY1 (YRS < 2 = 1, otherwise=0) DummyY2 (2 ≤YRS ≤ 5 = 1; otherwise = 0) DummyY3 (5 < YRS ≤ 10 = 1; otherwise = 0) DummyY4 (YRS > 10 = 1; otherwise = 0)	Survey	+	+ or ?
Interaction and Other Variables				
SECTNCUS	NCUSMN*NSECTORS	Survey	+	+
DENSE	SSMN/NCUSMN	Survey	?	?

4.2.1. System Complexity

We would expect system complexity to be the main direct driver of staff numbers. The complexity variables also define the scale or size effect on regulatory staff. We might expect there to be evidence of substantial fixed cost effects and related economies of scale in regulatory agencies – these will particularly penalise small developing countries. To

[2] World Development Indicators of the World Bank downloaded from World Bank's Web Site http://devdata.worldbank.org/data-query/.

[3] Percentage of children starting primary school who eventually attain Grade 5 (UNESCO, 1999).

reduce multi-collinearity between size variables (given that number of customers is usually highly correlated with the units supplied or with generation capacity), we identify only four size variables (or at least two, to proxy for complexity) and then use some interaction variables.

4.2.2. Economic Environment

We would expect the level of per capita income (PCGDP) and population (POP) to be positively correlated with number of regulatory staff and both the supply and demand for regulation is increasing in these variables. However the sign on the percentage in post-secondary education (POSTSEC) is difficult to predict. On the one hand, more effective regulation may yield higher economic returns in low-income countries – particularly where there is a poorly educated and possibly more corrupt society; but, conversely, there are more limited financial resources to employ professional staff and many competing (and high-paying) uses for such staff

4.2.3. Regulatory Environment

The general regulatory environment in a country can impact on the way regulatory institutions are initially designed. The social environment and general institutional endowment of the country can also significantly affect the quality and commitment of staff in regulatory institutions. CORRUPT (index of government corruption) is an indicator of the distortion of economic and financial incentives which reduces the efficiency of government and business by enabling people to assume positions of power through patronage rather than ability, and it introduces instability into the political process. The Corruption index ranges from 10 (highly clean) and 0 (highly corrupt).

Similarly, the efficiency and integrity of the regulatory environment (REGENV) determines the ability of the regulatory body to rely on impartial and independent recruitment and training. It also defines to a considerable extent the state of governance of the country. The Index used is from Kauffman et al. (1999)[4].

The use or otherwise of civil service pay scales (CSERV), the source of funding (FUNDING) and its autonomy or otherwise from government control (ORGTYPE) relate to the extent to which the regulatory agency is constrained directly or indirectly by central government. We might expect non-civil service salary scale, non-government funded, autonomous regulators to have more freedom to recruit extra staff.

The type of regulation (REGTYPE) employed by a regulator relates to its degree of sophistication. We assume that price-cap (or any variant of a performance-based incentive regulation) is, in principle, superior to rate of return regulation, following for example, Braeutigam and Panzar (1993). However, whether performance-based regulation requires more or fewer regulatory staff is not obvious in the literature, but there is a feeling that it would require a higher proportion of professionally qualified ones. For this reason, small and low-income countries with limited regulatory resources are sometimes advised to avoid high-powered incentive regulation (see Levy and Spiller, 1996).

An important variable of interest in our analysis is the number of years since an electricity Act was passed or regulatory legislation came into force that legitimised the existence of the regulatory institution. In Table 1, this is described by the variable YRS and it is used as an indication of the organic growth structure of regulatory institutions. We believe that the number of years is directly related to the level of staff employed, given that regulation become more entrenched and the scope of regulatory functions tends to become larger over time, perhaps because of 'regulatory creep' (or, for newly established regulatory agencies, success in building up the agency and in recruitment.

4.3 Estimation of the model

[4] www.worldbank.org/wbi/governance/gov_data.htm is the source of the data from which it was downloaded. It gives aggregated indices based on 6 indices of governance. The governance indicators reported reflect the statistical compilation of perceptions of the quality of governance of a large number of survey respondents in industrial and developing countries, as well as non-governmental organisations, commercial risk rating agencies, and think-tanks during 1997 and 1998. REGENV is measured in units ranging from about -2.5 to 2.5, with higher values corresponding to better governance outcomes.

In the absence of *a priori* information on the functional form of the cost function for regulation we estimate equation (1) above using a translog functional form (following Christensen et al., 1971). This involves using a log-log specification, including squares of the system complexity and economic environment variables. Such a specification assumes a reasonably flexible functional form, which is appropriate given the complex nature of the underlying production function. In addition, this specification corresponds to the standard functional form for estimating cost functions. Our model is best thought of as providing a regulatory cost function for countries wishing to establish an electricity industry with substantial elements of private finance/investment *and/or* a significant degree of competition in generation or supply.

We estimate separate equations with (natural log of): (a) STAFF and (b) PROF as dependent variables. In section 6 we denote the log variables with the prefix L.

We might expect that the coefficient estimates and key elasticities may well be different for developed from those for developing countries. Thus, we estimate separate cost equations for the full sample and for each of the sub-samples of developed and developing countries.

5. Data

A one-page postal questionnaire survey was used to collect the original data for the study. This was carried out in two phases: the first series was carried out in February 2001 administered on 150 countries. 54 replies were received (33% response rate), which may be considered good for this type of primary data collection by post. There were telephone follow-ups to the questionnaires but most countries were unable to provide additional information, except on the number of companies regulated.

A second attempt at carrying out a similar survey was made in February through March 2002. A total of 30 questionnaires sent out mainly by e-mail to US public utilities commissions, regulatory institutions in Eastern European, South Africa and Tasmania, returned 8 positive replies. Other data had to be collected from additional phone follow-ups and Internet searches, and also some additional data on regulators published in World Bank (2001).

We finally obtained usable data for 60 countries (see Appendix 1). There are important issues of data quality[5]. Even after cross-checking of some of the responses, there still remains some doubt on some of them. (For instance, Cambodia's total of 105 staff seems very large, though this could genuinely reflect a large number of non-core service staff.) In addition, it seems that countries vary in terms of the implicit skill levels used in the definition of "professional" when reporting their numbers of professional staff. These imply that both the results and inferences from the reported empirical estimates should be treated with some degree of caution given the possible idiosyncratic interpretation of some of the questions in the survey questionnaire.

Table 2 below provides some descriptive statistics comparing developing and developed countries. Appendix 1 lists the full dataset.

For the purpose of our analyses, developing countries include all the countries with a per capita GDP of less than US$ 4,300 in 2001, which conforms to World Bank definitions (WDI, several years). This allows us to have a split of the overall sample into two nearly balanced samples of 34 developed countries and 26 developing ones (see Appendix 1). The high mean population size for developing countries is due to the inclusion of India in the sample.

A quick inspection of the summary statistics indicates, not surprisingly, a large gap between developing and developed countries, with the latter having higher mean professional and total staff numbers (though similar median staff numbers) and also having much larger electric systems. Variables relating to both the regulatory and economic environment also indicate a significant difference between the two groups, with developed

[5] The reported number of companies regulated by regulatory institutions is assumed to be for electricity businesses only (as per the questionnaire requirement). There is no guarantee that the reported figures are

countries indicating a both a less corrupt regulatory environment as well as a longer time period of existence of utility regulatory institutions.

accurate and to what extent the companies are actually subject to regulation. Furthermore, we do not have the number of non-electricity companies regulated.

Table 2: Descriptive Statistics

	Developed Countries					Developing Countries				
	Mean	***SE***	***Median***	***Min***	***Max***	***Mean***	***SE***	***Median***	***Min***	***Max***
Total Staff	130.88	33.39	51.00	5.00	946.00	72.19	13.98	51.00	6.00	285.00
Professional Staff	81.06	22.19	31.50	2.00	600.00	47.77	10.74	36.50	4.00	232.00
Number of Customers	5.50	1.16	2.98	0.10	26.25	11.23	7.49	1.03	0.03	195.99
Number of Companies	73.35	44.10	5.50	1.00	1500.00	68.96	48.94	5.00	1.00	1276.00
Generating Capacity (MW)	21316	3914	13444	186	110000	16250	8533	2270	28	203803
Number of Sectors	3.00	0.27	3.00	1.00	6.00	1.96	0.27	1.00	1.00	6.00
Units Supplied (mn)	141.84	62.38	48.00	0.79	2112.00	24.34	11.57	4.35	0.12	292.05
Per Capita GCP (000)	19.33	1.41	20.82	4.47	32.72	1.60	0.28	1.06	0.07	4.22
Population (mn)	20.27	5.64	8.46	0.27	167.97	65.42	37.97	16.95	0.10	997.52
Percentage attaining tertiary level qualifications	53.74	4.44	49.85	8.20	87.30	15.17	2.56	11.75	0.70	49.00
Corruption Index	7.23	0.28	7.60	3.50	9.50	2.95	0.23	2.75	1.00	5.40
Index of Regulatory Environment	0.91	0.04	0.90	0.13	1.21	0.19	0.10	0.19	-0.83	1.23
Dummy: Civil Service Pay	0.76	0.07	1.00	0.00	1.00	0.54	0.10	1.00	0.00	1.00
Funding Type	0.74	0.08	1.00	0.00	1.00	0.62	0.10	1.00	0.00	1.00
Organisational Type	0.71	0.08	1.00	0.00	1.00	0.58	0.10	1.00	0.00	1.00
Type of Regulation	0.50	0.09	0.50	0.00	1.00	0.42	0.10	0.00	0.00	1.00
Jurisdiction	0.56	0.09	1.00	0.00	1.00	0.96	0.04	1.00	0.00	1.00
Years	20.24	5.00	5.50	0.50	87.50	6.85	2.69	4.00	0.50	72.50
Density (Units per Customer)	32.15	7.12	16.52	0.92	163.73	4.97	0.60	4.97	0.17	14.88

We note here that the average number of sectors regulated by the agencies in developing is 2.0 whereas it is 3.0 for developed countries (though the developed country average is increased by the presence of several state level US regulators with a large number of sectors regulated). This is counter to our expectations and to standard regulatory policy advice. It suggests that the developing countries may not be making best use of multi-sector regulators. We discuss this issue further in Sections 6 and 7.

Given the similar median staff numbers in developing and developed countries combined with the lower median number of sectors regulated and customer numbers for developing countries, Table 2 suggests that the median number of staff per million customers per sector regulated is substantially higher for the 26 developing countries in the dataset than it is for the 34 developed countries in the dataset. This is strongly indicative of the possibility that there may be significant fixed costs to regulation which developing economies may not be able to mitigate. We discuss this further in Section 6 below.

6. Results

6.1 Preliminary Data Analysis

Before presenting our regression analysis of the determinants of costs it is useful to examine some of the simple staff per million customers per sector ratios for the sample countries. This allows us to take a preliminary view on whether there are any significant differences between the characteristics of regulatory agencies in developed and developing countries.

Table 3 shows that most developing countries have a very high ratio of STAFF (and PROF) per customer per number of regulated sectors.

Table 3: Staff per Regulated Customers per Number of Sectors Regulated

Developed Countries			Developing Countries		
	Total Staff per million customers per sector regulated	Professional Staff per million customers per sector regulated		Total Staff per million customers per sector regulated	Professional Staff per million customers per sector regulated
Argentina	11.49	5.75	Albania	21.31	6.56
Australia-IPART	4.17	2.92	Armenia	20.39	16.86
Australia-Tasmania	17.49	13.45	Bolivia	49.67	39.74
Australia-Victoria	3.10	0.55	Cambodia	774.98	708.56
Austria	13.00	7.00	Costa Rica	21.44	12.86
Barbados	49.35	19.74	Dominican Republic	29.78	20.84
Belgium	4.08	2.91	Ecuador	23.69	15.11
BRAZIL-Sao Paulo	2.54	1.53	El Salvador	26.98	17.67
Canada_NEB	4.59	1.57	Etiopía	45.26	22.63
Canada_Newfoundland	13.02	7.01	Grenada	64.63	53.86
Canada_OEB	18.33	10.00	India_CERC	0.32	0.14
Czech Republic	4.42	3.09	India_Orissa	1.51	0.69
Denmark	29.82	20.81	Jamaica	19.56	13.27
Hawaii	19.57	10.08	Kenya	49.44	17.80
Hong Kong	2.92	2.50	Lithuania	7.95	6.82
Hungary	5.75	5.29	Malaysia	13.64	3.82
Ireland	18.57	8.17	Namibia	98.77	43.21
Israel	9.66	6.28	Nicaragua	103.56	74.80
Mexico	3.65	2.09	Nigeria	16.95	7.26
Netherlands	17.49	15.40	Peru	15.21	10.65
Northern Ireland	5.07	3.49	Philippines	29.20	22.07
Portugal	9.45	7.37	Poland	3.77	3.07
Spain	2.90	1.95	Romania	3.58	3.28
Sweden	2.83	2.36	Russia	3.80	3.80
The Bahamas	42.23	16.24	Sudan	8.33	2.78
Trinidad and Tobago	13.73	8.45	Uganda	70.18	29.24
United Kingdom	6.27	3.75			
USA-California	12.22	7.75			
USA-Delaware	12.84	10.63			
USA-Florida	9.10	6.60			
USA-Kansas	31.34	7.39			
USA-New York	98.86	74.15			
USA-North Carolina	2.35	0.97			
USA-Wisconsin	22.02	14.88			
Mean	***15.42***	***9.18***		***58.61***	***44.51***
Standard Error	***3.19***	***2.17***		***29.18***	***26.79***
Median	***10.58***	***6.80***		***21.37***	***14.19***
Minimum	***2.35***	***0.55***		***0.32***	***0.14***
Maximum	***98.86***	***74.15***		***774.98***	***708.56***

This suggests that small developing countries do suffer from a high ‘fixed cost’ element in regulation. Indeed many developing countries have been reluctant to set up independent electricity sector regulators precisely because of the high fixed costs of regulation relative to the small size of their electricity sectors.

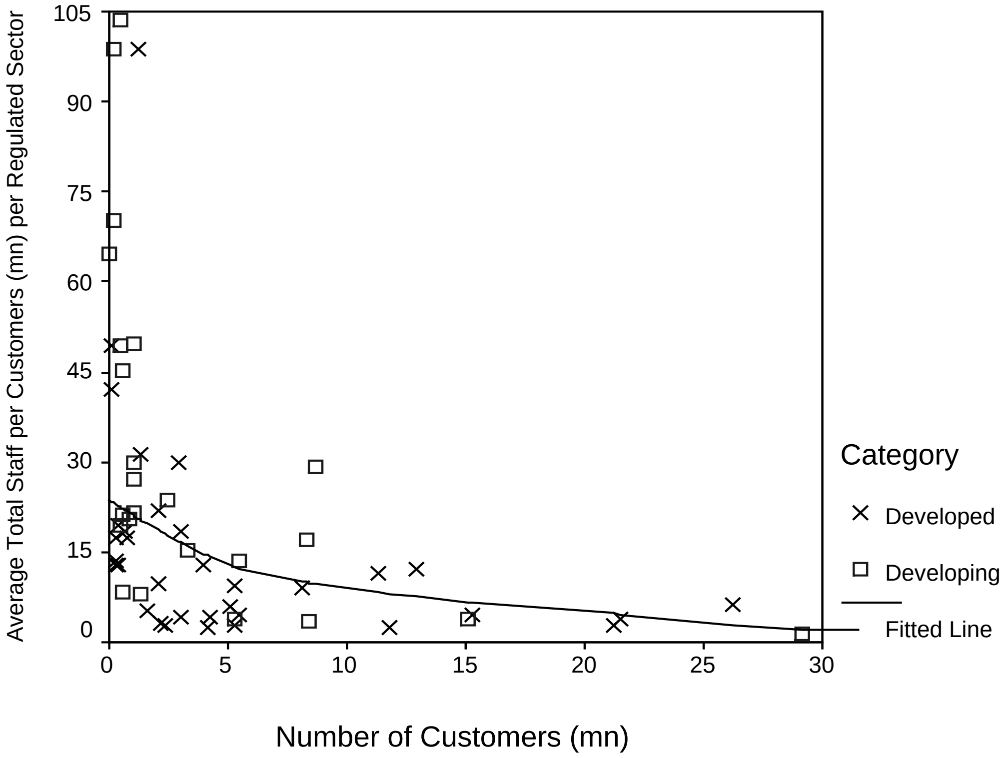
A major reason for the high staff per customer per regulated sector ratio in developing countries is their much smaller level of connections as reflected in the low number of electricity customers relative to population. Indeed it is striking that the summary statistics for staff per population per regulated sector show almost identical median values when comparing the developing and developed country samples (see Table 4). However, Table 4 also shows the particular difficulties faced by small developing countries (viz Grenada and Namibia).

Table 4: Staff per Population Size per Number of Sectors Regulated

Developed Countries			Developing Countries		
	Total Staff per million population per sector regulated	Professional Staff per million population per sector regulated		Total Staff per million population per sector regulated	Professional Staff per million population per sector regulated
Argentina	3.55	1.78	Albania	3.85	1.19
Australia-IPART	1.91	1.34	Armenia	4.55	3.76
Australia-Tasmania	9.21	7.09	Bolivia	6.14	4.92
Australia-Victoria	1.40	0.25	Cambodia	8.93	8.17
Austria	6.43	3.46	Costa Rica	6.27	3.76
Barbados	18.73	7.49	Dominican Republic	3.58	2.51
Belgium	1.71	1.22	Ecuador	4.67	2.98
BRAZIL-Sao Paulo	0.18	0.11	El Salvador	4.71	3.09
Canada_NEB	2.30	0.79	Etiopía	0.41	0.21
Canada_Newfoundland	0.11	0.06	Grenada	20.62	17.18
Canada_OEB	1.80	0.98	India_CERC	0.06	0.03
Czech Republic	2.37	1.65	India_Orissa	1.20	0.54
Denmark	16.59	11.58	Jamaica	3.59	2.44
Hawaii	6.25	3.22	Kenya	0.85	0.31
Hong Kong	1.04	0.89	Lithuania	2.84	2.43
Hungary	2.91	2.68	Malaysia	3.30	0.92
Ireland	3.33	1.47	Namibia	9.41	4.12
Israel	3.28	2.13	Nicaragua	9.15	6.61
Mexico	0.81	0.47	Nigeria	1.13	0.48
Netherlands	0.79	0.70	Peru	1.98	1.39
Northern Ireland	4.73	3.25	Philippines	3.42	2.59
Portugal	5.01	3.90	Poland	1.47	1.20
Spain	1.56	1.05	Romania	1.34	1.22
Sweden	1.69	1.41	Russia	0.14	0.14
The Bahamas	14.44	5.56	Sudan	0.17	0.06
Trinidad and Tobago	3.35	2.06	Uganda	0.56	0.23
United Kingdom	2.76	1.66			
USA-California	4.65	2.95			
USA-Delaware	6.16	5.10			
USA-Florida	4.62	3.35			
USA-Kansas	15.77	3.72			
USA-New York	6.32	4.74			
USA-North Carolina	1.20	0.50			
USA-Wisconsin	8.62	5.83			
Mean	***4.87***	***2.78***		***4.01***	***2.79***
Standard Error	***0.83***	***0.43***		***0.86***	***0.71***
Median	***3.30***	***1.92***		***3.36***	***1.91***
Minimum	***0.11***	***0.06***		***0.06***	***0.03***
Maximum	***18.73***	***11.58***		***20.62***	***17.18***

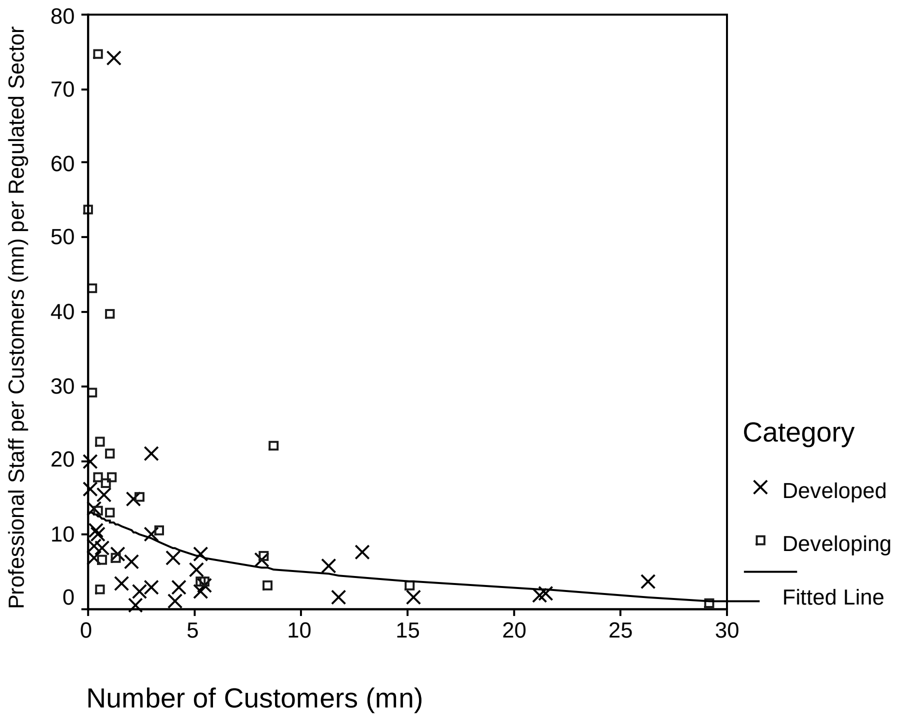
The fixed cost element is well illustrated if we plot the relationship between staff per million customers per sector regulated against number of customers. This effectively plots out the average cost curve for regulation. Figures 2 and 3 give the results of this exercise for total staff and professional staff. We can see that there is an average cost curve[6] for the full sample that slopes downwards (hence a high fixed cost element) and that developing countries are concentrated in the relatively steep portion of the curve (indeed mostly lie above the fitted line).

Figure 2: Average Regulatory Cost (Total Staff)



[6] The Lowess method (from SPSS software package) is used to fit the relevant curves in Figures 2 through 5. This method uses an iterative locally weighted least-squares method to fit a curve to a set of points. Our curves fit 90% of data points based on 3 iterations.

Figure 3: Average Regulatory Cost (Professional Staff)



We can further illustrate the relative human resource burden that regulation puts on a human resource poor developing country by examining the relationship between staff numbers per sector divided by population times percentage in post-secondary education (i.e. $Staff_i$/NSECTORS/POSTSEC) and customer numbers. This gives us a measure of the size of the regulatory agency relative to the pool of qualified staff. Figures 4 and 5 plot the results of this exercise for total staff and professional staff[7]. Once again we can see that there is high fixed resource burden - illustrated by the downward sloping nature of the fitted curve - and that developing countries are concentrated in the relatively steep portion of the curve (and mostly lie above the fitted line).

[7] We normalise the staff human resource burden figures relative to their respective mean values.

Figure 4: Human Resource Burden (Total Staff)

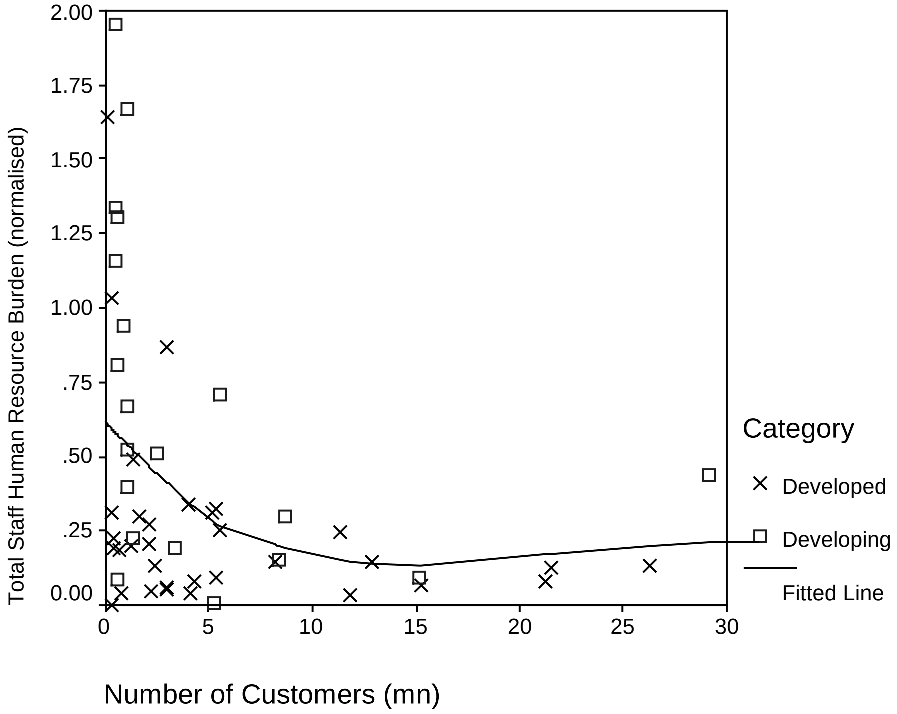
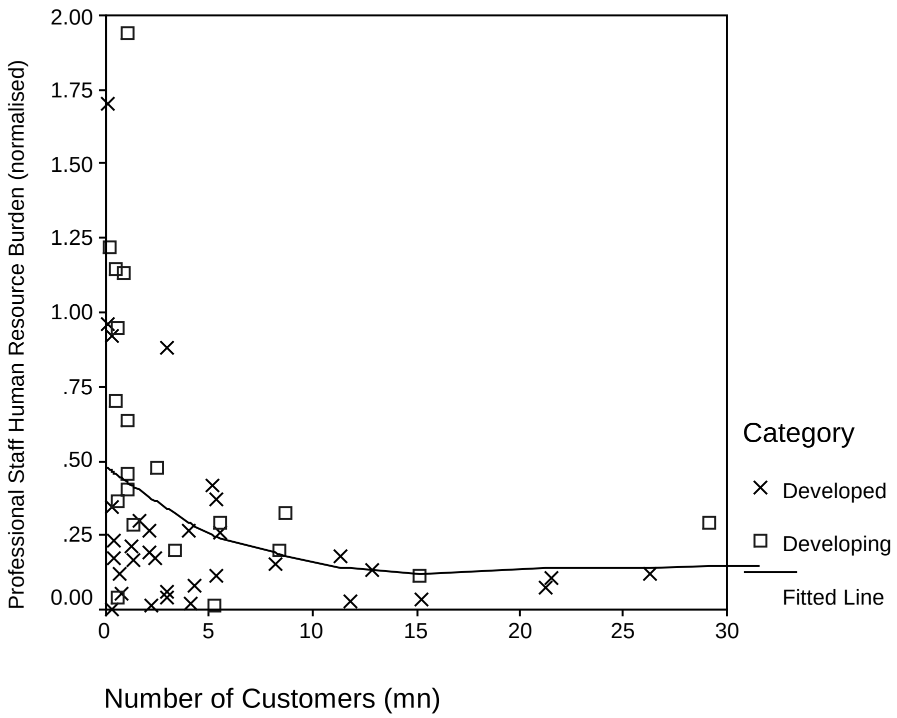


Figure 5: Human Resource Burden (Professional Staff)



6.2. Regression Results for Total Numbers of Regulatory Staff

Our regression models were run using heteroscedastic-corrected (HCSE) ordinary least squares (OLS). In Table 5 we present the results of regression analyses of (log of) total staff (STAFF), as defined in equations (1) to (4) in section 4.2 above, based on the full sample of 60 utility regulatory institutions. Model S1 reports our preferred equation for the full sample of 60 countries, Model S2 the preferred equation for the 34 developed countries and Model S3 is the regression of the functional form in Model S2 for 26 developing countries, and the preferred equation for these developing countries is given by Model S4.

Table 5: Regression Results for Log of Total Number of Staff Employed by Regulatory Institutions

LSTAFF	Model S1	Model S2	Model S3	Model S4
Number of Observations	60 Countries	34 Developed Countries	26 Developing Countries	26 Developing Countries
(Constant)	-11.8156 (9.2053)	1.9342 (3.3250)	-2.0061 (2.2997)	1.1358 (1.1665)
LNCUSMN	2.4335* (1.4321)	0.4713*** (0.1440)	0.2786 (0.1911)	
$LNCUSMN^2$	-0.0697 (0.0460)			0.0134** (0.0045)
LNCOMP	0.4626*** (0.1516)	0.4492** (0.2133)	-0.0289 (0.2470)	
$LNCOMP^2$	-0.0508** (0.0235)	-0.0600* (0.0314)	0.0356 (0.0394)	0.0196 (0.0132)
LGENCAP		-1.3598* (0.7043)	0.6244 (0.6265)	
$LGENCAP^2$	-0.0199** (0.0095)	0.0738* (0.0404)	-0.0500 (0.0401)	-0.0285*** (0.0094)
LSECTORS	-2.5313* (1.4185)	0.5081** (0.2255)	0.2316 (0.2864)	-6.4476*** (2.0744)
LPCGDP	-0.2211** (0.1085)			
LPOSTSEC	-0.7197 (0.5422)			
$LPOSTSEC^2$	0.0580 (0.0358)	0.0107 (0.0086)	0.0039 (0.0165)	
REGENV	0.8322** (0.3167)			
CSERV				-0.3923 (0.2454)
FUNDING		0.3938 (0.2612)	-0.5855 (0.4086)	-0.6926** (0.2959)
ORGTYPE	-0.6432*** (0.2053)	-1.0143*** (0.2629)	0.1480 (0.4582)	
REGTYPE	-0.1730* (0.0921)			
JURISD				2.3861** (0.9168)
DummyY2				0.4499 (0.3134)
DummyY3				0.6676* (0.3667)
DummyY4				1.7419*** (0.4483)
LSECTNCUS†	0.2149** (0.0987)			0.4670*** (0.1493)
LNDENSE				-0.4627* (0.2083)
R^2	0.7441	0.8467	0.6006	0.8522
R^2 Adjusted	0.6718	0.7892	0.3760	0.7157
F (.,.)	10.2901*** (13,59)	14.7284*** (9,33)	2.6738** (9,25)	6.2443*** (12,25)

† LSECTNCUS=LSECTORS*LNCUSMN

*** Significant at 1%, ** Significant at 5%, * Significant at 10%, Standard error in parentheses.

As is apparent in Table 5, a modified translog-cost equation is used whereby the dependent variable and most explanatory variables are in natural logs. Squared values of explanatory variables are also used together with one log-log interaction variable.

Model S1 is our preferred regression equation for the full sample with the highest R-bar squared value and is also the result of stepwise regression (whereby each variable with the lowest t-value was successively rejected until we ended up with few variables that explain nearly the same amount variation in the dependent variable LSTAFF).

In Model S1, the two important size variables (number of customers and the number of regulated companies) have the expected positive signs and are also significant. The 'economic environment' variable per capita GDP has a negative sign indicating that richer countries all being equal have lower staff numbers (perhaps due to greater efficiency). The 'regulatory environment' variable REGENV is also statistically significant implying that a less corrupt regulatory environment is associated with more staff. ORGTYPE and REGTYPE are significant and have negative signs. This indicates that autonomous regulatory institutions with performance-based regulation tend to have *fewer* staff. Model S1 has an R^2 of 74% (and adjusted value of 67%) and is a relatively good fit (as reflected in the F Value).

Model S2, is the best fitting equation for developed countries only. It suggests that the nature of the relationship between the system complexity, economic environment, and regulatory environment, and total staff employed is different from what the above results have suggested so far. Installed capacity is a more influential variable in the model compared to model S1. The number of sectors regulated (SECTORS) is also significant and positive at 1%, although this seems primarily to be due to the large multi-sectoral regulators in the United States. FUNDING has a positive coefficient (although not statistically significant) suggesting that licence fee or levy funding increases staff numbers. ORGTYPE is significant but has a negative sign. This suggests that, in developed countries, licence fee or levy funded non-autonomous regulators have *more* staff than licence fee or levy funded autonomous regulators.

Model S2 has an adjusted-R^2 of 79% (and an $F_{(9,33)}$ value of 14.7). This shows not only a good fit – and superior to the larger 60 country sample - but also indicates the extent to which the variability in data is increased when the developing country sample is combined with the developed country sample.

These results strongly suggest a well-determined model for staff numbers in developed countries and a relatively less well-determined model for staff numbers in developing countries. This is confirmed in the results for Models S3 and S4 reported and also for the regression results for professional staff reported below.

Model S3, estimates the regression equation for developing countries only using the functional form of S2. This allows differences between the shapes of the cost functions to be easily observed. The resulting equation confirms the significant difference in the nature of the regulatory cost function between developed and developing countries. The adjusted-R^2 is lower at 38%, indicating much greater variance around the estimated cost function, and the $F_{(9,25)}$ value is only 2.7 and none of the individual variables is significant even at the 10% level. The parameter values are also significantly different between S2 and S3. For instance, looking at the size variable LNCUSMN the difference in the parameter values is statistically significant at the 5% level (using a one tailed t test).

Model S4 represents the best unrestricted equation for developing countries. This demonstrates clearly the point about significant differences between the regulatory cost functions between the two samples. S4 is very different from S3 but fits the data much better as shown in an adjusted-R^2 of 72% and an $F_{(12,25)}$ value of 6.2. However, the only significant system complexity coefficients are for (the square of) generation capacity and the number of regulated sectors. The significant coefficient on JURISD arises at least in part from the large relative size of the Indian Federal regulator as against the State regulators. Finally, S4 shows that the age of the regulatory agency has a substantial impact on the number of staff employed in developing country electricity regulators – much more than for developed countries.

An interesting difference between S2 and S4 exist in the sign of the parameter on the FUNDING and ORGTYPE dummies. This indicates that regulatory institutions in developing countries with licence fee or levy funding and which are not autonomous of government have *fewer* staff (in contrast to the result for developed countries).

We performed a number of tests of the differences in functional form of the cost functions faced by developed and developing countries. These included investigation of the elasticities of staff numbers with respect to numbers of customers and number of units distributed. The most directly comparable equations are S2 and S3 in this regard. These indicate that the elasticity at median values for developing countries with respect to customer numbers is 0.47 using S2 and 0.28 using S3. However this difference is not statistically significant (given the large amount of noise in the data). More telling however are the very significant differences in the predicted total staff numbers for the sample of developing countries using equations S2 and S4. These predictions are reported in Appendix 3.[8]

6.3. Regression Results for Numbers of Professional Staff

In this section we follow the same principles as in the previous section 6.2, but we analyse the number of professional staff employed by regulatory institutions (PROF) and its determinants. Table 6 presents the results.

[8] The Spearman rank correlation coefficient indicates a very low correlations between the predicted values using S2 and S4 (0.149); this value is not significantly different from zero.

Table 6: Regression Results for the Log of Professional Staff Employed by Regulatory Institutions

LPROF	Model P1	Model P2	Model P3	Model P4
Number of Observations	60 Countries	34 Developed Countries	26 Developing Countries	26 Developing Countries
(Constant)	-18.8667* (11.0914)	-0.5136 (3.5276)	3.5874 (3.0849)	5.4588 (7.8526)
LNCUSMN	3.5840** (1.7284)	0.5601** (0.2285)	0.2415 (0.2001)	
$LNCUSMN^2$	-0.1081* (0.0553)			0.0143* (0.0067)
LNCOMP	0.4010** (0.1798)			-0.2718 (0.2378)
$LNCOMP^2$	-0.0398 (0.0277)			0.0969** (0.0357)
LGENCAP		-1.4255 (0.9366)	-0.8176 (0.7562)	1.2855** (0.5101)
$LGENCAP^2$	-0.0169 (0.0114)	0.1042* (0.0536)	0.0371 (0.0402)	-0.1044** (0.0351)
LSECTORS	-1.7684 (1.6762)	3.2496 (2.5219)	-5.6442* (2.9687)	
LPCGDP	-0.3236** (0.1277)			-3.3914 (2.5342)
$LPCGDP^2$				0.2608 (0.1836)
LPOSTSEC	-1.1438* (0.6578)			
$LPOSTSEC^2$	0.0835* (0.0434)			
REGENV	1.2000*** (0.3755)			
CSERV				-0.9495*** (0.3062)
FUNDING		0.8183*** (0.2567)	-0.8827* (0.4851)	-0.9493** (0.3921)
ORGTYPE	-0.6715*** (0.2447)	-1.2898*** (0.2807)	0.9755** (0.4506)	
REGTYPE	-0.1552 (0.1087)			
JURISD				3.4106** (1.1590)
DummyY2	0.3497 (0.2490)			0.9865** (0.4509)
DummyY3				1.0387* (0.5526)
DummyY4		-0.4307 (0.2793)	0.7470 (0.5732)	1.7040* (0.5719)
LSECTNCUS	0.1626 (0.1164)	-0.2004 (0.1708)	0.4275* (0.2090)	
LDENSE				-0.7043* (0.3381)
R^2	0.6960	0.8388	0.5920	0.8613
R^2 Adjusted	0.6014	0.7872	0.4000	0.6847
F (.,.)	7.3583*** (14,59)	16.2551*** (8,33)	3.0836** (8,25)	4.8773*** (14,25)

*** Significant at 1%, ** Significant at 5%, * Significant at 10%, Standard error in parentheses.

Model P1 is the preferred equation for the (log of) professional employment in electricity regulation, based on the sample of 60 regulators. Model P2 presents the result of the same exercise using the sample of developed countries and Model P3 applies the P2 functional form to generate results for our developing country sample. Model P4 represents the best fit for the developing country data without restricting the choice of variables in the equation.

The estimated coefficients on *both* the number of customers *and* the number of companies have the expected positive signs and are statistically significant in Model P1. While system complexity variables explain a considerable amount of variation in the number of total professional staff employed, ORGTYPE is also a significant explanatory variable with a negative parameter sign, implying that (cet par) autonomous regulators have *fewer* professional staff. This somewhat surprising result reflects that for our analysis of total staff numbers.

Model P2 gives another well fitting equation for developed countries. This indicates that the number of sectors and number of customers have the expected positive impact on professional staff. However, the number of companies is not statistically significant in P2. In general, the pattern of significant dummy variables is similar to the pattern observed in the overall staff equation S2.

Comparing Model P3, for developing countries, with Model P2, we see that once again there are major differences in the cost functions between developed and developing countries. Model P3 fits the data relatively poorly (adjusted-R^2 of 40% and an $F_{(8,25)}$ of only 3.08) compared to Model P2 (adjusted-R^2 of 79% and an $F_{(8,33)}$ of 16.3). The nature of the estimated cost function also differs substantially. For instance, there is a significant difference between the parameter value on LNCUSMN in P2 and P3, similar to the result we found in our analysis of total staff.

Model P4 confirms the significance of the differences between the developed and developing country cost functions by comparison with P2. There are significant differences in the signs on FUNDING, the year dummy (DummyY4) and other dummy variables. The unrestricted P4 again fits the developing country data better than the restricted P3 with an adjusted-R^2 of 68% and an $F_{(14,25)}$ value of 4.9.

In terms of system complexity, P4 provides coefficients that are statistically significant at the 5% level for generation capacity (and its square) and also for (the square of) the number of companies – unlike developed countries. Interestingly, imposing civil service pay scales has a highly significant negative impact (at the 1% level) in P4 on the number of professional staff employed in developing countries. This effect is not found in P2 or S4. As with total staff, P4 shows that the age of the regulatory agency has a substantial and statistically significant effect on the number of professional staff employed. In P2 (for developed countries), the only age effect is negative, albeit insignificant at the 10% level.

We note that in comparing P2 with P4 (as well as S2 with S4), the equations for developed countries clearly fit the data better, taking account of the differences in the number of degrees of freedom. We also observe significant differences in functional form. These results suggest that developed countries have better defined, but significantly different regulatory cost functions relative to those in developing countries

As for total staff we performed a number of tests of the differences in functional form of the cost functions faced by developed and developing countries. The most directly comparable equations are P2 and P3. These indicate that the elasticity at median values for developing countries with respect to customer numbers is 0.34 using P2 and 0.24 using P3. However this difference is not statistically significant (given the large amount of noise in the data). However there are the very significant differences in the predicted total staff numbers for the sample of developing countries using equations P2 and P4. These predictions are reported in Appendix 3.[9]

6.4. Discussion of Results in the Context of Developing Countries

We have demonstrated that:

(i) there are large fixed costs in electricity regulation for developing countries; and

(ii) the nature of the cost function is significantly different from that of developed countries.

These general results can readily be illustrated by some representative examples.

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[9] The Spearman rank correlation coefficient indicates a very low correlations between the predicted values using P2 and P4 (0.04); this value is not significantly different from zero.

Consider Sweden and Jamaica. They have regulatory agencies which are approximately the same size in terms of total staff (30 and 28) but the population of Sweden is more than 3 times that of Jamaica and the number of electricity customers 10 times as many. In addition, the Jamaican regulator is responsible for 3 sectors (including telecoms and water) unlike the Swedish regulator, which is responsible for 2 sectors only – electricity and natural gas. Clearly Jamaica has to spread more staff over a smaller electricity sector.

Evaluating the required number of staff at the mean and median values customer numbers, generation capacity and number of companies we find that the predicted numbers using the different equations are as in Table 7.

Table 7: Predicted Staff Numbers at Typical Values[10]

Category	Based on	Actual Total Staff	Actual Professional Staff	S2	P2	S3	P3	S4	P4
Developed	Mean	130	81	130	42				
	Median	51	32	53	34				
Developing	Mean	72	48			43	23	47	30
	Median	51	37			34	20	30	15

Table 7 indicates that using median values of the variables, a typical developing country regulator needs a total staff of between 30 and 34 total staff (using equations S3 and S4) compared to a developed country, which needs an estimated 53 staff. This is in spite of the median developed country having 3 times the number of electricity customers and three rather than two sectors to regulate. This clearly illustrates the nature of the high fixed resource cost facing small developing countries.

Our equations can also be used to suggest the number of staff required for countries that are not included in our current sample. For instance we predict staff numbers for three developing countries in Table 8 using the S4 and P4 regressions. The predictions indicate the reasonably large independent regulatory office that these relatively small (compared to developed countries) developing countries would require.

Table 8: Predicted Staff Numbers for Non-Sample Regulators[11]

[10] The mean and median values for developing countries were estimated excluding India CERC and Poland from the sample, being apparent 'outliers' in terms of characteristics. This is because India CERC contains ¾ of the total population of the developing countries sample and Poland contains ¾ of the total number of companies in the developing country sample. Together these give rise to a mean country with characteristics not very similar to any particular country.

	NCUSMN	NCOMP	GENCAP	PCGDP	KWh/Capita	Predicted STAFF (S4)	Predicted PROF (P4)
Zambia	1.816	1	2436	0.465	540	57	45
Sri Lanka	3.560	1	1600	0.856	255.3	48	26
Guatemala	2.073	17	1150	1.667	341.2	58	33

7. Conclusions

One major finding of this paper is that there is a very substantial 'fixed cost' element in regulation. This 'minimum staffing cost' incurred by regulatory institutions is needed to ensure it's the continuity and effectiveness of electricity regulatory agencies. The necessary minimum varies between countries or jurisdictions depending on the size of the system, regulatory and economic environments. However, even for small countries with limited electricity systems, our estimates suggest that the number of regulatory staff required is around 30 including 15 professional staff. This is a significant fixed cost for small, low-income countries.

We also find significant differences in the nature of regulatory cost functions between developed and developing countries. The cost equation for developing countries is much better defined than that for developing countries and the shape of the cost functions are significantly different. This suggests that many developing countries face a difficult struggle to establish an effective regulatory structure for the particular conditions that they face.

Although competition within the regulated industry is believed, eventually, to reduce the need for regulation (and hence the number of personnel required to conduct regulatory affairs), there is no sign of this happening as yet. Furthermore, regulation is becoming more challenging with rapidly changing structure of utilities often combining monopolistic elements with competitive segments of the industry. With this increasing complexity, regulation appears to require more rather than fewer professionals, but our results provide only weak support for this view.

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[11] The number of customers (NCUSMN) has been estimated using population (WDI) times the ratio of NCUSMN to population for other developing countries (equal to 0.18). The number of companies for Guatemala was obtained from the EIA website: www.eia.doe.gov/emau/cabs. From the same source, data on the installed generating capacity, per capita electricity consumption and per capita GDP, were obtained. Unless otherwise known we set the dummy variables to represent non-civil service pay scale, privately

The positive relationship between staff numbers and the age of the regulatory agency (at least in developing countries) may be a sign that regulatory complexity has increased in recent years as regulators have become more established and actively promoted competition over their networks. Alternatively, it may indicate that regulatory institutions have become less efficient as the institution has aged (at least with respect to minimising their own costs). It remains to be established which of these factors is more important; whether the effects are largely offsetting or whether some other factors are at work. The interpretation of the results in this area is particularly difficult since no significant age effects and only limited complexity effects (e.g. in terms of number of companies) were found in the better determined equations for developed countries.

Smaller economies can benefit from some scope economies by choosing multi-sectoral regulatory institutions. This paper confirms that the effort to set up effective regulatory institutions for utility regulation may be hampered not only by the general level of corruption or the budget allocated to these institutions, but more importantly by the lack of availability of adequately trained staff to run the regulatory agencies. For developing country governments and aid agencies, the message is that tackling corruption and having multi-sectoral agencies are the best short-term responses, with higher education and training, as the necessary long-term response. In addition, sharing regulatory resources between countries, formally or informally, (as in small Caribbean island telecom regulation) may also help alleviate human resource problems, particularly for professional staff.

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APPENDIX 1: Survey Questionnaire

Questionnaire on the Regulation of Electric Utilities in the World

1. Please specify the size of the electricity supply industry in your country or under your jurisdiction based on the following criteria:

Total (route) *Length* of (transmission and distribution) network (km), __________

Total installed generation *Capacity* (MW), __________

Total Number of *Customers*,__________ of which __________(%) are residential

Area under Jurisdiction, ______________Km^2

Total units *Supplied* (MWh), _____________

2. What proportion (%) of assets in each of the following are privately owned:

Generation ☐ Transmission ☐ Distribution ☐ Supply ☐

3. Which of the function(s) are regulated by you or your institution? (Please tick)

Generation ☐ Transmission ☐ Distribution ☐ Supply ☐

4. Is there an Electricity or Energy Regulatory Act or Law, which defines the aims, and scope of such regulations? *Yes* ☐ *No* ☐ **When was the Law (Act) first in force __________ and when was it last amended _________?**

5. Is electricity the only sector that is regulated by your organisation? *Yes* ☐ *No* ☐

If *No*, please specify the other sector (s) __________________________

6. How many staff (total) are employed by your Regulatory Agency? __________ *Out of which* ________ are professional (example, lawyers, economists, accountants, engineers, etc.) and _____ are supportive (photocopiers, general clerical, etc.) staff?

7. How is the regulatory body financed? Please tick the appropriate box(es).

Customer levy-financed ☐ Government Budget ☐ Company licence-financed ☐

8. Is there any specific type of regulation that is applied to the electricity industry such as: *price-cap* ☐ *rate of return* ☐ *supply quality* ☐ *and/or others* ____(please specify).

9. With respect to the price of electricity, does your institution advise ☐ decide ☐ regulate ☐ and/or impose sanctions ☐ on the industry? (Please tick).

10. What is the *budgetary* (average annual) *costs* of the regulatory agency? _________ *(state currency)* _________ *(amount) as at* _________ *(date).*

(In case there is no definite value assigned within the budget, then please provide an estimate based on staff costs (total staff number *times* average salary) *plus* an administrative overhead cost).

11. Is there a civil service pay scale applicable to your Regulatory Agency? Yes ☐ No ☐

APPENDIX 2: DATA

Developed Countries

Country	STAFF	PROF	NCUSMN	NCOMP	GENCAP	NSECTORS	SSMN	PCGDP	POP	TERTED	CORRUPT	CSERV	REGENV	FUNDING	ORGTYPE	JURISD	REGTYPE	YRS
Argentina	130	65	11.313	35	22950	1	72.550	7.741	36.58	36.2	3.5	1	0.668	1	1	1	1	8.5
Australia-IPART	50	35	3	5	37906	4	45.577	19.796	6.55	79.8	8.5	1	0.962	0	1	0	0	0.5
Australia-Tasmania	13	10	0.248	5	2509	3	9.6	19.797	0.4704	75	8.5	0	0.962	1	1	0	1	5.5
Australia-Victoria	34	6	2.194	38	7824	5	50.417	19.798	4.844	79.8	8.5	0	0.962	0	1	0	1	6.5
Austria	52	28	4	158	18004	1	52.440	25.726	8.092	48.3	7.8	1	0.901	0	1	1	1	2.5
Barbados	5	2	0.101	1	185.5	1	0.788	9.273	0.267	28.7	6.3	1	0.612	1	1	1	0	0.5
Belgium	35	25	4.29	35	16200	2	80.182	24.291	10.226	56.3	6.6	0	0.794	1	1	1	1	2.5
BRAZIL-Sao Paulo	60	36	11.8	8	13289.6	2	97.961	4.474	167.967	14.5	4	1	0.134	1	1	0	1	5.5
Canada_NEB	280	96	15.245	122	110000	4	505.260	20.822	30.491	87.3	8.9	1	0.869	1	1	1	0	41.5
Canada_Newfoundland	13	7	0.250	2	7400	4	40.640	20.822	30.491	87.3	8.9	1	0.869	1	1	0	0	51.5
Canada_OEB	110	60	3	30	30900	2	144	20.822	30.491	87.3	8.9	1	0.869	1	1	0	0	2.5
Czech Republic	73	51	5.501	1500	15443	3	53.775	5.167	10.278	23.5	3.9	1	0.570	0	0	1	1	0.5
Denmark	265	185	2.963	8	12500	3	34.327	32.722	5.326	48.2	9.5	1	1.048	1	0	1	0	1.5
Hawaii	33	17	0.422	3	1755.75	4	10.161	28.325	1.321	69	8.25	1	1.151	0	0	0	0	87.5
Hong Kong	7	6	2.4	2	11568	1	35	23.649	6.721	19.4	7.9	1	1.207	0	0	1	0	10.5
Hungary	88	81	5.103	6	8029	3	32.221	4.811	10.068	23.6	5.3	1	0.854	1	1	1	1	6.5
Ireland	25	11	0.673	1	2063	2	7.605	24.896	3.752	45	7.5	1	1.157	1	1	1	1	8.5
Israel	20	13	2.070	1	8579	1	34.298	16.518	6.105	40.9	7.6	1	0.533	0	1	1	1	4.5
Mexico	157	90	21.5	4	34815	2	164.800	5.008	96.586	16	3.7	1	0.608	0	1	1	0	5.5
Netherlands	25	22	0.715	43	20000	2	85	24.909	15.805	47.3	8.8	1	1.141	1	1	1	1	2.5
Northern Ireland	16	11	1.577	1	4165	2	21.649	16.748	1.692	40	8.2	0	0.650	1	1	0	1	0.5
Portugal	50	39	5.292	31	10500	1	36.278	11.384	9.989	38.8	6.3	0	0.889	1	1	1	1	5.5
Spain	123	83	21.236	5	45663	2	19.435	15.121	39.41	51.4	7	0	0.864	0	1	1	0	3.5
Sweden	30	25	5.3	231	30885	2	142.900	26.948	8.857	45	9	1	0.853	1	1	1	0	4.5
The Bahamas	13	5	0.103	4	487.2	3	1.402	15	0.3	12	5.53	0	0.870	1	1	1	1	0.5
Trinidad and Tobago	13	8	0.316	2	1416.7	3	5.195	5.312	1.293	8.2	5.3	1	0.718	1	1	1	1	36.5
United Kingdom	329	197	26.25	96	65697	2	381.042	24.231	59.501	52	8.3	1	1.206	1	1	1	1	14.5
USA-California	946	600	12.899	12	53157	6	2111.981	26.401	33.872	80.9	7.6	1	1.135	1	0	0	0	54.5
USA-Delaware	29	24	0.376	2	3286	6	10.468	26.186	0.784	80.9	7.6	1	1.135	1	0	0	1	1.5
USA-Florida	371	269	8.153	5	45719	5	195.843	27.765	16.054	80.9	7.6	1	1.151	1	0	0	0	49.5

USA-Kansas	212	50	1.353	28	10300	5	35.921	23.464	2.688	80.9	7.6	1	1.151	1	0	0	0	84.5
USA-New York	600	450	1.214	62	35000	5	129.834	28.371	18.976	80.9	7.6	1	1.135	1	0	0	0	87.5
USA-North Carolina	58	24	4.106	3	22962	6	119.855	26.883	8.077	80.9	7.6	0	1.151	1	1	0	0	87.5
USA-Wisconsin	185	125	2.1	5	13600	4	54	23.877	5.364	80.9	7.6	1	1.135	1	0	0	0	2.5

Developing Countries

Country	STAFF	PROF	NCUSMN	NCOMP	GENCAPC	NSECTORS	SSMN	PCGDP	POP	TERTED	CORRUPT	CSERV	REGENV	FUNDING	ORGTYPE	JURISD	REGTYPE	YRS
Albania	13	4	0.610	5	1642	1	3.348	1.089	3.375	12	2.3	1	-0.700	1	0	1	0	5.5
Armenia	52	43	0.850	21	3471	3	5.193	0.484	3.809	12.2	2.9	0	-0.570	0	1	1	0	3.5
Bolivia	50	40	1.007	8	1228.65	1	3.037	1.023	8.138	9.3	2	0	0.876	1	1	1	0	6.5
Cambodia	105	96	0.135	1	169	1	0.367	0.265	11.757	1.2	2	0	-0.036	0	0	1	0	4.5
Costa Rica	135	81	1.050	5	1501	6	6.189	4.224	3.586	30.3	4.5	0	0.927	1	1	1	0	72.5
Dominican Republic	30	21	1.007	26	2899	1	6.800	2.349	8.373	22.9	3.1	1	0.539	0	1	1	0	2.5
Ecuador	58	37	2.448	27	3350.12	1	10.612	1.530	12.412	23	2.3	1	0.377	1	1	1	1	4.5
El Salvador	58	38	1.075	14	1004.4	2	3.370	2.026	6.154	17.8	3.6	0	1.233	1	1	1	1	4.5
Ethiopia	26	13	0.574	1	422	1	1.332	0.103	62.782	0.8	1.1	1	-0.033	1	0	1	1	1.5
Grenada	6	5	0.031	1	28	3	0.119	3.773	0.097	8	2.32	1	0.452	1	0	1	1	6.5
India_CERC	63	27	195.994	10	104000	1	292.046	0.448	997.515	6.9	2.7	1	-0.040	0	0	1	1	2.5
India_Orissa	44	20	29.131	3	3200	1	9.104	0.460	36.706	6.9	2.9	0	-0.040	1	1	0	0	5.5
Jamaica	28	19	0.477	1	668.7	3	2.739	2.652	2.598	7.8	3.8	0	0.760	1	1	1	1	5.5
Kenya	25	9	0.506	1	1010	1	3.504	0.362	29.41	1.6	2	1	-0.133	1	1	1	0	2.5
Lithuania	42	36	1.320	2	6127.3	4	6.814	2.875	3.699	31.4	4.8	1	0.089	0	0	1	1	3.5
Malaysia	150	42	5.499	3	15800	2	55.629	3.480	22.71	11.7	5	1	0.477	0	0	1	0	10.5
Namibia	16	7	0.162	6	380	1	2.411	4.174	1.701	6	5.4	0	0.267	1	0	1	1	0.5
Nicaragua	90	65	0.435	77	630	2	2.395	0.461	4.919	11.8	2.4	0	-0.103	1	1	1	0	5.5
Nigeria	140	60	8.260	1	5900	1	18.700	0.373	123.89	0.8	1	1	-0.352	0	0	1	0	0.5
Peru	100	70	3.288	5	4200	2	17.400	2.058	25.23	25.8	4.1	0	0.669	1	1	1	1	7.5
Philippines	254	192	8.700	140	12068	1	36.987	1.031	74.259	29	2.9	1	0.565	0	1	1	0	13.5
Poland	285	232	15.100	1276	33000	5	100.000	4.014	38.654	40	4.1	1	0.565	1	1	1	1	3.5
Romania	60	55	8.385	156	15000	2	40.000	1.515	22.458	22.5	2.8	0	0.199	1	1	1	0	2.5
Russia	20	20	5.269	1	203803	1	0.870	0.074	146.2	49	2.3	1	-0.303	0	0	1	1	0.5
Sudan	15	5	0.600	1	750	3	2.500	0.335	28.99	5	2.5	1	-0.828	0	0	1	0	0.5
Uganda	12	5	0.171	1	260	1	1.342	0.298	21.479	0.7	1.9	0	0.184	1	1	1	0	1.5

APPENDIX 3: Predicted Staff Numbers for Developing Countries using different equations

	Prediction S2	Prediction S4	Prediction P2	Prediction P4
Albania	34	24	19	7
Armenia	19	47	6	47
Bolivia	21	66	7	38
Cambodia	15	103	5	66
Costa Rica	47	135	10	101
Dominican Republic	15	39	3	31
Ecuador	36	32	13	18
El Salvador	38	63	9	55
Ethiopia	32	29	19	15
Grenada	60	6	45	4
India CERC	1242	99	2038	39
India_Orissa	76	44	51	20
Jamaica	14	30	9	36
Kenya	8	19	4	8
Lithuania	47	34	32	26
Malaysia	85	141	45	37
Namibia	29	13	9	5
Nicaragua	28	49	7	43
Nigeria	41	55	49	28
Peru	51	67	19	36
Philippines	55	269	12	174
Poland	135	284	102	228
Romania	85	93	50	81
Russia	145	19	545	19
Sudan	35	28	15	12
Uganda	7	19	3	5