

# **Regulation of Utilities in Developing Countries**

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The efficient operation and expansion of utilities in developing countries is crucial for growth and poverty reduction. However, recent reforms aimed at improving the performance of these sectors through privatization and the introduction of new regulatory regimes have had limited success. This thesis aims to consider the most pertinent problems for utility regulation in developing countries and how policy may need to be adapted appropriately.

The thesis begins by surveying the most recent empirical and theoretical work on the area. I argue that four key institutional limitations commonly found in developing countries must be considered when designing regulatory policy: Limited capacity, limited accountability, limited commitment and limited fiscal efficiency. The remainder of the thesis then focuses on two of these weaknesses – limited commitment and limited accountability – to develop further insights into how regulatory policy may be most suitably adapted.

In considering the effect of limited commitment, I pursue a theoretical approach. I first focus on the relationship between the government and the utility operator when the government cannot commit to a time-inconsistent policy of not expropriating investment. After building a model where reputation is used to sustain investment in equilibrium, I consider the model's implications for policy. The thesis then builds a different model to consider the impact of governments' inability to commit when trading electricity internationally. I focus on the resulting hold-up problem and the impact this has on investment levels within trading countries.

The effect of limited accountability is then investigated empirically through the analysis of data on electricity firms and regulators in Latin America. In particular, I consider how firms' performance is affected by corruption, ownership and regulatory governance, looking in detail at interactions between these variables and attempting to break down regulatory governance into its various components.

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# Overview of Thesis

The efficient operation and expansion of infrastructures in developing countries is crucial for growth and poverty reduction. However, recent reforms aimed at improving the performance of these sectors have had limited success. Evidence suggests that in many instances this was because the traditional regulatory theory relied on by policy makers was not suitable for the institutional context in developing countries. This thesis aims to consider the most pertinent problems for utility regulation in developing countries and how policy may need to be adapted appropriately. We use a range of theoretical and empirical tools to understand these problems in more detail and suggest potential solutions.

We begin in Chapter 1 by surveying the recent literature on regulation in developing countries.<sup>1</sup> At the heart of the survey is the work of Jean-Jacques Laffont, who in the last decade of his life set about developing a theoretical framework for regulation in developing countries. We consider the implications of his work, which focused on the key institutional limitations faced in developing countries. We then discuss where experience suggests that there are important omissions from this modelling, bringing in extensions and alternative approaches pursued by other authors. Though the focus is on the theoretical literature, we also reference the limited empirical work on this topic in order to understand further the strengths and weaknesses of the existing theory. We conclude by summarizing the key ways in which regulatory policy will be different when institutions are weak and discussing the avenues in need of further research. Overall, we find that an understanding of the institutional context and its implications are crucial when designing a regulatory framework for developing countries. In particular, we argue that one must take into account four key institutional weaknesses when designing regulatory policy: limited regulatory capacity, limited accountability, limited commitment and limited fiscal efficiency. The remainder of the

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<sup>1</sup> This chapter is a version of an article published in the *Journal of Economic Literature* (2009: Vol 47, No. 3) co-authored with Antonio Estache.

thesis then investigates two of these limitations in more detail. Chapters 2 and 3 study the problem of limited commitment from a theoretical perspective, whilst Chapters 4 and 5 analyse panel data to investigate the effects of limited accountability.

Chapter 2 builds a dynamic model of utility regulation where a government cannot commit to a time-inconsistent policy of not expropriating investment. By allowing the government's type to change over time, I explore how reputation concerns may generate partial commitment. Restricting attention to equilibria that are strongly renegotiation proof, I show that there is a unique such perfect Bayesian equilibrium. This contains episodes of investment and good behaviour followed by periods of expropriation and non-investment. I then apply the model to consider how the power of the incentive scheme and decentralization may influence the properties of this equilibrium. In the case of the power of incentives, the model suggests that price-caps may worsen commitment in developing countries, but not in developed ones. Similarly, the model suggests that decentralisation is likely to have a significant effect on commitment, but that this effect will depend on the general ability of the government to commit. Overall, I conclude that the effect of such policies on commitment will be different across countries, depending on the institutional environment.

The focus of Chapter 3 remains the governments' limited ability to commit, but in a somewhat different context. In particular, I consider the issue of trade in electricity between two publically regulated national monopolies. Building a model where trade is determined by Nash bargaining, I show that if countries cannot commit to future trade levels, a hold-up problem will lead to investment distortions in both countries. Due to the existence of long-term investments necessary in the sector and the inability of countries to commit, countries will be reluctant to make investment decisions that leave them highly dependent on future international trade. Moreover, by considering investment in access as well as in electricity production, I show that the commitment problem results in under-investment of one variety or another in both countries, and this is likely to add to existing causes of under-investment. Finally, I consider a range of potential policy solutions that may mitigate these distortions.

In Chapter 4, we move to consider empirically an aspect of limited accountability – in particular, the effect of corruption. Using a panel of 153 electricity distribution firms across 18 different countries in Latin America between 1995 and 2007, we analyse the effect of corruption, ownership and institutional governance on firms' efficiency. We find evidence that corruption, a lack of good regulatory governance and public ownership are each associated with less efficient firms. Indeed, the analysis suggests that the creation of an Independent Regulatory Agency (IRA) may increase efficiency if regulatory governance is strong, but decrease efficiency if governance is weak. Moreover, both the creation of a well-governed IRA and privatisation appear to significantly reduce the effect of corruption on efficiency. These results broadly survive a range of robustness checks including separately instrumenting for corruption, ownership and regulatory governance. Overall, we conclude that the creation of well governed sector-specific institutions can help to counter the adverse effects of the high corruption levels present in many developing countries.

Chapter 5 then explores further the effects of regulation found in Chapter 4. First, I analyse whether the effect of regulation changes over time, and find that firms' efficiency appears to be negatively correlated with an IRA's age. Second, I decompose the measure of regulatory governance to study which aspects have the most significant effect on firms' efficiency. Finally, the chapter looks at the role of other aspects of regulation and ownership, finding that the power of incentives and foreign ownership are important determinants of efficiency.

The general conclusion of the thesis is that we have consistently found evidence that there is no universal 'best-practice' when it comes to regulating utilities in developing countries. This not only comes out of the literature review in Chapter 1, but also the original theoretical and empirical work in the other chapters of the thesis. For example, our analysis of limited commitment in Chapter 2 has shown that the effect on commitment of two major policy variables – the incentive regime and the level of decentralisation – is dependent on the country's characteristics. Similarly, our empirical analysis has shown that the creation of an independent regulator may increase or decrease efficiency, depending on governance and the level of corruption

in the country. Furthermore, the type of governance that is important depends on the ownership of the regulated firms and the level of corruption. It is thus insufficient and possibly damaging to advocate simply for a regulatory framework that is close to some universal ideal. An understanding of the institutional context and its implications are crucial when designing a regulatory framework for developing countries.

# Chapter 1

## Regulation of Utilities in Developing Countries: A Survey of the Literature<sup>1</sup>

### 1 Introduction

*Developing economies are often described as “economies with missing markets.” In the contractual world of regulation, missing markets translate into incomplete contracts. Contracts are incomplete because of players’ bounded rationality, as in any economy—but also because of institutional weaknesses.*

*Laffont (2005, p.245)*

With this insight, Jean-Jacques Laffont concludes his argument that utility regulation in developing countries faces problems fundamentally different from those in advanced economies. The accumulation of information on the unsatisfactory results of reforms in the least developed countries increasingly vindicates Laffont’s viewpoint. Policy makers and advisors are indeed finding that the framework of traditional regulatory theory, elaborated and applied in the developed world, is of much more limited use in developing countries than anticipated 10-15 years earlier.

The need for a regulatory theory specific to LDCs is exemplified by the recent case of the privatization of the water and electricity company of Mali. Following the recommendations of international advisors, the project started in 2000 using a model of regulation successful in developed countries. Prices were to be set at a level that allowed costs to be recovered, which theoretically would increase efficiency and allow

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<sup>1</sup> This chapter is a version of an article co-authored with Antonio Estache published in the Journal of Economic Literature (2009: Vol 47, No. 3)

the firm to meet its investment responsibilities. This contract was then overseen by an independent regulator in order to prevent too much political interference.

However, the project did not proceed as planned. The population's limited ability to pay made large price-rises politically intolerable, forcing the government to pay subsidies to the firm. Belatedly the firm became aware of the financial and political risks involved in such a poor country, and this made meeting its investment objectives practically impossible. Finally, the combination of gaps in the contract, public subsidies and the framework's unsuitability meant that there was constant negotiation involving politicians, undermining the regulator's independence. A major renegotiation was attempted in 2005, but there was no consensus amongst experts as to how the framework should be adapted to the country's context. The conflict ended soon after with the foreign operator leaving the country.

The risks associated with a failure to adapt infrastructure regulation to developing countries are not minor given the context of insufficient infrastructure provision. In 2000, approximately 20% of the population of low income countries lacked access to improved water sources, 40% to networked electricity and to sanitation, and 70% to telephone services.<sup>2</sup> Except for phone services (since here technology has more than compensated for policy failures), the growth rates in access in many countries are only slightly higher than the population growth rates. Widening access and improving services have become a top priority as evidence on the importance of infrastructure for poverty reduction and growth continues to mount.<sup>3</sup>

In an attempt to increase investment and improve efficiency in infrastructure, international agencies generally advised countries to open their infrastructure industries to the private sector. However, for many countries, particularly those with the lowest income, private sector participation has been disappointing. Frequently private ownership and management have not improved performance, notably in sectors where

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<sup>2</sup> Furthermore, those with access tend to be wealthy. Of the poorest quintile in low-income countries, only about 40% had access to improved water sources, 25% to sanitation, 10% to electricity, and 5% to a telephone. These statistics are from Estache (2008).

<sup>3</sup> See Estache (2008) for a survey. Studies showing the importance of infrastructure include Esfahani and Ramírez (2003), Calderon and Servén (2004), Maiorano and Stern (2007) and Straub (2008) on growth; Estache, Foster, and Wodon (2002), Calderon and Servén (2004), Fay, Leipziger, Wodon, and Yepes (2005), and UNDP (2006) on poverty.

there is no competition.<sup>4</sup> These failures, accompanied by increases in prices, have led to widespread dissatisfaction with privatization.<sup>5</sup>

What went wrong? It appears that both regulatory policy and the institutional framework are each greater determinants of performance than the form of ownership or management used in the sector.<sup>6</sup> This view was recently re-emphasized by Bourguignon (2005, pp.xi-x) who states: “Today, it is increasingly recognized that, in many instances, the problem was that reformers disregarded the functioning of regulatory institutions, assuming implicitly they would work as in developed countries.” In sum, the facts and the casual observations are all consistent with Laffont’s argument that weaknesses in institutions complicate regulation in LDCs.<sup>7</sup> This mirrors the growing emphasis placed on institutions in development economics, as in economics more generally.<sup>8</sup>

This chapter aims to discuss explicitly the limitations of traditional regulatory theory by considering the critical problems in developing countries that are not typically included in models of regulation. The survey draws insights from more recent theoretical work that has concentrated on examining these problems and finding solutions that are tailored to LDCs. At the heart of our survey is the work of Jean-Jacques Laffont. Before his untimely death in 2004, he set about creating a new theoretical framework for regulation in developing countries that aimed to address the risk of mismatch between imported regulation and local regulatory needs.

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<sup>4</sup> See Parker and Kirkpatrick (2005), Megginson and Sutter (2006), and Boubakri, Cosset, and Guedhami (2008) for surveys of the empirical literature on privatization in LDCs. The latter survey in particular argues that the institutional environment plays a greater role in determining performance than in developed countries. See Bayliss (2002) and Birdsall and Nellis (2003) for surveys of the distributional impact of privatization.

<sup>5</sup> Hall, Lobina, and Motte (2005), Shirley (2005), Estache (2006), and Checchi, Florio, and Carrera (2009) each document this increasing dissatisfaction and provide possible explanations, including equity effects and the negative effects on particular interest groups.

<sup>6</sup> For example, Estache and Rossi (2005) and Zhang, Parker, and Kirkpatrick (2008) find evidence of the importance of regulatory policy and governance over ownership in the electricity sector using country-level and firm-level data respectively. Cook and Uchida (2003) and Jalilian, Kirkpatrick, and Parker (2007) find regulation (and not privatization) has a significant positive effect on growth, while Chisari, Estache, and Romero (1999) show with a CGE model that while the rich have benefited from privatization in Argentina, the poor only gain through regulation. Williamson (2000) argues that the failure of mass privatization in Russia surprised many economists precisely because institutions had not been included in the analysis.

<sup>7</sup> We will use the expressions “developing countries” and “less developed countries” (LDCs) interchangeably.

<sup>8</sup> See Williamson (2000), Acemoglu, Johnson, and Robinson (2004), Dixit (2004), and Rodrik, Subramanian, and Trebbi (2004)

The chapter is divided into three parts. In section 2, we set out a basic model of monopoly regulation similar to that used by Laffont, and consider the baseline case of a developed country with complete institutions. We then explore how the model can be adapted to consider four key institutional limitations common in developing countries: limited regulatory capacity, limited accountability, limited commitment and limited fiscal efficiency. We thereby introduce numerous results obtained by Laffont regarding both the problems caused by the institutional weaknesses and potential solutions. Where appropriate we then relate these insights to examples and results in the empirical literature. Section 3 then considers where experience suggests there are important omissions from this modelling. We discuss how work by other authors may be used to fill some of these gaps, bringing in further literature focused on incentive theory as well as insights from other theoretical approaches. Finally in section 4 we outline what we consider to be the priorities for future research in this area.

From the overall analysis, we conclude that institutional weaknesses in developing countries will make the optimal regulatory policy different from that of developed countries. We summarize some of the ways in which regulatory policy should be designed differently in LDCs, including the implications for the type of regulatory regime and structure of agencies. Since different types of institutional weakness push for different solutions, we argue that there will not be a complete policy set of 'best practice' in LDCs. An understanding of the institutional context and its implications are thus crucial when designing a regulatory framework for developing countries.

## **2 Laffont's Focus on Institutional Weakness**

The theory of economic regulation has advanced significantly over the last quarter-century.<sup>9</sup> Jean-Jacques Laffont has played a key part in that advance, using the tools of mechanism design to emphasize the importance of incentives and

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<sup>9</sup> For reviews of the economic theory of infrastructure regulation see, for example, Laffont and Tirole (1993), Armstrong, Cowan, and Vickers (1994), Newbery (2000), Vogelsang (2002), and Armstrong and Sappington (2007).

asymmetric information.<sup>10</sup> However, in the last 10–15 years of his life Laffont became increasingly concerned that this impressive progress in the theory of regulation had ignored the specific characteristics of LDCs. This, he argued, was particularly critical since the difficulty of implementing reforms in developing economies was being grossly underestimated. Laffont worried that advisers in developing countries did not have an appropriate intellectual framework to draw upon. As a result, not enough importance was being given to regulation and reforms might not yield the expected results.

Laffont's last book, *Regulation and Development*, summarizes some aspects of what can go wrong with regulation if the characteristics of developing countries are not taken into account properly. On the one hand, these lessons are humbling: Laffont exposes the difficulty of applying most theoretical models to the developing country context. On the other hand, the book instills optimism: It shows the tools of incentive theory have the potential to increase our understanding of many of these problems and indicate potential solutions.

Within the book and in his other works on the subject, Laffont has focused on problems stemming from institutional failures. For the purposes of this survey we use a broad definition of institutions, which we take to be the "rules of the game" that structure players' behavior, as well as the organizations that implement these rules.<sup>11</sup> Clearly one way to deal with institutional limitations is to change the institutions themselves. However we do not consider broad institutional change here since this generally comes about slowly and due to factors outside of regulation.<sup>12</sup>

We argue that the key aspects of institutional failure affecting regulation in LDCs can be grouped into four broad limitations: limited regulatory capacity, limited

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<sup>10</sup> This was recognized by the Nobel Prize Committee (2007), which credited Laffont's work on regulation as a key application of mechanism design. See Maskin (2004) and Tirole (2008) for overviews of Laffont's work. Crew and Kleindorfer (2002) and Vogelsang (2002), for example, provide critiques of such an approach.

<sup>11</sup> This is thus slightly broader than the definition of North (1990), since he separates institutions from organizations, and is closer to that of Greif (2001, p.257) who defines them as "a system of social factors - such as rules, beliefs, norms and organizations - that guide, enable and constrain the actions of individuals". For other definitions of institutions, see Williamson (2000) and Acemoglu, Johnson, and Robinson (2004).

<sup>12</sup> See Acemoglu and Robinson (2008) for an explanation as to why institutions are persistent, and North (1990), Williamson (2000), and Greif and Laitin (2004) for theories of how they change. Following the idea of relative price changes, Saleth and Dinar (2004) suggest that water scarcity may prompt institutional reform.

commitment, limited accountability and limited fiscal efficiency. While many developed countries also suffer from some of these limitations, there they are generally of second-order importance both in theory and in practice. In developing countries, on the other hand, the size and nature of these four limitations often dominates regulatory outcomes. Furthermore, since the relative importance of each of these areas varies across LDCs there should not be a uniform approach to regulatory policy.

*Limited regulatory capacity.* From his frequent interactions with regulators throughout the developing world, Laffont was concerned by the need to have a theory that explicitly recognized their limited capacity—notably their limited ability to implement policy. Regulators are generally short of resources, usually because of a shortage of government revenue and sometimes because funding is deliberately withheld by the government as a means of undermining the agency. The lack of resources prevents regulators from employing suitably skilled staff, a task that is made even harder by the scarcity of highly educated professionals and the widespread requirement to use civil service pay scales.<sup>13</sup> Beyond the regulator itself, an underdeveloped auditing system and inexperienced judiciary place further limits on implementation.

*Limited accountability.* The second recurring institutional failure discussed in Laffont's work is the fact that institutions in developing countries are often less accountable than those in the developed world. Institutions that are designed to serve on behalf of the government or the people, including regulatory agencies, may in fact not be answerable to their principals, and hence are free to carry out their own objectives. While Laffont does not report any systematic statistics, his casual observations have been documented by other authors.<sup>14</sup> Where accountability is lax, collusion between the government and various interest groups, including regulated firms, is more likely to occur. Indeed, there is abundant evidence of corruption in both

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<sup>13</sup> See Domah, Pollitt, and Stern (2002) for evidence of capacity constraints. The Africa Forum for Utility Regulation (2002) and Kirkpatrick, Parker, and Zhang (2005) both undertake surveys of regulatory agencies in LDCs. The findings of the former concluded that a third of surveyed agencies are bound to paying government set salaries and two thirds of surveyed agencies require government approval of their budget.

<sup>14</sup> For instance, Stern and Holder (1999) show in a survey of Asian regulators that very few are transparent or accountable.

the privatization process and in regulation in LDCs.<sup>15</sup> The risk of collusion underpins Laffont's dissatisfaction with modeling regulators and governments as benevolent welfare maximizers.

*Limited commitment.* Laffont's work also reveals that he was convinced that the institutional framework in many developing countries makes it impossible to rely on contracts. The difficulty is demonstrated best by the prevalence of contract renegotiation which Laffont analyzed empirically in the last couple of years of his life.<sup>16</sup> With J. Luis Guasch and Stéphane Straub he investigated why in Latin America between 1985 and 2000 more than 40 percent of concessions (excluding the telecoms sector) were renegotiated, a majority at the request of governments. Fear of future renegotiation is a serious impediment to attracting private sector participation. Moreover, the inability to rely on contracts is particularly damaging given the greater uncertainties about cost, demand, and macroeconomic stability that exist in LDCs.

*Limited fiscal efficiency.* The final source of institutional failure explicitly addressed by Laffont is the weakness of fiscal institutions. There is a clear concern that public institutions are unable to collect adequate revenue to allow direct subsidies when the ability of consumers to pay for services is limited. In infrastructure, this limitation is apparent in the slow progress that state-owned enterprises have made in increasing access to networks.<sup>17</sup> When both fiscal surpluses and the ability to pay of the majority of users are limited (as is often the case in Sub-Saharan Africa, for instance) the speed at which investment can be financed is much slower than when governments can finance any resource gap.<sup>18</sup> Unfortunately, governments and regulators are in a catch-22 situation. The scale of network expansion required to widen access to services, and the inability of many citizens to pay tariffs at a level that will ensure cost-recovery, mean that private or public enterprises are unlikely to be

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<sup>15</sup> For example, see Bjorvatn and Søreide (2005) and Ghosh Banerjee, Oetzel, and Ranganathan (2006) for evidence of corruption in private sector involvement.

<sup>16</sup> Guasch, Laffont, and Straub (2006, 2007, 2008)

<sup>17</sup> Clarke and Wallsten (2003) give evidence of the limited success of state-subsidized network expansion, and suggest that mistargetting is a major problem.

<sup>18</sup> In terms of consumers' ability to pay, Komives, Foster, Halpern, and Wodon (2005) find about 20% of Latin American households and 70% of households in Africa or Asia would have to pay more than 5% of their income for water or electricity services if tariffs were set at cost recovery levels.

financially autonomous.<sup>19</sup> However, the limited fiscal efficiency of the poorest countries is such that governments will not be able to finance high levels of subsidies.

When studying the implications of these institutional limitations, Laffont's strategy is two-fold. In the first approach, existing models are considered with reference to ranges of parameter values that are likely in LDCs. In these cases, it is the scale of the problem that is different from rich countries and the implications for policy may be discernable using a framework applicable to both. In the second approach, models are extended to allow for the relaxation of traditional assumptions that are no longer appropriate. This is necessary for situations where the nature of the problem is qualitatively different and hence the standard structure is not useful.

In the rest of this section, we summarize the key insights that come from Laffont's analysis of each of these institutional limitations. To do so, it is helpful to build a basic model of monopoly regulation very similar to that used in Laffont (2005), and provide a complete institutions benchmark to compare results to. We then use this model to illustrate the methods and implications of Laffont's work when considering each of the four institutional limitations. For each limitation, we consider the problems that arise as a result and a number of solutions that theory suggests.

## 2.1 A Basic Model of Monopoly Regulation

The model centers on a monopolist producing a quantity  $q$  of a good for domestic consumption. Its cost function is  $C(q) = (\beta - e)q - F$ , where  $\beta$  is a firm-specific characteristic representing its underlying cost,  $e$  is an effort level that decreases the marginal cost and  $F$  is a fixed cost.<sup>20</sup>

$\beta$  represents costs that are outside of the firm's control, such as factor prices or technology. We use a binary model whereby the firm is either low-cost,  $\beta = \underline{\beta}$

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<sup>19</sup> Trujillo, Martin, Estache, and Campos (2003) finds that the fiscal benefits of privatization decrease over time, and argue that it is because the need for public investment is gradually realized.

<sup>20</sup> See Laffont and Tirole (1993), Armstrong, Cowan and Vickers (1994) and Armstrong and Sappington (2007) for detailed expositions of models in this style.

(occurring with probability  $v$ ) or high-cost,  $\beta = \bar{\beta}$  (occurring with probability  $1-v$ ).  $e$  is the part of the marginal cost that is controllable by the firm directly. For example, the manager may be able to reduce costs by purchasing from the cheapest supplier or by reducing mistakes. Exerting an effort level of  $e$  causes the firm a disutility of  $\psi(e)$  ( $\psi' > 0, \psi'' > 0, \psi''' \geq 0$ ).

The monopoly's revenue from sales is  $qp$ , where  $p$  is the price level. In addition to this revenue, the monopoly receives a transfer  $t$  from the government.<sup>21</sup> The monopoly's welfare is then  $U = qp - (\beta - e)q - F - \psi(e) + t$ . We will also describe  $U$  as the 'rent' the firm receives from being the monopoly supplier. The monopoly has a participation constraint such that, after  $\beta$  is revealed, its welfare must be no less than 0, i.e.

$$(1) \quad \underline{U} \geq 0$$

$$(2) \quad \bar{U} \geq 0$$

where  $\underline{U}$  is the firm's utility when  $\beta = \underline{\beta}$ , and  $\bar{U}$  that when  $\beta = \bar{\beta}$ . We similarly define  $\underline{e}, \bar{e}, \underline{p}, \bar{p}, \underline{q}, \bar{q}, \underline{t}$  and  $\bar{t}$  and as the effort levels, price levels, quantities produced and transfers made in these respective cases. This participation constraint assumes that the firm can leave and obtain a reservation utility of zero after it has discovered its type (i.e. its cost level). The assumption is crucial since it prohibits the government motivating the firm by giving one type a negative utility. We further assume that the government wishes the firm to participate regardless of its type. If the firm chooses to participate, it decides upon levels for price and effort, but it must abide by a contract agreed with the government.

Consumers' gross surplus from consuming a quantity  $q$  of the good is  $S(q) = \int_0^q P(q') dq'$ , where  $P(q)$  is the inverse demand function ( $S' > 0, S'' < 0$ ). Consumers also pay taxes to fund the transfer to the monopoly. Raising an amount  $t$  in taxes costs consumers  $(1 + \lambda)t$ , where  $\lambda > 0$  is the opportunity cost of public funds. Hence consumers' net surplus is  $V = S(q) - qp - (1 + \lambda)t$ . Consumers are welfare

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<sup>21</sup> See Laffont and Tirole (1993, p.145-155) for details of how the model changes when transfers are removed. Generally, when prices must be used to generate the revenue here provided by transfers there will be a loss of efficiency. This may however be mitigated if the firm can use two-part tariffs rather than linear prices.

maximizing and therefore in equilibrium we have  $p = P(q) = S'(q)$ , i.e. demand is determined such that price is equal to the marginal benefit.

The benevolent government aims to maximize the following social welfare function:

$$(3) \quad W = U + V = S(q) - (\beta - e)q - \psi(e) - F - \lambda t$$

We assume here that  $F$  is common knowledge. We also assume that the government can observe price and marginal cost  $c = \beta - e$  but they do not observe the components of this cost – i.e. they do not observe  $\beta$  and  $e$ . The contract between the government and the firm can therefore specify the price the firm should sell at, the marginal cost level it should obtain and the transfer from the government to the firm.

The asymmetry of information between the government and the firm is at the heart of Laffont's model of regulation. The government does not know directly what proportion of the firm's costs are controllable in the short term ( $e$ ) and what proportion is uncontrollable ( $\beta$ ). Here  $e$  is therefore a moral hazard variable – the inability of the government to observe the effort level means that it cannot directly ensure that the firm is doing all it should to reduce costs. On the other hand, the non-observation of  $\beta$  introduces an element of adverse selection. Even though  $\beta$  is not controllable by the firm, the government would like to know this information to make sure that the firm isn't pricing higher than it should.

A regulator is employed to reduce the asymmetry of information by learning the value of  $\beta$ . The regulator is endowed with an information technology that obtains a private signal  $r$  that may give information about the firm's cost. With probability  $\xi$  the firm's cost is revealed to the regulator ( $r = \beta$ ) and with probability  $1 - \xi$  they receive no information ( $r = \emptyset$ ). We assume that the signal the regulator receives is 'hard' information. This means that the regulator cannot report that the firm is of a particular type unless it has received a signal revealing this to be true. However, it can hide information and report that the signal is  $\emptyset$  even if this was not the case. In other words, the signal can be hidden but it cannot be faked.

To make use of the regulator's information  $r$ , the government asks it to report the signal. We assume that the government can write an enforceable contract with the

regulator that specifies transfers to be paid to the regulator as a function of its report. These transfers are paid from government revenue, so paying the regulator a transfer  $s$  costs consumers  $(1+\lambda)s$ . If the regulator's welfare is included in the social welfare function, the excess burden to society of this transfer is therefore  $\lambda s$ .

We also assume that the firm observes both the regulator's signal and their report to the government. The firm can contract on the regulator's report and make dependent transfers. Transfers between the regulator and the firm are costly because they are illegal, i.e. there may be costs undertaken to hide the transfer or a penalty if the parties are caught. Hence for any bribe given by the firm the regulator only enjoys a fraction  $k$  of the bribe, where  $k \in (0,1)$ .  $k$  here represents the ease with which bribes can be made, i.e. a higher value of  $k$  means that there are fewer costs involved.

Finally, we assume that the government decides upon the set of contracts offered to the firm before the regulator makes its report. The set of contracts offered will be conditional on the regulator's report and this allows the government to influence through the contract specification the firm's decision of whether to bribe or not.

## 2.2 Complete Institutions Benchmark

Let us briefly detail the core results of the model in a situation where the country does not suffer any of the four institutional limitations outlined above. When the regulator reports the value of  $\beta$  there is no asymmetric information. Hence for this case the government can simply maximize the welfare function (3) subject to the participation constraints (1) and (2) binding. Since constraints (1) and (2) bind, it must be the case that

$$t = -qp + (\beta - e)q + F + \psi(e)$$

Substituting this into equation (3) then gives the government's welfare function as

$$W = S(q) - (1 + \lambda)(\beta - e)q - (1 + \lambda)\psi(e) - (1 + \lambda)F + \lambda qp$$

Differentiating with respect to  $q$  then gives

$$\frac{dW}{dq} = S'(q) - (1 + \lambda)(\beta - e) + \lambda p + \lambda q \frac{dp}{dq}$$

We can note that  $p = S'(q)$  and  $q \frac{dp}{dq} = p \frac{q}{p} \frac{dp}{dq} = p \times \frac{1}{\eta}$ , where  $\eta$  is the elasticity of demand. Hence maximizing welfare by setting  $\frac{dW}{dq}$  to 0 gives

$$0 = p - (1 + \lambda)(\beta - e) + \lambda p + \lambda \frac{p}{\eta}$$

Rearranging then gives the following equation for the markup of price above marginal cost:

$$(4) \quad \frac{p - (\beta - e)}{p} = \frac{\lambda}{1 + \lambda} \frac{1}{\eta}$$

We can similarly obtain the effort the government will desire to induce by differentiating the welfare function by  $e$ , i.e.

$$\frac{dW}{de} = (1 + \lambda)q - (1 + \lambda)\psi'(e)$$

Maximizing by setting  $\frac{dW}{de}$  then gives  $\psi'(e) = q$ .

Overall therefore, when  $\beta$  is known, the government sets the price at a level above marginal cost where the distortion caused is of the same magnitude as the distortion caused by taxation. The transfer  $t$  is set at such a level such that there will be no excess rent given to the firm, i.e. it will have its minimum utility of zero ( $\underline{U} = \bar{U} = 0$ ). Furthermore, the effort level exerted by the firm will be efficient for both types, i.e.  $\psi'(e) = q$ .

When the regulator reports a signal of  $r = \emptyset$ , the government is unaware of the value of  $\beta$ . From the revelation principle, there is no loss of generality in restricting the

analysis to direct revelation mechanisms  $\{(\underline{t}, \underline{c}, \underline{p}), (\bar{t}, \bar{c}, \bar{p})\}$  which specify for each message from the firm the transfer, marginal cost and price that will occur.<sup>22</sup> In order for the firm to be willing to accept the contract designed for their type, such a mechanism must satisfy the participation constraints (1) and (2) as well as the incentive compatibility constraints:

$$(5) \quad \underline{U} \geq \bar{U} + \Phi(\bar{e})$$

$$(6) \quad \bar{U} \geq \underline{U} - \Phi(\bar{e} + \Delta\beta)$$

Here  $\Delta\beta = \bar{\beta} - \underline{\beta}$  and  $\Phi(e) = \psi(e) - \psi(e - \Delta\beta)$ , which is the utility the low-cost type can gain by mimicking the high-cost type. These incentive compatibility constraints make sure that neither type of firm wishes to pretend to be the other type – i.e. they will reveal their type truthfully.

A standard result is that, when there is an asymmetry of information ( $r = \emptyset$ ), the binding constraints will be the participation constraint of the high-cost firm (2) and the incentive compatibility constraint of the low-cost firm (5).<sup>23</sup> Solving the government's optimization problem for this case results in prices again set as in equation (4). However, while the high-cost firm will again receive no rent, the low-cost firm will receive a rent  $\underline{U} = \Phi(\bar{e})$ . We label this the firm's 'information rent' since it is received as a result of the firm holding more information than the government. Since this rent effectively comes out of public funds, it costs society  $\lambda\Phi(\bar{e})$ .

The low-cost firm receives an information rent of  $\underline{U} = \Phi(\bar{e})$  when the regulator reports a signal of  $r = \emptyset$  and no rent when it reports the signal  $r = \underline{\beta}$ . Hence the low-cost firm will want the regulator to hide its signal if it receives one. Indeed it will be willing to bribe the regulator an amount of up to  $\Phi(\bar{e})$  to report  $r = \emptyset$  if in fact  $r = \underline{\beta}$ , of which the regulator would receive  $k\Phi(\bar{e})$ . If the government wishes to prevent collusion from occurring, it can do so by paying an incentive payment of  $s = k\Phi(\bar{e})$  every time the regulator reports that  $r = \underline{\beta}$ . Though this costs society  $\lambda k\Phi(\bar{e})$ , it will

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<sup>22</sup> The revelation principle states that mechanisms involving the agent revealing their type truthfully can achieve the same results as any other mechanism that satisfies the agents incentive compatibility constraints. See Laffont and Tirole (1993, p.120) for a proof in this context.

<sup>23</sup> See Laffont and Tirole (1993).

always be optimal for the government to prevent collusion in this way since otherwise the cost of the firm's information rent is  $\lambda\Phi(\bar{e})$  and  $k < 1$ .<sup>24</sup>

If  $r = \bar{\beta}$  then the firm has no incentive to keep this information hidden and will not want to bribe the regulator. The government therefore will not need to give any incentive payment to the regulator for reporting  $r = \bar{\beta}$ .

Given this payment to the regulator, we can now recalculate the governments optimal choice of  $q$  and  $e$ . The government's expected welfare is now

$$\mathbb{E}[W] = v\xi[\gamma\underline{U}^* + \underline{V}^* - \lambda k\Phi(\bar{e})] + v(1-\xi)[\underline{U} + \underline{V}] + (1-v)\xi[\bar{U}^* + \bar{V}^*] + (1-v)(1-\xi)[\bar{U} + \bar{V}]$$

where  $U^*$  and  $V^*$  are the utilities of the firm and consumers in the case where the regulator reports  $\beta$  to the government. Since we know that  $\bar{U}^* = \bar{U} = \underline{U}^* = 0$  and  $\underline{U} = \Phi(\bar{e})$ , we have the following expressions for the transfers given to the monopoly in each case:

$$\begin{aligned} -\underline{t}^* &= \underline{q}^* \underline{p}^* - (\underline{\beta} - \underline{e}^*) \underline{q}^* - F - \psi(\underline{e}^*) \\ -\underline{t} &= \underline{q} \underline{p} - (\underline{\beta} - \underline{e}) \underline{q} - F - \psi(\underline{e}) - \Phi(\bar{e}) \\ -\bar{t}^* &= \bar{q}^* \bar{p}^* - (\bar{\beta} - \bar{e}^*) \bar{q}^* - F - \psi(\bar{e}^*) \\ -\bar{t} &= \bar{q} \bar{p} - (\bar{\beta} - \bar{e}) \bar{q} - F - \psi(\bar{e}) \end{aligned}$$

Substituting this in to the government's expected welfare function then gives

$$\begin{aligned} \mathbb{E}[W] &= v\xi[S(\underline{q}^*) - \underline{q}^* \underline{p}^* + (1+\lambda)(\underline{q}^* \underline{p}^* - (\underline{\beta} - \underline{e}^*) \underline{q}^* - F - \psi(\underline{e}^*)) - \lambda k\Phi(\bar{e})] \\ &+ v(1-\xi)[\Phi(\bar{e}) + S(\underline{q}) - \underline{q} \underline{p} + (1+\lambda)(\underline{q} \underline{p} - (\underline{\beta} - \underline{e}) \underline{q} - F - \psi(\underline{e}) - \Phi(\bar{e}))] \\ (7) \quad &+ (1-v)\xi[S(\bar{q}^*) - \bar{q}^* \bar{p}^* + (1+\lambda)(\bar{q}^* \bar{p}^* - (\bar{\beta} - \bar{e}^*) \bar{q}^* - F - \psi(\bar{e}^*))] \\ &+ (1-v)(1-\xi)[S(\bar{q}) - \bar{q} \bar{p} + (1+\lambda)(\bar{q} \bar{p} - (\bar{\beta} - \bar{e}) \bar{q} - F - \psi(\bar{e}))] \end{aligned}$$

We now need to find the optimal quantities and effort levels that the government will induce. Differentiating the above expression with respect to  $\bar{q}$  and setting it to 0 gives

<sup>24</sup> See chapter 11 of Laffont and Tirole (1993) for further details.

$$0 = \bar{p} + \lambda \bar{p} - \lambda \bar{p} \frac{1}{\eta} - (1 + \lambda)(\bar{\beta} - \bar{e})$$

Hence, as before, we have

$$\frac{\bar{p} - (\bar{\beta} - \bar{e})}{\bar{p}} = \frac{\lambda}{1 + \lambda} \frac{1}{\eta}$$

We obtain similar results for  $\underline{q}$ ,  $\bar{q}^*$  and  $\underline{q}^*$ . Now, differentiating (7) with respect to  $\underline{e}$  is again simple, giving:

$$\underline{q} = \psi'(\underline{e})$$

We obtain similar results for  $\underline{e}^*$  and  $\bar{e}^*$ . However, for  $\bar{e}$ , we obtain the expression:

$$0 = v\xi[-\lambda k\Phi'(\bar{e})] + v(1 - \xi)[(-\lambda)\Phi'(\bar{e})] - (1 - v)(1 - \xi)(1 + \lambda)(-\bar{q} + \psi'(\bar{e}))$$

Rearranging this then gives

$$\psi'(\bar{e}) = \bar{q} + \frac{v}{1 - v} \frac{1}{1 + \lambda} \frac{\xi}{1 - \xi} [-\lambda k\Phi'(\bar{e})] + \frac{v}{1 - v} \frac{1}{1 + \lambda} [(-\lambda)\Phi'(\bar{e})]$$

which can be rewritten as

$$(8) \quad \psi'(\bar{e}) = \bar{q} - \frac{\lambda}{1 + \lambda} \frac{v}{1 - v} \left[ 1 + \frac{\xi}{1 - \xi} k \right] \Phi'(\bar{e})$$

This expression can be understood as follows. The rent that the low-cost firm receives is costly to society since it comes through higher distortive taxation, and hence the government will wish to reduce it. Furthermore, a larger potential rent for the firm increases the size of the incentive payment the government pays the regulator, and hence this is a further reason to decrease the low cost firm's rent. In order to reduce the rent, the government can make the high-cost firm's production level less appealing to the low-cost firm by increasing the high-cost firm's cost level, which

reduces  $\bar{e}$  and hence  $\Phi(\bar{e})$ . This is disadvantageous for the low-cost firm because it decreases the quantity they would be allowed to sell.

The second term on the right hand side is negative, and hence the exerted effort is lower than the efficient level. This term is increasing in  $\nu$ , since the more likely the firm is to be low-cost the less likely this distortion in effort will occur, and therefore the government can allow the distortion to be greater. Similarly, the high-cost firm exerts less effort the greater the values of  $\lambda$ ,  $\xi$ , and  $k$  - effects which we discuss in more detail in the sections below. On the other hand, there is no reason for the government to distort the low-cost firm's effort level, so  $\psi'(\underline{e}) = \underline{q}$ .

So far we have assumed that the government controls the firm's effort by directly setting its cost level  $c = \beta - e$ , along with the price and size of the transfer. However, we can equivalently interpret the firm's effort level as being determined by an incentive scheme that the government gives to the firm. Rather than directly setting the firm's price, cost and transfer, the government can set the price and offer them a cost reimbursement rule, where a proportion  $\alpha$  of the firm's costs are reimbursed through the transfer. The firm will then choose its effort level (and hence its marginal cost) to maximize its welfare function. Doing so means they exert an effort level according to the equation  $\psi'(e) = (1 - \alpha)q$ .

This then allows us to define the 'power' of an incentive scheme. If the scheme gives the firm strong incentives to reduce costs by allowing it to reap the benefits of cost reduction, then it is described as 'high-powered'. An example of such a scheme is a 'price-cap' regime, where the government sets a price and the transfer is independent of marginal cost. Here the firm is keen to reduce costs because they translate directly into increased profits, and hence they will choose the efficient level of effort. On the other hand, under a 'low-powered' regime the firm will have less of an incentive to reduce cost because a greater marginal cost means they will receive a higher transfer.

In our model, the power of the incentive scheme is equivalent to the firm's effort level. When there is symmetric information, both types of firm exert the efficient level of effort, and we can view this as them having been offered a high-powered incentive

scheme with  $\alpha = 0$ . When there is asymmetric information, equation (8) shows us that the high-cost firm's effort level corresponds to an incentive scheme with  $\alpha > 0$ . The existence of asymmetric information therefore decreases the power of incentives in expectation.

## 2.3 Limited Regulatory Capacity

### Problems

The lack of developed accounting and auditing systems in LDCs and the inability of the regulator to penalize the firm for non-compliance means that the regulator is less able to extract information from the firm. Furthermore, if regulatory agencies are staffed by inexperienced non-specialists then the knowledge gap between the regulator and the firm is likely to be more difficult to close without the firm's help. In the above model, these factors correspond to a lower value of  $\xi$ , the probability of the regulator observing the firm's type.

A lower value of  $\xi$  means that there is a higher probability that the government will have to incentivize the firm to reveal its information through offering the low-cost firm a positive rent. In expectation therefore, the firm will earn a greater rent. This is consistent with cross-country evidence from LDCs suggesting that insufficient regulatory capacity leads to excessive returns for regulated firms, beyond those that could be expected from the high risks often associated with doing business there.<sup>25</sup> In our model, this greater profit comes through a higher transfer from the government, and since this is funded through distortive taxation this leads to lower social welfare.

In a more extreme situation, common in the poorest countries, auditing systems may be so under-developed that auditing of cost is too unreliable to be used. In this case, we depart from the model's assumption above that  $c = \beta - e$  is observable. In this case the contract offered to the firm will just specify a quantity/price and a transfer.

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<sup>25</sup> See Sirtaine, Pinglo, Guasch, and Foster (2005) and Andres, Guasch, and Straub (Forthcoming).

Since the government cannot fix the high-cost firm's effort level, they cannot use this as a tool to decrease the low-cost firm's information rent. Instead the government will increase the price mark-up of the high-cost firm. This is a less efficient tool, and hence the loss of a policy instrument decreases welfare.

## Solutions

One way the model suggests that the government may mitigate problems resulting from the limited capacity of the regulator is to alter the power of incentives. From equation (8), which specifies the high-cost firm's effort level, we can see that less monitoring of costs (smaller  $\xi$ ) implies that the government should make the high-cost firm exert more effort. In other words, the cost reimbursement scheme the government sets should include more powerful incentives. This is because the regulator discovers the firm's cost less frequently, and hence the government has to pay collusion-preventing incentive payments to the regulator less often. The cost of paying the regulator's incentive payments was one of the motivations for decreasing the firm's potential rent. As these payments are now less of a concern in expectation, there is less reason to distort the high-cost firm's effort. Moreover, in the extreme case where costs are not observed, high-powered incentives are the only option. Here the government cannot offer a cost-reimbursement rule since it does not observe costs, and hence the firm will exert the efficient effort level.<sup>26</sup>

Moving away from the situation of monopoly regulation, Laffont also suggests that competition may mitigate capacity problems. Competition may help to provide the regulator with more information or may serve as an alternative pressure on the firm to keep prices low.<sup>27</sup> If competition is to be introduced, care still needs to be taken over the implications of limited regulatory capacity, for the regulator will still have several important tasks. For instance, the regulator may be involved in reducing market power

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<sup>26</sup> See Laffont and Tirole (1993, pp.516-30) for a broader analysis involving the monitoring of effort and cost-padding.

<sup>27</sup> Laffont and N'Guessan (1999) for example model competition as an increase in  $\xi$ .

and setting access prices. Experience in developing countries suggests that the regulation of partially competitive sectors may be as demanding on regulators as monopoly regulation.<sup>28</sup>

Chapter 5 of Laffont (2005) considers the implications that limited capacity has on access prices, which are the prices set for access to the network (or similar intermediate good). He suggests that when there are multiple usages of a network, regulation of access should be based on broad categories of usage. For example, the price of electricity transmission should theoretically vary according to which point of the network it enters and exits, but enforcing such prices would involve detailed inspection and complex calculation. Similarly, access prices should theoretically be used to subsidize firms that have relatively little market power, but Laffont recommends against this in LDCs since the complexity of doing so gives the regulator too much discretion. These recommendations go against some results derived for access prices in developed countries,<sup>29</sup> but these results are deemed inappropriate to LDCs since the informational requirements are very large.

A further consideration Laffont discusses is how limited regulatory capacity impacts the design of regulatory structures.<sup>30</sup> Generally, a lack of skilled human resources in developing countries is likely to push towards the creation of fewer regulatory agencies. By pooling resources, a regulator is more likely to be able to afford the professionals required to process the information it receives and experts will be able to share their knowledge more easily. In practice, this is reflected in the tendency for advisors to recommend multisectoral agencies in LDCs. This allows, for instance, legal experts to be shared by departments since many of the legal issues are the same across sectors.

There is also a preference for national rather than decentralized regulation in technically demanding sectors such as telecommunications and electricity. In politically demanding sectors such as water and transport, the regulatory responsibilities are

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<sup>28</sup> This point is emphasized in Kessides (2005). Domah, Pollitt, and Stern (2002) study electricity regulators in LDCs and find that competition does not appear to make regulation any less complex.

<sup>29</sup> See Armstrong, Doyle, and Vickers (1996), Laffont and Tirole (2000), and Vogelsang (2003) for developed country focused analyses of access prices.

<sup>30</sup> See chapter 7 of Laffont (2005) which is based on Laffont and Aubert (2001).

often distributed across government levels, with local monitoring of performance and national monitoring of prices and environmental spillovers. Going a step further, practitioners have suggested that developing countries would benefit from a greater use of international and regional bodies to provide support and coordination for national agencies.<sup>31</sup> Again, the sharing of resources and experiences may help to mitigate the limited regulatory capacity faced in LDCs.

Overall, limited regulatory capacity reduces the information available to the government. High powered incentives and competition may therefore be useful as ways to reduce the reliance on this information within the regulatory framework. Furthermore, efforts should be made to boost the ability of regulators to deal with the information by pooling resources both within and across countries and sectors.

## 2.4 Limited Accountability

### Problems

Within the model above, we can represent the fact that accountability is more limited in developing countries as a higher value of  $k$ , the ease of making bribes. Illegal transfers between the firm and the regulator will be less costly in a situation where the regulator is less accountable.<sup>32</sup> For example, the sanctions may be less or it may be easier to keep the transfer hidden from the government. In the model above, collusion is always prevented, and the government pays the regulator a transfer of  $s = k\Phi(\bar{e})$ , costing society  $\lambda k\Phi(\bar{e})$ . Hence we can see that lower accountability (greater  $k$ ) will increase the size of this transfer and decrease social welfare.

However, the increase in transfers to the regulator predicted by the model appears inconsistent with experience. If anything, regulators in developing countries have fewer financial incentives to produce information than in developed countries,

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<sup>31</sup> This point is argued by Noll (2000), for example.

<sup>32</sup> In other situations, different interest groups will also have an incentive to capture the regulator. For example, Laffont and Tirole (1993) consider the case of environmentalists who desire lower output, while Estache, Laffont, and Zhang (2006) consider taxpayers who desire less network expansion.

contrary to the model. Indeed, the more striking difference one notes in LDCs is that collusion occurs much more frequently, which does not occur in the traditional modelling above. One interpretation is that developing country governments are not behaving benevolently, but by extending the model we can also provide a normative explanation. Let us assume that with probability  $\zeta$  the regulator is 'dishonest' and will take bribes from the firm in the way described above. On the other hand, with probability  $1-\zeta$  the regulator is 'honest' and will not take bribes from the firm. The government is not aware of the regulator's type.<sup>33</sup>

With the model extended in this way, it is no longer clear that the government will always wish to prevent collusion. Doing so would mean paying the regulator an incentive payment of  $s = k\Phi(\bar{e})$  for reporting that the firm is low-cost. At times, this will be a waste of public funds because the regulator will be honest and would not have colluded anyway. In developed countries, where  $k$  is small, the incentive payments involved are sufficiently inexpensive that it is worth paying them regardless of this possible waste. Hence here there will indeed be no collusion. However, in developing countries, where  $k$  is large, it will be optimal for the government not to make these payments and instead allow collusion some of the time. We would therefore expect to see more collusion taking place in LDCs than in countries with stronger institutions. This reduces welfare because the regulator will report a useful signal less often and hence there will be more asymmetric information.

Models of regulatory capture including this one typically assume a self-interested regulator under a benevolent government. However, this jars with developing country experience, where often the greatest fear is the unaccountability of the government, rather than the regulator. If the government is unaccountable to the populace, then it may itself collude with an interest group. This could lead it to place a different relative weight on consumer surplus in its objective function. For instance, a government who colludes with the firm will then have the welfare function

$$(9) \quad W = V + \gamma U$$

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<sup>33</sup> This is an extension similar to that used in Laffont and N'Guessan (1999) and Martimort and Straub (2006).

where  $1 + \lambda > \gamma > 1$ .<sup>34</sup>

Since the government now favors the firm over the consumers, they will care less about the distortion caused by taxes to pay for the firm's rent. Instead of equation (7) we then have

$$\begin{aligned}\mathbb{E}[W] &= v\xi[S(\underline{q}^*) - \underline{q}^* \underline{p}^* + (1 + \lambda)(\underline{q}^* \underline{p}^* - (\underline{\beta} - \underline{e}^*)\underline{q}^* - F - \psi(\underline{e}^*)) - \lambda k\Phi(\bar{e})] \\ &+ v(1 - \xi)[\gamma\Phi(\bar{e}) + S(\underline{q}) - \underline{q}\underline{p} + (1 + \lambda)(\underline{q}\underline{p} - (\underline{\beta} - \underline{e})\underline{q} - F - \psi(\underline{e}) - \Phi(\bar{e}))] \\ &+ (1 - v)\xi[S(\bar{q}^*) - \bar{q}^* \bar{p}^* + (1 + \lambda)(\bar{q}^* \bar{p}^* - (\bar{\beta} - \bar{e}^*)\bar{q}^* - F - \psi(\bar{e}^*))] \\ &+ (1 - v)(1 - \xi)[S(\bar{q}) - \bar{q}\bar{p} + (1 + \lambda)(\bar{q}\bar{p} - (\bar{\beta} - \bar{e})\bar{q} - F - \psi(\bar{e}))]\end{aligned}$$

For the most part, maximizing gives the same results as before since the condition that  $1 + \lambda > \gamma > 1$  ensures the government prefers to keep public funds than transfer it to the firm. However, in place of equation (8), we will have

$$(10) \quad \psi'(\bar{e}) = \bar{q} - \frac{1}{1 + \lambda} \frac{v}{1 - v} \left[ \lambda + \frac{\xi}{1 - \xi} \lambda k + 1 - \gamma \right] \Phi'(\bar{e})$$

We can see from this equation that the power of incentives is increasing in  $\gamma$ . This is because the government places a higher value on the firm's rent, and hence is not so concerned with decreasing it through offering lower powered incentives. Furthermore, if  $\gamma > 1 + \lambda(1 - k)$ , then the government would rather pay the firm an information rent than prevent collusion with the regulator. Hence the non-benevolence of the government may mean we also get more regulatory capture.

Laffont also studies the effect of a government's non-benevolence on the decision to privatize.<sup>35</sup> This is commonly a contentious decision and one in which accusations of corruption are frequent in LDCs. Suppose that, under public ownership, the government can extract private benefits in a way that is costly to society, and the government's welfare function is a linear combination of these benefits and social welfare. If the government weighs these private benefits very highly, it may be optimal

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<sup>34</sup> If  $1 + \lambda < \gamma$  then the model becomes uninteresting as the government simply transfers all of consumers wealth to the firm through taxation.

<sup>35</sup> See chapter 3 of Laffont (2005), which is based on Laffont and Meleu (1999). In this case, non-benevolent means that the government can take some rents for their personal use. Laffont (1999) surveys various ways in which incentive theory can be used to model aspects of political economy.

for society to privatize the firm in order to prevent this corruption – the government, however, will be unwilling. Now suppose that, in addition, the government can siphon off a portion of the revenues from privatization. If this portion is significantly large, the government may be willing to privatize even when it is not in the interests of society (i.e. even if the costs of the former type of corruption are not too large). Hence limited accountability may distort the privatization decision either way, with the distortion depending on the government's non-benevolence and the methods through which it can extract private benefits.

## Solutions

In terms of contract design, from equation (8), we can see that more limited accountability (higher  $k$ ) calls for less powerful incentives. This is because the temptation for collusion comes through the possibility of information rents accruing to the low-cost firm. Since these rents are smaller when the power of incentives is lower, the government can decrease the stakes involved in collusion by making incentives less powerful. This may also help to undo the distortion caused by the non-benevolence of the government shown in equation (10).

Reducing the size of the potential information rent is an instance of the general principle that one can decrease the costs of corruption by lowering the incentives of interest groups to hide information. Another example can be found in the case where there is the potential for collusion between taxpayers and the regulator. Here taxpayers may wish to bribe the regulator if asymmetric information results in a higher price and hence less taxpayer-subsidized network expansion.<sup>36</sup> Again, the costs of corruption can be mitigated by the government lowering the incentive of tax-payers to bribe. In this case, the government does so by promising less network-expansion. Hence, if governments are responding optimally to the threat of collusion, then we would expect to see less efficiency and less network expansion in corrupt countries. This is indeed consistent with empirical evidence from LDCs.<sup>37</sup>

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<sup>36</sup> This is explored in Estache, Laffont, and Zhang (2006)

<sup>37</sup> See, for example, the cross-country regressions in Estache and Kouassi (2002), Estache, Goicoechea, and Trujillo Castellano (2009), and Dal Bó and Rossi (2007).

Limited accountability in developing countries also has implications for the design of the regulatory structure. In particular, governments may find it easier to prevent regulatory capture if there are more regulators. If different agencies collect similar information, each regulator may ignore the externality it imposes on the others by revealing this information.<sup>38</sup> To see this effect in our model, suppose that in place of there being one technology that may reveal the costs of the firm, there are two -  $r_1$  and  $r_2$  - with the stochastic structure of the signals given by:

$$\xi_{11} = \mathbb{P}(r_1 = r_2 = \beta)$$

$$\xi_{12} = \mathbb{P}(r_1 = \beta \text{ and } r_2 = \emptyset)$$

$$\xi_{21} = \mathbb{P}(r_1 = \emptyset \text{ and } r_2 = \beta)$$

$$\xi_{22} = \mathbb{P}(r_1 = r_2 = \emptyset)$$

The case where both technologies are operated by a single regulator is equivalent to the model above with  $\xi = \xi_{11} + \xi_{12} + \xi_{21}$ . As we have shown, in order to prevent collusion in this case the government will be required to give an incentive payment of  $k\Phi(\bar{e})$  with probability  $v\xi = v(\xi_{11} + \xi_{12} + \xi_{21})$ .

Now suppose that two different regulators collect these two signals. We assume that each regulator is aware of the signal the other receives and they cannot collude with each other.<sup>39</sup> In equilibrium, each regulator expects the other to report their signal truthfully. Hence if both regulators receive informative signals, each will anticipate that the other will reveal it, and hence they will believe any collusion would be ineffective. Therefore, the government just needs to give incentive payments to the regulatory agencies when only one reports an informative signal. In particular, it will pay  $k\Phi(\bar{e})$  to agency  $i$  if  $r_i = \beta$  and  $r_j = \emptyset$ . Since this only occurs with probability  $v(\xi_{12} + \xi_{21})$ , the cost of collusion has been reduced.<sup>40</sup>

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<sup>38</sup> This model is an adaptation of Laffont and Martimort (1999). This can be seen as an example of the general principle that competition amongst bureaucrats decreases corruption, as discussed in Rose-Ackerman (1978) and Wilson (1980), amongst other places.

<sup>39</sup> Of course, limited accountability is also likely to make such inter-agency collusion more probable. See Laffont and Meleu (1997) for an analysis.

<sup>40</sup> See chapter 8 of Laffont (2005), which is based on Laffont and Meleu (2001), for further comparative statics. Linked to this idea is the effect decentralization has on collusion, which is considered in Laffont and Pouyet (2004).

As well as competition between agencies, competition within the industry may appear to be a possible avenue to reduce corruption. If competition reduces the need for regulation, then the regulator will have less power and hence cannot demand such large bribes. Empirical results however do not show a clear link between competition and corruption in LDCs.<sup>41</sup> One explanation can be given by using the extension of the model with honest and dishonest regulators already outlined. Suppose one result of competition is an increase in the ease with which the regulator can obtain information, i.e. larger  $\xi$ . We have seen in section 2.3 that a higher value of  $\xi$  implies lower powered incentives. In other words, the regulator's signal quality and low-powered incentives are complementary instruments for reducing the firm's expected information rent. We have also seen that if the government allows collusion between the firm and the dishonest regulator, the power of incentives will be lower (since asymmetric information occurs more frequently). Since competition and low-powered incentives are complementary, competition is therefore more valuable in the case with collusion. In other words, the greater information available through competition increases welfare whether corruption is tolerated or not, but the increase is greater when there is more corruption. Hence an increase in competition means the government will be less tempted to reduce corruption.

A final way suggested by many practitioners to make the regulator more accountable is by increasing direct consumer participation.<sup>42</sup> This can help make decisions more pro-consumer, but it may be ineffective in preventing capture if the regulator colludes by hiding information (since the regulator will simply hide the information from the consumers also).<sup>43</sup> Consumer groups may therefore only be useful when they have the ability to discover or reveal information hidden from the government. This relative ineffectiveness is vindicated in practice. The success of consumer participation in LDCs has been limited by the low capacity of representative groups, which has often left the process open to capture by better-organized interest groups. Furthermore, as we have discussed, consumer participation may be damaging

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<sup>41</sup> See Laffont and N'Guessan (1999) for this result and the following analysis.

<sup>42</sup> See Ugaz (2003), for example.

<sup>43</sup> See Laffont and Tirole (1993), Ch. 11.

if current consumers, but not potential ones, are represented since they are likely to discourage network expansion.

In summary, limited accountability is fundamentally linked to the information flows between actors. A general solution to regulatory capture in LDCs is therefore to reduce the importance of information that any potentially unaccountable agent holds. This may be through decreasing the system's dependence on such information (for instance, by lowering the power of incentives) or creating alternative information sources (by, for example, creating multiple regulatory agencies or competition). Additionally, it is worth noting that even if these measures increase total welfare, they may not decrease the frequency of corruption in developing countries.

## **2.5 Limited Commitment**

### **Problems**

In his analysis, Laffont distinguishes between three forms of limited commitment.<sup>44</sup> The first form, 'commitment and renegotiation' means that the contract can be renegotiated at a later date if both parties wish to do so. However, so long as one party does not wish to renegotiate, both will continue to be committed to it. The second form, which is labeled 'noncommitment', means there is the possibility that the government may break the contract in the future even if this disadvantages the firm. 'Limited enforcement', the third form, is essentially the opposite of this. Here the firm may be able to force the government against its will to renegotiate the contract.

In general, commitment and renegotiation is damaging as it restricts contracts to being efficient ex-post. In the model above, the possibility of mutually advantageous renegotiation decreases welfare. This is because the government may no longer (credibly) offer a contract to the firm that involves low-powered incentives. Once the high-cost firm reveals its type by picking this contract, both parties would like to

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<sup>44</sup> The first of these cases is studied in section 1.9 and chapter 10 of Laffont and Tirole (1993), and the second in chapter 9. The third case is modeled in chapter 4 of Laffont (2005), which is based on Laffont (2003), and is then extended in Guasch, Laffont, and Straub (2006).

renegotiate to a contract involving the firm exerts its efficient effort level  $\psi'(\bar{e}) = \bar{q}$ . Foreseeing that the high-cost firm's effort would in fact not be distorted, the low-cost firm will want to pretend to be high-cost. As a result, the government will have to offer a higher information rent to the low-cost firm, reducing welfare.

While the threat of commitment and renegotiation is a problem, in many developing countries the greatest concern amongst practitioners is government noncommitment. Large-scale investment, which is desperately needed in many LDCs, may not take place if governments cannot promise to allow investors to make a sufficient return. Investment in utilities is particularly vulnerable to government noncommitment because governments are always very involved in their operation and the investment is long-lived and non-transferable.

To explore this problem in the model, we can add investment in the following way. Let us suppose that, rather than  $\beta$  being given completely exogenously, the firm can influence its value by undertaking investment  $I$  before  $\beta$  is revealed. This investment increases the probability that the firm will be a low cost type, i.e.  $v = v(I)$  ( $v' > 0, v'' < 0$ ).<sup>45</sup> If the government is able to commit to reimbursing a chosen level of investment then they will set  $v'(I) = 1 / [\underline{U} - \bar{U} + \underline{V} - \bar{V}]$ , where  $\underline{V}$  and  $\bar{V}$  are consumers' surpluses defined in the standard way. Optimal investment increases as the benefits of having a low-cost firm increase.

However, if the government can make no commitments to the firm at the investment stage, then the firm will only take into account its private benefits of investing. We will then have  $v'(I) = 1 / [\underline{U} - \bar{U}]$ . Hence noncommitment will produce under-investment. This is consistent with cross-country evidence from LDCs documenting a negative correlation between the government's ability to commit and investment.<sup>46</sup>

Furthermore in a repeated game setting, a lack of commitment will lead to what is called the 'ratchet effect'. If the firm reveals itself to be low-cost, the regulator will use this information and become more demanding. Consequently, the low-cost firm has an

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<sup>45</sup> This component is taken from Laffont and Tirole (1993) since investment isn't modeled in Laffont (2005).

<sup>46</sup> See, for example, the cross-country evidence of Ghosh Banerjee, Oetzel, and Ranganathan (2006) that greater political stability increases private investment.

extra incentive not to reveal its information to the government. The government could hence increase welfare if they could commit not to use this information.

While problems of noncommitment have also received significant attention in the context of developed countries, limited enforcement has been relatively absent from the traditional regulation literature. This is because a strong rule of law normally prevents renegotiation in developed countries if the government is unwilling. For example, if a firm were to refuse to produce unless the contract was renegotiated, it would likely be fined a large amount of damages by the government. However, in developing countries, Laffont identifies limited enforcement as a serious concern. In Ghana, for example, he notes that the incumbent monopoly for fixed telephony entered the mobile business, despite this being explicitly prohibited. Similarly in Tanzania, the regulator attempted to enforce regional mobile licenses, but the dominant operator disagreed and began to expand nationally. These cases are backed up by evidence that about a third of infrastructure renegotiations in the Latin America sample he studied were at the initiative of the firm.<sup>47</sup>

To demonstrate theoretically why limited enforcement is problematic, Laffont considers the case where the firm only has the option of rejecting the contract before  $\beta$  is revealed to them, instead of afterwards as previously assumed. Hence we replace the *ex-post* participation constraints (1) and (2) with the *ex-ante* condition  $v\underline{U} + (1-v)\bar{U} \geq 0$ . With the changed participation constraint, the government can now offer a contract to the firm that gives it zero rent in expectation and still meets the incentive compatibility constraints (5) and (6).<sup>48</sup> Since the information asymmetry now generates no positive rent for the firm in expectation, expected social welfare is the same as in the complete information case. Such a contract will however require  $\bar{U} < 0$ , and we assume that in this case the firm may attempt to renegotiate when it is revealed that  $\beta = \bar{\beta}$  and enforcement is limited.<sup>49</sup>

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<sup>47</sup> See chapter 4 of Laffont (2005) for details of these examples, and Guasch, Laffont, and Straub (2008) for details of firm-led renegotiations in Latin America.

<sup>48</sup> For instance, we could set  $\underline{U} = (1-v)\Phi(\bar{e})$  and  $\bar{U} = -v\Phi(\bar{e})$ .

<sup>49</sup> This is in practice equivalent to considering when it is optimal for the firm to attempt renegotiation.

If renegotiation takes place, the government and the firm will split the ex-post social welfare in a way dependent on their bargaining power and status quo payoffs. If the firm expects to definitely be able to renegotiate, then contracting ex-ante brings no benefits and the firm will earn an information rent, which brings with it the problems already discussed.<sup>50</sup> Furthermore, renegotiation processes often involve costs. For example, investment programs may be postponed, as happened in the five years that followed the Argentina 2001 crisis and the Mali case discussed earlier. Throughout the negotiations, the parties tend to receive no more than their inefficient status quo positions. Hence limited enforcement will decrease social welfare in expectation.

## Solutions

Let us first consider the impact of limited commitment on the optimal power of incentives. In many developing countries, government-led renegotiation has been partially caused by dissatisfaction at the profits made by the firm. This would suggest that the probability of the government renegeing on its commitment is a function increasing in the size of the rent promised. In this case there will be an upper bound on the expected rent the government can commit to paying the firm. Let us label this maximum expected rent  $c$ . Then in order for the low-cost firm not to mimic the high-cost firm we require that  $c \geq \Phi(\bar{e})$ . If this constraint is not satisfied immediately, then the government should reduce  $\Phi(\bar{e})$  appropriately by reducing  $\bar{e}$ . Hence government noncommitment may favor a less powerful incentive regime, because the threat of renegotiation constrains its ability to offer the firm the possibility of making large profits.<sup>51</sup>

Limited enforcement may also have implications on the power of incentives. Consider for example moving from the extreme case of complete enforcement to no

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<sup>50</sup> On the other hand, if there is a positive probability of the government enforcing the contract, then in theory the threat of renegotiation does not mean the firm earns any extra rent in expectation. This is because  $\bar{U}$  can be reduced further to compensate for the positive rent the firm receives should it be successful.

<sup>51</sup> Similarly, Gilbert and Newbery (1994) show using a dynamic game that price-caps are less sustainable than rate-of-return schemes, while Guthrie (2006) argues that benchmarking to hypothetical firms requires stronger commitment since profits are more volatile. See Guthrie (2006) for a survey of the link between investment and risk.

enforcement. Here we go from the efficient contract outlined above that involves high-powered incentives to the case with asymmetric information where incentives are reduced.<sup>52</sup>

Other commitment problems may increase in severity as the power of incentives decreases. Commitment and renegotiation, for instance, forces all contracts to be efficient ex-post. As Laffont (2005, p.23) points out, “no general analysis exists of how easy commitment is depending on the type of regulatory regime”, and there is a need for further research in this area. However, the preceding analysis has shown us that perhaps the two most serious commitment problems facing developing countries may be mitigated by using less powerful incentives. This should therefore be the result borne in mind by policy makers, and indeed it is consistent with experience in developing countries. For instance, empirical results from renegotiations in Latin America suggest that price-caps generally cause more renegotiations than less powerful incentive regimes, and this applies for both renegotiations led by the firm and those led by the government.<sup>53</sup>

A further empirical result found in the study of renegotiations in Latin America is that partial public financing of the firm reduces government-led renegotiation but increases instances of firm-led renegotiation. The reduction of government-led renegotiation is consistent with traditional theory arguing that greater government ownership discourages the expropriation of profit by increasing the weight politicians put on the firm’s rents. Similar theory also suggests government commitment may be improved if the company is financed by loans rather than equity, since debt financing increases the minimum return that the government has to allow.<sup>54</sup> The modelling of limited enforcement above then adds to this argument by helping to explain the increase in firm-led renegotiation. If the government puts a higher weight on the firm’s rent, then they will have less of an incentive to increase enforcement and prevent the

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<sup>52</sup> In the simple model here incentives are not intermediary in the case of a partial reinforcement because the firm’s information rent can be extracted ex-ante. However, if we were to consider there is some lower bound on the firm’s ex-post welfare, then limited enforcement will lead to an information rent and it would therefore be optimal to reduce incentives.

<sup>53</sup> See Guasch, Laffont, and Straub (2007, 2008).

<sup>54</sup> See Perotti (1995) for the result on government ownership and Spiegel and Spulber (1994) for debt financing.

firm renegotiating.<sup>55</sup> How public financing of the firm may be used to solve commitment problems will therefore depend on which aspect is the greater risk in a given developing country.

A different type of solution commonly advised by practitioners is to increase the independence of the regulator.<sup>56</sup> One possible reason that independent regulation may increase commitment is that then the regulator may hold a different objective function from the government. This can be modeled in the same way as we have modeled an unaccountable government, i.e. we can suppose that the independent regulator has the objective function  $W = V + \gamma U$  rather than  $W = V + U$ . If the regulator is biased towards the firm ( $\gamma > 1$ ) and is given control over regulatory policy, then this works in a similar way to the 'conservative central banker' idea used in monetary policy.<sup>57</sup> The independent regulator will then be less keen to renegotiate than the government since they will care less about reducing the firm's profit. Furthermore, a regulator with this objective function will encourage investment, as incentives will be more powerful (from equation(10)) and hence  $\underline{U} - \bar{U}$  will be larger. These results are supported by empirical literature showing the beneficial effects of independent regulation on commitment and investment.<sup>58</sup> If limited enforcement is the most pertinent commitment problem, an independent regulator biased towards consumers could be helpful in a similar manner.

Finally, Laffont notes that in developed countries commitment may be deliberately limited in order to prevent a non-benevolent government binding the country to a bad outcome. By retaining flexibility, a future government can correct the mistakes of previous ones, and this may suggest that the existing lack of complete

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<sup>55</sup> See Guasch, Laffont, and Straub (2006) for this analysis. Furthermore, Corria da Silva, Estache, and Jarvela (2006) argue that greater debt financing is inappropriate for LDCs due to the associate foreign exchange risk.

<sup>56</sup> According to Estache (2008), by 2004 two-thirds of LDCs had introduced some form of independent regulatory agency in telecoms sector, 54% in electricity, and 23% in water. Henisz, Zelner, and Guillen (2005) and Gual and Trillas (2006) study motivations for creating independent regulators.

<sup>57</sup> See Rogoff (1985).

<sup>58</sup> Using cross-country evidence, Guasch, Laffont, and Straub (2007, 2008) find that the existence of an independent regulator does decrease renegotiation, while in telecoms, Wallsten (2001), Gutiérrez (2003), Ros (2003), Maiorano and Stern (2007), and Montoya and Trillas (2007) each find that independent regulation increases network expansion.

commitment powers is in fact optimal.<sup>59</sup> In developing countries, where accountability is more limited, the chance of the government being non-benevolent is higher. We may therefore reason that commitment should be more limited in LDCs as a result – i.e. limited commitment is not necessarily a problem, but in fact is a solution to the accountability problem.

However, it is important to note that the optimal level of commitment is not always increasing in the level of accountability. If, for example, governments are always non-benevolent, then there is no probability of a future correction, and hence commitment should be allowed in order to increase investment. In developing countries, where investment is so vital and commitment abilities already generally weak, increasing a government's powers of commitment is likely to be a positive move.

Overall, limited commitment comes in several different forms, and each may cause different problems and call for different solutions. In particular, biasing regulation towards the firm in some way may be sensible in countries where government noncommitment is the binding problem, but inadvisable if the enforcement of contracts is weak. In addition to this insight, Laffont's framework allows us to understand the success of two solutions that emerge from developing country experiences, namely less powerful incentives and independent regulators.

## **2.6 Limited Fiscal Efficiency**

### **Problems**

In the baseline model above we defined the parameter  $\lambda$  to be the opportunity cost of public funds. In developing countries, where tax systems are often extremely inefficient, this cost is likely to be much greater: Laffont (2005, p.2) reports that it is well beyond 1 in many developing countries, as opposed to something like 0.3 in developed

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<sup>59</sup> For more details, see chapter 16 of Laffont and Tirole (1993). Faure-Grimaud and Martimort (2003) also provide a model where commitment increases the damage caused by non-benevolent governments. Bardhan (2005, p.68-74) considers the accountability/commitment trade-off in reform more generally.

countries.<sup>60</sup> Such a significant difference has profound implications for regulation in LDCs. We have already seen that it is likely to worsen problems of limited accountability, since the cost of incentive payments to the regulator becomes higher. Limited fiscal efficiency is also clearly a fundamental barrier when considering solutions to limited regulatory capacity and building institutions that will enforce commitment.

Equation (4), which specifies the optimal pricing of the firm, tells us that the price mark-up should be greater the higher the opportunity cost of public funds. Hence more limited fiscal efficiency unambiguously leads to higher prices faced by consumers when there is the possibility of transfers. This is because taxing the firm represents a relatively efficient way of raising government revenue, given the general fiscal inefficiency in the economy.<sup>61</sup> The possible implication is that sectors that are subsidized in developed countries should be taxed in LDCs.

As well as government transfers paying to cover fixed costs and maintain regulatory agencies, they have also traditionally been used to increase the size of the network. While in developed countries the vast majority of the population has access to centralized networks, the need in developing countries for rapid expansion of access is urgent. It is the limited fiscal efficiency of LDCs that makes the problem of access significantly different from developed countries. Many rich countries also have policies designed to encourage universal access to networks, but the relative budget required is extremely small in comparison. A good estimate is that the infrastructure expenditure requirements for low income countries are at least 9% of GDP, more than twice the needs of middle income countries.<sup>62</sup> The challenge is all the more demanding since the geography of many poor countries means that utilities often cannot exhaust economies of scale to the extent that firms in developed countries are already able to do.

We can demonstrate the problems associated with limited access by extending the model to consider two regions – a rich one (region 1) and a poor one (region 2) –

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<sup>60</sup> Jones, Tandon, and Vogelsang (1990) and Auriol and Warlters (2007) estimate this cost for various countries.

<sup>61</sup> This is an example of a traditionally inefficient tax being optimal in developing countries, as explored in Gordon and Li (2009). See Burgess and Stern (1993) for a survey of taxation in LDCs.

<sup>62</sup> See World Bank (2005).

each with a unit mass of consumers.<sup>63</sup> We assume that the network is completely developed in the first region but only a share  $\theta$  are connected in the second. We ignore problems of asymmetric information by assuming the marginal cost in each region is public knowledge and exogenous. Let  $F_i$ ,  $c_i$ ,  $q_i$  and  $p_i$  be the fixed cost, marginal cost, quantity per capita and price in region  $i$ . Suppose the fixed cost in region 2 is a function of the share of people connected, i.e.  $F_2 = F_2(\theta)$ , and that the cost is increasing in the size of the network (i.e. the cheaper areas are connected first), so  $F_2'(\theta) > 0$  and  $F_2''(\theta) > 0$ . Let us further assume that there is unit elasticity of demand. The government's welfare function is then given by the expression

$$W = S(q_1) + \lambda p_1 q_1 - (1 + \lambda)(c_1 q_1 - F_1) + \theta S(q_2) + \theta \lambda p_2 q_2 - (1 + \lambda)(\theta c_2 q_2 - F_2(\theta))$$

Differentiating with respect to  $\theta$  and setting to 0 gives

$$0 = S(q_2) + \lambda p_2 q_2 - (1 + \lambda)(c_2 q_2 - F_2'(\theta))$$

Hence the optimal size of the network is then given by

$$(11) \quad (1 + \lambda)F_2'(\theta) = S(q_2) + \lambda p_2 q_2 - (1 + \lambda)c_2 q_2$$

Differentiating this equation by  $\lambda$  we obtain  $\frac{d\theta}{d\lambda} < 0$ . This shows that as fiscal efficiency becomes more limited the optimal size of the network decreases. Hence in the poorest countries where network expansion is most needed, the opportunity cost of public funds prevents governments from being able to connect poor users.

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<sup>63</sup> This is a modified version of the models considered in Laffont and N'Gbo (2000) and chapter 6 of Laffont (2005) with the latter based on Estache, Laffont, and Zhang (2006). Laffont and N'Gbo (2000) additionally allow for an alternative technology in the poor region and varying quality, while Estache, Laffont, and Zhang (2006) consider the effects of asymmetric information and collusion in the two region case.

## Solutions

Let us return temporarily to consider ways to mitigate the problems of limited fiscal efficiency in the model with asymmetric information and one region. If transfers between the government and the firm are permitted, then any expected rent that the firm receives will effectively come from government revenue. Equation (8), which specifies the effort level of the high-cost firm, shows us that a greater value of  $\lambda$  implies it is optimal for the government to use less powerful incentives. This is because transferring rent to the firm and the regulator becomes more costly for society as the taxes raised to pay these transfers become less efficient. Hence the government prefers to decrease the efficiency of the high-cost firm in order to lower the rent going to the low-cost firm. This is therefore another reason why we might expect the power of incentives should be lower in LDCs.

In developing countries there still exist a multitude of price restrictions that are used to reduce high prices in costly areas. A common example is incumbent firms being compelled to charge the same price in relatively sparse rural areas as in cities. Let us consider such a restriction in the model with two regions, symmetric information and unit elasticity and consider the case where the poor area has a higher marginal cost than the rich one, i.e.  $c_2 > c_1$ . Then in this case uniform pricing serves to decrease prices in the rural area, since we now have  $p_2 = (1 + \lambda) \frac{c_1 + c_2 \theta}{1 + \theta}$  rather than  $p_2 = (1 + \lambda) c_2$ . However, we can note from equation (11) that a lower price in the poor area will result in decreased network expansion. Hence there exists a trade-off between affordability and access. This is illustrated by the Chinese government's adoption of a policy of uniform pricing in telecoms in 2001. Though the reform decreased the price discrimination that previously penalized rural users of the network, it also reduced the expansion of the network into rural areas.<sup>64</sup>

One way to mitigate the lack of public funding for network expansion is to institute cross-subsidies from the rich region to pay for greater access in the poor region. Let us consider the case where there are no transfers between the government and the firm. The government can mandate the firm to expand the network into the

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<sup>64</sup> See Estache, Laffont, and Zhang (2006) for details.

poor area through a 'universal service obligation' – i.e. an obligation to serve a specified population. Then the government's optimization problem can be represented as the following Lagrangian

$$S(q_1) - p_1 q_1 + \theta S(q_2) + \theta p_2 q_2 + \mu(p_1 q_1 + \theta p_2 q_2 - c_1 q_1 - \theta c_2 q_2 - F_1 - F_2(\theta))$$

with  $\mu$  the coefficient on the firm's budget constraint. Solving this gives us  $\mu F'(\theta) = S(q_2) + (\mu - 1)p_2 q_2 - \mu c_2 q_2$ . When fiscal efficiency is very limited, we will have  $1 + \lambda > \mu$ , and hence from equation (11) we can see that cross-subsidies achieve a greater amount of network expansion than public financing.<sup>65</sup> This condition is likely to be met in many LDCs, and here cross-subsidies should be encouraged as the most efficient way to bring consumers onto the network.

In summary, limited fiscal efficiency generally implies that the governments of developing countries should subsidize firms less (and tax them more) than in developed countries. The result will be high prices and small networks. To mitigate the effect of this on the poor, cross-subsidies may be the best option in many developing countries.<sup>66</sup> When designing such subsidies, it is important to bear in mind that there is a fundamental trade-off between increasing access and increasing affordability.

### 3 Extensions and Critiques

The previous section has summarized some of the key insights from Laffont's work on regulation in developing countries. We have shown that the model used by Laffont succeeds in providing lessons on the problems and solutions related to each of the four key institutional limitations LDCs face. However, as Laffont (2005, p.xx) states,

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<sup>65</sup> A more sophisticated analysis is provided in Gasmi, Laffont, and Sharkey (2000) who develop an engineering process model of a competitive telecoms sector and provide conditions for when urban-to-rural cross-subsidies are a useful mechanism for funding universal service. They find that, unlike in developed countries, these conditions are likely to hold for many LDCs.

<sup>66</sup> Indeed, cross-subsidies have historically been used in many developed countries as a means of resolving distributional concerns. Such subsidies still often exist in these countries' telecommunications sector - see, for example, Waverman and Crandall (2000) for further details.

“the results ... should be considered as only a first step towards a more comprehensive theoretical framework”. Indeed, practitioners’ experiences tell us that there are many important omissions from the model above. The aim of this next section is to consider how the theoretical work of other economists has filled some of these gaps.

We proceed as before by considering the four institutional limitations that we believe are the most pressing concerns for regulatory policy in LDCs. The work considered in each part includes various extensions and modifications of the model used by Laffont that other authors have made. Moreover, we also draw on literature that has taken an alternative theoretical approach when we find the framework of Laffont unsatisfactory. This review enables us to build a greater understanding of the robustness of Laffont’s model and the next steps needed to be taken in order to construct a more comprehensive theoretical framework.

### **3.1 Limited Regulatory Capacity**

Within the framework of Laffont’s models we have concentrated on asymmetric information as the key way in which to model limited regulatory capacity. While this illuminates some of the problems of limited capacity, there are other aspects that are not purely based on concerns of information asymmetry. For example, in a recent survey of regulators in LDCs, 44% conceded that they did not have a good understanding of the different ways of regulating profits and prices.<sup>67</sup> Such a lack of educated professionals and relative inexperience of regulatory bodies may be better captured by considering the limits of the regulator’s cognition and rationality.

A key result of the regulator’s limited cognition is that there will be contingencies that are unforeseen when the contract is being drawn up. This is compounded by the lack of funds to pay lawyers and consultants who might be able to advise on such contingencies. We would therefore expect that more limited regulatory capacity will lead to a more incomplete regulatory contract. A contract is described as ‘incomplete’ if

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<sup>67</sup> This result is from Kirkpatrick, Parker, and Zhang (2005).

it is not contingent on all the possibilities that it would optimally be.<sup>68</sup> Contracts are likely to be incomplete in developed countries also, but in developing countries the problem moves from a relative side-issue to centre stage. One piece of evidence for this is that complaints over 'lack of clarity' are much more frequent in the developing country context. Once we recognize the incompleteness of the regulatory contract we are forced to move away from the (relatively) complete contracting model of Laffont.

The incompleteness of the regulatory contract is made even more damaging by the greater uncertainty that exists within developing countries. For example, one contingency that was not included in regulatory contracts is the 1997 East Asia crisis. This resulted in such a dramatically widespread exchange rate crisis that almost all infrastructure contracts in LDCs had to be renegotiated simultaneously. Even though contracts had clauses relating to the exchange rate, such large changes were not envisaged at the time of writing and hence it was not possible to proceed without renegotiating.

When a contingency not envisaged by the contract arises, bargaining will occur over how the contract should be changed (assuming that it is in the interest of both parties to change the contract). In addition to the bargaining inefficiencies already discussed, the expectation of the process may reduce the incentives of the parties to invest or exert effort efficiently – the so-called 'hold-up' problem.<sup>69</sup> The typical hold-up problem in regulation is that the firm will not invest if they fear a future renegotiation will give them an insufficient return on the investment. Thus the reduction in contractual completeness caused by limited regulatory capacity may prevent much needed investment.

A further result of this contractual incompleteness is that the firm is likely to earn a greater expected rent. This occurs for two reasons. First, the government's

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<sup>68</sup> Tirole (1999) describes incomplete contracts as being caused by three transaction costs: The cost of foreseeing future contingencies, the cost of writing them into contracts and the cost of then enforcing these contracts. Each of these is clearly applicable within the regulatory context. Furthermore, Maskin and Tirole (1999) show that some bounded rationality is required to motivate incompleteness, else contracts could be drawn up based upon the assumed probability distribution over agents' payoffs. See Hart and Moore (1999) and Segal (1999) for further discussion on the foundations of incomplete contracts.

<sup>69</sup> See Williamson (1975, 1985) for details of the hold-up problem and its relationship with transaction costs. Note that while incompleteness may result in the renegotiation of the contract, it does not necessarily imply limited commitment in the sense that we have previously considered, because parties may not be able to commit to actions in states of the world which they did not foresee.

bargaining power is likely to be weaker *ex post* than *ex ante*, since finding an alternative supplier is more difficult mid-contract.<sup>70</sup> This shift will be particularly strong in developing countries since here utilities are often one of the greatest forms of foreign investment. If a private investor pulls out mid-contract, then this will send a large negative signal to markets, reducing much needed future FDI. Second, since writing contingencies into contracts is costly, the process of making a contract more complete will involve rent-seeking.<sup>71</sup> Both parties will try to make sure that contingencies that would put them in a bad bargaining position are included in the contract. Since the limited capacity of the regulator is not likely to be matched by the firm, contracts will be incomplete in a biased sense - i.e. the contingencies that are not included will be those where the firm has a greater bargaining power. The regulatory contract should therefore take account of this expected positive rent a firm will earn from unforeseen contingencies.

Taking the contractual incompleteness into account may also have implications for the optimal power of incentives that are not considered in the model above. Suppose an unforeseen contingency occurs that results in a change in the firm's marginal cost. Under a contract where a proportion of the firm's costs are reimbursed, costs will be monitored and renegotiation should be fairly straightforward. On the other hand, under a high powered fixed price contract, there is no direct need for the government to collect data on the firm's cost. In developing countries, reliable cost accounting may therefore not occur. Hence, under a price-cap regime, there will be a greater amount of relevant asymmetric information between the firm and the government. Since asymmetric information means there will be a higher chance of breakdown in bargaining, renegotiation to a new price-cap regime has a greater

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<sup>70</sup> Williamson (1985) describes this change from ex-ante competition to ex-post monopoly as the 'fundamental transformation'. The high risk of future renegotiation further undermines the classic argument of Demsetz (1968) that regulation is unnecessary due to competition for the contract.

<sup>71</sup> Hence we may get a contract that is 'too complete' – see the model of Tirole (2009) for this analysis.

expected cost. Therefore, as limited regulatory capacity will lead to less complete contracts in LDCs, this mitigates in favor of starting off with less powerful contracts.<sup>72</sup>

A further suggestion from the incomplete contracting approach is that efficiency may be retained if the parties can at least fix ex ante their respective bargaining powers and default positions for future renegotiations.<sup>73</sup> In regulatory contracts, this may be best done through an arbitration process. Bargaining power could, for example, be determined by setting up an expert panel with an appropriate bias, or through the creation of a litigation fund.<sup>74</sup> One may also be able to change the default positions through the use of fines or international guarantees.

To summarize, it is essential to recognize the limited cognition of the regulator as an aspect of limited regulatory capacity additional to the informational issues studied by Laffont. The transaction costs involved in writing contracts and the resulting incompleteness have implications for the optimal design of the regulatory contract. Contracts that are relatively complete in developed countries may be incomplete in developing ones, and hence this emphasizes the danger of importing best-practice models.<sup>75</sup> Contractual incompleteness may decrease investment and increase the firm's rent, but these effects may be mitigated by anticipating future renegotiation and implementing policies to make it relatively fair and efficient. However, there has been relatively little work applying the ideas from the theory of incomplete contracts to the case of regulation. More work is needed in order to help policy makers understand the full consequences of the limited regulatory capacity and greater uncertainties present in developing countries.

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<sup>72</sup> This is modeled in Bajari and Tadelis (2001) in the case of construction contracts. In the case of utility regulation, Guthrie (2006) indeed argues that price-caps based on a hypothetical benchmark firm should be avoided when capacity is limited due to informational requirements.

<sup>73</sup> See, for example, Aghion, Dewatripont, and Rey (1994). Fares (2006) provides a general survey of contract solutions to the hold-up problem. Hart and Moore (1988) argue that a key problem is that such mechanisms may rely on being able to identify the party that caused the renegotiation, which is often difficult to prove to a third party.

<sup>74</sup> Estache and Quesada (2001) show how the government may wish to balance renegotiation bargaining powers to improve welfare. Garcia, Reitzes, and Benavides (2005) show that the government can mitigate the commitment problem by having a litigation fund which it commits to using in event of renegotiation.

<sup>75</sup> For example, a contract may specify different actions for two states of the world that a well-resourced regulator, backed by an experienced judiciary, could distinguish between. However, capacity constraints may make these two states indistinguishable and hence the contract will be vague for all practical purposes.

## 3.2 Limited Accountability

Laffont's work on limited accountability concentrated on the ability of the regulatory agency to hide information from the government. The model gave us a number of important insights, but we noted that in developing countries particularly we are also worried about the limited accountability of other actors. Hence it is necessary to consider how far Laffont's framework can be extended to help us understand other types of corruption.

While the model set out above has a three-tier hierarchy of government/regulator/firm, it can be adapted to consider other circumstances. For example, decentralization of regulation has been a popular idea amongst international advisers to LDCs, and this can be studied by considering the hierarchy of central agency/local agency/firm. In this setting, it may be in the interest of a local regulator to collude with the firm by hiding information from a centralized administration. In China, for example, local governments have been known to collude with small-scale inefficient coal power plants in order to prevent them being shut-down by the central government. This is because the local government has an incentive to keep power plants in their region open as they provide jobs and tax revenue, which aid the local officials' personal objectives such as promotion.<sup>76</sup> More generally, if the central administration shares costs with the local regulator, then the local regulator has an incentive to collude with the firm to exaggerate the value of a project. In this case, the central regulator may have to reward the local regulator for reporting low costs, in a similar way to the model above.<sup>77</sup>

A further extension of the regulatory capture model is to use the framework to understand the unaccountability of the government to its citizens. This may help us to understand the importance of the public's perception of corruption. Experiences in

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<sup>76</sup> See Laffont (2005, pp.22-24) for further details.

<sup>77</sup> The model of Besfamille (2004) considers such as a situation in the case of public works. Bardhan and Mookherjee (2006) construct a general model of accountability for the case of decentralizing publicly operated infrastructure.

developing countries suggest that even if a reform is welfare-enhancing, it may lose support from the populace if corruption is seen to have increased. This is a potential explanation for the dissatisfaction with privatization in Latin America, where surveys reveal that increasing discontent with privatization is correlated with increasing perceptions of corruption.<sup>78</sup>

This correlation may be explained by modelling an alternative hierarchy of general public/government/firm, which focuses on the limited accountability of the government to its electorate. Suppose a key change resulting from privatization is the removal of transfers between the government and the firm. Collusion under public ownership results in an additional government transfer to the firm, while under private ownership it will take the form of higher prices. If the cost of public funds is sufficiently higher than the cost of raising prices, corruption will be less costly and hence more frequent under private ownership. Since the high cost of public funds in LDCs makes this condition quite likely to hold, this suggests privatization may increase corruption.<sup>79</sup> Furthermore, in developing countries, where fiscal accounts are likely to be opaque to most citizens, revenue raised through prices is less likely to go unnoticed than budget transfers.

This extension continues to model collusion in the form of hiding information, as did the decentralization application. Whilst this is an important aspect of unaccountability, there are many other decisions that are open to corruption.<sup>80</sup> In addition to the privatization choice analyzed by Laffont, the government or the regulator will make decisions including the amount of competition to allow in the market, who to sell the enterprise to and the permitted profit. Each of these decisions is vulnerable to influence by the firm or other interest groups.<sup>81</sup> Distinguishing between different types

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<sup>78</sup> This explanation and evidence is from Martimort and Straub (2009).

<sup>79</sup> This analysis is from the model of Martimort and Straub (2009). Other literature, such as Boycko, Shleifer, and Vishny (1996) and Sappington and Stiglitz (1987), has argued that privatization limits the non-benevolent behavior of the government. See Martimort (2006) for a survey of the costs and benefits of privatization. More generally, Acemoglu and Robinson (2008) show how *de jure* institutional changes such as privatization may not result in *de facto* changes in power or policy.

<sup>80</sup> See Kenny (2009) for a general survey of corruption in infrastructure. One form of corruption we do not discuss here is that between the utility and the users, on which little work has been done - Clarke and Xu (2004) is one notable exception which uses data on the paying of bribes to utilities.

<sup>81</sup> For example, Armstrong and Sappington (2006) note that introducing competition may require entry assistance, which can encourage regulatory capture and unproductive use of public funds, while Bjorvatn and Søreide (2005) argue that if firms bribe for licenses then the government will choose a less

of corruption is important in deciding upon the appropriate solution. If corruption takes place in the bidding for a contract, increased accountability in the bidding process may prevent an inefficient yet well-connected firm from winning. On the other hand, if corruption takes place between the firm and the regulator post-contracting, then the same firm may win the contract in a completely fair auction.<sup>82</sup>

In the model of section 2, we represented the decisions made in such cases as the solution of a non-benevolent principal maximizing the welfare function (9), with the weight  $\gamma$  dependent on the influence of the interest groups. However, this does little to illuminate why some interest groups have more power than others. For instance why could farmers in the North of Argentina and parts of Peru manage to get regulators to adjust the pricing of energy they need to pump water while leather producers, also heavy users of pumped water, could not? Similarly, why are farmers who are responsible for a large share of many African countries' output so much less powerful in their relation with utility regulators? The model of a single principal maximizing a weighted welfare function leaves little room to explore how the structure of government and the regulatory agencies influence the power of interest groups on policy.<sup>83</sup>

In the developing country context where the lack of accountability is widespread, it is therefore necessary to move beyond models with a single principal and instead consider the multiplicity of actors that exist within the government.<sup>84</sup> The existence of multiple principals can aid accountability if they are under the influence of different interest groups with conflicting aims. Hence one way of dealing with the risk of regulatory capture is to ensure that the selection process involves these different

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competitive environment. Grossman and Helpman (1994) create a general model where interest groups bid for their preferred policy. Dal Bó (2006) provides a survey of regulatory capture in general.

<sup>82</sup> This example comes from Dixit (2003). As an example of considering different forms of corruption, Hellman, Jones, and Kaufmann (2003) distinguish between 'influential' firms, who affect rule making, and 'captor' firms, who capture bureaucrats. They find that the two types of corruption are not equivalent, and produce significantly different results.

<sup>83</sup> Grossman and Helpman (1996) provide one way in which such weights can be made endogenous by considering campaign contributions to political parties.

<sup>84</sup> The multiplicity of principals is one of the factors considered by Kassim and Waddams Price (2005) in the introduction to a special issue on the limits of the principal-agent model in regulation.

actors. An example advocated by practitioners is to include both the executive and the legislative branches in the regulator's appointment.<sup>85</sup>

On the other hand, when different principals are affected by the activities of the bureaucrat-regulator the latter can play one principal off against the other. The bureaucrat may then become less accountable with each principle unable to constrain its actions. Whether or not the existence of multiple principals is a curse or blessing for accountability depends on the regulatory process and structures in place.<sup>86</sup> For example, one way to increase accountability is to expose the regulatory bureaucrat by making available private information on the effectiveness of the bureaucrat's behavior. Simple institutional rules like the public release of regulatory information may allow this kind of information sharing between multiple principals. Furthermore, restrictions on the set of instruments available to the different actors may help to reduce their scope to extract rent or align the decision maker's incentives. For instance, if the elected executive does not have power over the funding of the regulator, then the regulator will be less responsive to short-term political concerns.

These aspects of regulatory governance with multiple principals also apply to some extent in developed countries. However, the key difference is that these factors are automatically considered in developed countries because here the regulatory framework comes about endogenously and the actors involved will be very aware of the influence of various interest groups. In developing countries, the risk is that these concerns are not taken into account because regulatory structures may be designed exogenously. Here the regulatory setup is partially constructed by international experts who are not automatically aware of the power of different principals within the government.

Overall, we can see that the framework used by Laffont has the potential to explain many aspects of limited accountability in LDCs. Not only does it give

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<sup>85</sup> Dal Bó (2006) finds evidence of regulatory behavior depending on their appointment method. For other models describing the risks and benefits of multiple principals see, for example, Martimort (1996) and Persson, Roland, and Tabellini (1997)

<sup>86</sup> See McCubbins, Noll, and Weingast (1987), Spulber and Besanko (1992), and Dixit (2003) for discussions on how the interaction of multiple actors in government is influenced by processes and structures.

implications for preventing regulatory collusion as discussed in the previous section, but it can be extended to consider the risks of decentralization and explain why corruption may increase with privatization. However, when external actors are advising on regulatory structures and processes in developing countries, they need to take account of the multi-principal nature of government. Here it is therefore necessary to go beyond a model with a strict hierarchy of actors.

### **3.3 Limited Commitment**

The implications of a limited ability to commit go beyond those studied by Laffont. Since in developing countries the probability of renegotiation is so large, anticipation of possible renegotiation will play a major role in actors' decisions. For instance, in the Buenos Aires water concession the winning firm had taken out a loan that, without renegotiation, it would not have been able to repay.<sup>87</sup> While Laffont focused on the problems after a particular firm has been chosen to contract with the government, limited commitment may also affect the auction process and the viability of reform.

Argentina also provides a good example of the effect of limited commitment on bidding for contracts. In selling an electricity contract, the government announced a change in the regulatory framework a few days before the auction, offering a higher rate of return and an extension to the contract length. This was expected to increase the value of the contracts, but in fact it is believed that the amounts bid were less as a result. This is because it heightened fears that the government was willing to alter the regulatory framework at short notice.<sup>88</sup> Hence a lack of faith in promised future returns may decrease the amount bid.

This effect on bidding raises the possibility of adverse selection in auctions. The contract may not go to the most efficient firm, but instead to the one that believes it has

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<sup>87</sup> This example comes from Alcazar, Abdala, and Shirley (2002).

<sup>88</sup> See Manzetti (1999) for this example. Bortolotti and Siniscalco (2004) also find evidence that privatization revenues increase with measures of government commitment.

the highest chance of renegotiating (or the lowest chance of expropriation). This issue was raised as a matter of concern by Argentina's National Public Auditor during the 1990s for several of the contracts awarded to toll roads operators. From the government's point of view, it also may want to bias the awarding of the contract to pick an inefficient firm if they have a lower chance of renegotiating.<sup>89</sup>

The fear of actors not living up to their promises may also undermine support for reform.<sup>90</sup> For example, large-scale sector reforms have often commenced with price-rises in order to allow the firm to recover a greater proportion of its costs. This is planned to enable the firm to make investments in cost reduction, which in the long-term should benefit users if translated into reduced prices. However, consumers are often suspicious that these promises will not be met, and hence attempt to derail the reform. The Mali privatization discussed in the introduction is a good example of this process. Thus, even if the overall reform could result in a Pareto improvement, the reform is not supported because the parties cannot commit to redistributing the gains appropriately. This is particularly troublesome in utility reform because the costs are often felt immediately while it takes time to realize many of the gains.

Let us now turn away from the further problems of limited commitment and move to consider in more detail a proposed solution for developing countries, namely regulatory independence. We have discussed previously how one may model the effects of independence in the framework of Laffont. However, many of the aspects of this policy emphasized by practitioners are not included in the model. Given the prominence given to this issue within the empirical literature and policy debate, it is necessary to take this analysis further.

In practice, one method through which regulatory independence may aid commitment is by reducing the accountability of the regulator to political representatives.<sup>91</sup> If there is a greater potential for collusion as a result of

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<sup>89</sup> Estache and Quesada (2001) explore this latter point in a model with alternating governments.

<sup>90</sup> See Campos and Esfahani (2000), Acemoglu (2003), and Bardhan (2005).

<sup>91</sup> There is some empirical evidence that independence interacts with corruption unfavorably. Estache, Goicoechea, and Trujillo Castellano (2006) find that the interaction of an independent regulator and high corruption levels has a number of negative effects on performance. Gual and Trillas (2006) find evidence suggesting incumbents may favor independent regulators, perhaps anticipating capture. Alternatively,

independence, then this will tend to favor regulatory regimes with less powerful incentives which, as mentioned above, may reduce commitment problems.<sup>92</sup> Alternatively, if independence makes the decision maker more susceptible to firm lobbying, then this may give them a pro-industry bias that creates the appropriate incentives for investment.<sup>93</sup> In some circumstances, increasing independence may therefore create extra space for this type of collusion and hence mitigate commitment problems.

Further aspects of an independent regulator that practitioners argue may aid commitment include the fact that the regulator may be able to tie its hands in a way the government cannot, or may hold a greater concern for its reputation.<sup>94</sup> This multitude of different ways that regulatory independence may reduce commitment problems emphasizes the need to examine the concept of independence more thoroughly. In particular, there is a need to breakdown the various aspects of 'independence' and consider which are likely to be more important, and which are likely to have the greatest risks. For example, is removing the regulator's budget from political control more important than having a staff of professionals that are not generalist civil servants? This is crucial for developing countries because political constraints mean that they may not be able to create entities that have all the aspects of independence immediately. While the empirical literature has begun to separate out aspects of regulatory governance, there is a lack of corresponding theoretical work. Progress in this area would help governments to define priorities when carrying out regulatory reform.<sup>95</sup>

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incumbents may favor independent regulators because they can commit to letting the firm keep information and efficiency rents.

<sup>92</sup> Olsen and Torsvik (1998) give this result.

<sup>93</sup> See Che (1995) and Evans, Levine, and Trillas (2008) for models in this category. Salant (1995) gives a similar effect with the opening of the 'revolving door' between careers in regulation and industry. Victor and Heller (2007) argue that in practice limited commitment has led to the rise of 'dual firms' that mitigate a lack of commitment by keeping close ties to the public sector.

<sup>94</sup> Reputational concerns are considered in Salant and Woroch (1992), Gilbert and Newbery (1994), and Levine, Stern, and Trillas (2005), while Cubbin and Stern (2006) finds evidence that the effect of good regulatory governance increases over time as a reputation is built up.

<sup>95</sup> Gutiérrez (2003) considers different levels of independence amongst independent regulators, while Pargal (2003) finds evidence in cross-country regressions that different aspects of independence may have different effects. Brown (2003) discusses the splitting of powers between policy makers and independent agents.

The lack of complete regulatory independence in many developing countries motivates a more holistic approach to the government when considering commitment problems. In developing countries, power is often very concentrated in the executive, and this can be the root cause of many commitment problems. Even if the regulator is independent, a powerful executive may be able to undermine the agency since it ultimately decides upon regulatory policy. Here regulatory transparency may be costly if it weakens the power the regulator holds through being better informed than the executive.

Concentrating solely on a single regulatory body is therefore likely to have limited effectiveness and it is worth considering other veto points or constraints on the executive. This might include a separation of powers through involving the judiciary or the legislature.<sup>96</sup> Generally, a separation of powers improves commitment because future renegotiation is more costly when there are many non-cooperating principals that have to agree to a renegotiation. Empirically this idea is verified by the existence of checks and balances having a positive effect on utility investment in LDCs.<sup>97</sup>

If it is possible to constrain the actions of the government through specific legislation or the judiciary, then this may be a superior method of regulatory governance to an unconstrained independent regulator. For example, in telecoms in Jamaica, the switch from a detailed operating license regime to one with an independent regulator in the 1960s was probably the cause of a following large decline in investment. This is because the operators feared the regulatory would misuse its discretion in a way that was not possible when the relatively specific license was enforced by the judiciary.<sup>98</sup> The challenge is to design a regulatory process that increases commitment in a way that is compatible with the country's institutional structure. An independent regulatory agency will work less well in a country where

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<sup>96</sup> This framework is set up for regulation by Spiller (1990), Levy and Spiller (1994, 1996) and Guasch and Spiller (1999). See also Tirole (1994) and Heller and McCubbins (1996).

<sup>97</sup> Using cross-country panels, Bergara, Henisz, and Spiller (1998), Henisz and Zelner (2001), and Gutiérrez (2003) find investment in electricity and telecoms suffers when there are fewer checks and balances.

<sup>98</sup> This example comes from Levy and Spiller (1994, p.232).

there is little tradition of bureaucratic autonomy. Here, if the legislator is fairly independent of the executive, specific legislation may instead increase commitment.

If general separation of powers is not feasible, then the splitting up of regulatory roles may similarly increase commitment.<sup>99</sup> This goes against the tendencies of policy makers in LDCs because generally it is easier to push through initial reform when there are fewer actors involved. Theoretically therefore, the optimal regulatory charter is to start off with few actors (or at least all actors cooperating) and then to increase the number of actors as time progresses. Such a charter is likely to be infeasible. However, the more important result that practitioners may want to keep in mind is that the excessive splitting of the responsibilities of regulatory agencies may be good for regulatory outcomes.

Laffont's framework therefore only analyses a subset of both the problems of limited commitment and the proposed solutions. In developing countries, limited commitment will cause problems at all points in the reform process. Furthermore, the origins of limited commitment are likely to be much more fundamental than in developed countries, stemming from a lack of separation of powers and checks and balances. Solutions must therefore go beyond the regulatory contract and take into account the processes and structures that define the framework as a whole.

### **3.4 Limited Fiscal Efficiency**

We have considered in section 2.6 the problem of a high cost of public funds in the case where transfers are allowed. However, since the existence of transfers was exogenous to the model, it did not help to answer the question of why the existence of transfers varies between countries and sectors and how this relates to fiscal efficiency. Making the existence of transfers endogenous may help us to understand the importance of transfers between the government and the firm. This is particularly

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<sup>99</sup> Olsen and Torsvik (1993) and Martimort (1999) give models showing that opportunistic renegotiation is decreased when there are several regulators.

pertinent since their existence tends to be linked to whether the firm is privatized and hence may help us to understand the costs and benefits of privatization.

Suppose that the cost of allowing transfers is that this gives greater responsibility for production decisions to the government. As shown previously, this will be costly in the presence of asymmetric information. If the monopoly is very profitable and the cost of public funds is not too high, it will be optimal to remove transfers and let the firm run efficiently. However, when fiscal efficiency is very limited, transfers should be re-established since high prices can be used to increase government revenue. The high cost of public funds may also push for less competition in order to increase taxable industry profits. Hence we would expect to see a greater role for transfers and more state-owned monopolies in LDCs. This is indeed consistent with experience.<sup>100</sup>

This extension focuses on the fact that limited fiscal efficiency increases the cost of public funds, as does the framework used by Laffont. Another crucial aspect of limited fiscal efficiency that is not well captured in the model above is that redistribution amongst consumers is much more difficult in developing countries. Without effective redistribution it is extremely important to distinguish between productive efficiency and Pareto efficiency, since the concepts will be significantly different.<sup>101</sup> For example, a simultaneous increase in prices followed by a decrease in taxes may increase overall 'consumer welfare' in the model above, but in reality the winners and losers from such a change are unlikely to be the same. This explains why we might reject the conclusion in section 2.6 that prices should be higher in developing countries where fiscal efficiency is limited. Since poor consumers may be outside of the tax system but receive some utilities, lowering prices through government subsidies may be the optimal means of increasing their welfare. This was indeed the concern that prevented large price rises in the Mali reform detailed in the introduction.

Once it has been accepted that there is a role for redistribution in regulation, there is a need to go beyond the two-region model used by Laffont and consider the

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<sup>100</sup> This analysis is from Auriol and Picard (2009). Auriol and Warlters (2005) show more generally that it may be optimal for LDCs to put barriers on entry in order to increase the tax base.

<sup>101</sup> See Bromley (1989) for further discussion on the link between institutions and the concept of efficiency.

distributive effects of policies on a more micro level.<sup>102</sup> A crucial problem in developing countries is targeting subsidies towards those that need them. Since gathering data on poverty is difficult, a popular type of subsidy has been some form of increasing block tariff or a 'lifeline' consumption quantity. Under such a pricing regime each consumer is allowed a basic amount of the service for a reduced price, and the marginal cost to the consumer then increases as consumption increases. This works on the premise that consumption is positively correlated with income, which appears reasonable. It is particularly appealing in LDCs because measuring service consumption is often significantly simpler than measuring income directly.

However, poor households tend to be larger than rich ones and a service may be shared between many poor households. These factors will reduce the correlation between income and measured household consumption. It is therefore important to examine empirically the theoretical assumptions that redistributive policies are based on before implementation, since their validity will vary between locations and sectors. For example, there is some evidence that the correlation between income and water consumption is significantly lower than that for electricity consumption. Moreover, in many developing countries large proportions of the population do not have water meters. Since consumers are generally charged to install them, poor households are probably less likely to be metered than rich ones, and hence are unable to take advantage of quantity based subsidies. This suggests that increasing block tariffs are likely to be more progressive in electricity than water.<sup>103</sup>

The introduction of competition also has implications for existing cross-subsidy regimes. In many developing countries, traditional cross-subsidies that took place within a monopoly have been disrupted by the introduction of competition in the more profitable parts of the sector. Theoretically these subsidies can be reinstalled through taxes on firms in the competitive sector being allocated to those operating in the subsidized area. This will require further administrative capacity, and in order to

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<sup>102</sup> Irwin (2003) and Komives, Foster, Halpern, and Wodon (2005) review the various options for subsidies in LDCs, while Trillas and Staffiero (2007) and Parker, Kirkpatrick, and Figueira-Theodorakopoulou (2008) provide surveys of the literature on regulation and redistribution/poverty.

<sup>103</sup> This result is from Komives, Foster, Halpern, and Wodon (2005).

decrease conflicts of interest and collusion these subsidies should probably be managed by a separate agency.

The claim made by some policy makers that competition limits redistribution is probably not true.<sup>104</sup> It does however add complications to schemes typically used in LDCs for this purpose, such as price restrictions and universal service obligations. For example, the stipulation that prices be the same across the network will soften competition since the firm subject to such restrictions will be reluctant to lower its prices in the competitive part of the sector. This may then discourage an incumbent firm from expanding the network, since the expected competition softening will make fighting entry more difficult. Furthermore, if subsidies for rural areas are auctioned, price restrictions will distort the bidding in favor of new entrants since they do not suffer the associated strategic disadvantage of serving these areas.<sup>105</sup> Each of these results suggests that simple price restrictions may not be an appropriate tool for redistribution in partially competitive sectors. Similarly, universal service obligations that apply to the incumbent only are likely to be distortive, and it will generally be better to auction contracts to supply high-cost areas.<sup>106</sup>

Finally, there is also a need to consider a positive approach to the theory of redistribution in developing country regulation. In the theory discussed so far, including that of Laffont, we have treated the motivation for subsidies either as exogenous or the result of some normative social welfare optimization problem. Such an approach misses many of the historical reasons for subsidies and is unadvisable since it does not take into account the need for political support for reform. One of the greatest mistakes of reformers in many developing countries has been to press for efficiency enhancing cost-recovery without sufficient consideration for making sure that the gains of reform

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<sup>104</sup> In telecoms, for example, Wallsten (2001), Fink, Mattoo, and Rathindran (2003), Ros (2003), and Wallsten (2004) all find evidence in cross-country regressions that competition increases network expansion in telecoms. Furthermore, exclusivity clauses discourage smaller-scale alternative providers that are not on the network, even though such providers often are the most realistic option for rural communities.

<sup>105</sup> See Anton, Vander Weide, and Vettas (2002), Valletti, Hoernig, and Barros (2002), and Hoernig (2006) for analyses of all these effects. On the other hand, as shown by Armstrong and Vickers (1993), allowing price discrimination by the incumbent may also give way to anti-competitive behavior.

<sup>106</sup> See Choné, Flochel, and Perrot (2002) and Bourguignon and Ferrando (2007) for analyses of the potential problems of applying service obligations to incumbents only. Sorana (2000) and Wallsten (2008) give surveys of issues related to the auctioning of subsidies.

are seen to be spread fairly. For example, the removal of inefficient subsidies has in many countries led to sharp price increases and the resulting unrest has derailed the reform.<sup>107</sup> While in the long-term it is obviously preferable to move towards the normative paradigm, political constraints must be constantly borne in mind.

To summarize, the basic modelling of limited fiscal efficiency by Laffont is a starting point for considering its influence on regulation in LDCs, but the analysis needs to go further on many issues. The need to consider distributional issues explicitly across regulatory policy has been accepted by practitioners, and theoretical work is beginning to catch up by considering the implications of privatization, competition and pricing for redistribution. It is important that this work comes from both a normative and a positive angle, because in developing countries these policies have a crucial impact on both poverty reduction and support for regulatory reform.

## **4 A Future Research Agenda**

The last section has outlined various ways in which the work of Laffont has been extended, as well as criticisms that show the limitations of the approach of the model above. This input has moved us one step closer to the comprehensive framework that Laffont sought. However, there is still a way to go before the theoretical tools developed for LDCs are as developed as those focusing on the key issues that richer countries face. In this section we suggest an agenda for future research in the area that will help to build a general framework for regulation in developing countries.

The analyses discussed above have provided us with many solutions for the problems that arise due to the four key institutional weaknesses. However, we have frequently seen that the implications for policy have been contradictory. For example, greater public financing of the firm may help the government commit not to expropriate, but will reduce their willingness to enforce the original contract. Deciding which holds

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<sup>107</sup> See Ahrend and Winograd (2006) for a political economy analysis of how the effectiveness of the tax system impacts upon support for privatization.

the greatest risk, government expropriation or firm-led renegotiation, is difficult to evaluate without a framework that analyzes this trade-off explicitly.

Furthermore, one institutional weakness may push for one solution while another calls for the opposite. This is unhelpful given that most developing countries suffer several of the weaknesses simultaneously, and therefore the policy choice is not obvious. For example, a lack of regulatory capacity favors creating as few agencies as possible in order to make best use of limited human capital. On the other hand, we have seen that there are theoretical benefits of having multiple principals in terms of increasing commitment and accountability. Practitioners have tended to favor multisectoral agencies, judging that the former is the most pressing concern. However, there is no theoretical framework which allows us to compare the costs and benefits of this option, so we cannot evaluate what assumptions are implicitly being made.

There is thus a need to develop models that take into account trade-offs between mitigating one institutional weakness and another. This may help to clarify exactly where potential trade-offs lie – for example, which aspects of regulatory governance might sacrifice accountability for commitment, and which ones may be able to improve both? Empirical work suggests that independent regulation increases investment, but how are we to tell whether this occurs due to greater commitment powers or the offering of excessive returns due to regulatory capture?<sup>108</sup> Furthermore, analyzing the trade-offs explicitly will create criteria for when the costs of one policy outweigh the benefits, which will help guide empirical work. Ultimately, optimal policy will vary between countries, and in any particular situation should be based on a diagnostic of the institutional environment.<sup>109</sup> A next step required from the theoretical work is thus to develop a mapping from this diagnostic to an advised policy set. A good starting point may be to combine two models from above that explore different institutional weaknesses and consider how they interact.

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<sup>108</sup> For example, Henisz and Zelner (2006) use cross-country panel data to show that a more powerful industry lobby reduces investment in SOEs generating electricity, and argue this is evidence that inefficient ‘white elephants’ are prevented. On the other hand, also using cross-country panel data, Cubbin and Stern (2006) show that independent regulation increases investment in electricity utilities, and they argue this shows the positive effects of commitment. While both interpretations may be correct, the contrary may also be the case.

<sup>109</sup> See Rodrik (2008) for a discussion of this approach to development in general, with a focus on growth.

As well as the optimal regulatory policy being dependent on the country, it will also change over time as the country moves along its development path. This dynamic element has been largely absent from the models discussed, where even if interactions are repeated the institutional context is assumed to be exogenous and constant over time. In reality, regulatory outcomes are likely to feed back into the surrounding environment and this will affect future optimal policy. For example, a newly created independent agency may lack the credibility, power or capacity to carry out many regulatory tasks. Loading it with many decisions may result in its failure. If it is instead given a small number of basic tasks that it executes successfully, this may increase its future ability and allow for it to gradually become completely independent. Ultimately, incorporating a dynamic element into models of regulation may allow the framework to tie together theory for LDCs with that for developed countries. One way to go about this may be to add elements from general theories of institutional change into the regulatory framework detailed above.

In our review, competition has been suggested in several places as a potential way of mitigating the regulatory problems caused by institutional limitations. However, competitive markets in developing countries suffer from greater information deficiencies and a smaller size than in developed countries, and there is also a difficulty in raising local capital and attracting foreign investors.<sup>110</sup> Moreover, many of the institutional weaknesses outlined above will also impact on competition. For example, limited regulatory capacity weakens anti-trust agencies and corruption may facilitate collusion and reduce entrance.<sup>111</sup> There is therefore a need to understand better the relationships between these market problems and the institutional limitations discussed in order to give better advice on the decision of liberalization.<sup>112</sup>

More generally, it is important to note that most of the work of Laffont detailed above has taken a normative approach, aiming to find the desirable policy set for governments in LDCs to implement. We have mentioned empirical evidence

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<sup>110</sup> This point was suggested by one of the referees.

<sup>111</sup> See Ades and Di Tella (1999) for a theoretical and empirical analysis of the effects of corruption on competition.

<sup>112</sup> Armstrong and Sappington (2006) provide a thorough survey of the existing work on the pros and cons of liberalization in general.

suggesting that in some cases governments indeed appear to follow the models' implications – for instance, governments whose commitment ability is weak are found to be more likely to create independent regulators.<sup>113</sup> We have also seen that in other cases this is not true – an example is the low prices that have often been set by state owned enterprises in situations where such a policy is both inefficient and regressive. However, little empirical work has tested directly whether or not governments set regulatory policy as normative theory tells us they should. This is increasingly possible as data availability improves and the implications of theoretical models become more precise.<sup>114</sup>

In many situations, such testing is likely to find that governments do not behave as the normative theory recommends. In this case, a positive theory of regulation may be better at explaining regulatory policy and outcomes. Positive theories of regulation already exist, but they may need some adaptation in order to explain outcomes in developing countries.<sup>115</sup> The survey above has included some theory that analyzes regulation in LDCs from a positive angle, but generally work in this area has been sparse. Further development of this approach should go alongside future empirical work. One advantage of understanding better why governments in LDCs implement the regulatory policy they do is that this will feed back into improving empirical work that attempts to measure the effects of these policies.

Finally, it should be noted that economic research on regulating utilities has been largely skewed toward privately operated firms, despite the fact that the regulation of publicly run enterprises is a common phenomenon in LDCs.<sup>116</sup> We have not excluded the regulation of publicly operated utilities from this survey, but the focus on private firms has been dictated by the literature. Partly this has stemmed from the belief that privatization has been a necessary step to get countries to set up serious

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<sup>113</sup> This result is found in cross-country regressions by Gual and Trillas (2006).

<sup>114</sup> Dal Bó and Rossi (2007) and Andres, Foster and Guasch (2008) are two recent examples of how, as data becomes available, new research can generate useful tests of some of the theories discussed in this survey.

<sup>115</sup> See, for example, Stigler (1971) and Peltzman (1976) for classic positive approaches to the theory of regulation. More generally, Besley (2006) provides a detailed analysis of why governments may not be benevolent welfare maximisers and analyses a theoretical framework that starts from this basis.

<sup>116</sup> The Africa Forum for Utility Regulation (2002) estimates that half of all regulated utilities are state-owned, while Estache (2008) reports that by 2004, 40% of LDCs had no significant private sector participation in their telecoms industry and 60% had none in electricity and water.

regulatory agencies. While this has been true in some cases, there are clear counter-examples – in a recent survey of electricity regulators in Latin America and the Caribbean, Trinidad and Tobago was found to have the best governance rating, despite it regulating a state-owned enterprise.<sup>117</sup> The danger is not only that the absence of knowledge in this regard may lead to inappropriate regulation, but also that advisers may be overly keen on private participation simply because of their greater familiarity with the regulation of private firms. There is thus an urgent need for further work considering the differences between regulating privately and publicly operated enterprises.<sup>118</sup>

## 5 Conclusions

Experiences in developing countries over the past two decades have shown us that the effects of institutional limitations on regulatory outcomes can be large. When institutions are weak, solving the related problems will be more important than resolving the concerns that are normally stressed in the regulation of utilities in developed countries. This underlines the importance of building a theoretical framework that has institutional failures at its heart. We argue that such a framework needs to take into account four key institutional weaknesses: limited regulatory capacity, limited accountability, limited commitment and limited fiscal efficiency.

Using Laffont's work as a springboard, this chapter has aimed to isolate where these institutional weaknesses found in developing countries matter and what the appropriate response should be. Several implications arise from our review as to how regulatory policy should be different in LDCs. In terms of the power of the incentive scheme, fixed-price contracts will be the only option when limited regulatory capacity

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<sup>117</sup> See Andres, Guasch, Diop, and Azumendi (2007).

<sup>118</sup> Gomez-Ibanez (2007) and Vagliasindi (2008) are examples of recent theoretical work on this area. Empirical comparisons of public and private utilities include Estache and Rossi (2002), Kirkpatrick, Parker, and Zhang (2006), and Clarke, Kosec, and Wallsten (2009) in the water sector and Berg, Lin, and Tsaplin (2005) and Andres, Foster, and Guasch (2008) in electricity.

means the observation of costs is unreliable. Once regulatory capacity is less of a constraint, incentives should be less powerful the weaker the institutions. A further implication is that some separation of regulatory powers is necessary in order to counter problems of limited accountability and limited commitment. In developed countries this separation is likely to be ingrained in the system of government already. However, in developing countries this needs to be an explicit consideration for reformers. One way this separation can come about is through the creation of an independent regulator. The limited fiscal efficiency in LDCs implies that redistribution needs to be an explicit consideration of regulatory policy, unlike in developed countries. This does not mean that prices should be universally low, but instead that there is a need for carefully designed subsidies and a consideration of how each policy impacts upon poverty and support for reform. Finally, effective competition, where possible, may mitigate the effects of several institutional limitations.

The analysis has also highlighted some areas where the framework of Laffont is somewhat insufficient and here there is a need for further research. In particular, limited regulatory capacity makes it essential to recognize the incompleteness of the regulatory contract. Furthermore, the reduced accountability and commitment powers of governments in LDCs imply that theory must understand better the way multiple principals interact in forming regulatory policy. Incorporating these elements into a theoretical framework will help to analyze the interaction of institutional weaknesses, which needs to be studied further. An aim of future research should be to build a dynamic model that explores the way in which the optimal policy set will change over time as institutions within a country develop.

Overall, the strongest conclusion is that institutional weaknesses in developing countries will make the optimal regulatory policy different from that of developed countries. Many of the policies proposed by the theory we have reviewed are divergent from those that are currently seen as 'best practice' within OECD countries. Moreover, since the strength of institutions varies considerably between developing countries, there will not be a complete policy set of 'best practice' in LDCs. It is thus insufficient and possibly damaging to advocate simply for a regulatory framework that is close to

some universal ideal. An understanding of the institutional context and its implications are crucial when designing a regulatory framework for developing countries.

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## Chapter 2

### **Commitment in utility regulation: A model of reputation and policy applications**

#### **1 Introduction and previous literature**

In many contexts, governments enter into a relationship with the private sector where the government's optimal policy is time-inconsistent. This is to say that the government would like to commit itself to carrying out certain actions in the future, but when it actually comes to that point in time it would prefer to carry out different actions. Examples include the taxation of investment, sovereign debt, inflation policy and the regulation of utilities, which is the focus of this paper. In some situations the government can use a third party to tie its hands, but where institutions outside the executive are relatively weak such constraints may not be possible. When the government cannot constrain itself in this way, it may still be able to commit through the use of reputation.

In general, reputation encourages commitment since the government fears a period of 'punishment' by the private sector should it lose its reputation. In some instances, government reputation is always maintained and hence such a punishment is never carried out. However, in other cases, particularly in developing countries, a loss of government reputation is a very real prospect. In order to understand how commitment can be aided in developing countries, it is therefore important to use a model of government reputation that includes periods where reputation is lost. This chapter therefore builds a simple model which aims to capture such a situation. In particular, we study a situation where the government promises to a single firm not to expropriate its gains from investment.

Central to the model is the fact that the government's preferences vary over time. This could be due to external factors such as a change in the need for government revenue. These environmental changes then translate into how much the government has to gain from expropriating. In good times, the gains may be fairly small, whilst in bad times the payoff from expropriating will be larger. Crucially, the firm is not aware of the government's preferences, and hence its investment decision may be dependent on its current beliefs as to the government's type.

One novelty of the paper is that we restrict our attention to studying equilibria that are renegotiation proof. This aims to rule out equilibria where at some point both parties would like to forget what has passed and instead play as if some other history had occurred. We believe that the renegotiation proofness criterion is an important one in a model between the government and one other player because in this situation renegotiation is a very real possibility. For example, Guasch et al. (2007, 2008) show that in infrastructure regulation in Latin America, renegotiation is a very common event.<sup>1</sup> We show that by restricting ourselves to renegotiation proof equilibria, we rule out traditional 'trigger' strategies where the firm proposes an arbitrarily long punishment period should the government expropriate.<sup>2</sup> These are not credible equilibria since, at some point during these proposed punishments, both the firm and the government would like to pretend expropriation had never happened and return to the firm investing.

Having rejected these equilibria, we then show that there is a unique perfect Bayesian strongly renegotiation proof equilibrium that may contain investment. In this equilibrium, the government's needs are sufficiently low in good times that it will not expropriate. However, when needs are particularly great, i.e. times are bad, the government finds expropriating the preferable option. Given this strategy, the firm's beliefs become the

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<sup>1</sup>Of course, renegotiation can occur for a variety of different reasons. Indeed, Guasch et al. (2007, 2008) argue that many of these renegotiations are in fact beneficial only for the firm or the government. 'Expropriation' in our model can therefore be viewed as renegotiation that disadvantages the firm and favours the government. For a study of renegotiation that benefits the firm and not the government, see the model of Guasch et al. (2006). Stern (2009) provides a discussion of the positive side of many renegotiations.

<sup>2</sup>For examples of models where trigger strategies are used to generate time-inconsistent behaviour, see Gilbert and Newbery (1994) and Salant and Woroch (1992) in the case of regulation; Green and Porter (1984) and Shapiro (1989) in the case of inter-firm collusion; Baker et al. (2002) in the case of inter-firm relational contracts; Barro (1986) and al Nowaihi and Levine (1994) in the case of monetary policy; Thomas and Worrall (1994) and Aguiar et al. (2007) in the case of FDI; Chari and Kehoe (1990) in the case of taxation.

key factor in determining its investment. If the firm believes that the government is likely to be facing 'good' times, it will invest, since it believes the probability of expropriation to be low. On the other hand, when a firm believes the government's needs are high, it will fear expropriation and not invest. Since expropriation is equated with a government in 'bad' times, a period of non-investment will follow government expropriation. It is fear of this non-investment that keeps the government from expropriating when the state of the world is good. The non-investment period is not set by the firm as an amount of punishment but instead it is the time it takes for the firm to believe that the government's type has probably changed and it is safe to invest again.

Since the firm does not observe the government's needs directly, the equilibrium relies on a system of signalling and built up reputation. At any given time, the government will wish to expropriate, but doing so sends the firm a signal that the government's needs are high, and hence the government is likely to expropriate next time. Not expropriating, on the other hand, sends the signal to the firm that needs are low (i.e. times are good), and hence expropriation next time is unlikely. The government therefore builds a reputation for having low needs by not expropriating, and the desire to keep this reputation is the only reason it does not always expropriate.

Building the model in this way allows us to apply it to the case of monopoly regulation in developing countries, where reputation (rather than the rule of law) is a crucial factor in making sure governments provide the promised return on their investment. In particular, we can use the model to analyse how policy decisions affect the government's ability to commit. We study the difference between two incentive schemes - a cost-plus contract and a price cap - and the effect of decentralising regulation.

Looking first at the effect of the incentive scheme, we find that in situations where the firm's profits are valued in a similar way to government revenues or consumer surpluses, a price-cap may enhance commitment. This is because, in this situation, expropriating is most tempting when the private firm is found to be inefficient, and the price-cap scheme makes sure that it is in this case that the firm's profits are smallest. On the other hand, in developing countries where the firm's profits are likely to be

significantly less valued, price-caps weaken a government's commitment ability. This is due to the fact that here the most tempting moment to expropriate is when profits are highest, and it is a price-cap system that creates the highest levels of potential profit.

In terms of decentralisation, we show that regulating at a more centralised level can average out the incentives to deviate in the two regions. The implication for policy thus depends on the context within a particular country. Centralisation may be a good idea if there is one region where private sector participation is very valuable, as this can incentivise a regulator not to expropriate in a less valuable region. On the other hand, if commitment under centralisation can not be achieved, then decentralising may at least allow those regions with the most valuable projects to receive investment.

Overall therefore, we find that in both the case of the incentive scheme and decentralisation there can be a significant effect of the policy on the equilibrium. Moreover, the results imply that the optimal policy in developing countries is likely to be different from that which works best in developed countries.

A few other theoretical papers have looked at the issue of government commitment in utility regulation. Gilbert and Newbery (1994) consider a case where the regulator and utility are restricted to a framework set by the legislator. Declared strategies are maintained by the utility threatening not to invest and the regulator threatening to minimise future profits. These threats are trigger strategies in which, once defection occurs, the two parties play the punishment strategies forever. They also compare the sustainability of a rate-of-return system to one with state-contingent linear price regulation when future demand is uncertain, and find a parameter range for which a rate-of-return regime is credible but not price regulation. Salant and Woroch (1992) offer a similar model where investment is maintained through trigger strategies and provide a description of many alternative equilibria, including ones where punishments are finite. Since in their model the two players effectively act simultaneously, the first-best solution cannot be achieved, but is tended to in the limit. In both models, expropriation does not take place in equilibrium.

Dassiou and Stern (2009) consider a continuous level of trust that the private sector has in the government honouring its commitment, which is updated over time dependent on the governments actions. They show that a misalignment in trust levels leads to suboptimal investment and explore how alternative contract types interact with this effect. Faure-Grimaud and Martimort (2003) build a model of limited commitment whereby a government may choose to constrain future governments by setting up an independent regulator. In their model it is certain that the identity of the political principle changes, and they suggest that making elections contestable and endogenous would be a valuable extension. Both these latter two models assume that the probability of a government renegeing is an exogenous parameter. Guasch et al. (2006) also build a model whereby contracts are renegotiated, but here it is due to imperfect enforcement of the regulatory contract rather than the temptation of the government to expropriate. They explore the effects of a range of parameters, including the degree of state capture and the cost of public funds, and find that the implications are broadly consistent with the results of their empirical work.

On a more theoretical level, several other papers have also explored the role of reputation where players types changed in an unobserved way. For instance, Cole et al. (1995) and Phelan (2006) study government commitment in the cases of sovereign debt and taxation respectively. Cole et al. (1995) consider an equilibrium where unstable governments renege on their debt commitments, and foreign lenders as a result do not lend to governments they believe to be unstable. Once the government becomes stable, they resume paying off their debts and hence signal to foreign lenders that they will not renege. In Phelan (2006) a low-tax government is committed to taxing reasonably, but an opportunistic type may decide to expropriate all capital. Phelan shows that the unique Markov equilibrium involves an opportunistic government playing a mixed strategy for some time after expropriation, since they benefit from households gradually increasing their production. In a different setting, Mailath and Samuelson (2001) model firms as either being able to only produce low quality goods or having the option of producing higher quality goods. Since firms' names can

change hands without consumers being aware, firms that can have an incentive to produce high quality products in order to indicate to consumers that their products are worth spending more on.

The model presented in this chapter differs in two significant ways from this previous literature. First, since we are studying a situation where there are only two players, we use renegotiation proofness as an equilibrium selection criterion. In the papers mentioned above, the authors have instead generally restricted themselves to looking at equilibria where strategies are dependent only on beliefs and types, rather than histories in general, i.e. Markov strategies. Such an assumption may be reasonable in the case where there are many players, as the coordination required for more general strategies would not be feasible. However, we cannot restrict our strategies in such a way here because when there are only two players, no such coordination is required and it is quite conceivable that contracts between the firm and the government include conditions on previous behaviour. In our setting renegotiation proofness lends itself as the natural criteria to use, whereas in the case with many players it is likely to be unnecessary since renegotiation would be infeasible.

Second, unlike the majority of the literature on reputation, we do not use a 'Stackelberg type' in our model.<sup>3</sup> Stackelberg types are players who do not optimise their payoff function, but instead are forced to play the strategy they would like to play where they are able to commit (they are called Stackelberg types as we can imagine them as a type that can publicly set their entire strategy before any other play takes place). The use of such types is common in the reputation literature since, as shown by Kreps et al. (1982), they allow cooperation when the horizon is finite. In a finite game, if one player knows for sure that another player is not such a type, then they know that this player will play the time-consistent strategy in the last period, and hence through backward induction reputation mechanisms will be ineffective. Whilst in many situations the existence of Stackelberg types may be a reasonable assumption, we believe that when modelling some cases of government behaviour it may be more realistic to assume that the horizon is infinite and that such types do not exist.

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<sup>3</sup>These are also called 'commitment types' or 'crazy types'.

The model in this chapter builds on previous work in Wren-Lewis (2007) which also constructed a model of commitment in the context of utility regulation in developing countries. Like in the model below, the government's preferences change over time in a way that alters their temptation to expropriate, resulting in subgame perfect equilibria where there are periods of investment followed by periods of expropriation. Unlike in the model below, Wren-Lewis (2007) allows for there to be a continuum of government types, which results in the possibility of multiple equilibria with investment for a given punishment time. For example, there may be an equilibrium where the government almost always keeps its promise (and hence pays the firm a small risk premium) alongside an equilibrium where the government frequently reneges (and hence has to pay the firm a large risk premium). Through developing a model in which the firm gradually learns over time about the government, it is then shown that the firm's initial beliefs are important in determining which equilibrium is converged to. For example, if the firm is initially skeptical, then it will demand a high rate of return to compensate for the perceived high risk. This higher rate of return leads to a greater probability of the government expropriating, which in turn worsens the firm's impression of the government and increases the necessary rate of return. On the other hand, had the firm started off confident that the government would not expropriate, it would demand a lower rate of return. This then reduces the probability of the government expropriating, and hence allows convergence to a more efficient equilibrium. However, unlike in the model below, in Wren-Lewis (2007) a government's type is independent of their prior type.<sup>4</sup> Hence the subgame perfect equilibria in this earlier model rely on trigger strategies with arbitrarily chosen punishment periods. The equilibria are therefore not renegotiation proof and the concept of 'reputation' is subtly different from that in the model below.

The chapter proceeds as follows. Section 2 presents the framework of the game, introducing the players and their payoffs. Section 3 then considers the equilibria of the game, focusing first on Perfect Bayesian equilibria before introducing the concept of renegotiation proofness and showing this produces a unique equilibrium. Section 4

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<sup>4</sup>It is hence similar to a situation where  $\nu = 0$  in the model below.

then uses the model to study the implications of a couple of policy decisions, before Section 5 concludes. Proofs of all propositions are given in the Appendix.

## 2 The game

In the game there are two players, F and G. We can think of player F as representing the private sector and player G as the government. For analytical ease, we construct our model in continuous time. However, the following results will also hold in a discrete time model, and indeed our continuous time framework can be shown to be the limit of a discrete time one as the time between periods tends to 0. Both players seek to maximise their discounted expected payoff, with each discounting at a constant rate  $r$ .

At a particular time  $t$ , nature decides whether the state of the world is ‘high’ or ‘low’, which we can regard as G’s type. Player G’s type is G’s private information - player F is not aware of G’s type. Player F chooses whether to invest or not. The choice is discrete - they can either invest (at a cost of 1) or not invest (at a cost of 0). Player G sets  $R$  (subject to some restrictions), a return received by player F. If player F has invested at time  $t - \tau$ , then player G’s payoff is  $\bar{R} - \theta R$ , where  $\theta = \theta_L$  if the state of the world is low and  $\theta = \theta_H$  if the state of the world is high. We assume that  $0 < \theta_L \leq \theta_H < 1$ . If player F did not invest at time  $t - \tau$ , then player G’s payoff is 0, and they are forced to set  $R = 0$ . In this way, we can view investment as creating a total return of  $\bar{R}$  at a time  $\tau$  after the investment is made.<sup>5</sup> The government then decides how much of this return is received by the firm, and the firm’s payoff is  $R - 1$  if they invested and  $R$  if they did not.

We can view the government’s payoff in the following way. Investment generates a total gross social surplus of  $\bar{R}$ . This return is then divided between the firm, which receives  $R$ , and the rest of society, which receives  $\bar{R} - R$ . The government’s payoff is then a weighted sum of these two returns, with the firm’s welfare weighted by

<sup>5</sup>We are thus assuming that both investment and the returns to investment are constant over time. Extending the model to consider a situation where investment is increasing or decreasing in value would complicate the model whilst probably adding little insight - if investment is increasing in value, expropriation would be less tempting, whilst it would be more tempting if the value of investment was decreasing.

$1 - \theta$  and the rest of society's welfare weighted by 1.  $\theta = 0$  therefore represents a government who is equally concerned with a firm's profit as tax revenue or consumer welfare, whilst  $\theta = 1$  represents a government who does not value the firm's profit directly. Since the part  $\bar{R} - R$  can be viewed as the returns that accrue directly to the government (through taxation say), we can view the variation in  $\theta$  as the variation in the government's need for public funds.

In order to incentivise player F to invest, player G may make a non-binding promise as to what  $R$  will be in the future. In order to impose some structure on the contracts, we restrict the government to only being able to offer the firm a constant level of  $R$  indefinitely. We assume that the firm does not take this offer as a signal of the government's type in any way. In other words, if the government sets a level of  $R$  at time  $t$ , the only non-zero rate or return it may pay between time  $t$  and  $t + \tau$  is this same level of  $R$ .<sup>6</sup> The government can however at any time set  $R = 0$ , essentially expropriating the firm's promised return on its investment. If the government does so, it is restricted to setting  $R = 0$  for a length of time  $\tau$ .<sup>7</sup>

We consider the game to be played over the infinite horizon. The use of an infinite horizon is crucial in our analysis, since many of the following equilibria would not occur in an equivalent finitely repeated game.<sup>8</sup> Our analysis is therefore not relevant to situations where there is a known limit to the number of times that the interaction will be repeated. However, we suggest that, in the majority of cases where the government interacts with the private sector, an infinite horizon is the most appropriate way to model the situation. This is not to say that the interaction has no finite limit, but rather that the government tends to approach the game without consideration of a finite horizon. For more details on this argument, see Osborne and Rubinstein (1994, p.135-136). Players are restricted to playing pure strategies in order to simplify the analysis.

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<sup>6</sup>This restriction simplifies our analysis without changing any fundamental results, since the firm is only concerned with the expected level of  $R$  over the infinite horizon, and this restriction does not decrease the range of potential expected returns that the government can offer.

<sup>7</sup>This restriction is necessary to prevent any type of signalling on the side of the government, which would substantially change the model. We can view the restriction as assuming that the process of expropriating is itself time-consuming.

<sup>8</sup>More precisely, our equilibria cannot be created by considering games repeated a finite number  $T$  times, and then taking the limit as  $T \rightarrow \infty$ .

The state of the world  $\theta$  evolves according to a time-homogeneous Markov process. We define the transition matrix  $Q$  to be

$$Q = \begin{pmatrix} -\nu\beta & \nu\beta \\ \nu(1-\beta) & -\nu(1-\beta) \end{pmatrix} \quad (1)$$

Here  $0 < \beta < 1/2$  is the long-run probability that the state of the world is high (or 'bad') and  $\nu > 0$  is the rate at which the government's type changes. Thus for a small time period  $\epsilon$ , the probability that the state of the world switches from high to low is approximately  $\nu\beta\epsilon$  and the probability that it switches from low to high is approximately  $\nu(1-\beta)\epsilon$ . The length of time that the government's type stays constant is then exponentially distributed.

Let us define the matrix  $P(s)$  to be made up of the elements  $p_{ij}(s)$  where

$$p_{ij}(s) = \mathbb{P}(\theta(t+s) = j | \theta(t) = i) \quad (2)$$

where  $i, j \in \{\theta_H, \theta_L\}$ . Then, as proven in the Appendix, we have

$$\begin{aligned} P(s) &= \begin{pmatrix} p_{\theta_L\theta_L} & p_{\theta_H\theta_L} \\ p_{\theta_L\theta_H} & p_{\theta_H\theta_H} \end{pmatrix} \\ &= \begin{pmatrix} 1 - \beta(1 - e^{-\nu s}) & \beta(1 - e^{-\nu s}) \\ (1 - \beta)(1 - e^{-\nu s}) & 1 - (1 - \beta)(1 - e^{-\nu s}) \end{pmatrix} \end{aligned} \quad (3)$$

This matrix represents the probabilities that the government is of a particular type at time  $t+s$  given its type at time  $t$ . We can see, for example, that at  $s = 0$ , this matrix is simply the identity matrix, since the probability of changing states in zero time is 0. At the other extreme, if we consider the limit as  $s \rightarrow \infty$ , then the probability of being in the high state is  $\beta$  and the probability of being in the low state is  $\beta$ , regardless of the state at time  $t$ . This reflects the fact that the state of the world at time  $t$  becomes gradually less important as we move away from  $t$ . Since the probability that the state of the world is high at time  $t$  may not be the same as at time  $t+s$ , we are therefore considering a dynamic game rather than a simply repeated one.

In this dynamic game, we assume that both player F (the firm) and player G (the government) are long-lived. At all times they are therefore maximising their expected discounted payoff over the infinite horizon. Since we are investigating a situation of weak government commitment, we assume that it can not commit itself - that is, its strategy must always be time-consistent.

## 2.1 Perfect Bayesian Equilibria

Let us first consider some of the perfect Bayesian equilibria of the game, without restricting ourselves to those that are renegotiation proof. In order to do so, it is helpful first to define two broad categories of equilibria: Full-investment equilibria and episodic-investment equilibria.

**Definition 1.** A *full-investment equilibrium with non-investment length*  $T$  is an equilibrium that meets the following description:

- Player F invests if and only if player G has not expropriated within a length of time  $T$ , where  $T$  is a constant in  $(0, \infty]$ .
- Along the equilibrium path, player G always shares.
- Hence, in equilibrium, there is constant investment.

Full investment equilibria are essentially those that achieve the first best - constant investment - and do so with the threat of a non-investment period should expropriation occur. Such a non-investment period however never occurs on the equilibrium path since governments share investment in both states of the world.

It is useful for us now to define some functions that summarise players' payoffs. In particular, define  $W_H(T, \bar{R})$  as:

$$W_H(T, \bar{R}) = \frac{1 - e^{-r(T+\tau)}}{r} (\bar{R} - (\beta\theta_H + (1 - \beta)\theta_L)R) - \frac{1 - e^{-(r+\nu)(T+\tau)}}{r + \nu} (1 - \beta)(\theta_H - \theta_L)R - \frac{1 - e^{-r\tau}}{r} \bar{R} \quad (4)$$

Here  $W_H(T, \bar{R})$  is the relative payoff to G of sharing rather than expropriating in a

full-investment equilibrium if  $\theta = \theta_H$  (this is shown in the proof of Proposition 2 in the Appendix). The first term is the payoff the government would receive between  $t$  and  $T + t + \tau$  from not expropriating were  $\theta$  independently drawn at each time  $t$ .  $\beta\theta_H + (1-\beta)\theta_L$  is the unconditional expectation of  $\theta$ , and hence  $\bar{R} - (\beta\theta_H + (1-\beta)\theta_L)R$  is the expected payoff at each time in between time  $t$  and  $t + T + \tau$  (the term  $\frac{1-e^{-r(T+\tau)}}{r}$  reflects the fact this payoff is discounted). The second term then corrects for the fact that  $\theta(t) = \theta_H$ , since this implies that the payoff from investment over the period  $[t, t + T + \tau]$  is lower than if we did not know  $\theta(t)$ . We can see that this is the case by taking the limit as  $\nu \rightarrow \infty$ , i.e. by reducing the persistence of states to 0. Finally, the last term is the payoff that the government would receive from expropriating investment.

The following proposition then gives conditions under which there exists a perfect Bayesian full-investment equilibrium, where a perfect Bayesian equilibrium is one as defined by Fudenberg and Tirole (1991, pp.325-326). Perfect Bayesian equilibria are essentially equilibria where at each information set (a set of histories that the player cannot distinguish between) a player's strategy is optimal given their beliefs. Furthermore, their beliefs are based on players' equilibrium strategies and updated using Bayes' rule.

**Proposition 1.** *There exists a perfect Bayesian full-investment equilibrium with non-investment length  $T$  if and only if  $W_H(T, \bar{R}) \geq 0$ . In such an equilibrium,  $R$  will be set according to the equation*

$$e^{-r\tau}R = 1 \tag{5}$$

The proof of the proposition is given in the appendix. Since the strategy of player G does not depend on her type, we do not need to consider the beliefs of player F. Hence we are essentially looking for a subgame perfect equilibrium. In order to prove these strategies form a subgame perfect equilibrium, we check that neither player wishes to deviate using a version of the one-stage deviation principle suitable for

perfect Bayesian equilibria.<sup>9</sup> In our case the principle effectively states:

A player's strategy is optimal from all his information sets if and only if there is no information set from which the player can gain by changing his strategy there, keeping it fixed at all his other information sets

The principle is useful as it means we only need to check that each player can do no better by deviating just once from their equilibrium strategy - we do not have to check all possible deviations. In our case, we only need to check that they do not wish to deviate from their equilibrium strategy for a time  $\epsilon$  as  $\epsilon \rightarrow 0$ .

The equilibrium can be sustained by F threatening not to invest for a length of time  $T$  were G to expropriate. The threat is credible if G's strategy is to expropriate all investment during this punishment phase, and hence F has no incentive to invest. The condition  $W_H(T, \bar{R}) \geq 0$  signifies the requirement that this punishment period needs to be sufficiently long to incentivise the government not to expropriate even when  $\theta = \theta_H$ . Clearly it is when needs are high that the temptation to expropriate is greatest, and therefore if this expression holds the government will not deviate when  $\theta = \theta_L$  either.  $R$  is set according to equation (5) since this is the value of  $R$  at which the firm is indifferent between investing and not, and the government has no incentive to offer anything higher.

Hence we can see that an efficient outcome can be generated as a perfect Bayesian equilibrium through player G fearing potential punishment for expropriating. This proposition would be the same in a game of complete information, since player G's type plays no role in equilibrium behaviour.

Let us now define a different type of equilibria which, rather than having investment all of the time, experiences episodes of investment and episodes of non-investment.

**Definition 2.** An *episodic-investment equilibrium with non-investment length  $T$*  is an equilibrium that meets the following description:

- *Player F invests if and only if player G has not expropriated within a length of time*

<sup>9</sup>See Fudenberg and Tirole (1991, p.110) for a statement and proof of the principle for subgame perfect equilibria, Hendon et al. (1996) for the extension to perfect Bayesian equilibria and Sannikov (2007, pp.1298-1300) for the details of the continuous time version.

$T$ , where  $T$  is a constant in  $(0, \infty]$ .

- Along the equilibrium path, player  $G$  shares if the state of the world is high and expropriates if the state of the world is low.
- Hence, in equilibrium, there are some periods of investment and some periods of non-investment.

Hence, episodic-investment equilibria are those where the first-best is not achieved, but there are periods of investment. Periods of non-investment are caused by the government entering the bad state of the world and expropriating. Investment resumes after a period of time  $T$ , independent of the state of the world. If needs happen to be high when investment resumes, it will be expropriated and we immediately enter a new phase on non-investment.

Let us now consider when an episodic-investment equilibrium is perfect Bayesian. Before coming to the proposition, it is again helpful to define some notation. In particular, let us first define the function  $R(T)$  according to the equation:

$$(1 - \beta) (1 - e^{-\nu(T+\tau)}) e^{-r\tau} \frac{R(T) - 1}{r + \nu\beta} = \frac{1 - e^{-r\tau}}{r} \quad (6)$$

Here  $R(T)$  is the level of  $R$  at which  $F$  is indifferent between investing and not investing in episodic-investment equilibrium. It is more complicated than the equivalent level of  $R$  in the full-investment equilibrium, since the firm must now take into account the probability that the government will not keep its promise.  $(1 - \beta) (1 - e^{-\nu(T+\tau)})$  is the probability that the state of the world is low at time  $T + \tau$  after it was high, and  $\frac{R(T)-1+r}{\nu\beta+r}$  is the expected discounted payoff if the state of the world is low. The term on the right hand side,  $\frac{1-e^{-r\tau}}{r}$ , is the cost of investment before the firm can expect any return.

Now let us define  $W_L(T, \bar{R})$  as:

$$W_L(T, \bar{R}) = \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \times ((1 - e^{-r(T+\tau)})(\bar{R} - \theta_L R) - (1 - e^{-r\tau})\bar{R}) \quad (7)$$

Similarly to before,  $W_L(T, \bar{R})$  is the payoff to  $G$  of sharing rather than expropriating

in an episodic-investment equilibrium if  $\theta = \theta_L$ . The expression is simpler than the previous one because the only potentially different payoff that accrues to player G under shared investment is when  $\theta(t) = \theta_L$ , since expropriation will occur anyway when  $\theta(t) = \theta_H$ . We can see that this is clearly dependent on  $R(T)$  as defined above, since a greater share going to the firm decreases the government's payoff.

We can now give the proposition of when an episodic-investment equilibrium is perfect Bayesian.

**Proposition 2.** *There exists a perfect Bayesian episodic-investment equilibrium with non-investment length  $T$  if and only if:*

$$\begin{aligned} W_L(T, \bar{R}) &\geq 0 \\ W_H(T, \bar{R}) &\leq 0 \end{aligned} \tag{8}$$

*In such an equilibrium,  $R(T)$  is given by equation (6)*

The proof of the proposition is in the appendix, and is very similar to the proof of Proposition 1 above. Here the punishment period is sufficiently long such that G does not expropriate when needs are low (Condition (8)) but is at the same time sufficiently short that G will expropriate when needs are high (Condition (9)). From examining the expressions for  $W_L(T, \bar{R})$  and  $W_H(T, \bar{R})$ , we can see that  $W_L(T, \bar{R}) > W_H(T, \bar{R})$ , and hence there is a range of  $T$  for which both conditions can hold.

These two propositions show that trigger strategies can sustain equilibria that include investment. A given period of post-expropriation non-investment  $T$  may be enough to prevent the government expropriating in both states of the world (if condition (4) holds) or at least when the state of the world is high (if condition (4) doesn't hold but conditions (8) and (9) do). Indeed, since  $T$  can take any value in  $(0, \infty)$ , both types of equilibrium may well exist for a given set of parameters, and a range of values of  $T$  will be able to support both. For the full-investment equilibrium this might not be a great concern, since the non-investment period is only hypothetical. However, for the episodic-investment equilibria, the value of  $T$  affects the discounted payoff of both

players, and hence it would be useful to analyse whether one particular value of  $T$  is more likely to arise than another. The next section therefore considers how we may use renegotiation proofness as an equilibrium selection device.

## 2.2 A unique renegotiation-proof equilibrium

We have thus shown that there are multiple equilibria that include at least some investment, each using a trigger-strategy style form of reputation. However, these equilibria in general suffer from not being robust to renegotiation. In particular, during the period of non-investment (the ‘punishment phase’) both players receive lower continuation payoffs than they do in the non-punishment phases. Hence they may both like to renegotiate and start over as if the government had never expropriated.

Formally, we use the criteria of an equilibrium being ‘weakly’ or ‘strongly’ ‘renegotiation-proof’ formulated by Farrell and Maskin (1989). To understand this criterion, we model players’ strategies as being dependent on a ‘state’, in addition to their payoffs and beliefs. A ‘state’ is an equivalence class of histories such that players’ strategies are functions of only this state, their beliefs and their type. In our case, our state is the time since the government last renegeed,  $s$ .

An equilibrium is then weakly renegotiation proof (WRP) if the payoffs at any pair of states cannot be Pareto ranked.<sup>10</sup> This is to say that there is no point in the equilibrium strategies where both players would prefer to play as if the state were different. In the case of the equilibria above, they would be WRP if there was no point in the players’ equilibrium strategies where they would both like to pretend that the government had expropriated more or less recently than it had.

Before we come to applying these conditions, it is again useful to define another expression. Let  $T^B$  be defined by the following differential equation:

$$\frac{\theta_L}{\nu\beta + r} \frac{dR}{dT}(T^B) + \bar{R} - \theta_L R(T^B) = 0 \quad (9)$$

The value  $T^B$  represents the value of  $T$  at which the government would most like

<sup>10</sup>The definition given by Farrell and Maskin (1989) in fact uses strict Pareto ranking, but for our purposes the definition with weak Pareto ranking is more appropriate.

the firm to recommence investment. This optimal point represents the solution of a trade-off between two competing desires. On the one side, the government would like investment to recommence sooner (smaller  $T$ ) since this brings closer in time the prospective gains, and hence they are discounted less. On the other hand, to incite investment at this earlier point, the government needs to promise the firm a higher value of  $R$  (as seen in the definition of  $R(T)$ ), and hence it would like to delay investment in order to reduce this required incentive.

Given this value of  $T$ , we can now move on to describe the set of WRP perfect Bayesian equilibria.

**Proposition 3.** *There exists a **WRP perfect Bayesian episodic-investment equilibrium** with non-investment length  $T$  if and only if  $W_L(T, \bar{R}) \geq 0$ ,  $T \geq T^B$  and  $W_H(T, \bar{R}) \leq 0$ . In such an equilibrium,  $R = R(T)$ . Furthermore, any WRP perfect Bayesian equilibrium is such an episodic-investment equilibrium with non-investment length  $T$ .*

We can see therefore that the range of values of  $T$  is a subset of the range for which there are perfect Bayesian equilibria set out in Proposition 2. If  $T^A < T^B$ , where  $T^A$  is the solution to the equation  $W_L(T^A, \bar{R}) = 0$ , we can see that this will be a strict subset, and hence the perfect Bayesian equilibria with  $T^A \leq T < T^B$  are not weakly renegotiation proof. This is because, for  $s < T^B$ , the government would prefer not to offer the firm a reasonable contract and instead wait until it could offer a rate of return that was lower.

This proposition thus shows that a subset of the equilibria discussed above are not weakly renegotiation proof. This includes any full-investment equilibria, since both parties would be willing to renegotiate out of the non-investment phase as they do better pretending expropriation hadn't happened. In the episodic-investment equilibrium, any equilibrium where the firm agrees to accept a contract now but threatens not to accept a contract at a later stage is ruled out, since such a threat is not credible to renegotiation. Hence, if it wishes, the government can postpone investment to a point where the required rate of return is lower .

The proposition however does not lead us to a unique equilibrium since we can not rule out equilibria where the non-investment period is longer than the government would desire, i.e. where  $T > T^*$ . This is because, within the equilibria with non-investment length  $T > T^*$ , there is no state where the government offers  $R(T^*)$ , and hence the parties cannot renegotiate to here. However, we can arrive at a unique equilibrium by requiring ‘strong renegotiation proofness’. Again formulated by Farrell and Maskin (1989), an equilibrium that is strongly renegotiation proof (SRP) is essentially one where at all points the players would not both wish to renegotiate to some state of an alternative WRP equilibrium. This then gives us the following proposition

**Proposition 4.** *Suppose that there exists a value  $T^A > 0$  that solves equation  $W_L(T^A, \bar{R}) = 0$ . Then, letting  $T^* = \max\{T^A, T^B\}$ ,*

- *If  $W_H(T^*, \bar{R}) \leq 0$ , then the **unique strongly renegotiation proof perfect Bayesian equilibrium** is an episodic investment equilibrium with non-investment length  $T^*$ .*
- *If  $W_H(T^*, \bar{R}) \geq 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium is that with no investment.*

*If there is no value  $T^A > 0$  that solves the equation  $W_L(T^A, \bar{R}) = 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium is that with no investment.*

We have thus identified a unique perfect Bayesian equilibrium by using strong-renegotiation proofness as an equilibrium selection criterion.

### 3 Applications

The previous section built a model of government reputation and commitment where non-investment resulted if the government reneged upon her promises for future rates of return. We then found a unique equilibrium by restricting our attention to those that were perfect Bayesian and strongly renegotiation proof. This section proceeds to apply this model to two policy issues. The model is first expanded to include uncertainty over future costs, and this is used to investigate the differences between a

cost-plus regime and a price-cap regime. The chapter then considers the regulation of two non-competing regional enterprises and analyses how decentralising regulation to the regions may alter investment. In each case, the previous model and results are used to consider how the government's ability to commit interacts with the regulatory framework.

### **3.1 Cost-Plus vs. Price-Cap**

One of the key decisions when forming regulatory policy is whether to operate a cost-plus/rate-of-return or a price-cap style mechanism. In essence, under a cost-plus or rate-of-return regime the enterprise is guaranteed a fixed amount of profits. By being allowed to set prices sufficiently above costs, the enterprise will make the amount of profit agreed to. On the other hand, a price-cap system sets future prices significantly in advance, and hence the amount of profit the enterprise makes is variable. The debate over which style is more appropriate has many facets, but fundamentally, under a rate-of-return framework, the investor is relatively insured against risk, and this may encourage investment. On the other hand, since profits are guaranteed, the incentives to lower costs are fewer than under price-cap regulation, where the enterprise will keep any efficiency gains. This trade-off may therefore take the form of weighing up the need for observable infrastructure investment against the need for unobservable cost-reducing investment.

In developing countries the decision between the two regimes is present, although some of the factors to consider may be different. Kirkpatrick et al. (2005) show in their cross-country survey that regulators in developing countries are varied in which approach they choose. Laffont (2005, p.23) argues that we need to build a general understanding of how the type of regime affects the commitment problem. Armstrong and Sappington (2006) describe that, since price-caps allow for greater volatility of profits, they may lead to either particularly large profits or financial distress, both possibly prompting renegotiation. They thus argue that a rate-of-return regime may increase the credibility of commitment. We seek to develop this argument by extending

the model of the previous section to consider the two regimes.

To compare a price-cap to a cost-plus regime we need to add to our model some uncertainty over future costs. Let us move to a situation where  $\bar{R}$  may either be  $\bar{R}_L$  or  $\bar{R}_H$ , and define  $\Delta\bar{R} = \bar{R}_H - \bar{R}_L$ . In other words, the total return to society may be high or low, implicitly depending on the costs involved. For analytical simplicity, we assume that  $\bar{R}$  follows a process whereby it is constant for a period of time  $\tau + S$ , and then is independently drawn anew at this time, with probability  $\mu$  that  $\bar{R} = \bar{R}_L$  and  $1 - \mu$  that  $\bar{R} = \bar{R}_H$ .  $S$  is a period of time greater than 0 but less than  $T^*$ , where  $T^*$  is the non-investment period in equilibrium.

We can then represent the two different types of regulatory regime in the following way:

- Cost-Plus - As before, the contract offered to the firm consists of a single value  $R$  which the firm will receive no matter the value of  $\bar{R}$  (so long as the firm invests and the government does not expropriate).
- Price-Cap - The regulator essentially fixes a price that the enterprise will be allowed to charge that is independent of  $\bar{R}$ , and in doing so transfers all the variation in costs to the firm. In this case the firm will receive a return of  $R_L$  when  $\bar{R} = \bar{R}_L$  and  $R_H = R_L + \Delta\bar{R}$  when  $\bar{R} = \bar{R}_H$ . Hence  $\mathbb{E}(R)(T) = R_L(T) + \mu\Delta\bar{R}$

Now, let us consider the cost-plus case. In place of  $W_L(T, \bar{R})$  we have the following expression

$$W_L^{CP}(T, \bar{R}_L) = \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \times [(1 - e^{-r(S+\tau)})(\bar{R}_L - \theta_L R(T)) + (e^{-r(S+\tau)} - e^{-r(T+\tau)})(\mathbb{E}[\bar{R}] - \theta_L R(T)) - (1 - e^{-r(T+\tau)})\theta_L R(T)]$$

As shown in the proof of Proposition 5 this is the relative payoff of sharing rather than

expropriating for player  $G$  in equilibrium when  $\theta = \theta_L$  and  $\bar{R} = \bar{R}_L$ . Similarly,

$$\begin{aligned} W_H^{CP}(T, \bar{R}_H) &= -\frac{1 - e^{-r(T+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)R(T) + \frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}\bar{R}_H \\ &\quad + \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}\mathbb{E}[\bar{R}] \\ &\quad - \frac{1 - e^{-(r+\nu)(T+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)R(T) \end{aligned}$$

We also need to slightly tweak our definition of  $T^B$ , since this will now be a function of  $\mathbb{E}[\bar{R}]$  rather than  $\bar{R}$ . Hence we have:

$$\frac{\theta_L}{\nu\beta + r} \frac{dR}{dT}(T^B) + \mathbb{E}[\bar{R}] - \theta_L R(T^B) = 0 \quad (10)$$

We can now give the equivalent of Proposition 4 for the cost-plus case:

**Proposition 5.** *Suppose that there exists a value  $T_{CP}^A$  that solves the equation  $W_L^{CP}(T_{CP}^A, \bar{R}_L) = 0$ . Then, letting  $T_{CP}^* = \max\{T_{CP}^A, T_{CP}^B\}$ ,*

- *If  $W_H(T^*, \bar{R}_H) \leq 0$ , then the **unique strongly renegotiation proof perfect Bayesian equilibrium** is an episodic investment equilibrium with non-investment length  $T^*$ .*
- *If  $W_H(T^*, \bar{R}_H) \geq 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium is that with no investment.*

*If there is no value of  $T_{CP}^A$  that solves the equation  $W_L(T_{CP}^A, \bar{R}_L) = 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium is that with no investment.*

In order to compare, let us now calculate the equivalent values under price-cap regulation. In place of  $W_L(T, \bar{R})$  we have the following two expressions:

$$\begin{aligned} W_L^{PC}(T, \bar{R}_H) &= (1 - e^{-r(S+\tau)})(\bar{R}_H - \theta_L R_H(T)) + (e^{-r(S+\tau)} - e^{-r(T+\tau)})(\mathbb{E}[\bar{R}] - \theta_L \mathbb{E}[R(T)]) \\ &\quad - (1 - e^{-r\tau})\bar{R}_H \end{aligned}$$

and

$$W_L^{PC}(T, \bar{R}_L) = (1 - e^{-r(S+\tau)})(\bar{R}_L - \theta_L R_L(T)) + (e^{-r(S+\tau)} - e^{-r(T+\tau)})(\mathbb{E}[\bar{R}] - \theta_L \mathbb{E}[R(T)]) - (1 - e^{-r\tau})\bar{R}_L$$

Again, we show in the proof of Proposition 6 that this is the relative payoff of sharing rather than expropriating for player  $G$  in equilibrium when  $\theta = \theta_L$ . We require the two functions here, since it is ambiguous under which value of  $\bar{R}$  it is more tempting for player  $G$  to expropriate. This is also the case for when  $\theta = \theta_H$ , and hence we also require the following two expressions:

$$\begin{aligned} W_H^{PC}(T, \bar{R}_H) = & -\frac{1 - e^{-r(S+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)R_H(T) \\ & -\frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)\mathbb{E}[R(T)] \\ & +\frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}\bar{R}_H + \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}\mathbb{E}[\bar{R}] \\ & -\frac{1 - e^{-(r+\nu)(S+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)R_H(T) \\ & -\frac{e^{-(r+\nu)(S+\tau)} - e^{-(r+\nu)(T+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)\mathbb{E}[R(T)] \end{aligned}$$

and

$$\begin{aligned} W_H^{PC}(T, \bar{R}_L) = & -\frac{1 - e^{-r(S+\tau)}}{r}(\beta\theta_L + (1 - \beta)\theta_L)R_L(T) \\ & -\frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)\mathbb{E}[R(T)] \\ & +\frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}\bar{R}_L + \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}\mathbb{E}[\bar{R}] \\ & -\frac{1 - e^{-(r+\nu)(S+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)R_L(T) \\ & -\frac{e^{-(r+\nu)(S+\tau)} - e^{-(r+\nu)(T+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)\mathbb{E}[R(T)] \end{aligned}$$

Since the return given to the firm is now variable, we use an expression for  $\mathbb{E}(R)(T)$

rather than  $R(T)$ , i.e.

$$(1 - \beta) (1 - e^{-\nu(T+\tau)}) e^{-r\tau} \frac{\mathbb{E}[R(T)] - 1}{r + \nu\beta} = \frac{1 - e^{-r\tau}}{r} \quad (11)$$

We also need to slightly tweak our definition of  $T^B$ , since this will now be a function of  $\mathbb{E}[R]$  rather than  $R$ , hence:

$$\frac{\theta_L}{\nu\beta + r} \frac{d\mathbb{E}[R]}{dT}(T^B) + \mathbb{E}[\bar{R}] - \theta_L \mathbb{E}[R(T^B)] = 0 \quad (12)$$

We can now state the equivalent proposition for the price-cap case:

**Proposition 6.** *Suppose that there exists values  $T_{PC,L}^A, T_{PC,H}^A > 0$  that solve the equations  $W_L^{PC}(T_{PC,L}^A, \bar{R}_L) = 0$  and  $W_L^{PC}(T_{PC,H}^A, \bar{R}_H) = 0$ . Then, letting  $T_{PC}^* = \max\{T_{PC,H}^A, T_{PC,L}^A, T_{PC}^B\}$ ,*

- *If  $W_H(T_{PC}^*, \bar{R}_L) \leq 0$  and  $W_H(T_{PC}^*, \bar{R}_H) \leq 0$ , then the **unique strongly renegotiation proof perfect Bayesian equilibrium** is an episodic investment equilibrium with non-investment length  $T^*$ .*
- *If  $W_H(T_{PC}^*, \bar{R}_L) \geq 0$  or  $W_H(T_{PC}^*, \bar{R}_H) \geq 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium is that with no investment.*

*If there are no solutions to the equations  $W_L^{PC}(T_{PC,L}^A, \bar{R}_L) = 0$  and  $W_L^{PC}(T_{PC,H}^A, \bar{R}_H) = 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium is that with no investment.*

In order to compare the price cap case with that of cost-plus, it is useful to define  $\theta_L^*$  as follows:

$$\theta_L^* = \frac{\bar{R}_H - \bar{R}_L}{R_H^{PC}(T_{PC}^*) - R^{CP}(T_{PC}^*)} \frac{e^{-r\tau} - e^{-r(S+\tau)}}{1 - e^{-r(S+\tau)}} \quad (13)$$

We can now formally compare the two in the following corollary.

Having characterised the unique strongly renegotiation proof equilibrium in both the case of a cost-plus regime and a price cap, we can now compare the two situations.

This is done in the following corollary:

**Corollary 1.** *Let  $\theta_L^*$  be defined as in equation (13). Then,*

- *If  $\theta_L \geq \theta_L^*$ , the non-investment length  $T^*$  in the unique SRP PBE under the cost-plus regime is greater than or equal to the non-investment length  $T^*$  in the corresponding equilibrium under the price-cap regime.*
- *If  $\theta_L \leq \theta_L^*$ , then the non-investment length  $T^*$  under the cost-plus regime is less than or equal to the non-investment length  $T^*$  under the price-cap regime.*

This corollary essentially says that the choice of regulatory regime may make a difference to the length of non-investment period in the model. If the non-investment period is determined by the government waiting until it is optimal to offer a contract to the firm (i.e.  $T^B > T^A$ ), then the choice of regime does not affect the length of non-investment. However, if the non-investment period is determined by the first time at which the firm feels comfortable that the government will not expropriate (i.e.  $T^B < T^A$ ), then the choice of regime matters.

The corollary shows that which regime is best can go either way, depending on the value of  $\theta_L$ , the amount by which the government under-values profits compared to consumer surplus. If  $\theta_L$  is low, and the government values profits fairly highly, then a price-cap regime is best for preventing expropriation. This is because a low  $\theta_L$  implies the government is mainly concerned with the joint surplus produced by investment. The most tempting time for the government to expropriate therefore is when  $\bar{R}$  is low - i.e. costs are high. When the investment of the firm is bringing relatively less to the economy (i.e. the firm is inefficient), the cost of non-investment is lower, and so the temptation to expropriate is greater. A price-cap is therefore helpful, because it is precisely when the firm is inefficient that the return they make is lowest. Hence this dampens the temptation of the government to expropriate compared to a cost-plus regime when the amount going to the firm is constant.

However, if  $\theta_L$  is high, and the government cares relatively little about profits, then it is in fact the profits of the firm that determine which cost-level is most tempting to renege under. Since under a price-cap profits may reach higher levels than at any time under a cost-plus regime (when  $\bar{R}$  is high), it is more difficult to prevent expropriation

under a price-cap regime. Hence a high  $\theta_L$  favours a cost-plus regime.<sup>11</sup>

One final point to note is that we might expect  $\theta_L$  to be higher in developing countries. This stems from two reasons. First, the population of the country is less likely to benefit from the firm's profits than in a developed country since share ownership is lower and utility firms are often foreign-owned. Second, if the government is concerned with equity, the gap between the majority of the population and those that receive the firm's profits is likely to be greater, and hence less weight will be placed on a firm's profits. This higher value of  $\theta_L$  would then translate into the fact that expropriation is most tempting when profits are high, and therefore a cost-plus regime would result in greater investment.

### **3.2 Decentralisation**

Decentralisation of regulation has been a lively debated issue in many developing countries, particularly in federal ones like Brazil (see, for example, Laffont and Pouyet (2004)). Devolving power to more local levels has been advocated more generally by institutions such as the World Bank (Bardhan, 2002) and some of the characteristics that have made it popular are very appropriate to improving regulation. Two key arguments given are that it makes government more responsive and that it means that better information is available to them. The first of these arguments is exemplified by the study of Faguet (2004), which finds that decentralisation in Bolivia did make local government more responsive to local needs, including extra investment in infrastructure (particularly water). Meanwhile, it is commonly assumed in the theoretical literature that local governments know more about the local environment than can be easily transmitted to the centre (Gilbert and Picard, 1996).

One issue that there has been very little consideration of is how decentralisation interacts with the commitment problem. This is despite the fact that the two issues just outlined, responsiveness and information, have strong implications for government

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<sup>11</sup>One potential extension that could be made would be to make the choice of regime endogenous to the model, such that it was chosen by the government. In this case, the government would simply pick that regime which was optimal (i.e. that with the smallest non-investment period). There would be no possibility of signalling, since a government with high needs is indifferent between the two regimes, since they would not pay the firm anything under either.

opportunism. In particular, if a local government is responsive to the local population, then it is likely to be tempted to renege on a regulatory contract if it benefits that region. Meanwhile, if they are well informed about the profits the enterprise is making, it may be less risky to attempt to steal them. We now consider the implication local responsiveness may have for decentralisation by extending our model of commitment.

We look at the setting where a country has two regions (Region 1 and Region 2), with each region having an independent enterprise running its utility. We consider two setups, one where regulation takes place at the regional level, and one where a central government regulates both enterprises. In each case, the enterprises' objective functions are as before, and we assume the firms are identical. Similarly, in the case where there is a local regulator, we assume that it is under the control of the local government which operates exactly as the government did in the basic model. Let  $\theta_{it}$  be the needs of government  $i$  at time  $t$ , where governments 1 and 2 represent regions 1 and 2 respectively and the central government is labelled as government 0. We assume that for each government  $\theta_{it}$  follows an independent Markov process as described above. The only parameter that varies between the two regions is the social return of the investment,  $\bar{R}_i$ .

It is clear that the case of local regulation is the same as in the basic model above. Hence  $W_H(T, \bar{R})$  and  $W_L(T, \bar{R})$  are defined as above in equations (4) and (7) and  $T_i^B$  is defined according to the equation

$$\frac{\theta_L}{\nu\beta + r} \frac{dR}{dT}(T_i^B) + \bar{R}_i - \theta_L R(T_i^B) = 0 \quad (14)$$

where  $R(T)$  is as defined above in equation (6). We then have the following proposition:

**Proposition 7.** *Suppose that there exists a value  $T_i^A > 0$  that solves the equation  $W_L(T_i^A, \bar{R}_i) = 0$ . Then, letting  $T_i^* = \max\{T_i^A, T_i^B\}$ ,*

- *If  $W_H(T_i^*, \bar{R}_i) \leq 0$ , then the **unique strongly renegotiation proof perfect Bayesian equilibrium** in region  $i$  under local regulation is an episodic investment equilibrium with non-investment length  $T_i^*$ .*

- If  $W_H(T_i^*, \bar{R}_i) \geq 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium in region  $i$  under local regulation is that with no investment.

If there is no solution to the equation  $W_L(T_i^A, \bar{R}_i) = 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium in region  $i$  under local regulation is that with no investment.

Now let us consider the case where regulation is centralised. Since both enterprises will act in the same way, we can treat them as just one enterprise. Hence the only difference will be that the social gain is now  $\bar{R}_1 + \bar{R}_2$  and the transfer given to the enterprise(s) is  $2R$ . This time,  $T_B^0$  will be defined by the equation

$$2 \frac{\theta_L}{\nu\beta + r} \frac{dR}{dT}(T_B^0) + \bar{R}_1 + \bar{R}_2 - 2\theta_L R(T_B^0) = 0 \quad (15)$$

Hence we have the following proposition:

**Proposition 8.** Suppose that there exists a value  $T_0^A > 0$  that solves the equation  $W_L(T_0^A, \frac{\bar{R}_1 + \bar{R}_2}{2}) = 0$ . Then, letting  $T_0^* = \max\{T_0^A, T_B^0\}$ ,

- If  $W_H(T_0^*, \frac{\bar{R}_1 + \bar{R}_2}{2}) \leq 0$ , then the **unique strongly renegotiation proof perfect Bayesian equilibrium** in region  $i$  under local regulation is an episodic investment equilibrium with non-investment length  $T_i^*$ .
- If  $W_H(T_0^*, \frac{\bar{R}_1 + \bar{R}_2}{2}) \geq 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium in region  $i$  under local regulation is that with no investment.

If there is no solution to the equation  $W_L(T_0^A, \frac{\bar{R}_1 + \bar{R}_2}{2}) = 0$ , then the unique strongly renegotiation proof perfect Bayesian equilibrium in region  $i$  under local regulation is that with no investment.

We see that in the proposition,  $\bar{R}$  has been replaced by  $\frac{\bar{R}_1 + \bar{R}_2}{2}$ . This is because the governments actions now essentially depend on the average of the two social returns. We can now compare the local regulation case to the central regulation case in the following corollary

**Corollary 2.** When  $\bar{R}_1 > \bar{R}_2$ , centralising regulation produces the following results:

1. *The range of parameters for which the WRP PBE with investment exists is smaller in Region 1 but larger in Region 2.*

2. *If a WRP PBE with investment exists in all cases, then  $T_2^* \geq T_0^* \geq T_1^*$*

*If  $R_1 < R_2$ , the opposite of each of these statements apply.*

Intuitively, centralising regulation is sharing the risk between the two regions. The temptation to renege in the region where future investment has a lower return is mitigated by the regulator not wishing to give up investment in the more profitable region. This result is similar to that of Bernheim and Whinston (1990) in their model of multi-market collusion. They find that firms competing in multiple markets are just as able to sustain collusion as when they operate in a single market so long as the markets are symmetric, but that with certain asymmetries collusion may be more easily achieved. In our case, this is equivalent to the fact that constant investment in both regions is easier to achieve in the centralised case when returns are different. Collusion in Bernheim and Whinston's model is equivalent to the agreements between the regulator and the enterprise that investment will take place and profits will be allowed.

The implications for (de)centralisation as a policy option are therefore mixed. The risk pooling mechanism has ambiguous effects on investment that depend on the asymmetries between the regions. In some cases, centralising regulation can create investment in an area where previously the threat of expropriation was too high. This may explain why Gomez Ibanez (2003, p.132) finds that in North and South America "nationalization was generally slower or less likely where the responsibility for regulation was at the national or provincial level". On the other hand, when it is difficult producing credible commitment anywhere, we have seen that the best option is to decentralise, at least to those regions where some commitment is possible. These are the regions where the social return on investment is greatest, and as such is consistent with the recommendation of Walker et al. (1999, p.77) that "the priority in the decentralisation program should be given to the cities where the problems are greatest and the potential for service improvement is highest".

We can therefore see that the impact of decentralisation will depend on the context,

and indeed if regions are fairly symmetric there may be no change in the commitment credibility at all. Spiller and Savedoff (1999, p.19) argue on the whole that decentralising itself is not a particularly effective tool in improving commitment, and instead one should focus on using it as a tool to fragment regulation. In this way, it would be interesting to extend the model to consider a hierarchy of regulation, where both central and local government play a role. By making regulation less dependent on the interests of a single executive, renegotiation may be harder. In Argentina, for example, the central government credibly committed to Aguas Argentina by devolving day-to-day regulation to the local level, but reserving the right to intervene in the case of dispute. Thus when the local regulator was taken over by a local government hostile to the privatised enterprise, they were unable to completely renegotiate the contract since the central government overruled with a more profitable deal (Alcazar et al., 2002). On the other hand, such a scheme has not worked so well in the Indian electricity sector, where the federal government has had less success in exerting its authority over state regulators, perhaps due to the large information asymmetry (Rufin, 2003). Modeling this process explicitly would enable us to better understand how a hierarchical system may work and what can be done to improve its effectiveness.

Another extension to this model of decentralisation that would also be interesting to pursue would be to introduce yardstick competition as a means to lessen the central government's informational disadvantage. Such an inclusion is likely to add another dimension to the role regional asymmetry plays in decentralisation. A further aspect not considered here is that, when limited investment is available, localities may compete for capital by offering high powered incentives. This is modeled by Laffont and Pouyet (2004), who show that decentralisation can lead to more stability since competition between the regions leaves less leeway for expropriation, and it would be worthwhile to mix this effect with that of risk pooling. Finally, it is sometimes argued that local governments are more vulnerable to capture by a local elite (Bardhan, 2002), and incorporating such an idea may be necessary if the general model were extended to allow for capture by the enterprise.

## 4 Conclusion

Overall, the model offers a step forward in thinking about ways in which reputation can sustain time-inconsistent government policy. We have shown how the government may play an efficient strategy through fear of future non-investment in a way that is robust to two criticisms that often apply to typical ‘trigger-strategy’ reputation mechanisms: The punishment length being arbitrary and the possibility of renegotiation. Such an equilibrium is sustained by considering the uncertainty that a firm may have about the government’s precise payoffs.

Unlike previous models with reputation created through changing types, the chapter has focused on a situation with two long-lived players. This has the advantage of being the appropriate context to model renegotiations in utility regulation, an issue that is particularly significant in developing countries. This has allowed us to consider how different regulatory policy may influence a government’s ability to commit. In particular, we have shown that the choice of regime and amount of centralisation may well have an impact on commitment. Furthermore, we have seen how the impact on commitment is likely to be different in developing countries where governments’ commitment abilities are much weaker. We can therefore conclude that it is necessary to model explicitly the way a government commits to a time-inconsistent policy in order to understand the ways in which policy is likely to affect this commitment

## 5 Appendix

*Proof of equation 3.* Let  $P(s)$  be a  $2 \times 2$  matrix whose elements  $p_{ij}(s)$  are defined by the equation

$$p_{ij}(s) = \mathbb{P}(x_{t+s} = j | x_t = i)$$

where  $i, j \in \{\theta_H, \theta_L\}$ . For a finite state space, the Chapman-Kolmogorov equations then give:

$$P(s) = e^{sQ} \quad (16)$$

where  $Q$  is the transmission matrix defined in equation 1. Furthermore, from the definition of exponential matrices, we have that if  $Q$  can be diagonalised such that  $D = M^{-1}QM$  then

$$P(t) = Me^{tD}M^{-1} \quad (17)$$

In particular, we have

$$D = \begin{pmatrix} 0 & 0 \\ 0 & -\nu \end{pmatrix}$$

and

$$M = \begin{pmatrix} 1 & -\nu\beta \\ 1 & -\nu(1-\beta) \end{pmatrix}$$

Hence

$$P(s) = \begin{pmatrix} 1 - \beta(1 - e^{-\nu s}) & \beta(1 - e^{-\nu s}) \\ (1 - \beta)(1 - e^{-\nu s}) & 1 - (1 - \beta)(1 - e^{-\nu s}) \end{pmatrix}$$

which is as required by equation 3. □

*Proof of Proposition 1.* We first show that the condition  $W_H(T, \bar{R}) \geq$  is sufficient by positing strategies for the two players and then showing that these indeed form a perfect Bayesian equilibrium.

Players' strategies are dependent on the time  $s$  since the government last expropriated. Player F plays a strategy of investing if and only if  $s \geq T$  and  $R \geq e^{r\tau}$ . We then posit that player G plays the strategy of sharing when  $s \geq T$  and expropriating when

$s < T$ . As stated above, we check the equilibrium is subgame perfect by considering the payoff of deviating for a time  $\epsilon$  as  $\epsilon \rightarrow 0$ .

First let us consider player F's strategy. Deviating when  $s \geq T$  and  $R \geq e^{r\tau}$  means not investing for a time  $\epsilon$ , giving an increase in the expected discounted payoff of

$$\int_0^\epsilon e^{-rt} dt - \int_\tau^{\tau+\epsilon} e^{-rt} R dt = \frac{1 - e^{-r\epsilon}}{r} - e^{-r\tau} R \frac{1 - e^{-r\epsilon}}{r}$$

Dividing by  $\epsilon$  and taking the limit as  $\epsilon \rightarrow 0$  then gives that this expression is equal to  $1 - e^{-r\tau} R$ . Hence, if  $R \geq e^{r\tau}$ , the deviating is sub-optimal. Similarly, if  $R < e^{r\tau}$ , then it is optimal not to invest and hence the firm has no incentive to deviate when  $s \geq T$ . If  $s < T$ , then any investment will be expropriated and hence clearly the firm does not wish to deviate by investing.

Let us now consider player G's promise of  $R$  to the firm. Clearly, if  $R < e^{r\tau}$ , then player F will never invest. Hence it is a dominant strategy for the government to choose  $R = e^{r\tau}$ , since investment always generates a positive return for the government.

Now let us consider player G's decision of whether or not to expropriate. First, we consider the case when  $\theta(s) = \theta_H$ . Let us first show that equation (4) is indeed the relative payoff to player G of sharing rather than expropriating in equilibrium. Since at a time  $\tau + T$  in the future the payoff will be independent of the government's action

now, we need only consider the differences in payoffs over this time. Hence:

$$\begin{aligned}
W_H(T, \bar{R}) &= \mathbb{E} \left[ \int_0^{T+\tau} e^{-rt} (\bar{R} - \theta(t)R) dt - \int_0^\tau e^{-rt} \bar{R} dt \mid \theta(0) = \theta_H \right] \\
&= \int_0^{T+\tau} e^{-rt} (\bar{R} - \mathbb{E}[\theta(t) \mid \theta(0) = \theta_H] R) dt - \int_0^\tau e^{-rt} \bar{R} dt \\
&= \int_0^{T+\tau} e^{-rt} (\bar{R} - ([1 - \beta(1 - e^{-\nu t})]\theta_L + e^{-rt}[\beta(1 - e^{-\nu t})]\theta_H) R) dt \\
&\quad - \int_0^\tau e^{-rt} \bar{R} dt \\
&= \int_0^{T+\tau} e^{-rt} (\bar{R} - (\beta\theta_H + (1 - \beta)\theta_L)R) - e^{-(r+\nu)t}(1 - \beta)(\theta_H - \theta_L)R dt \\
&\quad - \int_0^\tau e^{-rt} \bar{R} dt \\
&= \frac{1 - e^{-r(T+\tau)}}{r} (\bar{R} - (\beta\theta_H + (1 - \beta)\theta_L)R) \\
&\quad - \frac{1 - e^{-(r+\nu)(T+\tau)}}{r + \nu} (1 - \beta)(\theta_H - \theta_L)R - \frac{1 - e^{-r\tau}}{r} \bar{R}
\end{aligned}$$

Given this expression is greater than 0 (a condition of the proposition) it is then trivial that the government has no incentive to deviate when  $\theta(t) = \theta_H$ . When  $\theta(t) = \theta_L$ , we can similarly obtain the following expression for the payoff of sharing rather than expropriating:

$$\frac{1 - e^{-r(T+\tau)}}{r} (\bar{R} - (\beta\theta_H + (1 - \beta)\theta_L)R) + \frac{1 - e^{-(r+\nu)(T+\tau)}}{r + \nu} \beta(\theta_H - \theta_L)R - \frac{1 - e^{-r\tau}}{r} \bar{R}$$

Since this expression is clearly greater than  $W_H(T, \bar{R})$ , the government has no incentive to deviate when  $\theta(t) = \theta_H$ . Therefore, overall, the government has no incentive to deviate, and the equilibrium is subgame perfect and thus (trivially) a perfect Bayesian equilibrium.

It only remains to show that the condition  $W_H(T, \bar{R}) \geq 0$  is necessary. If this were not to hold, then, as shown above, player G would rather expropriate when  $\theta(t) = \theta_H$  and  $s > T$ . Hence they cannot be best-responding, and therefore an equilibrium where player F plays such a strategy is not perfect Bayesian.

This therefore concludes our proof that condition  $W_H(T, \bar{R}) \geq 0$  is both necessary and sufficient.

□

*Proof of Proposition 2.* We again first show that these conditions are sufficient by positing strategies for the two players. This time we also need to specify beliefs for player F.

Players' strategies are as before dependent on the time  $s$  since the government last expropriated. Furthermore, player G's strategy is dependent on her type.

Player F plays a strategy of investing if and only if  $s \geq T$  and  $R = R(T)$ , where  $R(T)$  is the rate of return given by equation (6).

If player G gets the opportunity, and the state of the world is high, she will share when  $s \geq T$  and  $R = R(T)$ , and expropriate otherwise. If player G gets the opportunity, and she is the low type, she will expropriate.

Since player G's strategy is dependent on her type, we need to posit beliefs for player F. Since player F must update her beliefs according to Bayes' rule when she sees actions that are in the equilibrium strategies, she will believe that the state of the world is high if player G shares and believe that it is low if player G expropriates. Furthermore, we assume she similarly updates her belief according to Bayes rule for any off-equilibrium investment. If player F does not invest, then player G will not have the opportunity to act. In this case, they will update their beliefs as is consistent with the Markov process - i.e. according to matrix (3).

To show that these strategies and beliefs constitute a perfect Bayesian equilibrium, we need to check that neither player can do better by deviating from their posited strategies given their beliefs. Again, we use the one-stage deviation principle stated in the previous proof.

First let us consider player F's strategy. Since  $R(T)$  is set by the government, it will set the firm's participation constraint to 0. Deviating is therefore uninteresting since all actions produce a 0 payoff. We need only check therefore that the definition of  $R(T)$  given by equation (6) is indeed that which satisfies the firm's participation constraint

exactly. The payoff to the firm of investing until the next expropriation is

$$-\frac{1 - e^{-r\tau}}{r} + e^{-r\tau} p_{\theta_L \theta_H}(s + \tau) \mathbb{E} \left[ \int_0^{S^B} e^{-rt} (R - 1) dt \right]$$

where  $p_{\theta_L \theta_H}(s)$  is defined by equation (2) and  $S^B$  is the next time the state of the world switches from good to bad, as before. Substituting in the the definition of  $p_{\theta_L \theta_H}(s)$  and the density function of  $S^B$  then gives that her expected payoff is

$$\begin{aligned} & -\frac{1 - e^{-r\tau}}{r} + (1 - \beta) (1 - e^{-\nu(s+\tau)}) e^{-r\tau} \int_0^\infty \int_0^{S^B} (R - 1) e^{-rt} \nu \beta e^{-\nu \beta S^B} dt dS^B \\ = & -\frac{1 - e^{-r\tau}}{r} + (1 - \beta) (1 - e^{-\nu(s+\tau)}) e^{-r\tau} \int_0^\infty \frac{1}{r} (R - 1) (1 - e^{-rS^B}) \nu \beta e^{-\nu \beta S^B} \\ = & -\frac{1 - e^{-r\tau}}{r} + (1 - \beta) (1 - e^{-\nu(s+\tau)}) e^{-r\tau} \frac{R - 1}{r + \nu \beta} \end{aligned}$$

This is, as we can see, set to zero if  $R(T)$  is as defined by equation (6).

Now let us consider player G. In order to do this, it is helpful to define  $W(\theta)$  to be the expected discounted payoff of player G at time  $s$  when  $\theta(s) = \theta$  and players follow their equilibrium strategies. Then we have:

$$\begin{aligned} W(\theta_L) &= \int_0^\infty \left[ \int_0^{S^H} e^{-rt} (\bar{R} - \theta_L R) dt + e^{-rS^H} W(\theta_H) \right] \nu \beta e^{-\nu \beta S^H} dS^H \\ &= \int_0^\infty \left[ \frac{e^{-\nu \beta S^H} - e^{-(r+\nu \beta)S^H}}{r} (\bar{R} - \theta_L R) + e^{-(r+\nu \beta)S^H} W(\theta_H) \right] \nu \beta dS^H \\ &= \frac{1}{\nu \beta + r} [(\bar{R} - \theta_L R) + \nu \beta W(\theta_H)] \end{aligned} \quad (18)$$

Where  $S^H$  is the next time at which the state of the world becomes high. For  $W(\theta_H)$ , we have

$$\begin{aligned} W(\theta_H) &= \frac{1 - e^{-r\tau}}{r} \bar{R} \\ &+ e^{-r(T+\tau)} [W(\theta_H) + (1 - \beta)(1 - e^{-\nu(T+\tau)})(W(\theta_L) - W(\theta_H))] \end{aligned} \quad (19)$$

Rearranging gives

$$W(\theta_H)(1 - e^{-r(T+\tau)}) = \frac{1 - e^{-r\tau}}{r}\bar{R} + (1 - \beta)(e^{-r(T+\tau)} - e^{-(\nu+r)(T+\tau)})(W(\theta_L) - W(\theta_H)) \quad (20)$$

From equation (18) we then have

$$rW(\theta_H) = \bar{R} - \theta_L R - (r + \nu\beta)(W(\theta_L) - W(\theta_H)) \quad (21)$$

substituting this into (19) and rearranging gives

$$W(\theta_L) - W(\theta_H) = \frac{(1 - e^{-r(T+\tau)})(\bar{R} - \theta_L R) - (1 - e^{-r\tau})\bar{R}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \quad (22)$$

If  $\theta(t) = \theta_H$ , deviating when  $s \geq T$  would mean delaying expropriation for time  $\epsilon$ .

The relative payoff of doing so is

$$\mathbb{E} \left[ \int_0^\epsilon e^{-rt} (\bar{R} - \theta(t)R) dt + e^{-r\epsilon} W(\theta(\epsilon)) \middle| \theta(0) = \theta_H \right] - W(\theta_H)$$

Expanding this out and taking the limit as  $\epsilon \rightarrow 0$  gives

$$\begin{aligned} & \lim_{\epsilon \rightarrow 0} \frac{1}{\epsilon} \left[ \int_0^\epsilon e^{-rt} (\bar{R} - \theta_H R) dt \right. \\ & \quad \left. + e^{-r\epsilon}(1 - \beta)(1 - e^{-\nu\epsilon})(W(\theta_L) - W(\theta_H)) - (1 - e^{-r\epsilon})W(\theta_H) \right] \\ & = \bar{R} - \theta_H R + \nu(1 - \beta)W(\theta_L) - W(\theta_H) - rW(\theta_H) \end{aligned}$$

Substituting in equation (21) then tells us this is equal to

$$-(\theta_H - \theta_L)R + (r + \nu)(W(\theta_L) - W(\theta_H))$$

Now, substituting in our expression for  $W(\theta_L) - W(\theta_H)$  from equation (22) gives us that the condition for the government to not wish to deviate when  $\theta = \theta_H$  is

$$\frac{(1 - e^{-r(T+\tau)})(\bar{R} - \theta_L R) - (1 - e^{-r\tau})\bar{R}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \geq \frac{\theta_H - \theta_L}{r + \nu} R$$

On closer inspection, we can see that this is a rearrangement of the expression

$$W_H(T, \bar{R}) \leq 0$$

If  $s \geq T$  and  $\theta(t) = \theta_L$ , then the temptation to deviate is as before: the player will receive a higher instantaneous payoff, but will set  $s$  to 0. To check that the temptation to deviate is not sufficiently great, we simply need to confirm that  $W_L(T, \bar{R})$  is indeed defined according to equation (7). We can show this as follows:

$$\begin{aligned}
W_L(T, \bar{R}) &= W(\theta_L) - \frac{1 - e^{-r\tau}}{r} \bar{R} \\
&\quad - e^{-r(T+\tau)} [W(\theta_L) - \beta(1 - e^{-\nu(T+\tau)})(W(\theta_L) - W(\theta_H))] \\
&= W(\theta_L)(1 - e^{-r(T+\tau)}) - \frac{1 - e^{-r\tau}}{r} \bar{R} \\
&\quad + \beta(e^{-r(T+\tau)} - e^{-(r+\nu)(T+\tau)})(W(\theta_L) - W(\theta_H)) \\
&= (W(\theta_L) - W(\theta_H))(1 - e^{-r(T+\tau)}) \\
&\quad + (e^{-r(T+\tau)} - e^{-(r+\nu)(T+\tau)})(W(\theta_L) - W(\theta_H)) \\
&= (W(\theta_L) - W(\theta_H))(1 - e^{-(r+\nu)(T+\tau)}) \\
&= \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\
&\quad \times ((1 - e^{-r(T+\tau)})(\bar{R} - \theta_L R) - (1 - e^{-r\tau})\bar{R})
\end{aligned}$$

If  $s < T$  or  $R \neq R(T)$ , deviating means sharing any investment rather than expropriating it. As before, this is clearly not optimal because expropriating brings a higher flow payoff than sharing, and their action does not affect future payoffs at all.

Finally, we need to consider whether the government has an incentive to deviate in their choice of  $R$ . Given player F's equilibrium strategy, any other choice of  $R$  will result in them not investing. Hence, since there is no reason for the government to postpone investment, they will always offer  $R = R(T)$ .

This therefore concludes our proof that the equilibrium is perfect Bayesian. We now need to show that each condition is necessary for the episodic-investment equilibrium to be perfect Bayesian.

First, suppose that  $T$  does not meet condition (8). In this case, player G will wish to expropriate when the state of the world is high, and therefore the equilibrium is not perfect Bayesian.

Second, suppose that  $T$  does not meet condition (9). In this case, player G will wish to share when it is the low type, and therefore the equilibrium is not perfect Bayesian.

Each condition is therefore necessary, and hence the combination of these conditions is both necessary and sufficient for the existence of a perfect Bayesian episodic-investment equilibrium with non-investment length  $T$ .

□

*Proof of Proposition 3.* Let us first show that there exists a weakly renegotiation proof perfect Bayesian episodic investment equilibria with non-investment length  $T$  for all  $T$  that satisfy the conditions in the proposition.

If the conditions hold, then Proposition 2 tells us that there exists a perfect Bayesian episodic-investment equilibrium with non-investment length  $T^*$ . We then simply need to show that there is such an equilibrium that is weakly renegotiation proof. We therefore need to check that the two players would not at any point like to agree to ‘change’  $s$  - the last time that the government expropriated.

We consider an equilibrium where player G’s strategy is to offer player F a contract with rate of return  $R(s)$  if  $s \geq T$  and offer no contract if  $s < T$ .

First, let us consider whether either player would wish to renegotiate from a state  $s$  to a state  $s'$  when  $s \geq T$ . If  $s' \geq T$ , then this simply represents another state where investment is happening at a rate of return  $R(T)$ , and hence there is no reason to move to it. If  $s' < T$ , then this will result in postponing investment, and hence will be worse for the government. Hence both players do not have the incentive to renegotiate when  $s \geq T$ . If  $s < T$ , then clearly player F will not wish to renegotiate to a state  $s' > s$  since this would bring forward investment, resulting in the rate of return  $R$  not being sufficient to compensate the firm for the risk it was taking. Furthermore, player F would not wish to renegotiate to a state  $s' < s$  since this would again simply postpone investment. Therefore the posited equilibrium is weakly renegotiation proof.

We now proceed to show that the equilibria described in the proposition are the only weakly renegotiation proof equilibria that involve some investment.

Since we are considering an equilibrium where there is some investment, and player F is behaving optimally given their beliefs, they must believe, at some point, the probability of the government expropriating is less than or equal to the value that gives an expected payoff of zero. Since the equilibrium is perfect Bayesian, this belief must be based on the equilibrium strategy of player G. Hence player G's equilibrium strategy involves sharing for at least one type for some  $R$  that it will offer. Since this is player G's equilibrium strategy, it must be a best response. However, sharing is strictly dominated as a strategy in the stage game, and hence there must be an incentive to share based upon the equilibrium strategy for future plays of the game. Therefore, in equilibrium, player G must receive an expected lower future payoff after they have expropriated, as compared to if they had shared. In particular, this lower future payoff must come about because player F will at some point not invest when they would have had there not been expropriation.

Let us first consider the case where for some state player F invests and both types of player G share (as in the full-investment equilibria). In this case, there is clearly an incentive for both player F and player G to renegotiate when they are in the 'no-investment' phase. In particular, they would both like to change to a state where there is investment and sharing, since here they both receive strictly positive expected payoffs. There are therefore no WRP perfect Bayesian equilibria that involve both types sharing for some state. In particular, no full-investment equilibria are WRP.

Let us now consider the case where player G's actions are dependent on her type. Since the non-investment resulting from expropriation harms the government when the world is high as least as much as when it is low, if the government wishes to expropriate when the state of the world is high it will wish to do so when the state of the world is low also. Hence there cannot be a situation where the low type shares and the high type expropriates. The only possibility therefore for the investment state is one where the low type expropriates and the high type shares (as in the episodic-investment equilibria). In this case, player F's beliefs of player G's type will be updated in the way described in the proof of Proposition 2.

We have therefore established that any WRP PBE consists of the high type sharing and the low type expropriating following investment. Without loss of generality, let us assume that player F invests at a time  $s$  after the world was known to be low. If there is no expropriation between time  $s$  and  $s' > s$ , then in any WRP equilibria there must be investment throughout the period  $[s, s']$ , since otherwise both parties would wish to renegotiate to state  $s$ . Hence player F's strategy must consist of investing if and only if the government has not expropriated within a length of time  $T$ , for some  $T$ . In other words, any WRP PBE must be an episodic-investment equilibria as defined above.

It now only remains to show that episodic-investment equilibria with non-investment length  $T$  outside the range given in the proposition are either not weakly renegotiation proof or not perfect Bayesian. Proposition 2 tells us that any equilibrium with non-investment length  $T < T^A$  is not perfect Bayesian, so we need only be concerned with those  $T$  in the range  $(T^B, T^A]$ . In such an equilibrium, the government is offering a return of  $R(T)$  to the firm at time  $T$  after it last expropriated. Instead, it could deviate an instant  $\epsilon$  by not offering anything until  $T + \epsilon$ , whereupon it could offer a lower rate of return  $R(T + \epsilon)$ . Supposing such an offer was accepted by the firm (i.e. player F invests), the payoff from not deviating in such a way would be

$$W(T) - e^{-r\epsilon}(e^{-\beta\nu\epsilon}W(T + \epsilon) + (1 - e^{-\beta\nu\epsilon})W(\theta_H)) \quad (23)$$

where  $W(T)$  is the payoff at state  $T$  when there has been investment and the state of the world is high, and  $W(\theta_H)$  is the payoff when there has been investment and the state of the world is low (which is independent of the time since expropriation). From equation (18) we have that

$$W(T) = \frac{1}{\nu\beta + r} [(\bar{R} - \theta_L R(T)) + \nu\beta W(\theta_H)] \quad (24)$$

Hence expression (23) can be written as

$$W(T) - W(T + \epsilon) + W(T + \epsilon)(1 - e^{-(r+\beta\nu)\epsilon}) - e^{-r\epsilon}(1 - e^{-\beta\nu\epsilon})W(\theta_H) \quad (25)$$

since we are only concerned with the sign of this expression, we can divide it by  $\epsilon$  and then take the limit as  $\epsilon \rightarrow 0$ . Doing this gives us

$$-W'(T) + W(T)(r + \beta\nu) - \beta\nu W(\theta_H)$$

and then after substituting in for  $W(T)$  from (24) we have

$$\frac{\theta_L}{\nu\beta + r} \frac{dR}{dT}(T) + \bar{R} - \theta_L R(T) = 0$$

Differentiating  $R(T)$  (as defined in equation (6)) gives

$$\nu(1 - \beta) (e^{-\nu(T+\tau)}) e^{-r\tau} \frac{R(T) - 1}{r + \nu\beta} + (1 - \beta) (1 - e^{-\nu(T+\tau)}) e^{-r\tau} \frac{1}{r + \nu\beta} \frac{dR}{dT} = 0$$

Hence

$$\frac{\theta_L}{\nu\beta + r} \frac{dR}{dT} = - \frac{\theta_L}{(1 - \beta)} \frac{\nu e^{-\nu(T+\tau)}}{(1 - e^{-\nu(T+\tau)})^2} \frac{1 - e^{-r\tau}}{r e^{-r\tau}}$$

which is clearly increasing in  $T$ . Since  $-R(T)$  is also increasing in  $T$  and  $T < T^B$ , the expression is negative. Hence the payoff from not deviating is negative, and player G would prefer to postpone offering a rate of return to the firm. If the firm would accept an offer of  $R(T + \epsilon)$  at  $T + \epsilon$ , the equilibrium is therefore not perfect Bayesian. However, if the firm would not accept such an offer, the equilibrium is not weakly renegotiation proof, since both players would prefer to renegotiate to the state  $T$  at  $T + \epsilon$ . Hence there are no WRP perfect Bayesian equilibria with  $T < T^B$ . This concludes our proof.  $\square$

*Proof of Proposition 4.* Suppose that the condition is met. Consider a WRP PBE shown to exist in Proposition 3 with non-investment length  $T > T^*$ . At time  $T > T^*$  after expropriation, player G would prefer for investment to take place at  $T^*$  than  $T$  since  $T^* > T^B$ , which is the optimal value of  $T$  for player G. Moreover, player F receives an expected discounted payoff of 0 in either case, and therefore the two states are Pareto ranked, i.e. renegotiation will take place and we move to the equilibrium with

non-investment length  $T^*$ . This is also trivially better than any WRP equilibrium with no investment, and hence the episodic investment equilibrium with non-investment length  $T^*$  is the unique strongly renegotiation proof perfect Bayesian equilibrium.

If  $W_H(T, \bar{R}) \geq 0$ , then from Proposition 2 there are no WRP perfect Bayesian equilibria with investment, and hence the equilibrium with no investment is trivially strongly renegotiation proof.  $\square$

*Proof of Proposition 5.* The proof is clearly by and large identical to that of Proposition 4, so here we simply present a sketch proof of the differences. Let us consider each equation in turn to examine how it does or does not differ from those in Proposition 4.

We now have  $W_L^{CP}(T_{CP}^A, \bar{R}_L) = 0$  in place of  $W_L(T^A, \bar{R}) = 0$ . In Proposition 4, this equation represented the value of  $T$  at which the government is indifferent between expropriating and not doing so. In the case of uncertain costs, there will clearly now be two such equations - i.e. in equilibrium we require that the government does not expropriate in the high state of the world neither when costs are high nor when they are low. We therefore need to calculate the incentive to deviate in both scenarios.

Let  $W_H^{CP}(T, \bar{R}_L)$  be the relative payoff from sharing rather than deviating when  $\theta = \theta_H$  and  $\bar{R} = \bar{R}_L$ . By modifying the expression for  $W_H(T, \bar{R})$  above appropriately, we have:

$$W_H^{CP}(T, \bar{R}_L) = -\frac{1 - e^{-r(T+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)R(T) + \frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}\bar{R}_L \\ + \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}\mathbb{E}[\bar{R}] - \frac{1 - e^{-(r+\nu)(T+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)R(T)$$

Similarly, for  $W_H^{CP}(T, \bar{R}_H)$  we have

$$W_H^{CP}(T, \bar{R}_H) = -\frac{1 - e^{-r(T+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)R(T) + \frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}\bar{R}_H \\ + \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}\mathbb{E}[\bar{R}] - \frac{1 - e^{-(r+\nu)(T+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)R(T)$$

In order to examine which of these two equations will form the binding constraint, we

calculate the difference, i.e.

$$W_H^{CP}(T, \bar{R}_L) - W_H^{CP}(T, \bar{R}_H) = -\frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}(\bar{R}_H - \bar{R}_L)$$

Clearly this expression is always negative. It is less tempting to share when returns are low, because losing the investment is less costly. So the binding state will be when  $\bar{R} = \bar{R}_H$ , since we need to have the government wish to expropriate when needs are high for both values of  $\bar{R}$ .

Now let us consider the expressions  $W_L^{CP}(T, \bar{R}_L)$  and  $W_L^{CP}(T, \bar{R}_H)$ . Again, modifying the expression for  $W_L(T, \bar{R})$  above appropriately we have

$$\begin{aligned} W_L^{CP}(T, \bar{R}_H) &= \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\ &\quad * [(1 - e^{-r(S+\tau)})(\bar{R}_H - \theta_L R(T)) + (e^{-r(S+\tau)} - e^{-r(T+\tau)})(\mathbb{E}[\bar{R}] - \theta_L R(T)) \\ &\quad - (1 - e^{-r\tau}\bar{R}_H)] \end{aligned}$$

and

$$\begin{aligned} W_L^{CP}(T, \bar{R}_L) &= \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\ &\quad * [(1 - e^{-r(S+\tau)})(\bar{R}_L - \theta_L R(T)) + (e^{-r(S+\tau)} - e^{-r(T+\tau)})(\mathbb{E}[\bar{R}] - \theta_L R(T)) \\ &\quad - (1 - e^{-r\tau}\bar{R}_L)] \end{aligned}$$

Again, we calculate the difference:

$$\begin{aligned} W_L^{CP}(T, \bar{R}_L) - W_L^{CP}(T, \bar{R}_H) &= \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1 - \beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\ &\quad * [-(e^\tau - e^{-r(S+\tau)})(\bar{R}_H - \bar{R}_L)] \end{aligned}$$

So, again, it is less tempting to go share when returns are low, because losing the investment is less costly. So the binding condition will be the case case when  $\bar{R} = \bar{R}_L$ , since we require that the low-needs government shares in both cases.  $\square$

*Proof of Proposition 6.* We proceed as in the proof above. In this case, we have:

$$\begin{aligned}
W_H^{PC}(T, \bar{R}_H) &= -\frac{1 - e^{-r(S+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)R_H(T) \\
&\quad - \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)\mathbb{E}[R(T)] \\
&\quad + \frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}\bar{R}_H + \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}\mathbb{E}[\bar{R}] \\
&\quad - \frac{1 - e^{-(r+\nu)(S+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)R_H(T) \\
&\quad - \frac{e^{-(r+\nu)(S+\tau)} - e^{-(r+\nu)(T+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)\mathbb{E}[R(T)]
\end{aligned}$$

and

$$\begin{aligned}
W_H^{PC}(T, \bar{R}_L) &= -\frac{1 - e^{-r(S+\tau)}}{r}(\beta\theta_L + (1 - \beta)\theta_L)R_L(T) \\
&\quad - \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)\mathbb{E}[R(T)] \\
&\quad + \frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}\bar{R}_L + \frac{e^{-r(S+\tau)} - e^{-r(T+\tau)}}{r}\mathbb{E}[\bar{R}] \\
&\quad - \frac{1 - e^{-(r+\nu)(S+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)R_L(T) \\
&\quad - \frac{e^{-(r+\nu)(S+\tau)} - e^{-(r+\nu)(T+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)\mathbb{E}[R(T)]
\end{aligned}$$

Subtracting one from the other gives us:

$$\begin{aligned}
W_H^{PC}(T, \bar{R}_H) - W_H^{PC}(T, \bar{R}_L) &= -\frac{1 - e^{-r(S+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L)(R_H(T) - R_L(T)) \\
&\quad + \frac{e^{-r\tau} - e^{-r(S+\tau)}}{r}(\bar{R}_H - \bar{R}_L) \\
&\quad - \frac{1 - e^{-(r+\nu)(S+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L)(R_H(T) - R_L(T)) \\
&= \Delta\bar{R} \left[ -\frac{1 - e^{-r(S+\tau)}}{r}(\beta\theta_H + (1 - \beta)\theta_L) \right. \\
&\quad + \frac{e^{-r\tau} - e^{-r(S+\tau)}}{r} \\
&\quad \left. - \frac{1 - e^{-(r+\nu)(S+\tau)}}{r + \nu}(1 - \beta)(\theta_H - \theta_L) \right]
\end{aligned}$$

This we can see is ambiguously signed, and hence either constraint might be the binding one in equilibrium.

Let us now consider the cases for when  $\theta = \theta_L$ :

$$W_L^{PC}(T, \bar{R}_H) = \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1-\beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\ * [(1 - e^{-r(S+\tau)})(\bar{R}_H - \theta_L R_H(T)) + (e^{-r(S+\tau)} \\ - e^{-r(T+\tau)})(\mathbb{E}[\bar{R}] - \theta_L \mathbb{E}[R(T)]) - (1 - e^{-r\tau})\bar{R}_H]$$

and

$$W_L^{PC}(T, \bar{R}_L) = \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1-\beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\ * [(1 - e^{-r(S+\tau)})(\bar{R}_L - \theta_L R_L(T)) + (e^{-r(S+\tau)} \\ - e^{-r(T+\tau)})(\mathbb{E}[\bar{R}] - \theta_L \mathbb{E}[R(T)]) - (1 - e^{-r\tau})\bar{R}_L].$$

Subtracting one from the other gives

$$W_L^{PC}(T, \bar{R}_H) - W_L^{PC}(T, \bar{R}_L) = \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1-\beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\ * \Delta \bar{R} [(1 - e^{-r(S+\tau)})(1 - \theta_L) - (1 - e^{-r\tau})] \quad (26)$$

Again, the sign of this expression is ambiguous, and hence either of the terms above might form the binding expression.  $\square$

*Proof of Corollary 1.* Comparing equations (6) and (11), it is clear that  $R(T)$  in the cost-plus case is equal to  $\mathbb{E}[R(T)]$  in the price-cap case. Hence, comparing (10) and (12), we can see that  $T^B$ , the optimal value of  $T$  as far as the government is concerned, will be the same, i.e.  $T_{CP}^B = T_{PC}^B$ . It is therefore only necessary to compare the values  $T_{CP}^A$  and  $T_{PC}^A$ , the values at which the low-need government is indifferent between expropriating and sharing.

In the cost-plus case, we have shown that it is when  $\bar{R} = \bar{R}_L$  that expropriation is most tempting, and ther

$$W_L^{CP}(T, \bar{R}_L) - W_L^{PC}(T, \bar{R}_L) = \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1-\beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\ * - (1 - e^{-r(S+\tau)})\theta_L(R(T) - R_L(T))$$

This is clearly negative. Hence, if the low state is the binding state under the price-cap regime, then a price-cap does better because it gives lower return to the firm in this case. Now let us consider the case where the high state is the binding state under the price cap regime:

$$\begin{aligned}
W_L^{CP}(T, \bar{R}_L) - W_L^{PC}(T, \bar{R}_H) &= \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1-\beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\
&\quad * [(1 - e^{-r(S+\tau)})\theta_L(R_H(T) - R(T)) - (e^{-r\tau} - e^{-r(S+\tau)})(\bar{R}_H - \bar{R}_L)] \\
&= \frac{1 - e^{-(r+\nu)(T+\tau)}}{(1-\beta)(1 - e^{-(r+\nu)(T+\tau)})r + \beta(1 - e^{-r(T+\tau)})(\nu + r)} \\
&\quad * [\theta_L - \theta_L^*]
\end{aligned}$$

where  $\theta_L^*$  is as defined by equation (13). Hence, if  $\theta_L$  large, this is positive, and the cost-plus regime is superior. It now only remains to show that, if  $\theta_L \geq \theta_L^*$ , the binding state of the world under the price cap regime is when  $\bar{R} = \bar{R}_H$ . From equation (26) we can see that the term which determines the binding state is  $(1 - e^{-r(S+\tau)})(1 - \theta_L) - (1 - e^{-r\tau})$ . Now, if  $\theta_L \geq \theta_L^*$ , we have

$$\theta_L \geq \frac{e^{-r\tau} - e^{-r(S+\tau)}}{1 - e^{-r(S+\tau)}} \frac{\bar{R}_H - \bar{R}_L}{R_H(T) - R(T)}$$

Rearranging therefore tells us that

$$1 - \theta_L \geq 1 - \frac{e^{-r\tau} - e^{-r(S+\tau)}}{1 - e^{-r(S+\tau)}} \frac{\bar{R}_H - \bar{R}_L}{R_H(T) - R(T)}$$

Hence

$$\begin{aligned}
(1 - e^{-r(S+\tau)})(1 - \theta_L) &\leq (1 - e^{-r(S+\tau)}) - (e^{-r\tau} - e^{-r(S+\tau)}) \frac{\bar{R}_H - \bar{R}_L}{R_H(T) - R(T)} \\
&< (1 - e^{-r(S+\tau)}) - (e^{-r\tau} - e^{-r(S+\tau)}) \\
&= 1 - e^{-r\tau}
\end{aligned}$$

This therefore gives us that the expression  $(1 - e^{-r(S+\tau)})(1 - \theta_L) - (1 - e^{-r\tau})$  will be negative and hence it is the case where  $\bar{R} = \bar{R}_H$  that will give the binding condition.

This thus concludes our proof.

□

*Proof of Proposition 2.* Since  $\overline{R}_1 > \frac{\overline{R}_1 + \overline{R}_2}{2} > \overline{R}_2$ , it is clear that  $W_L(T, \overline{R}_1) > W_L(T, \frac{\overline{R}_1 + \overline{R}_2}{2}) > W_L(T, \overline{R}_2)$ . Hence if there exists a value of  $T$  satisfying  $W_L(T, \overline{R}_2) = 0$ , then clearly there is also a value of  $T$  satisfying  $W_L(T, \frac{\overline{R}_1 + \overline{R}_2}{2}) = 0$ , and hence the range of parameters for which such a value of  $T$  exists increases. A similar logic applies to show  $T_2^* \geq T_0^* \geq T_1^*$ . □

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## Chapter 3

### Hold-up problems in international electricity trade

#### 1 Introduction and previous literature

The integration of national electricity networks in Africa has been moving up the agenda as part of a general program to improve access to infrastructure in the continent. Various studies have shown the large potential gains that might arise from interconnecting electricity networks, stemming from significant differences in potential generating costs across the continent (see, for example, Bowen et al. (1999); Gnan-sounou et al. (2007); Sparrow et al. (1999) ). Moreover, it has been noted that the small size of many domestic markets in Africa necessitates electricity network inter-connection to take advantage of economies of scale in power production.

However, despite the finance and encouragement of many bilateral and multilateral donors, interconnecting electricity networks in Africa has proved challenging. Several articles and reports have noted a lack of ‘political will’ amongst African governments, and a tendency for countries to be unwilling to consider projects in a regional frame-work (see, for example, Pineau (2008); Robinson (2009)). In particular, countries appear to be reluctant to rely on imports even when doing so would appear to be cheaper than developing domestic generation capacity.

To help understand some of the potential problems with interconnection, we build a simple model of international trade in electricity in Africa. Since under-investment is a crucial problem facing the electricity sector, we focus on potential ‘hold-up’ problems that may arise from the limited commitment abilities of governments.<sup>1</sup> Hold-up prob-

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<sup>1</sup> See Estache and Wren-Lewis (2009) for a more general discussion of the problems of limited commitment and other institu-tional weaknesses

lems may arise since countries cannot commit sufficiently far into the future over how much they will trade, partly because there is no effective international court which can sanction agreements.

In Section 2 we show that, when countries cannot commit to a contract, problems of hold-up distort investment decisions. In particular, the importing country over-invests in domestic production in order not to be too dependent on imports, which we can describe as the cost of 'energy security'.<sup>2</sup> Similarly, the exporting country under-invests in production to decrease its dependence on exporting. Both distortions are greater when the respective country has lower bargaining power, with a country investing optimally when it has complete bargaining power. This result follows the general literature on hold-up with no contracts, such as that modelled in Grossman and Hart (1986a); Grout (1984) and Koss and Eaton (1997).

We then extend the model to consider a number of generalisations. First, we study a case of imperfect commitment, where the two countries can commit to a contract which has a certain probability of breaking down. This may apply to situations where, for example, contracts are sensitive to changes in the regime in either country. We next explore how bargaining over electricity may relate to other strategic issues that exist between the two countries. We show that more general strategic bargaining games may mean that any commitment that is restricted to electricity trade may be insufficient to prevent the previously outlined hold-up problems. Moreover, if different agents are involved within a particular country, we show that the option of trade in electricity may leave a country worse off than it would be in autarky. Finally, we extend the model to consider investment in a consumption technology such as within-country transmission and distribution lines. This type of investment is particularly important in Africa since low access rates and relatively low levels of industrialization mean there is a huge potential to increase domestic demand for electricity. We show that the hold-up problem will also impact upon investment in access, inefficiently reducing access in the importing country and increasing it in the exporting country.

Section 3 then considers a number of ways in which this hold-up problem may

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<sup>2</sup>See Bohi et al. (1996) for other aspects of energy policy that may be described as relating to 'security'.

be mitigated. We first consider the effect of expanding the trade network to three countries rather than two, showing that doing so in certain ways may mitigate some investment distortions. We then explore two ways in which allowing international investment may reduce distortion in investment - first by considering whether countries have an incentive to invest in their trading partner's electricity sector, and second by considering whether cross-country ownership may improve investment incentives. We find that the former policy may help to reduce problems of under-investment in cases where bargaining power is very asymmetric, whilst the latter may help to reduce problems of over-investment. Finally, we consider a possible difference between the case where governments bargain over trade and where this bargaining is delegated to the firms, which we find to have an ambiguous effect on joint welfare.

Within the economic literature, several other papers have noted the potential commitment problems that may arise in bilateral trade deals, particularly in energy. For example, Pollitt (2004) relates that Argentina has exported gas to Chile for many years, yet there is no long term contract specifying exactly how much will be traded. Evidence that such a contract would be unenforceable came when Argentina cut gas supplies significantly without warning in 2004, despite this being against a treaty signed between the two countries in 1995. Similarly, Glachant and Hallack (2009) note that, in gas trade between Bolivia and Brazil, it was not possible to maintain the original contract once the investment phase had finished due to a lack of enforcing third party.

Several papers have looked at the potential problems relating to investment that these international commitment problems may create. In discussing trade in natural resources, Collier and Venables (2010) note the international hold-up problem arising in the extraction of iron ore in Guinea: 'The closest port, with an existing rail connection, was Buchanan. However, because Buchanan is in Liberia the government of Guinea was concerned that were export to be dependent upon this route the investment needed for extraction would be subject to hold-up by the government of Liberia. To avoid the problem the government decided to construct a new railway and a new port within Guinea, adding \$ 4bn to the cost of the project.' McLaren (1997), Wallner

(2003) and Friberg and Tinn (2009) consider cases where the private sector makes sector-specific investment decisions prior to trade liberalisation. In each case it is shown that countries may be made worse off by anticipated trade liberalisation since the private sector investment in specialisation damages the countries bargaining position by making the country too trade-dependent.<sup>3</sup> One major difference between these papers and the model below is that they assume investment decisions are undertaken by decentralized agents, rather than the government or a regulated monopoly. Haley et al. (2008) explore the optimal government policy in response to this effect, which they show results in less specialisation than is ex-ante efficient, as we find in our model below.

More broadly, our model can be seen as fitting into a literature that focuses on the link between trade and institutions (see, for example, Levchenko (2007)). One part of this literature emphasizes that, since trade relies on functioning institutions, weak institutions in a country reduces the potential for international trade (see Anderson and Marcouiller (2002) for empirical evidence). Indeed, the existence of relationship specific investments and the potential for hold-up is cited as a significant part of this reasoning. Moreover, Ranjan and Lee (2007) show that trade in sectors that are more dependent on institutions is more like to be reduced by weak contract enforcement. In this regard, we can view the electricity sector as one that is highly dependent on institutions due to the relationship specific investments necessary (since trade is by nature bilateral) and the presence of government regulation. Therefore, our result is consistent with the literature arguing that problems of hold-up reduce international trade in sectors dependent on institutions.

## **2 The model**

We focus on a setting where there are two countries, Country A and B. In our model we assume that the electricity sector consists of a state-owned vertically integrated monopoly in each country. Trade in electricity between the two countries therefore

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<sup>3</sup>Park (2000) extends the model of McLaren (1997) and shows that, in a dynamic setting, specialisation may improve a country's bargaining position since it improves their ability to enforce agreements through punishment.

consists of sale from one country to the other. In this sense, our model differs from those focusing on electricity integration in the European Union, which consider competition between national electricity firms.<sup>4</sup> Significant competition in Africa is infrequent due to the relative scarcity of sizable national firms. Moreover, as discussed by Vickers and Yarrow (1991), competition in electricity markets is limited when there is a lack of spare capacity, which is certainly the case in Africa. Our approach is therefore closer to the approach used to model gas markets, such as in Hoel et al. (1990), which uses bargaining games.

Our game consists of two stages:

1. Investment stage: Countries decide on how much they will invest in electricity generation
2. Production stage: Trade in electricity occurs and payoffs are resolved

Let the total consumer surplus in Country  $i$  be given by  $S_i(Q_i)$  where  $Q_i$  is the electricity consumed domestically. We assume that  $S'_i(\cdot) > 0$  and  $S''_i(\cdot) < 0$ , i.e. we have decreasing marginal utility. Moreover, we make the simplifying assumption that there are no losses or costs involved in the international transmission of electricity.

Each government controls the level of domestic generation by undertaking investment. Let the cost of producing  $q_i$  in Country  $i$  be  $I_i(q_i)$ , with  $I'_i(\cdot) > 0$  and  $I''_i(\cdot) \geq 0$ .<sup>5</sup> In order to ensure solutions with positive investment levels, we assume that the marginal benefit of investing at  $q_i = 0$  is positive, i.e.  $S'_i(0) > I'_i(0)$ . We also assume that the share of these costs occurring at the operating stage are sufficiently small that any capacity installed will always be used.

Finally, in stage 2, the countries bargain over the amount of electricity to be traded and at what price. We assume that countries bargain over both quantities and prices and that bargaining is efficient. As originally shown by Bowley (1928), the theory of bilateral monopoly therefore tells us that the quantity traded will be that which max-

<sup>4</sup>See, for example, Auriol and Biancini (2009); Biancini (2008); Calzolari and Scarpa (2009), which each consider a situation where 'integration' implies allowing national incumbents to compete in other countries.

<sup>5</sup>To keep the analysis simple, we are assuming increasing marginal costs in electricity production, which in some circumstances may be inappropriate. However, the results generally follow in the case of decreasing marginal costs, though there are a number of instances where only one country will produce.

imises joint welfare. We assume that the transfer between the two countries will then be determined by the asymmetric Nash bargaining solution, where we assume that Country A has relative a bargaining power of  $\alpha$ , with  $0 \leq \alpha \leq 1$ . In this case, the status quo payoffs are the payoffs that the country would receive were there no electricity trade. This is the natural status quo payoff to assume, and is consistent with observations such as that in Glachant and Hallack (2009) that when ‘unable to reach an agreement in this matter with [the Brazilian firm], [the Bolivian firm] brandished the threat of cutting off the supply’.

We assume that both governments maximise their domestic consumer welfare minus domestic investment costs and the transfer paid to the other country, i.e.

$$W_i = S_i(Q_i) - I_i(q_i) - T_i \quad (1)$$

where  $T_i$  is the net transfer paid from Country  $i$  to Country  $j$  (so  $T_A = -T_B$ ).

Before we consider the hold-up problem, it is useful to establish some baseline results. We therefore first explore the cases where no trade is possible and where countries are able to commit perfectly.

## 2.1 No trade

When there is no trade, we have  $q_i = Q_i$  - i.e. domestic consumption equals domestic generation. Governments therefore maximise the domestic welfare function

$$W_i = S_i(q_i) - I_i(q_i) \quad (2)$$

with respect to  $q_i$ . This gives us the following equation that determines the level of investment in generation:

$$S'_i(q_i^{NT}) = I'_i(q_i^{NT}) \quad (3)$$

Since we have assumed that  $S''_i(\cdot) < 0$  and  $I''_i(\cdot) > 0$ , this has a unique solution.

For the rest of the analysis we make the following assumption:

**Assumption 1.** *In autarky, the marginal benefit of an extra unit of electricity is higher in Country A than in Country B, i.e.*

$$S'_A(q_A^{NT}) > S'_A(q_B^{NT}) \quad (4)$$

In other words, were trade enabled between these two countries with no change in the levels of production, Country A would import electricity from Country B. Since we have assumed no other differences between the two countries, it is clear that this assumption can be made without loss of generality.

## 2.2 Trade with commitment

Now suppose that the two countries are interconnected and can trade in electricity. Moreover, in order to provide a first-best baseline, suppose that they can agree on the quantity and transfer to be exchanged prior to investing. In this case, the theory of bilateral monopoly tells us that the quantity traded will be that which maximises joint welfare, with bargaining power determining only the transfer payment made between the two countries. Since the contract is agreed before investments are made,  $q_i$  and  $Q_i$  will be set to maximise joint welfare. The following proposition then gives us the levels of investment and consumption in equilibrium:

**Proposition 1.** *When trade occurs with commitment, quantities produced and consumed will be determined by the equations:*

$$S'_B(Q_B^*) = S'_A(Q_A^*) = I'_A(q_A^*) = I'_B(q_B^*) \quad (5)$$

*Country A will therefore import from Country B and we will have  $q_A^* < q_A^{NT}$  and  $q_B^* > q_B^{NT}$ .*

Proof of this proposition, along with those of all following propositions, are given in Appendix B.

The proposition shows us that trade in electricity increases joint welfare for two reasons. First, taking the quantity of produced electricity as given, asymmetries in

consumption can be smoothed out such that electricity is consumed in the country that values it most. Second, the production of electricity is rebalanced to favour more production in the cheaper country. Both countries will gain from these effects since the gain in joint welfare is shared between the two countries through the transfer paid for the electricity, with gains distributed according to countries' bargaining powers.

Having now established the autarky and perfect commitment baselines, let us move to consider the hold-up problem when trade is possible but there is no commitment.

### 2.3 Trade without commitment

Now suppose that it is not possible to commit to any trade during the investment stage. In this case, trade will be determined in the second stage taking the levels of investment as given - i.e. trade will determine  $Q_A$  and  $Q_B$  taking  $q_A$  and  $q_B$  as given.

Since bargaining is efficient, the quantities consumed will be such that the marginal value of further consumption in the two countries is equal, i.e.

$$S'_A(Q_A^T) = S'_B(Q_B^T) \quad (6)$$

In order to compensate Country B for the electricity exported, a transfer is paid from Country A to Country B. From the theory of Nash bargaining, this transfer will be such that each country receives its status quo payoff plus a share of the total gains from trade.<sup>6</sup> The gains from trade will be divided according to the countries' relative bargaining powers, and hence the countries' welfare functions are given by the following equations:

$$W_A^T = \alpha [S_A(Q_A^T) + S_B(Q_B^T) - S_A(q_A) - S_B(q_B)] + S_A(q_A) - I_A(q_A) \quad (7)$$

$$W_B^T = (1 - \alpha) [S_B(Q_B^T) + S_A(Q_A^T) - S_A(q_A) - S_B(q_B)] + S_B(q_B) - pI_B(q_B) \quad (8)$$

Each country then chooses the quantity produced to maximise its respective welfare

<sup>6</sup>See the proof of Proposition 2 in Appendix B for details.

function, which we can see is a linear combination of their welfare in autarky (their status quo payoff) and the total gains from trade. Since  $Q_A$  and  $Q_B$  are determined to maximise the gains from trade, they are also those which will maximise each of the above welfare functions. We can therefore use the envelope theorem to derive the interior solutions. In other words, in equilibrium, the marginal benefit of consuming an extra unit of electricity is equal in the two countries, and hence each country can behave as if an extra unit of production will be consumed domestically. They will therefore behave as if they are equating the marginal cost of production with the marginal benefit of domestic consumption weighted appropriately between the case where the country is autarkic and the case where trade takes place. This is shown in the following proposition:

**Proposition 2.** *In equilibrium, production levels  $q_A^T$  and  $q_B^T$  will be determined by the equations:*

$$(1 - \alpha)S'_A(q_A^T) + \alpha S'_A(Q_A^T) = I'_A(q_A^T) \quad (9)$$

$$\alpha S'_B(q_B^T) + (1 - \alpha)S'_B(Q_B^T) = I'_B(q_B^T) \quad (10)$$

*Country A will import electricity from country B and, for  $0 < \alpha < 1$ , production levels will lie strictly in between those in the autarky case and those in the commitment case, i.e.  $q_A^{NT} > q_A^T > q_A^*$  and  $q_B^{NT} < q_B^T < q_B^*$*

*Furthermore, in equilibrium, Country A over-invests in production, whilst Country B under-invests, i.e. a reduction in investment in Country A, or an increase in investment in Country B, would increase joint welfare.*

Country A over-invests in the sense that it would improve joint welfare were it to invest less. This is because the marginal net benefit of production in Country A is  $S'_A(Q_A^T) - I'_A(q_A^T)$ , which we can see from equation (9) is less than 0 in equilibrium, since  $Q_A^T > q_A^T$ . This distortion occurs because a lack of complete bargaining power means that Country A is concerned with improving its status quo payoff, even though in equilibrium trade always occurs. Similarly, Country B does not invest enough since

it does not wish to be too dependent on exporting. These investment distortions can be seen as a specific example of the results of Grossman and Hart (1986b) or Koss and Eaton (1997) who build general models of hold-up in conditions of co-specific investment.

These equations also show us how a country's bargaining power affects their investment decisions. If a country has complete bargaining power, it bases its investment decision on the amount it will consume after trade,  $Q_i$ , as is optimal. However, as its bargaining power decreases, the country becomes more concerned with the quantity it would consume were there no trade,  $q_i$ . In the extreme, when a country has no bargaining power, it invests as if it were in autarky, since its lack of bargaining power means it will receive none of the gains from trade.

Overall therefore, trade still improves welfare, but not by as much as in the commitment case. In particular, whilst asymmetries in electricity consumption are completely smoothed out (as in the commitment case), it is not the case that production is completely rebalanced. In the next section, we shall see that this is also the case when commitment abilities are somewhere in between this no-commitment case and the previously considered perfect-commitment.

## **2.4 Imperfect commitment**

We have previously considered two cases - that where commitment is possible and the contract will certainly be enforced, and that where commitment is impossible and any contract written in the investment stage will certainly not be honoured. However, we may believe that reality lies somewhere between these two extremes.

One way of modelling such imperfect commitment would be to employ an incomplete contracting approach. In this setting, there exists uncertainty over some future state variable that is unverifiable. Hence, even if countries have the ability to commit to a contract, they cannot contract on this unverifiable information. Since such a model assumes that some third-party can enforce such a contract, we do not believe that such an approach is best suited to our situation. We therefore do not include an

incomplete contracting analysis in the main model here, but such an approach can be found in Appendix A, where we use a model similar to those used in Hart and Moore (1988), Aghion et al. (1994) and Bolton and Dewatripont (2005). Again, we find that in general imperfect commitment will lead to a distortion in investment levels. However, the result differs in that the direction of these distortions is dependent on the precise functional forms. Moreover, we show that the first best is achievable if it is possible to alter the bargaining powers of the two countries.

In this section, we consider a model of imperfect commitment where a contract is written at the investment stage, but that with probability  $\nu$  this contract will not be enforced at the production stage, and the parties renegotiate. Such a situation might occur if, for example, contracts would be enforced so long as the ruling regime did not change in either country, but that there was a risk of a regime change in at least one country which would then prompt contract renegotiation.

In order to consider this situation with imperfect commitment, it is important to specify a little more on the form of a contract undertaken at the investment stage. We assume that countries cannot contract on investment levels, but are restricted to simply agreeing on a quantity traded and a transfer that will take place in the production stage. Furthermore, let us assume initially that this contract must be renegotiation proof in the sense that it cannot be that both parties would wish to renegotiate at the production stage. As a result, it must be the case that the quantities traded are ex-post efficient, i.e. we must have  $S_A(Q_A) = S_B(Q_B)$ . We therefore arrive at the following proposition:

**Proposition 3.** *In equilibrium, investment levels  $q_A^T$  and  $q_B^T$  will be determined by the equations:*

$$(1 - \nu(1 - \alpha))S'_A(Q_A^T) + \nu(1 - \alpha)S'_A(q_A) = I'_A(q_A) \quad (11)$$

$$(1 - \nu\alpha)S'_B(Q_B^T) + \nu\alpha S'_B(q_B) = I'_B(q_B) \quad (12)$$

*As in Proposition 2, Country A will import electricity from country B, and we will have  $q_A^{NT} > q_A^T > q_A^*$  and  $q_B^{NT} < q_B^T < q_B^*$ . Moreover,  $\frac{dq_A^T}{d\nu} > 0$  and  $\frac{dq_B^T}{d\nu} < 0$ , and both*

$\mathbb{E} [W_A^T]$  and  $\mathbb{E} [W_B^T]$  are decreasing in  $\nu$ .

This proposition shows that, as the ability of countries to commit decreases, the expected welfare of both countries decreases, with the quantities produced in both countries heading away from those which maximise joint welfare towards the production levels in autarky. We therefore see that this imperfect commitment case lies exactly between our two prior cases, with  $\nu = 0$  being equivalent to the no commitment case and  $\nu = 1$  resulting in the same outcome as the commitment case. Moreover, the proposition shows that any action that increases the probability of commitment will increase welfare in both countries, even if we do not arrive at the full commitment case.

For the proposition above, we have assumed that the countries could never commit to a contract that they would both like to renegotiate in the future. This seems a reasonable assumption given the likely inability of a third party to enforce such a contract. However, let us briefly consider the case where such a contract was enforceable, perhaps by an external party such as an aid donor. In this case, we arrive at the following proposition:

**Proposition 4.** *If the countries can commit to a non-renegotiation proof contract with probability  $1 - \nu$ , then this contract will involve an agreed level of exports  $X$  such that  $S'_B(q_B - X) > S'_A(q_A + X)$ .*

This proposition states that the ideal non-renegotiation proof contract that parties would like to commit to is one where exports are greater than is ex-post efficient. This 'over-exportation' is designed to mitigate some of the distortions arising from the hold-up problem. In particular, the higher level of expected exports will encourage Country B to invest more in production and discourage Country A from investing so much. This second best result shows that some of the distortion in investment can be mitigated by countries committing to distort trade with a certain probability.

## 2.5 Bargaining outside electricity trade

We have so far framed our model within the context of the two countries bargaining over electricity trade. However, it may be interesting to consider how this particular bargain may relate to negotiations going on between the countries over other matters. In particular, when might decisions over trade in electricity be affected by (or affect) other bargains between the two countries?

Let us model this potential relationship by assuming that, at the production stage, the countries are simultaneously bargaining over some other project. Suppose that this other project yields a total payoff of  $V$ , and that this payoff is shared between the two countries according to the Nash bargaining solution as before. Hence, taking electricity trade as given, Country  $A$  would receive  $\alpha V$  whilst Country  $B$  would receive  $(1 - \alpha)V$ .

If this project was independent of trade in electricity, then it is clear from the nature of the Nash Bargaining solution that the two bargains will not affect one another. However, suppose instead that they are interrelated in the following way: If the countries fail to agree on the other project, then they cannot agree on an electricity deal. This might be the case if the other project was some larger issue such as negotiating sustainable peace between the two countries - clearly, if the two countries go to war, then they are unlikely to simultaneously continue their trade in electricity.

If the countries cannot commit in advance to a deal in electricity, then the existence of this other project will not affect our analysis above despite the relationship between the two projects. Within the simple framework we use here, the combination of the two bargains does not affect countries' payoffs since the gains and status quo payoffs are simply added linearly.

However, if the countries can commit in advance to a deal over electricity, but cannot commit to a deal in advance over this other project, then the effect is to render the commitment in electricity useless. For example, suppose that the commitment in electricity is such that it cannot be broken unless the two countries go to war. If war is threatened in the latter period in any case, then the value of the electricity contract will

be added to total the value of peace between the two countries. Hence, even though there is no possibility of the electricity contract being broken on its own, the transfer that occurs for the other project will incorporate the difference between the agreed transfer in the electricity contract and the transfer that would occur were the electricity contract renegotiated.

Considering this possibility gives further weight to our analysis of the hold-up problem. Even where it appears that commitment in the electricity sector is quite possible, the hold-up problem will remain so long as there is the possibility of a future transfer related to another bargain whose failure would also imply the cancellation of the electricity contract. Similarly, we can interpret the imperfect commitment model of the previous section as representing a case where there is commitment in electricity trade, but some chance  $\nu$  of another related bargain arising.

If we believe that part of the transfer above is likely to come about outside of the direct payment for electricity, then this has implications for who should be in charge of investment decisions. If the government makes decisions on investment and is also the one likely to pay the future transfer, then our analysis follows as above. However, suppose that the investment decision is made by a private utility and the future transfer is paid by the government. Suppose that the private utility receives the full welfare benefits of producing a quantity  $q_i$  and distributing a quantity  $Q_i$ , i.e.  $V_i = S_i(Q_i) - I_i(q_i)$ , but for its imports will only pay the transfer agreed at the investment stage. In this case, the private utility will invest as in the commitment case above (i.e. producing  $q_i^*$ ), despite this not being in the best interest of the country as a whole.

The effect of devolving the investment decision in this way has ambiguous effects on welfare. If both countries were to devolve power in such a way, then clearly we arrive at the efficient production levels, and hence joint welfare is maximised. However, welfare in one of the countries may decrease if its bargaining power is low. For example, if  $\alpha = 0$ , then clearly welfare in Country A is maximised when  $q_A = q_A^{NT}$ . In this case, the country will actually be made worse off from the ability to trade with Country B, since it will receive a payoff of  $S_A(q_A^*) - I_A(q_A^*)$  which is lower than the

payoff it would achieve in autarky of  $S_A(q_A^{NT}) - I_A(q_A^{NT})$ . This result is similar to the one found in McLaren (1997), Wallner (2003) and Friberg and Tinn (2009), where investment decisions are decentralised. Driving the result is the fact that the entity making the investment decision is not taking into account the effect of this investment on the country's future bargaining position. Hence the private utility will invest in such a way that makes the country highly dependent on international trade, resulting in the government having to pay more at the production stage in order to ensure such trade occurs.

## 2.6 Investment in access

In the model so far we have explored the various ways in which lack of commitment of various degrees may impact upon countries' investment in electricity production. In this section, we extend the model to consider another important investment decision that countries may face - investment in access to electricity. This type of investment is particularly important in Africa since low access rates mean there is a huge potential to increase domestic demand for electricity. Investing in access involves investments in intranational transmission lines and distribution networks and therefore, like investment in production, is a long-term investment. Though we will describe such investment as access in this section, we can equally imagine it including other investments that increase the demand for electricity, such as investment in electricity intensive industrial plant. One key difference between investment in access and investment in production is that the final product - demand for electricity - cannot be traded, unlike the electricity itself.

We extend the model in the following way. The gross surplus of consuming a quantity of electricity  $q_i$  in Country  $i$  is  $S_i(q_i, a_i)$  where  $a_i$  is the level of access in Country  $i$ . We assume that there are diminishing returns to investing in access,  $\partial^2 S_i / \partial a_i^2 < 0$ , but that access is complementary with electricity consumption,  $\partial^2 S_i / \partial q_i \partial a_i > 0$ . Investing in producing a level of access  $a_i$  costs  $A_i(a_i)$ , with  $A_i'(\cdot) > 0$  and  $A_i''(\cdot) > 0$  (decreasing returns to scale). Let us now consider the levels of investment in produc-

tion and access under the various assumptions about trade.

In the case with no trade or trade with commitment, we will have access in country  $i$  determined by the equation:

$$\partial S_i(Q_i, a_i)/\partial a_i = A'_i(a_i) \quad (13)$$

In other words, the efficient level of investment in access is such that the marginal cost of increasing access is equal to the marginal benefit of increasing access given the quantity that will be consumed. Trade in electricity therefore increases access investment in Country A (since the amount of electricity consumed is higher) and decreases access investment in Country B (since the amount of electricity consumed is lower).

However, in the case with trade without commitment, access will be determined according to the following proposition:

**Proposition 5.** *In equilibrium, access investment levels will be determined by the equations:*

$$(1 - \alpha) [\partial S_A(q_A^T, a_A^T)/\partial a_A] + \alpha [\partial S_A(Q_A^T, a_A^T)/\partial a_A] = A'_A(a_A^T) \quad (14)$$

$$\alpha [\partial S_B(q_B^T, a_B^T)/\partial a_B] + (1 - \alpha) [\partial S_B(Q_B^T, a_B^T)/\partial a_B] = A'_B(a_B^T) \quad (15)$$

*Moreover, given the quantities consumed in each country, there will be under-investment in access in Country A, and over-investment in access in Country B, i.e. extra investment in access in Country A, or less investment in access in Country B would increase joint welfare, taking the quantities consumed as fixed.*

The distortions in investment here follow for exactly the same reasons as the distortions described in Proposition 2. Access is determined to be somewhere in between what would be optimal given the quantity consumed were trade to occur and that which would be optimal in autarky. Hence Country A invests too little, because it does not want to become too dependent on importing electricity. Similarly, Country B invests too much in order to increase the value of the extra electricity it would consume

were trade not to occur. However, since in equilibrium trade always occurs, these distortions are inefficient. Though we do not consider the case of imperfect commitment here, we would achieve a similar result were we to extend the model in this way.

Unlike in the previous section, we cannot conclude how  $(q_i^T, a_i^T)$  compares to  $(q_i^{NT}, a_i^{NT})$  or  $(q_i^*, a_i^*)$  since the game is no longer supermodular. In particular, whilst  $q_A$  is a strategic substitute for  $q_B$ ,  $c_A$  is a strategic complement for  $q_B$  despite being a complement for  $q_A$ . Hence an increase in  $q_B$  has an ambiguous effect on player A's best response. Since there will be greater imports, the direct effect is that Player A wishes to reduce their own production ( $q_A$ ) and increase their investment in access ( $a_A$ ). However, since these two variables are complements, they push each other in opposite directions - for example, the decrease in domestic production will encourage a decrease in investment access. Hence it is not possible to predict the effect on  $q_A$  of an increase in  $q_B$  without making further assumptions on each country's payoff function.

One effect of introducing access into our model is that we now face a problem of under-investment in both countries - in Country B we see under-investment in production, and in Country A we see under-investment in access. This is important since we might consider that in Africa there is a general tendency towards under-investment due to problems such as high government discount rates or credit constraints. If we were to believe that generally under-investment was of greater concern than over-investment, then one conclusion from the previous model might have been to allocate all bargaining power to the exporter (or to favour building international transmission lines in situations where the country with greatest bargaining power is the exporter). This would have been optimal because it eliminates any under-investment in Country B and the only distortion is too much investment in Country A - in other words, investment in production is maximised. However, by including investment in access in the model, we can see that such a conclusion no longer holds even in a situation where over-investment is non-problematic. This is because allocating bargaining power to Country B worsens the under-investment in access in Country A. Hence, even if we

consider under-investment to be a greater problem than over-investment, considering investment in access explains why a situation with extreme bargaining powers is unlikely to be optimal.

### 3 Potential Solutions

The previous section has explored the various scenarios under which hold-up may occur and the ways in which this may distort investment decisions. In this section, we explore various policy options that may work towards mitigating these distortions. We first consider the effect of expanding the trade network to three countries rather than two, showing that doing so may mitigate some investment distortions. We then explore two ways in which allowing international investment may reduce distortion in investment - first by considering whether countries have an incentive to invest in their trading partner's electricity sector, and second by considering whether cross-country ownership may improve investment incentives. Finally, we consider a possible difference between the case where governments bargain over trade and where this bargaining is delegated to the firms. For the purpose of simplicity in these solutions, we generally focus on the model without investment in access.

#### 3.1 Additional trading partners

Suppose that an additional connection is made such that trade can take place with a further potential trading partner, Country C. Furthermore, suppose that trade is determined through bargaining between these three countries, and that this bargaining is efficient, i.e.  $S_A(Q_A^T) = S_B(Q_B^T) = S_C(Q_C^T)$ . Hence quantities traded result in an ex-post efficient outcome. To remain consistent with our use of the asymmetric Nash Bargaining solution previously, we assume that the payoffs each country receives are given according to the asymmetric Shapley Value, where countries have weights of  $w_i$ , with  $w_A + w_B + w_C = 1$ .<sup>7</sup>

<sup>7</sup>An alternative approach would be to instead only assume that the result lay in the core, which is the assumption used in Hoel et al. (1990) when they consider a multilateral bargaining game in the European gas market. Since in our model the Shapley Value always lies in the core, we use this as a way of specifying exact investment levels, though the noted distortions would remain were we to consider a more general solution.

The Shapley Value then gives that countries will receive a payoff of  $\phi_i$ , as given by the following equation:

$$\phi_i = \sum_{S \subseteq N \text{ s.t. } i \in S} \left[ \sum_{T \subseteq N-S} (-1)^{|T|} \frac{w_i}{\sum_{j \in S} w_j + \sum_{j \in T} w_j} \right] [v(S) - v(S - \{i\})]$$

where  $N$  is the set of all three countries and  $v(S)$  is the joint welfare of all three countries when the countries in set  $S$  trade with each other and those in set  $N - S$  are autarkic. To remain consistent with the previous section, we assume that weights are such that  $w_1/(w_1 + w_2) = \alpha$ .

In order to make clear the effect of adding a third country, let us make a couple of simplifying assumptions. Suppose that Country C is only connected to Country A, such that if Country A decides not to trade with Country B then Country C cannot trade with Country B. Moreover, we assume that the cost of production in Country C is such that, were Country B not to enter into trading, Country A would import from Country C. Finally, suppose that, in an equilibrium where Country A trades with Country B, the amount produced in Country C happens to be such that it neither exports nor imports - i.e.  $S_C(q_C^T) = S_A(Q_A^T) = S_B(Q_B^T)$ . Whilst this latter assumption is clearly unrealistically strong, it means that we can focus on the option value of trade with Country C, rather than the direct effects of trade with C.

Given these assumptions, we then arrive at the following proposition:

**Proposition 6.** *The existence of Country C mitigates the over-investment problem in Country A, but encourages over-investment in Country C.*

Country A is now maximising a weighted function of its welfare when trading with B, its welfare when trading with C and its payoff in autarky. Since we have that  $w_1/(w_1 + w_2) = \alpha$ , the weight it places on trade with B is the same as before. However, rather than placing a weight of  $1 - \alpha$  on its autarky payoff, as it did previously, it places a weight  $w_1/(w_1 + w_3)$  on its welfare when trading with C and a weight  $1 - \alpha - w_1/(w_1 + w_3)$  on its welfare in autarky. Since investment in production is less valuable when trading with C than in autarky (since Country A would import from Country C), the

total marginal benefit for Country A of investing is lower, and hence this mitigates the previously arising over-investment problem.

However, Country C now over-invests since it receives a payoff from Country A in return for providing such an outside option. This payment is greater if Country C provides a more attractive outside option - i.e. if Country C has more electricity to export - and hence Country C increases domestic production in order to improve its bargaining position with Country A. Such investment is inefficient since in equilibrium Country C remains in autarky (as Country A trades solely with Country B).

Clearly this idea could also apply to reducing the under-investment of the exporter (Country B) by providing an alternative export market. Moreover, this solution would also potentially reduce distortions in access investment were we to re-introduce access into the model.

This policy will be most valuable when the country receiving the extra connection is that with low bargaining power with respect to its original trading partner. Indeed, the first best investment decisions (for Countries A and B) could be achieved were B to have full bargaining power in the relationship with Country A, but Country A to have full bargaining power when dealing with Country C, and Country C to be identical to Country B in terms of how much it would potentially export.

This policy solution can be seen as a general instance of the idea of improving one's bargaining position through investing in alternatives.<sup>8</sup> For example, Hubert and Ikonnikova (Forthcoming) consider similar options in international trade in gas. Indeed, they show that in a repeated relationship the mere threat of building such an alternative route may help to improve the bargaining situation of the exporter.

An alternative approach, taken by Felli and Roberts (2002) for example, is to consider that matching between players occurs after investments have occurred. In this sense, hold-up may be prevented since countries invest in order to be paired with more attractive partners. In our case, this would translate into countries investing in production/demand in order to be more attractive to those who have invested in the

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<sup>8</sup>It is therefore related to the idea of 'second sourcing' or 'dual sourcing' found in the procurement literature - see, for example, Anton and Yao (1987); Riordan and Sappington (1989).

complementary good. However, given the limited number of possible connections any individual country faces and the time required to build international transmission lines, such competition is likely to be limited.

### 3.2 International investment

We have so far assumed that each country could only invest in production or demand in its own country. Let us now relax this assumption and suppose that each country can invest in either production or consumption in the other country. In particular, suppose Country  $i$  sets  $q_{j+}$  and  $a_{j+}$  in addition to setting  $q_i$  and  $a_i$ , with the total production in Country  $j$  being  $q_j + q_{j+}$  and the total level of access being  $a_j + a_{j+}$ . Furthermore, we suppose that the cost of these investments are  $I_j(q_j + q_{j+}) - I_j(q_j)$  and  $A_j(a_j + a_{j+}) - A_j(a_j)$  respectively, and they accrue to Country  $i$ .

Clearly, as an importer, Country  $A$  has no incentive to invest in the consumption technology in Country  $B$ , since this will just improve Country  $B$ 's bargaining position and decrease their willingness to export. Similarly, Country  $B$  has no wish to invest in production in Country  $A$ . However, it may be in the interest of Country  $A$  to invest in production in Country  $B$ , since this will increase the amount it can import. Similarly, Country  $B$  may have an incentive to invest in the consumption technology in Country  $A$ , since this will increase the demand for its exports. The following propositions give the conditions under which this occurs.

**Proposition 7.** *Country  $B$  will invest in the consumption technology if and only if*

$$\frac{1 - 2\alpha}{2 - 2\alpha} > \frac{\partial S_A(q_A, a_A)/\partial q_A}{\partial S_A(Q_A^T, a_A)/\partial q_A} \quad (16)$$

*Similarly, Country  $A$  will invest in the production technology of country  $B$  if*

$$\frac{2\alpha - 1}{2\alpha} > \frac{\partial S_B(q_B, a_B)/\partial a_B}{\partial S_B(Q_B^T, a_B)/\partial a_B}$$

Hence, a country will only invest in the other if their bargaining power is strong enough to ensure they reap a sufficient portion of the gains from such investment. A

country's bargaining power needs to be high since this investment improves the other country's outside option as well as the total gains from trade. This suggests that, when a country with clearly superior bargaining power is entering into an electricity trade agreement with another, there may be potential for the deal to contain a responsibility for the country with greater bargaining power to invest in the other. Even if such investment was not enforceable, the above result suggests that the investing country may be happy to comply.

### 3.3 Cross-country ownership

An alternative way to consider cross-country investment is to allow for the possibility of one country to own a portion of the firm in the other country. We have so far assumed that the firms in each country are vertically integrated and domestically owned, so we have abstracted from questions of to who profits directly accrue. In this section, we suppose instead that it may be possible for a firm in one country to be partly owned by citizens in the other country, either privately or publicly.

In particular, suppose that a fraction of the electricity firm in country  $i$  is owned by the other country. We assume that each country still regulates their domestic firm, so that the investment and trading decisions are still essentially made by the respective domestic governments. Moreover, investment costs are still entirely paid by the domestic government as well as the transfer resulting from bargaining. However, we assume that a fraction  $\beta_i$  of the gross welfare of domestic consumption in country  $i$ ,  $S_i(Q_i)$ , accrues to the other country, even if no trade occurs.

Suppose that, prior to deciding on investment levels, the two countries can buy a share of each others electricity firm. If we assume that such purchases are efficient, then we arriving at the following proposition.

**Proposition 8.** *Country A will not purchase any of the the firm in Country B, whilst Country B will purchase a fraction  $\beta_A$  of the firm in Country A such that*

$$\beta_A = (1 - \alpha) \frac{S'_A(q_A^T) - S'_A(Q_A^T)}{S'_A(q_A^T)} \quad (17)$$

where  $q_A^T$  is such that  $S'_A(Q_A^T) = I'_A(q_A^T)$ .

When a fraction of a country's electricity sector is owned by another country, the incentive to produce is reduced since the gains are not entirely accrued to the domestic population. Hence it is optimal for the exporting country to buy a sufficient share of the importing country's firm to reduce investment in this country to the efficient level.<sup>9</sup>

Were we to extend the model to include investment in access, we would find a similar result indicating Country A would be willing to purchase the firm in Country B in order to reduce Country B's investment in access. This result therefore complements that of the previous solution, which showed how international investment might correct problems of under-investment. Taken together, the two results suggest that there are likely to be benefits in liberalising investment in the two countries to at least a country's trading partner.

### 3.4 Deregulation of trade decision

We have so far assumed that bargaining over electricity trade takes place between the two governments directly. In this section, we will consider the effect of bargaining instead taking place between the two national firms. We will assume that this does not change the parties' respective bargaining powers, but that the only difference is that the firms themselves only receive a share of the total welfare generated from consumption. This is likely since it is difficult for a firm to be able to extract all consumer surplus, particularly if the government regulates the firm so as to prevent price discrimination. In particular, let us assume that the domestic firm only receives a fraction  $\gamma$  of the total welfare of consumption,  $S_i(Q_i)$ .<sup>10</sup> We assume however that the investment decision is still essentially undertaken by the government, and hence is chosen to maximise total domestic welfare.

Since we continue to assume that trade is efficient, we will have  $\gamma S_A(Q_A) = \gamma S_B(Q_B)$ , and hence the amounts traded will be the same as if the government it-

<sup>9</sup>Bolle and Ruban (2007) find a similar result in exploring whether Russian gas producers should purchase downstream distribution companies in other countries.

<sup>10</sup>This is similar to the assumption made in Hoel et al. (1990) where they study the difference between imports being negotiated by a private rather than a public distribution firm.

self were negotiating. However, the transfer will now be different since the status quo payoff of the firm in country  $i$  is  $\gamma S_i(q_i)$  now rather than  $S_i(q_i)$  and the joint gains from trade are also smaller. This will in turn affect the investment decisions of the government, leading to the following proposition:

**Proposition 9.** *If  $\frac{S_B''(Q_B)}{S_A''(Q_A)+S_B''(Q_B)} S_B'(Q_B) > (1 - \alpha) S_B'(Q_B) + \alpha S_B'(q_B)$ , then devolving the bargaining to firms will improve joint welfare for at least some values of  $\gamma$ . Otherwise, the effect on welfare is ambiguous.*

This proposition stems from the fact that devolving bargaining to the firm has two effects. First, it decreases the importance of the status quo payoff in the government's welfare function relative to the post-trade outcome. This decreases production in Country A and increases production in Country B. This effect therefore improves joint welfare since it helps to unwind the previous distortions. Second, it decreases the importance of the gains from trade, so that each country does not take into account the fact that by producing more it will mean the other country can afford to produce less. This second effect decreases production in both countries.

Overall therefore, production in Country A unambiguously falls, whilst the effect on production in Country B is ambiguous. If  $\frac{S_B''(Q_B)}{S_A''(Q_A)+S_B''(Q_B)} S_B'(Q_B) > (1 - \alpha) S_B'(Q_B) + \alpha S_B'(q_B)$ , then the first effect is smaller than the second for  $\gamma$  close to 1, and hence overall production in Country B rises. Since production falls in Country A and increases in Country B, this unambiguously increases joint welfare. However, if  $\frac{S_B''(Q_B)}{S_A''(Q_A)+S_B''(Q_B)} S_B'(Q_B) \leq (1 - \alpha) S_B'(Q_B) + \alpha S_B'(q_B)$ , then the second effect is greater than the first in terms of investment in Country B, and hence investment falls in both countries for all  $\gamma$ . It is therefore unclear whether the decrease in investment in Country A will compensate for the decrease in investment in Country B, and the effect on joint welfare is ambiguous. Whether devolving bargaining to firms rather than governments should be recommended as a policy solution in this circumstance is therefore uncertain.

## 4 Conclusion

Overall, this chapter has helped us to understand the potential hold-up problems that may arise when firms trade in electricity. Due to the existence of long-term investments necessary in the sector and the inability of countries to commit, countries will be reluctant to make investment decisions that leave them highly dependent on future international trade. We have shown that this problem arises even if some commitment is possible and even if the commitment problem lies not in the electricity sector but in some other potentially related agreement between the two countries. Moreover, by considering investment in access as well as in electricity production, we have shown that the commitment problem results in under-investment of one variety or another in both countries, and this is therefore likely to add to under-investment in the sector arising for other reasons not considered here.

The model of hold-up built in the chapter has also allowed us to consider various potential policy solutions to mitigate these problems of hold-up. We have shown that distortions may be reduced by expanding the network and hence providing an outside option to those countries that have a low bargaining power. We have also considered the ways in which international investment may reduce distortions, both through providing an additional investor to reduce under-investment and through discouraging over-investment by allowing domestic firms to be partially owned by the trading partner. Finally, we have shown that whether bargaining is undertaken by firms or governments may impact upon investment decisions and hence improve or worsen the previously noted distortions.

## Appendix A: Incomplete contract version

In the main model we have assumed that hold-up occurred due to a problem of limited commitment - writing a contract was not possible due to the lack of a third-power to enforce the contract. An alternative model of hold-up revolves around unverifiable information which cannot be contracted upon. In this framework, contracts can be written and enforced, but cannot depend on some piece of unverifiable information. In this appendix, we explore how such a framework would work in our context.

Suppose now that the gross social benefit in country  $i$  is  $S_i(Q_i; \theta_i)$ , with  $\theta_i \in \Theta_i$  and  $\theta_i$  independent from  $\theta_j$ . Since we will not require  $S_i(Q; \theta)$  to be differentiable with respect to  $\theta$ , we use the simplifying notation that  $S'_i(Q; \theta) = \frac{\partial S_i(Q; \theta)}{\partial Q}$ .

### No trade

When there is no trade, we have  $q_i = Q_i$  - i.e. domestic consumption equals domestic generation. Governments therefore maximise the domestic welfare function  $W_i = \mathbb{E}[S_i(q_i; \theta_i)] - I_i(q_i)$  with respect to  $q_i$ . Hence

$$I'_i(q_i) = \mathbb{E}[S'_i(q_i; \theta_i)] \quad (18)$$

### Complete contract

Since trade is efficient, quantities consumed in each country will be determined by the equations

$$\begin{aligned} S'_A(Q_A^*(\theta_A, \theta_B); \theta_A) &= S'_B(Q_B^*(\theta_A, \theta_B); \theta_B) \\ Q_A^* + Q_B^* &= q_A + q_B \end{aligned}$$

From our theory of bilateral monopoly, levels of investment will be those that maximise total expected welfare.<sup>11</sup> Hence we will have:

$$\begin{aligned}\mathbb{E}[S'_A(Q^*(\theta_A, \theta_B); \theta_A)] &= I'_A(q_A^*) \\ \mathbb{E}[S'_A(Q^*(\theta_A, \theta_B); \theta_B)] &= I'_B(q_B^*)\end{aligned}$$

### Spot contracts

Suppose that the two parties do not write a contract ex-ante - i.e they use a 'spot contract', where a contract is only written once  $\theta_A$  and  $\theta_B$  have been resolved. This is equivalent to the no-commitment case analysed previously. As before, quantities consumed in each country will then be determined by the equations

$$\begin{aligned}S'_A(Q_A^{Sp}(\theta_A, \theta_B); \theta_A) &= S'_B(Q_B^{Sp}(\theta_A, \theta_B); \theta_B) \\ Q_A^{Sp} + Q_B^{Sp} &= q_A^{Sp} + q_B^{Sp}\end{aligned}$$

Then investment levels will be:

$$\begin{aligned}(1 - \alpha)\mathbb{E}[S'_A(q_A^{Sp}; \theta_A)] + \alpha\mathbb{E}[S'_A(Q_A^{Sp}(\theta_A, \theta_B); \theta_A)] &= I'_A(q_A^{Sp}) \\ \alpha\mathbb{E}[S'_B(q_B^{Sp}; \theta_B)] + (1 - \alpha)\mathbb{E}[S'_B(Q_B^{Sp}(\theta_A, \theta_B); \theta_B)] &= I'_B(q_B^{Sp})\end{aligned}$$

Hence, unless by chance  $\mathbb{E}[S'_A(q_A^{Sp}; \theta_A)] = \mathbb{E}[S'_A(Q_A^{Sp}(\theta_A, \theta_B); \theta_A)]$ , we again get distortions in investment.

### Sales contract

Now suppose that the parties choose to write a contract that neither can break unilaterally. We assume however that such a contract cannot bind the parties if they both wish to renegotiate. Using the terminology of Bolton and Dewatripont (2005), we label this a 'sales contract' since the contract includes a specified fixed quantity/transfer bundle that will be carried out if the contract is not renegotiated. However, assuming

<sup>11</sup>This holds due to the assumption that bargaining is efficient - i.e. were the contract to involve investment levels that did not maximise total expected welfare, it would be dominated by one that did, with transfers altered to make sure both players preferred this other contract.

renegotiation is efficient, renegotiation will take place at the production stage unless the quantity agreed to happens to be that which is ex-post efficient. The contract will therefore act mainly as a reference point for these renegotiations.

Suppose that the contract is based on Country B exporting a quantity  $X$  to Country A. Given renegotiation will occur if this is not the efficient amount to trade, we will again always have:

$$S'_A(Q_A^S(\theta_A, \theta_B); \theta_A) = S'_B(Q_B^S(\theta_A, \theta_B); \theta_B)$$

$$Q_A^S + Q_B^S = q_A + q_B$$

Investment levels will then be set according to the following proposition:

**Proposition 10.** *Suppose that the sales contract specifies the quantity exported to be  $X$ . Then investment levels will be set according to the equations.*

$$(1 - \alpha)\mathbb{E} [S'_A(q_A^S + X; \theta_A)] + \alpha\mathbb{E} [S'_A(Q_A^S(\theta_A, \theta_B); \theta_A)] = I'_A(q_A^S) \quad (19)$$

$$\alpha\mathbb{E} [S'_B(q_B^S - X; \theta_B)] + (1 - \alpha)\mathbb{E} [S'_B(Q_B^S(\theta_A, \theta_B); \theta_B)] = I'_B(q_B^S) \quad (20)$$

From this proposition, we can see that investment levels will be somewhere between optimal and those appropriate for the state specified in the contract. The optimal contract will therefore minimise the welfare cost of these distortions. In general however it will not be possible to reduce this to zero since we have two equations to solve but only one flexible parameter,  $X$ .

However, let us now suppose that Country A's bargaining power  $\alpha$  can be set as part of the contract. Aghion et al. (1994) argue that this may be possible if parties can contract on the renegotiation process, and they show that first-best investment levels may be achievable through the appropriate setting of bargaining powers. In particular, they show that the optimal solution involves giving one party complete bargaining power whilst setting the default option to be that which optimises the other player's investment decision. In this way, both parties have the right incentives to invest.

From equations (19) and (20), we can see that this result will also hold in our model.

In particular, we have at least two options that will arrive at efficient investment levels. If we can set  $\alpha = 0$ , such that Country B has all the bargaining power, then from equation (20) we can see that Country B will invest efficiently. Moreover, we can then set  $X$  such that the following equation holds.

$$\mathbb{E} [S'_A(q_A^S + X; \theta_A)] = \mathbb{E} [S'_A(Q_A^S(\theta_A, \theta_B); \theta_A)]$$

Hence, as we can see from equation (19), Country A will also invest efficiently. We therefore arrive at the efficient investment levels. Alternatively, we could set  $\alpha = 1$  and set the default position such that it favours investment by Country B. This would also hold in the extended version of our model where countries also invest in access.

Aghion et al. (1994) suggest bargaining powers could be influenced through the use of penalties for delays in renegotiation or the use of 'hostages'. In a context of international relations where there is no enforcing third party, it is unclear whether these techniques could work in setting bargaining powers. An alternative reading of the result may be that, if countries are able to commit to some contract ex-ante, then the efficient outcome is easiest to achieve when one country has a significantly greater bargaining power than the other.

## Appendix B: Proofs of Propositions

*Proof of Proposition 1.* Investments and quantities consumed will be determined by maximising the following expression

$$W_A + W_B = S_A(Q_A) + S_B(Q_B) - I_A(q_A) - I_B(q_B)$$

with the constraint that  $q_A + q_B = Q_A + Q_B$ . Differentiating this equation and setting to zero therefore gives us the following expressions:

$$S'_A(Q_A^*) = S'_B(Q_B^*) = I'_A(q_A^*) = I'_B(q_B^*)$$

Since we have  $S'_A(Q_A^*) = S'_B(Q_B^*)$ , from Assumption 1 it must be the case that either  $Q_A^* > q_A^{NT}$  or  $Q_B^* < q_B^{NT}$ . Supposing the former, this then gives us that  $I'_A(q_A^*) < I'_A(q_A^{NT})$  and hence  $q_A^* < q_A^{NT}$ . Hence  $Q_A^* > q_A^*$  and  $Q_B^* < q_B^*$  (i.e. Country A is the importer), which in turn gives us that  $I'_B(q_B^*) > I'_B(q_B^{NT})$  and hence  $q_B^* > q_B^{NT}$ . Similarly, if  $Q_B^* < q_B^{NT}$ , then this gives us that  $I'_B(q_B^*) > I'_B(q_B^{NT})$  and hence we must have  $q_B^* > q_B^{NT}$ . Again, it therefore follows that Country A is the importer and hence we derive similarly that  $q_A^* < q_A^{NT}$ , as desired. □

*Proof of Proposition 2.* Since bargaining is efficient,  $Q_A$  and  $Q_B$  will be set to maximise joint welfare:

$$W_A + W_B = S_A(Q_A) + S_B(Q_B) \tag{21}$$

Since and  $q_A + q_B$  is treated as given, and  $q_A + q_B = Q_A + Q_B$  we have  $\frac{dq_B}{dQ_A} = -1$ . Hence differentiating welfare with respect to  $Q_A$  and setting to zero tells us that

$$S'_A(Q_A^T) = S'_B(Q_B^T) \tag{22}$$

Such an allocation of electricity consumption will involve a trade of electricity and hence will be accompanied by a payment. Let us define  $T$  to be the transfer from

Country A to Country B (with  $T$  potentially either negative or positive). Since the equilibrium value of  $T$  is determined by asymmetric Nash bargaining, it will be that which maximises

$$(W_A^T - W_A^{NT})^\alpha (W_B^T - W_B^{NT})^{(1-\alpha)} \quad (23)$$

where  $W_i^T$  and  $W_i^{NT}$  are Country  $i$ 's welfare with and without trade respectively. These welfare levels are given by the following equations:

$$W_A^T = S_A(Q_A^T) - p_A I_A(q_A) - T \quad (24)$$

$$W_A^{NT} = S_A(q_A) - p_A I_A(q_A) \quad (25)$$

$$W_B^T = S_B(Q_B^T) - p_B I_B(q_B) + T \quad (26)$$

$$W_B^{NT} = S_B(q_B) - p_B I_B(q_B) \quad (27)$$

Substituting these values into expression (23) and maximising with respect to  $T$  gives us

$$\begin{aligned} T &= (1 - \alpha) (W_A^T + T - W_A^{NT}) - \alpha (W_B^T - T - W_B^{NT}) \\ &= (1 - \alpha) (S_A(Q_A^T) - S_A(Q_A^{NT})) - \alpha (S_B(Q_B^T) - S_B(Q_B^{NT})) \end{aligned} \quad (28)$$

Given that we now have the quantity traded and transfer in stage 2 of the game, we can now calculate the investments that will be made by each country in stage 1. By substituting the transfer  $T$  defined in equation (28) into the welfare functions (24) and (26) we obtain the following expressions for post-trade welfare:

$$W_A^T = (1 - \alpha) S_A(q_A) + \alpha (S_A(Q_A^T) + S_B(Q_B^T) - S_B(q_B)) - p_A I_A(q_A)$$

$$W_B^T = \alpha S_B(q_B) + (1 - \alpha) (S_B(Q_B^T) + S_A(Q_A^T) - S_A(q_A)) - p_B I_B(q_B)$$

Differentiating each with respect to  $q_i$  and setting to 0 gives us:

$$(1 - \alpha)S'_A(q_A^T) + \alpha \left( \frac{dQ_A^T}{dq_A} S'_A(Q_A^T) + \frac{dQ_B^T}{dq_A} S'_B(Q_B^T) \right) = p_A I'_A(q_A^T) \quad (29)$$

$$\alpha S'_B(q_B^T) + (1 - \alpha) \left( \frac{dQ_B^T}{dq_B} S'_B(Q_B^T) + \frac{dQ_A^T}{dq_B} S'_A(Q_A^T) \right) = p_B I'_B(q_B^T) \quad (30)$$

Since we have  $q_A + q_B = Q_A^T + Q_B^T$ , we therefore have

$$\frac{dQ_A^T}{dq_A} + \frac{Q_B^T}{dq_A} = \frac{dQ_A^T}{dq_B} + \frac{Q_B^T}{dq_B} = 1 \quad (31)$$

Substituting this and the fact that  $S'_A(Q_A^T) = S'_B(Q_B^T)$  into equations (29) and (30) therefore gives the equations (9) and (10) as desired.

To confirm that Country A is the importer in this equilibrium, we again note that since  $S'_A(Q_A^T) = S'_B(Q_B^T)$  it must be that either  $Q_B^T < q_B^{NT}$  or  $Q_A^T > q_A^{NT}$ . Supposing the former, we have that

$$(1 - \alpha)S'_B(q_B^{NT}) + \alpha S'_B(q_B) < I'_B(q_B)$$

This in turn gives us that

$$\alpha(S'_B(q_B) - S'_B(q_B^{NT})) < (I'_B(q_B) - I'_B(q_B^{NT}))$$

Hence it must be the case that  $q_B^{NT} < q_B^T$ , since otherwise the RHS of this expression is negative whilst the LHS is positive. Hence  $q_B^T > Q_B^T$ . We can show this similarly from the inequality  $Q_A^T > q_A^{NT}$ , and hence it must be the case that Country A is the importer.

Let us now show that  $q_A^T < q_A^{NT}$  and  $q_B^T > q_B^{NT}$  for  $\alpha \in (0, 1)$ . Since Country A is the importer, we have  $Q_A^T > q_A^T$  and  $Q_B^T < q_B^T$ . Hence from equations (9) and (10) we have:

$$S'_A(q_A^T) - I'_A(q_A^T) > 0$$

$$S'_B(q_B^T) - I'_B(q_B^T) < 0$$

Now, since  $S_i'' < 0$  and  $I_i'' > 0$ ,  $S_i'' - I_i'' < 0$ , we thus have  $q_A^T < q_A^{NT}$  and  $q_B^T > q_B^{NT}$ .

In order to show  $q_A^T > q_A^*$  and  $q_B^T < q_B^*$ , we use the concept of supermodularity as defined in Fudenberg and Tirole (1991).  $q_A$  and  $q_B$  are substitutes, since  $\frac{d^2W_i}{dq_i dq_j} < 0$ . Hence  $q_A$  and  $-q_B$  are complements, and thus the game is supermodular in  $(q_A, -q_B)$ . To show that  $(q_A, -q_B)$  increases as we move from commitment to no commitment (i.e.  $q_A$  increases whilst  $q_B$  decreases), we need to show that there are increasing differences in lack of commitment - i.e.  $\frac{dW_A^T}{dq_A} > \frac{dW_A^*}{dq_A}$  and  $\frac{dW_B^T}{dq_B} < \frac{dW_B^*}{dq_B}$ . Now, under no commitment we have

$$\frac{dW_A^T}{dq_A} = \alpha [S'_A(Q_A^T) - S'_A(q_A)] + S'_A(q_A) - I'_A(q_A)$$

whilst under commitment we have

$$\frac{dW_A^*}{dq_A} = S'_A(Q_A^T) - I'_A(q_A)$$

Hence

$$\begin{aligned} \frac{dW_A^T}{dq_A} - \frac{dW_A^*}{dq_A} &= \alpha [S'_A(Q_A^T) - S'_A(q_A)] + S'_A(q_A) - I'_A(q_A) - S'_A(Q_A^T) + I'_A(q_A) \\ &= \alpha [S'_A(Q_A^T) - S'_A(q_A)] + S'_A(q_A) - S'_A(Q_A^T) \\ &= (1 - \alpha) [S'_A(q_A) - S'_A(Q_A^T)] > 0 \end{aligned}$$

Similarly, we can show that  $\frac{dW_B^T}{dq_B} < \frac{dW_B^*}{dq_B}$ , and hence we have  $q_A^T > q_A^*$  and  $q_B^T < q_B^*$ , as required.

To derive our final result, we differentiate joint welfare with respect to  $q_A$ :

$$\begin{aligned} \frac{d(W_A + W_B)}{dq_A} &= \frac{dQ_A}{dq_A} S'(Q_A) + \frac{dQ_B}{dq_A} S'(Q_B) - p_A I'(q_A) \\ &= S'(Q_A) - p_A I'(q_A) \\ &= (1 - \alpha)(S'(Q_A^T) - S'(q_A^T)) \leq 0 \end{aligned}$$

Similarly, for  $q_B$ :

$$\begin{aligned}
\frac{d(W_A + W_B)}{dq_B} &= \frac{dQ_A}{dq_B} S'(Q_A) + \frac{dQ_B}{dq_B} S'(Q_B) - p_B I'(q_B) \\
&= S'(Q_B) - p_B I'(q_B) \\
&= \alpha(S'(Q_B^T) - S'(q_B^T)) \geq 0
\end{aligned}$$

□

*Proof of Proposition 3.* Suppose that two countries agree upon trade such that Country  $B$  is compelled to export  $X$ . Then welfare levels are as follows:

$$\begin{aligned}
W_A^T &= \nu [\alpha [S_A(Q_A^T) + S_B(Q_B^T) - S_A(q_A) - S_B(q_B)] + S_A(q_A)] \\
&\quad + (1 - \nu) S_A(q_A + X) - I_A(q_A) + T
\end{aligned} \tag{32}$$

$$\begin{aligned}
W_B^T &= \nu [(1 - \alpha) [S_B(Q_B^T) + S_A(Q_A^T) - S_A(q_A) - S_B(q_B)] + S_B(q_B)] \\
&\quad + (1 - \nu) S_B(q_B - X) - I_B(q_B) - T
\end{aligned} \tag{33}$$

Then we have  $q_A$  and  $q_B$  chosen to maximise these respectively, which gives

$$\begin{aligned}
\nu [\alpha S'_A(Q_A^T) + (1 - \alpha) S'_A(q_A)] + (1 - \nu) S'_A(q_A + X) &= I'_A(q_A) \\
\nu [\alpha S'_B(Q_B^T) + (1 - \alpha) S'_B(q_B)] + (1 - \nu) S'_B(q_B - X) &= I'_B(q_B)
\end{aligned}$$

Since  $X$  must be chosen to be ex-post efficient, we must have  $q_A + X = Q_A$  and  $q_B - X = Q_B$ . Hence we arrive at equations (11) and (12) as desired.

As shown in the proof of Proposition 1, the game is supermodular in  $(q_A, -q_B)$ .

Now, let us consider  $\frac{d^2W_A}{dq_A d\nu}$  and  $\frac{d^2W_A}{dq_B d\nu}$ :

$$\begin{aligned}
\frac{d^2W_A}{dq_A d\nu} &= \alpha [S'_A(Q_A^T) - S'_A(q_A)] + S'_A(q_A) - S'_A(q_A + X) \\
&= \alpha [S'_A(Q_A^T) - S'_A(q_A)] + S'_A(q_A) - S'_A(Q_A^T) \\
&= (1 - \alpha) [S'_A(q_A) - S'_A(Q_A^T)] \\
&> 0 \\
\frac{d^2W_A}{dq_B d\nu} &= (1 - \alpha) [S'_B(Q_B^T) - S'_B(q_B)] + S'_B(q_B) - S'_B(q_B - X) \\
&= (1 - \alpha) [S'_B(Q_B^T) - S'_B(q_B)] + S'_B(q_B) - S'_B(Q_B^T) \\
&= \alpha [S'_B(q_B) - S'_B(Q_B^T)] \\
&< 0
\end{aligned}$$

Hence our game can be indexed by  $\nu$ , as described in Fudenberg and Tirole (1991).

Then the Nash equilibrium is necessarily increasing in  $\nu$ , which in our case means

$\frac{dq_A}{d\nu} > 0$  and  $\frac{dq_B}{d\nu} < 0$ , as desired.

Finally, joint welfare is given by:

$$W_A^T + W_B^T = S_A(Q_A^T) + S_B(Q_B^T) - I_A(q_A) - I_B(q_B)$$

Hence

$$\begin{aligned}
\frac{dW_A^T + W_B^T}{d\nu} &= \frac{dQ_A^T}{d\nu} S'_A(Q_A^T) + \frac{dQ_B^T}{d\nu} S'_B(Q_B^T) - \frac{dq_A^T}{d\nu} I'_A(q_A) - \frac{dq_B^T}{d\nu} I'_B(q_B) \\
&= \frac{dq_A^T}{d\nu} [S'_A(Q_A^T) - I'_A(q_A)] + \frac{dq_B^T}{d\nu} [S'_B(Q_B^T) - I'_B(q_B)]
\end{aligned}$$

Now,  $\frac{dq_A^T}{d\nu} > 0$ ,  $\frac{dq_B^T}{d\nu} < 0$ ,  $S'_A(Q_A^T) - I'_A(q_A) < 0$  and  $S'_B(Q_B^T) - I'_B(q_B) > 0$ . Hence  $\frac{dW_A^T + W_B^T}{d\nu} < 0$ . Moreover, since there is a contract agreed at the first stage, the transfer

will be set such that a country's expected welfare is their status quo payoff plus a fixed fraction of the joint expected gains from trade. Since the status quo payoffs do not change as a function of  $\nu$ , the decrease in joint welfare will feed directly through to a decrease in the expected welfare of each country.  $\square$

*Proof of Proposition 4.* From equations (32) and (33) we have

$$\begin{aligned} \frac{d\mathbb{E}[W_A + W_B]}{dX} &= \frac{dq_A}{dX} [\nu S'_A(Q_A^T) + (1 - \nu)S'_A(q_A + X) - I'_A(q_A)] + S'_A(q_A + X) \\ &\quad + \frac{dq_B}{dX} [\nu S'_B(Q_B^T) + (1 - \nu)S'_B(q_B - X) - I'_B(q_B)] - S'_B(q_B - X) \end{aligned}$$

If  $X$  is chosen optimally, the LHS of this equation will be 0. Hence rearranging gives

$$\begin{aligned} S'_B(q_B - X) - S'_A(q_A + X) &= \frac{dq_A}{dX} [\nu S'_A(Q_A^T) + (1 - \nu)S'_A(q_A + X) - I'_A(q_A)] \\ &\quad + \frac{dq_B}{dX} [\nu S'_B(Q_B^T) + (1 - \nu)S'_B(q_B - X) - I'_B(q_B)] \end{aligned} \quad (34)$$

Now, since  $q_A$  is chosen to maximise  $\mathbb{E}[W_A]$ , we have  $\frac{dW_A}{dq_A} = 0$  and  $\frac{d^2W_A}{dq_A^2} < 0$ . Hence  $\frac{d(\frac{dW_A}{dq_A})}{dX} = 0$  and furthermore  $\frac{d^2W_A}{dq_A^2} \frac{dq_A}{dX} + \frac{d^2W_A}{dq_A dX} = 0$ . Hence  $\frac{dq_A}{dX} < 0$ . Similarly, we can derive that  $\frac{dq_B}{dX} > 0$ . Meanwhile, we have

$$\begin{aligned} \nu S'_A(Q_A^T) + (1 - \nu)S'_A(q_A + X) - I'_A(q_A) &= \nu S'_A(Q_A^T) - \nu [\alpha S'_A(Q_A^T) + (1 - \alpha)S_A(q_A)] \\ &= \nu(1 - \alpha) [S'_A(Q_A^T) - S'_A(q_A)] < 0 \end{aligned}$$

Similarly,  $\nu S'_B(Q_B^T) + (1 - \nu)S'_B(q_B - X) - I'_B(q_B) > 0$ . Hence, substituting these each into equation (34) gives us that  $S'_B(q_B - X) - S'_A(q_A + X) > 0$ .  $\square$

*Proof of Proposition 5.* This follows similarly to the proof of Proposition 2. In addition, we need to calculate the optimal investments in access. These are derived by differentiating the following welfare functions:

$$\begin{aligned} W_A^T &= (1 - \alpha)S_A(q_A, a_A) + \alpha(S_A(Q_A^T, a_A) + S_B(Q_B^T, a_B) - S_B(q_B, a_B)) \\ &\quad - I_A(q_A) - A_A(a_A) \\ W_B^T &= \alpha S_B(q_B, a_B) + (1 - \alpha)(S_B(Q_B^T, a_B) + S_A(Q_A^T, a_A) - S_A(q_A, a_A)) \\ &\quad - I_A(q_B) - A_A(a_B) \end{aligned}$$

$\square$

*Proof of Proposition 6.* From the definition of the Shapley value we have

$$\begin{aligned}
\phi_A &= \left[ 1 + w_A - \frac{w_A}{w_A + w_B} - \frac{w_A}{w_A + w_C} \right] v(\{A\}) \\
&\quad + \left[ \frac{w_A}{w_A + w_B} - w_A \right] [v(\{A, B\}) - v(\{B\})] \\
&\quad + \left[ \frac{w_A}{w_A + w_C} - w_A \right] [v(\{A, C\}) - v(\{C\})] \\
&\quad + [w_A] [v(\{A, B, C\}) - v(\{B, C\})]
\end{aligned}$$

Given our assumptions that trade there's no benefit of Country C being in when the other two are in and that only Country A is connected to Country C, this reduces to

$$\begin{aligned}
\phi_A &= \left[ 1 + w_A - \frac{w_A}{w_A + w_B} - \frac{w_A}{w_A + w_C} \right] v(\{A\}) \\
&\quad + \left[ \frac{w_A}{w_A + w_B} \right] [v(\{A, B\}) - v(\{B\})] \\
&\quad + \left[ \frac{w_A}{w_A + w_C} - w_A \right] [v(\{A, C\}) - v(\{C\})] \\
&= v(\{A\}) + \left[ \frac{w_A}{w_A + w_B} \right] [v(\{A, B\}) - v(\{A\}) - v(\{B\})] \\
&\quad + \left[ \frac{w_A}{w_A + w_C} - w_A \right] [v(\{A, C\}) - v(\{A\}) - v(\{C\})]
\end{aligned}$$

Were trade with Country C not possible, we would have

$$\begin{aligned}
\phi_A &= \left[ 1 - \frac{w_A}{w_A + w_B} \right] v(\{A\}) \\
&\quad + \left[ \frac{w_A}{w_A + w_B} \right] [v(\{A, B\}) - v(\{B\})] \\
&= v(\{A\}) + \left[ \frac{w_A}{w_A + w_B} \right] [v(\{A, B\}) - v(\{A\}) - v(\{B\})]
\end{aligned}$$

Hence we can see that the welfare of Country A increases as a result of Country C's presence. Furthermore, since Country C would potentially export to Country A,  $v(\{A, C\}) - v(\{A\}) - v(\{C\})$  is a decreasing function in  $q_A$ . Hence production in Country A is reduced.

For Country C, we have:

$$\phi_C = v(\{C\}) + \left[ \frac{w_C}{w_A + w_C} \right] [v(\{A, C\}) - v(\{A\}) - v(\{C\})]$$

Country C would potentially export to Country A,  $v(\{A, C\}) - v(\{A\}) - v(\{C\})$  is a increasing function in  $q_C$ . Hence Country C over-invests in production.  $\square$

*Proof of Proposition 8.*

$$\begin{aligned} W_A^T &= \alpha [S_A(Q_A^T) + S_B(Q_B^T) - S_A(q_A) - S_B(q_B)] \\ &\quad + (1 - \beta_A)S_A(q_A) - I_A(q_A) + \beta_B S_B(q_B) \\ W_B^T &= (1 - \alpha) [S_B(Q_B^T) + S_A(Q_A^T) - S_A(q_A) - S_B(q_B)] \\ &\quad + (1 - \beta_B)S_B(q_B) - I_B(q_B) + \beta_A S_A(q_A) \end{aligned}$$

Taking production levels as fixed, we can see that the fraction of a particular company is worth the same to either country - it essentially improves their status quo payoff. Ownership will therefore be transferred depending on whichever distribution produces the most efficient levels of investment. Differentiating the above expressions of welfare gives us

$$\begin{aligned} (1 - \beta_A - \alpha)S'_A(q_A^T) + \alpha S'_A(Q_A^T) &= I'_A(q_A^T) \\ (\alpha - \beta_B)S'_B(q_B^T) + (1 - \alpha)S'_B(Q_B^T) &= I'_B(q_B^T) \end{aligned}$$

Hence investment  $q_i$  is decreasing in  $\beta_i$ . Since joint welfare is increasing in  $q_B$ , clearly  $\beta_B = 0$  is optimal. On the other hand, welfare is decreasing in  $q_A$ . In particular, given  $q_B$  it is optimal to have  $S'_A(Q_A^T) = I'_A(q_A^T)$ . Hence it is optimal for  $\beta_A$  to be such that  $(1 - \beta_A - \alpha)S'_A(q_A^T) = (1 - \alpha)S'_A(Q_A^T)$ , i.e.  $\beta_A = (1 - \alpha) \frac{S'_A(q_A^T) - S'_A(Q_A^T)}{S'_A(q_A^T)}$ .  $\square$

*Proof of Proposition 9.* The transfer will ensure that firm A's payoff is as follows:

$$V_A = \gamma S_A(q_A) + \alpha(\gamma(S_A(Q_A) - S_A(q_A)) + \gamma(S_B(Q_B) - S_B(q_B)))$$

Since  $V_A = \gamma S_A(Q_A) - T$ , we have

$$\begin{aligned} T &= \gamma S_A(Q_A) - V_A \\ &= (1 - \alpha)\gamma(S_A(Q_A) - S_A(q_A)) - \alpha\gamma(S_B(Q_B) - S_B(q_B)) \end{aligned}$$

So, overall welfare from the governments point of view is

$$\begin{aligned} W_A &= S_A(Q_A) - I_A(q_A) - (1 - \alpha)\gamma(S_A(Q_A) - S_A(q_A)) + \alpha\gamma(S_B(Q_B) - S_B(q_B)) \\ &= (1 - \gamma)S_A(Q_A) + \alpha\gamma(S_A(Q_A) + S_A(Q_B)) \\ &\quad + (1 - \alpha)\gamma S_A(q_A) - \alpha\gamma S_B(q_B) - I_A(q_A) \end{aligned}$$

and

$$\begin{aligned} W_B &= S_B(Q_B) - I_B(q_B) + (1 - \alpha)\gamma(S_A(Q_A) - S_A(q_A)) - \alpha\gamma(S_B(Q_B) - S_B(q_B)) \\ &= (1 - \gamma)S_B(Q_B) + (1 - \alpha)\gamma(S_A(Q_A) + S_B(Q_B)) \\ &\quad - (1 - \alpha)\gamma S_A(q_A) + \alpha\gamma S_B(q_B) - I_B(q_B) \end{aligned}$$

Hence

$$\begin{aligned} I'_A(q_A) &= (1 - \gamma) \frac{dQ_A}{dq_A} S'_A(Q_A) + \gamma [\alpha S'_A(Q_A) + (1 - \alpha) S'_A(q_A)] \\ I'_B(q_B) &= (1 - \gamma) \frac{dQ_B}{dq_B} S'_B(Q_B) + \gamma [(1 - \alpha) S'_B(Q_B) + \alpha S'_B(q_B)] \end{aligned}$$

We have

$$\frac{dQ_A}{dq_A} S''(Q_A) = \left(1 - \frac{dQ_A}{dq_A}\right) S''(Q_B)$$

and hence

$$\frac{dQ_A}{dq_A} = \frac{S''_B(Q_B)}{S''_A(Q_A) + S''_B(Q_B)}$$

Therefore, since  $\frac{dQ_A}{dq_A} S'_A(Q_A) < \alpha S'_A(Q_A) + (1 - \alpha) S'_A(q_A)$ , we will certainly get less investment in Country A. Hence for  $\gamma$  close to 1, investment must be more efficient

under devolved bargaining. In Country B, we require  $\frac{dQ_B}{dq_B} S'_B(Q_B) > (1 - \alpha)S'_B(Q_B) + \alpha S'_B(q_B)$  for investment to certainly increase.  $\square$

*Proof of Proposition 7.* The welfare of country A is

$$W_A^T = (1 - \alpha)S_A(q_A, a_A) + \alpha(S_A(Q_A^T, a_A) + S_B(Q_B^T, a_B) - S_B(q_B + q_B^+, a_B)) \\ - p_A I_A(q_A) - A_A(a_A) - (p_B I_B(q_B + q_B^+) - p_B I(q_B))$$

Hence

$$\frac{dW_A^T}{dq_B^+} = \alpha \left( \frac{dQ_A^T}{dq_B^+} \partial S_A(Q_A^T, a_A) / \partial a_A + \frac{dQ_B^T}{dq_B^+} \partial S_B(Q_B^T, a_B) / \partial a_B - \partial S_B(q_B + q_B^+, a_B) / \partial a_B \right) \\ - p_B I'_B(q_B + q_B^+) \\ = \alpha \left( \partial S_B(Q_B^T, a_B) / \partial a_B - \partial S_B(q_B + q_B^+, a_B) / \partial a_B \right) - p_B I'_B(q_B + q_B^+)$$

At  $q_B^+ = 0$ , this equals

$$\frac{dW_A^T}{dq_B^+}(0) = \alpha \left( \partial S_B(Q_B^T, a_B) / \partial a_B - \partial S_B(q_B, a_B) / \partial a_B \right) - p_B I'_B(q_B) \\ = \alpha \left( \partial S_B(Q_B^T, a_B) / \partial a_B - \partial S_B(q_B, a_B) / \partial a_B \right) \\ - \alpha \partial S_B(q_B^T, a_B^T) / \partial a_B - (1 - \alpha) \partial S_B(Q_B^T, a_B^T) / \partial a_B \\ = (2\alpha - 1) \partial S_B(Q_B^T, a_B) / \partial a_B - 2\alpha \partial S_B(q_B, a_B) / \partial a_B$$

Now,  $q_B > Q_B$ , hence there will be investment if

$$\frac{2\alpha - 1}{2\alpha} > \frac{\partial S_B(q_B, a_B) / \partial a_B}{\partial S_B(Q_B^T, a_B) / \partial a_B}$$

Similarly, the welfare of Country B is

$$W_B^T = \alpha S_B(q_B, a_B) + (1 - \alpha)(S_B(a_B, Q_B^T) + S_A(Q_A^T, a_A + a_A^+) - S_A(q_A, a_A^+ a_A^+)) \\ - p_B I_B(q_B) - A_B(a_B) - (A_A(a_A + a_A^+) - A_A(a_A))$$

Hence

$$\begin{aligned}
\frac{dW_B^T}{da_A^+}(a_A^+) &= (1 - \alpha) \left( \frac{dQ_B^T}{da_A^+} \partial S_B(Q_B^T, a_B) / \partial a_B + \frac{dQ_A^T}{da_A^+} \partial S_A(a_A + a_A^+, Q_A^T) / \partial a_A \right. \\
&\quad \left. + \partial S_A(a_A + a_A^+, Q_A^T) / \partial q_A - \partial S_A(a_A + a_A^+, q_A) / \partial q_A \right) \\
&\quad - A'_A(a_A + a_A^+) \\
&= (1 - \alpha) (\partial S_A(Q_A^T, a_A + a_A^+) / \partial q_A - \partial S_A(q_A, a_A + a_A^+) / \partial q_A) - A'_A(a_A + a_A^+)
\end{aligned}$$

Since we are treating  $q_A$  and  $q_B$  as given,  $\frac{dQ_B^T}{da_A^+} + \frac{dQ_A^T}{da_A^+} = 0$ . Hence at  $a_A^+ = 0$

$$\begin{aligned}
\frac{dW_B^T}{da_A^+}(0) &= (1 - \alpha) (\partial S_A(Q_A^T, a_A) / \partial q_A - \partial S_A(q_A, a_A) / \partial q_A) - A'_A(a_A) \\
&= (1 - \alpha) (\partial S_A(Q_A^T, a_A) / \partial q_A - \partial S(q_A, a_A) / \partial q_A) \\
&\quad - (1 - \alpha) \partial S_A(q_A^T, a_A^T) / \partial q_A - \alpha \partial S_A(Q_A^T, a_A^T) / \partial q_A
\end{aligned}$$

Hence investment will take place if

$$\frac{1 - 2\alpha}{2 - 2\alpha} > \frac{\partial S_A(q_A, a_A) / \partial q_A}{\partial S_A(Q_A^T, a_A) / \partial q_A}$$

□

*Proof of Proposition 10.* Expected total welfare ex-ante is:

$$\begin{aligned}
W_A^S &= \alpha \mathbb{E} [S_A(Q_A^S(\theta_A, \theta_B); \theta_A) + S_B(Q_B^S(\theta_A, \theta_B); \theta_B) - S_A(q_A + X; \theta_A) - S_B(q_B - X; \theta_B)] \\
&\quad + \mathbb{E} [S_A(q_A + X; \theta_A)] - I_A(q_A) + T \\
W_B^S &= (1 - \alpha) \mathbb{E} [S_A(Q_A^S(\theta_A, \theta_B); \theta_A) + S_B(Q_B^S(\theta_A, \theta_B); \theta_B) - S_A(q_A + X; \theta_A) - S_B(q_B - X; \theta_B)] \\
&\quad + \mathbb{E} [S_B(q_B - X; \theta_B)] - I_B(q_B) - T
\end{aligned}$$

where  $T$  is a pre-arranged transfer not dependent on investment levels. Differentiating these expressions, we therefore find that investment levels are as given in the proposition. □

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## Chapter 4

# Do infrastructure reforms reduce the effect of corruption? Evidence from electricity firms in Latin America

### 1 Introduction

Corruption has been identified as a key factor that may reduce growth and worsen poverty in developing countries.<sup>1</sup> One particular area of the economy where corruption is a major concern is the operation and regulation of network infrastructure such as electricity, telecoms and water. A high level of government intervention and frequent lack of competition make firms in these sectors particularly vulnerable to corrupt behavior.<sup>2</sup> Whilst the empirical work on the issue is limited, there is increasing evidence that corruption can significantly reduce the performance of utilities.<sup>3</sup>

A wish to reduce this corruption has been part of the reason why developing countries have been urged to undertake large-scale reform of their utilities in the last twenty years. In sectors where the introduction of competition is difficult, reform has generally consisted of privatization and improving the institutional environment. Work on this latter aspect of reform has generally been focused on the creation of an Independent Regulatory Agency (IRA) with specific responsibility for regulation of one or more infrastructure sectors. These agencies are 'independent' in the sense that they are not part of a government ministry or subject to direct executive control, and therefore

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<sup>1</sup>See, for example, Mauro (1995). Bardhan (1997) provides a survey. As an example of the way in which corruption is damaging to firms performance, Fisman and Svensson (2007) provide evidence that paying bribes decreases firms' growth in Uganda.

<sup>2</sup>See Dal Bó (2006); Estache and Trujillo (2009); Kenny (2009) for overviews of corruption in regulation and infrastructure

<sup>3</sup>Dal Bó and Rossi (2007); Estache et al. (2009); Estache and Kouassi (2002); Seim and Soreide (2009) provide cross-country empirical evidence of the negative effect of corruption on utility performance. Cubbin and Stern (2006), on the other hand, find no significant effect of corruption on generation capacity. This may be because corruption mitigates commitment problems and hence its effect on efficiency is different from that on long-term investment.

they are viewed to be less sensitive to the wills of political elites. However, their exact degree of autonomy varies across countries and sectors. Over the last twenty years, the creation of such an agency has come to be seen internationally as a key first step towards improving the institutional environment in which regulated firms operate. Their role is to implement regulatory policy, which may include setting tariffs, publishing information on firms' performance and enforcing firms meet agreed standards of quality and supply.

Previous empirical work has attempted to evaluate the effect of privatisation and the creation of an IRA on various performance measures. There is some evidence that privatization has often improved performance, although this has also frequently not been the case.<sup>4</sup> Evidence is also emerging that a key determinant of performance is the institutional environment utility firms operate in, and in particular the quality of regulatory governance. In particular, several studies have shown that performance has been improved by the creation of an IRA that is in some sense separated from the executive. A few of these studies have also tried to gauge the degree to which these agencies are well governed, and here they have found evidence that good regulatory governance also improves the performance of the regulated sector.<sup>5</sup>

This paper aims to contribute to the literature in two ways. Firstly, I wish to add to the evidence on the direct effect of the regulatory environment and ownership by testing the effects that corruption, regulatory governance and ownership have on efficiency. Secondly, I wish to extend this analysis a step further in order to consider how these factors interact. In particular, I aim to investigate whether regulatory governance and ownership may interact with corruption. I carry out the analysis on a sample of electricity distribution firms in Latin America over the period 1995-2005. The electricity distribution sector is suitable for analysis of these issues since govern-

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<sup>4</sup>See Boubakri et al. (2008); Megginson and Sutter (2006); Parker and Kirkpatrick (2005) for surveys of the empirical literature on privatization in developing countries. The latter survey in particular argues that the institutional environment plays a greater role in determining performance than in developed countries.

<sup>5</sup>For example, in the telecoms sector (where data is best) Berg and Hamilton (2000); Maiorano and Stern (2007); Ros (2003); Wallsten (2001) find evidence of the positive effect of creating an IRA. Estache and Rossi (2005) finds similar results for the electricity sector. Andres et al. (2008); Cubbin and Stern (2006); Gutiérrez (2003a); Gutiérrez and Berg (2000); Montoya and Trillas (2007); Pargal (2003); Zhang et al. (2008) look at a range of other aspects of regulatory governance and generally find that these also can have positive effects. Estache and Wren-Lewis (2009) provide a survey of the theoretical literature on the importance of institutions in utility regulation in developing countries.

ment regulation is important and direct competition is limited. Moreover, the period and region is one that includes a number of important reforms as well as variation in the level of corruption both within and between countries.

The paper can be regarded as an extension of the empirical part of Dal Bó and Rossi (2007), who use a dataset that is very close to a subset of the data used in this paper. The panel they use contains data on 80 electricity distribution firms across 13 Latin American countries for the years 1994-2004. They construct a labour demand function and find that greater corruption leads to a greater number of employees for a given function of outputs and other inputs. They consider a number of other factors that affect efficiency, including whether the firm is public or private and the level of law and order in the country, but these effects appear to be separate and do not significantly interact with corruption.

Using a similar methodology to Dal Bó and Rossi (2007), I also find evidence that corruption and public ownership decrease efficiency. My results suggest that an increase in the level of corruption in a country by one standard deviation may lead to a 18% increase in the number of workers employed for a given level of outputs, if the firm is public and not regulated by an IRA. I then extend the analysis by introducing regulatory governance into consideration, using data collected by Andres et al. (2007). I find that whilst the creation of an independent regulatory agency on its own does not increase efficiency, better regulatory governance significantly increases efficiency. Indeed, the regressions suggest that the creation of poorly governed IRAs has in fact decreased efficiency compared to prior regulation within the government. This result highlights the importance of going beyond stressing solely the need for an independent agency and considering more complex aspects of regulatory governance.

The paper then turns to consider whether privatization or good regulatory governance may mitigate the negative effect of corruption on efficiency. By introducing interaction terms I find evidence that privately managed firms are less affected by national corruption than publicly managed ones. The results suggest that private ownership reduces the negative effect of corruption by about 40 %. Similarly, the existence of an

IRA significantly reduces the effect of corruption, with the effect of corruption may be reduced by about 65 %. I then test for the robustness of these results using several permutations of the baseline equation, including introducing various control variables and instrumenting for corruption, regulatory governance and ownership. Whilst the coefficient on the corruption multiplied by private ownership term loses significance when we instrument for ownership, the significance of good regulatory governance in mitigating the adverse effect of corruption is robust.

One way of interpreting this result is that the combination of corruption measured at the country level and the sector/firm-level interaction terms proxy the amount of corruption that occurs in the relationship between the firm and the regulator. In this interpretation, a greater level of corruption in the country as a whole increases the corruption between the firm and the bureaucracy in charge of regulating it, and therefore decreases efficiency. This corruption between the firm and the bureaucracy can then be reduced by creating an IRA or privatizing the firm.

There are a few other papers that explore the interaction of corruption and aspects of utility reform. In terms of ownership, Dal Bó and Rossi (2007) find no robust effect of the interaction of corruption and ownership. Taking a different approach, Clarke and Xu (2004) study how firm characteristics influence the frequency with which utilities demand bribes. They find that utility employees are more likely to take bribes in countries with greater constraints on utility capacity, lower levels of competition in the utility sector, and where utilities are state-owned. They do not however look at whether this impacts on other aspects of utility performance.

I have found three papers that interact corruption with the existence of an independent regulatory agency. Estache and Rossi (2008) extend the sample used in Dal Bó and Rossi (2007) to countries outside of Latin America and test the effect of a regulatory agency's existence on efficiency, using corruption as a control. Whilst they find a regulatory agency significantly increases efficiency, the interaction term with corruption is not significant. Estache et al. (2009) consider the impact of corruption, privatization and the existence of a regulatory agency on a range of performance mea-

tures and find mixed results. They find privatization and regulatory agencies interact in a positive way with corruption in telecoms, but this is not so clearly the case for electricity. Finally, Guasch and Straub (2009) study the impact of corruption and reforms on the probability of contract renegotiation. They find that corruption increases firm-led renegotiation but decreases government-led renegotiation. The existence of an independent regulator at the awarding of the contract appears to mitigate this first effect and enable the second - i.e. the existence of a regulator in a corrupt environment decreases the probability of renegotiation.

## **2 Data and variable definitions**

The main data I use consists of three different components: corruption, regulatory governance and firms' inputs and outputs.

Data on corruption is from the International Country Risk Guide, which is collected by Political Risk Services. This is the same dataset as used by Dal Bó and Rossi (2007) and contains annual country-level data since 1970. I use this dataset since it is specifically designed to allow for comparisons between years and countries and contains observations for the entire period for which I have data on firms' performance.<sup>6</sup> The ICRG corruption index is meant to capture the likelihood that government officials will demand special payments, and the extent to which illegal payments are expected throughout government tiers as ranked by panels of international experts. The ICRG index ranges globally between 6 (highly clean) and 0 (highly corrupt). In order to make the results more evident to read, I reverse the ordering of the data such that greater values represent higher levels of corruption. Moreover, I transform the data such that the mean level of corruption in the total sample is 0. A positive value therefore represents an environment where corruption is above the sample average whilst a negative value represents a level of corruption that is below the sample average. Table 1 gives summary statistics of the variable by country.

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<sup>6</sup>Two commonly used alternative measures of corruption are those compiled by Transparency International and the World Governance Indicators. Neither of these is designed for comparison over time, and both have less coverage than the ICRG data.

Table 1: **Corruption summary statistics by country**

<b>country</b>	<b>mean</b>	<b>sd</b>	<b>min</b>	<b>max</b>
Argentina	0.22	0.41	-0.29	0.71
Bolivia	0.14	0.51	-0.29	0.71
Brazil	0.01	0.61	-1.29	0.88
Chile	-0.97	0.64	-1.79	0.21
Colombia	0.30	0.55	-0.29	1.21
Costa Rica	-0.99	1.42	-2.29	1.21
Dominican Republic	0.19	0.90	-1.29	0.71
Ecuador	-0.23	0.43	-0.70	1.09
El Salvador	-0.51	0.67	-1.29	0.21
Guatemala	-1.23	0.10	-1.29	-1.12
Haiti	1.38	0.35	0.80	1.71
Honduras	0.61	0.21	0.21	0.80
Jamaica	1.21	0.00	1.21	1.21
Mexico	0.32	0.51	-0.70	0.71
Nicaragua	-0.25	0.68	-1.29	0.21
Panama	0.71	0.00	0.71	0.71
Peru	-0.07	0.43	-0.95	0.71
Uruguay	-0.29	0.00	-0.29	-0.29
<b>Total</b>	<b>0.00</b>	<b>0.82</b>	<b>-2.29</b>	<b>1.71</b>

*Source:* International Country Risk Guide.

Data is for years where a firm is present in the sample

The data on regulatory governance is from Andres et al. (2007), and includes information on national electricity regulators in over twenty countries as well as for provincial regulators for certain states in Brazil and provinces in Argentina respectively.<sup>7</sup> The data is cross-sectional but, since it includes the year in which each regulatory agency was created, I transform it into a panel by giving zero values for all variables in each year before the agency's creation. I am therefore implicitly assuming that regulatory governance remains constant during the reign of the agency and that it is unrelated to the quality of regulation prior to the creation of the agency. This is obviously a strong assumption, but if it has any effect on my results it is likely to bias them towards insignificance and therefore should not be of too great a concern when interpreting my results.

The data is compiled from a survey containing over fifty different questions to produce indices of various aspects of regulatory governance, including accountability, autonomy and transparency. These include questions such as whether the regulator is financed directly by the government, whether minutes are available publicly and the

<sup>7</sup>I am very grateful to Luis Andres for allowing me access to this data.

way in which the head of the agency is appointed (see Andres et al. (2007) for more details). I make use primarily of the Electricity Regulatory Governance Index (ERGI) constructed by Andres et al. (2007), where a rating of 0 represents the worst possible measure of governance and 1 the best.<sup>8</sup> For Argentina and Brazil, I use the ERGI of the provincial/state regulatory agency, since regulation of electricity distribution firms is carried out at this level. From henceforth, I use the term 'province' to mean the area for which the regulatory agency is responsible - either national or state/province as appropriate. Firms that are in provinces for which I have no data on whether an IRA has been created (including those with no IRAs in 2007) are not included in the sample. Table 2 gives summary statistics of the regulatory governance index (ERGI) and when agencies have been created in each country/province.

Data on firm performance is from the World Bank Latin American and Caribbean Electricity Distribution Benchmarking Database.<sup>9</sup> It contains data on 249 utilities across 25 countries between the years 1995-2007, and overall the firms represent 88 percent of all electricity connections in the region. It is almost a pure extension of the dataset used by Dal Bó and Rossi (2007). I use data on the total number of employees, the total number of connections, total electricity sold (in GWh) and whether the firm is privately managed. Summary statistics of firms' characteristics are given in Table 3.

In total, these three data sources combine to create a database of 153 firms across 18 countries with a total of 1359 observations (i.e. this is the largest possible intersection of the three datasets). Table 4 shows the number of firms of each type in each country. Of the 153 firms, 53 change ownership over the period (all but three from public to private) whilst 66 begin in the sample without a regulator and then become regulated.

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<sup>8</sup>Of course, notions of 'good' governance are somewhat subjective. In future work, I therefore analyse the extent to which the ERGI is the best measure of governance to use when constructing a total measure from the various components of governance.

<sup>9</sup>Data for the period 1995-2005 can be found on-line at [info.worldbank.org/etools/lacelectricity/home.htm](http://info.worldbank.org/etools/lacelectricity/home.htm)

Table 2: Regulation summary statistics by regulator

province	Start year	ERGI
Bolivia	1996	0.84
Chile	1990	0.56
Colombia	1994	0.76
Costa Rica	1996	0.74
Dominican Republic	1998	0.75
Ecuador	1999	0.61
El Salvador	1997	0.82
Guatemala	1996	0.79
Haiti	1983	0.37
Honduras	1995	0.56
Jamaica	1997	0.72
Mexico	1995	0.72
Nicaragua	1985	0.75
Panama	1996	0.63
Peru	1996	0.84
Uruguay	2000	0.73
Argentinian Provinces		
Chaco	1973	0.25
Cordoba	2001	0.68
Fromosa	1995	0.52
Jujuy	1996	0.64
Rio Negro	1996	0.76
Salta	1996	0.76
Tucuman	1993	0.55
Brazilian States		
Alagoas	2002	0.63
Amazonas	2001	0.61
Bahia	1999	0.73
Ceara	1998	0.74
Espirito Santo	2005	0.52
Goiias	2000	0.81
Mato Grosso	1999	0.67
Mato Grosso do Sul	2002	0.84
Para	1998	0.72
Paraiba	2002	0.57
Pernambuco	2000	0.75
Rio Grande do Norte	1999	0.67
Rio Grande do Sul	1997	0.69
Sao Paulo	1997	0.83
Overall median	1997	0.72

Source: Andres et al. (2007)

Table 3: Summary statistics of firm characteristics

variable	mean	sd	min	max
Employees	1338	3906	12	42783
Connections	692521	2078358	2499	25311248
Electricity (GWh)	3649	12910	3	150457

Source: World Bank

Table 4: Ownership and regulation of firms

Country	Firms	Ownership			Regulation		
		Private	Public	Changed	Regulated	Unregulated	Changed
Argentinian Provinces	7	2	2	3	5	0	2
Bolivia	7	1	0	6	1	0	6
Brazilian States	35	10	4	21	9	1	25
Chile	23	23	0	0	23	0	0
Colombia	20	0	16	4	20	0	0
Costa Rica	8	0	8	0	4	0	4
Dominican Rep	2	0	0	2	2	0	0
Ecuador	20	0	19	1	11	0	9
El Salvador	5	1	0	4	1	0	4
Guatemala	1	1	0	0	1	0	0
Haiti	1	0	1	0	1	0	0
Honduras	1	0	1	0	1	0	0
Jamaica	1	1	0	0	1	0	0
Mexico	2	0	2	0	2	0	0
Nicaragua	2	0	0	2	2	0	0
Panama	3	0	0	3	1	0	2
Peru	16	2	7	7	3	0	13
Uruguay	1	0	1	0	0	0	1
Total	155	41	61	53	88	1	66

Source: World Bank and Andres et al. (2007)

### 3 Econometric Methodology

Kumbhakar and Hjalmarsson (1998) note that while productivity in electricity generation is mainly determined by technology, productivity in distribution is, to a large extent, driven by management and efficient labour use. Moreover, since electricity distribution is highly regulated, decisions on technology and capital are likely to be outside of the firm's control, whilst the firm typically has control over labour. I therefore focus on labour efficiency.

As stated by Dal Bó and Rossi (2007), Latin American electricity distribution firms have the obligation to meet demand. For a given firm, I can therefore consider the amount of electricity sold to final customers and the number of final customers served as exogenous outputs.<sup>10</sup>

I therefore follow Dal Bó and Rossi (2007) in estimating a parametric labour requirement function.<sup>11</sup> In particular, I follow their use of a translog functional form because it provides a good second-order approximation to a broad class of functions and they

<sup>10</sup>This assumption is also held in Dal Bó and Rossi (2007).

<sup>11</sup>The idea of input requirement functions goes back to Diewert (1974)

rejected the hypothesis that the function was Cobb-Douglas. In addition to electricity produced and connections, Dal Bó and Rossi (2007) also include the service area as an exogenous output and transformer capacity and the length of the distribution lines as exogenous capital variables. Unfortunately the first two of these variables are not available in the extended dataset that I use, and including the latter reduces my sample by over a half. Since these variables are likely to vary little over time, I therefore use a firm fixed effects approach to control for time-invariant unobservables.<sup>12</sup>

A translog labour requirement model with two outputs, for a panel of  $i = 1, \dots, N$  firms producing in  $c = 1, \dots, C$  countries, and observed over  $t = 1, \dots, T$  periods, may be specified as

$$l^{i,t} = \alpha_i + \psi_t + \sum_{m=1}^2 \omega_m y_m^{i,t} + \frac{1}{2} \sum_{m=1}^2 \sum_{n=1}^2 \omega_{mn} y_m^{i,t} y_n^{i,t} + \nu_{it} \quad (1)$$

where  $l$ ,  $y_1$  and  $y_2$  are the natural logarithms of labour, sales and customers and  $\nu$  is the random error term. To account for time effects in a flexible way I include year fixed effects  $\psi_t$ . The year fixed effects measure the efficiency impact of sector-level shifts over time, such as secular technology trends, international macroeconomic fluctuations or energy price shocks. To control for potential biases caused by any omitted variables that are country, province or firm specific and time invariant, I include firm fixed effects ( $\alpha_i$ ). We will then add to this equation a dummy indicating whether the firm is privately owned, a dummy indicating the presence of an IRA, the level of corruption in the country, the ERGI of any regulator that exists (which takes a value of 0 if there is no regulator), and appropriate interaction terms.

I am therefore using a fixed effects regression. A concern in this type of study is that the shocks affecting all firms in a given country in the same year may be correlated, thus biasing standard error estimates. To address this issue, all standard errors are clustered on country-year combinations, as in Dal Bó and Rossi (2007).

<sup>12</sup>To test for the assumption that firm fixed effects are sufficient, I have run the baseline regression over the reduced sample with the length of the distribution lines in the translog function. In the baseline equation all the terms are insignificant and it does not change any results significantly in any of my regressions. Moreover, using the dataset from Dal Bó and Rossi (2007), I find that their results are not sensitive to the removal of the service area and transformer capacity.

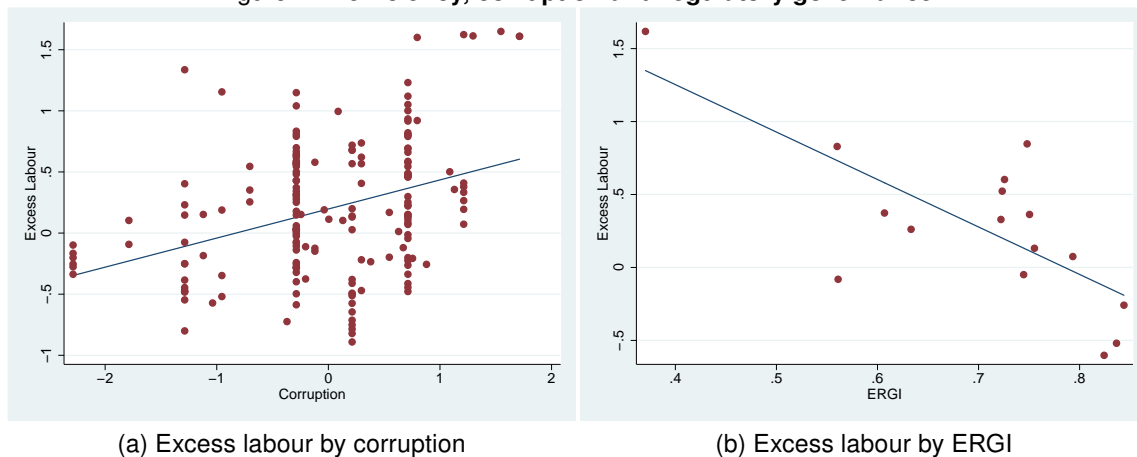
## 4 Empirical Results

### 4.1 Graphical Analysis

Before beginning with the econometric analysis, let us display the data graphically to consider the link between inefficiency, corruption and regulatory governance. For this subsection, we measure inefficiency by regressing the log of employees on the translog function described in (1) and storing the residuals.<sup>13</sup> This thus creates a measure of ‘excess labour’, which gives us an idea of how efficient the firm is in any year compared to the average of all firms over the whole period.

Figure 1(a) plots this measure of excess labour against corruption for each country year pair, collapsing the data down to the country level by taking the simple average ‘excess labour’ of all the firms in a given country for each year. Figure 1(b) then plots excess labour against the index of regulatory governance (ERGI) for those countries with national regulators, averaging excess labour over the years for which an IRA exists.

Figure 1: Inefficiency, corruption and regulatory governance

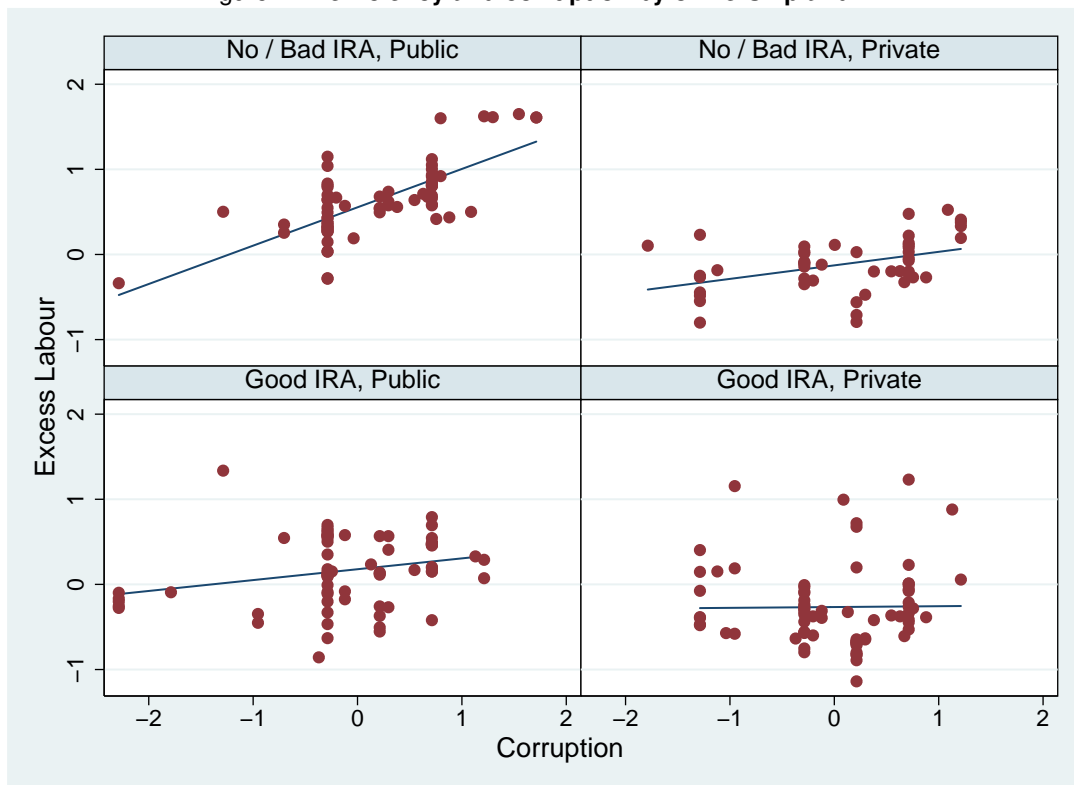


From the fitted line in Figure 1(a), we can see that there therefore appears to be a positive correlation between corruption and inefficiency. However, there is clearly a lot of heterogeneity in this relationship, with some relatively efficient firms operating in relatively corrupt environments. Figure 1(b) suggests that inefficiency appears to decrease as regulatory governance improves.

<sup>13</sup>We do not include firm or year fixed effects

Let us now consider whether either of the reforms - privatization or improved regulatory governance - have an effect on the relationship between corruption and inefficiency. Figure 2 plots excess labour against corruption separately for firms in four different environments. Results are split by ownership and regulatory governance, which takes a value of 0 if there is no IRA or if the IRA has an ERGI score below the sample median. The upper two panels consider observations of firms operating where regulatory governance is 'low', whilst the lower two panels consider observations of firms operating where there is an IRA with an above median ERGI score regulating. These pairs are then each divided into publicly operated firms on the left panel and privately operated firms on the right.

Figure 2: **Inefficiency and corruption by ownership and IRA**



From figure 2, we can see that both reforms appear to affect the relationship between corruption and inefficiency. The upper left panel, where firms are publicly owned and not regulated by an above average IRA, shows the clearest positive relationship between corruption and inefficiency. The upper right panel and the lower left panel then show that, for firms that are either privately operated or regulated by an IRA

with above median governance, the relationship between corruption and inefficiency is weaker. Moreover, there appears to be no clear relationship between corruption and inefficiency when both of these reforms has been undertaken, as shown in the lower right panel. We now investigate these results more formally using our econometric analysis.

## 4.2 Econometric analysis

Table 5 presents various specifications based on the regression methodology outlined in Section 3. Coefficients on the terms in the translog function are given in Appendix A, and we can note that the coefficients on the translog function are reasonable. The coefficients suggest that if both output measures were to double then the increase in labour required would be 59%. This suggests that the firms have increasing returns to scale, which is what we would expect for the sector. Moreover, it is very close to the value we obtain by using the data from Dal Bó and Rossi (2007), which suggest a doubling of outputs requires a 62 % increase in employees. We also note that the coefficients on the translog function are very similar if we split the sample into private and public firms, supporting our assumption that the translog function is relatively unaffected by ownership.

Column (1) of Table 5 explores the effect of corruption on efficiency. We can see that the coefficient on the corruption term is positive and strongly significant, which suggests that higher corruption causes a greater number of workers to be employed for a given function of outputs. Corruption is therefore negatively associated with efficiency. However, we also see that corruption interacts significantly with both the private ownership dummy and the dummy indicating the presence of an IRA. In both cases the coefficient is negative and of a smaller magnitude than the coefficient of corruption. This suggests that the negative effect of corruption on efficiency is significantly mitigated if the firm is either privately owned or regulated by an IRA.<sup>14</sup>

We may also note that the coefficient on the IRA dummy in column (1) is insignif-

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<sup>14</sup>If we introduce an extra term with corruption interacted with both the IRA and ownership dummy, then we find that this term is insignificant. This is unsurprising given the relative lack of firms in our sample that are privately owned and not regulated by an IRA.

icant. Given that corruption is scaled such that its mean sample value is zero, this suggests that the creation of a regulatory agency does not affect efficiency if corrup-

Table 5: **Baseline Regression**

	(1)	(2)	(3)	(4)	(5)
Corruption	0.21*** (0.033)	0.21*** (0.030)	0.21*** (0.028)	0.21*** (0.028)	
Corruption * IRA	-0.14*** (0.032)	-0.12 (0.096)		-0.14*** (0.027)	
Corruption * Private	-0.092*** (0.025)	-0.089*** (0.025)	-0.084*** (0.024)	-0.084*** (0.023)	
Private dummy	-0.29*** (0.036)	-0.28*** (0.036)	-0.27*** (0.035)	-0.27*** (0.035)	-0.23*** (0.038)
IRA dummy	-0.027 (0.037)	0.48** (0.22)			
ERGI		-0.73** (0.31)			
Corruption * ERGI		-0.024 (0.12)			
Bad IRA dummy			0.11*** (0.037)	0.11*** (0.036)	
Good IRA dummy			-0.12*** (0.039)	-0.12*** (0.039)	
Corruption * Bad IRA			-0.14*** (0.037)		
Corruption * Good IRA			-0.14*** (0.027)		
High corruption dummy					0.20*** (0.057)
High Corruption * Private					-0.14*** (0.033)
High Corruption * Good IRA					-0.16** (0.067)
Low Corruption * Good IRA					-0.076** (0.035)
High Corruption * Bad IRA					0.058 (0.059)
Low Corruption * Bad IRA					0.19*** (0.038)
Observations	1359	1359	1359	1359	1359
Number of firms	153	153	153	153	153
Adjusted $R^2$	0.35	0.36	0.37	0.37	0.37

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

tion is at the average sample level. On the other hand, the significant coefficient on the private dummy suggests private firms are more efficient than public ones at average corruption levels.

In column (2) we introduce our measure of regulatory governance, ERGI, both linearly and interacted with corruption. We observe that the linear term is significant and negative, suggesting that better regulatory governance is associated with more efficient firms. However, the term on ERGI interacted with corruption is insignificant and very close to zero, suggesting that this measure of regulatory governance is not particularly effective at reducing the effect of corruption. In this regression, the corruption multiplied by the IRA term also becomes insignificant due to its close correlation with the IRA dummy, but the two terms together are significantly different from zero.

Column (3) considers regulatory governance in a different way, by creating a binary measure of governance rather than using a continuous variable. The 'Bad IRA' dummy here indicates the presence of an IRA which is in the bottom 30 % of regulators scored on ERGI, whilst the 'Good IRA' dummy represents the presence of an IRA which has an ERGI placing it in the top 70 % of regulators.<sup>15</sup> It is interesting to note that the coefficient on the 'Bad IRA' dummy is significantly positive whilst that on the 'Good IRA' dummy is significantly negative, again suggesting that governance is important in determining the effect on efficiency of creating an IRA. On the other hand, the coefficients on the two terms interacted with corruption are almost identical, suggesting that both types of regulator are equally good at mitigating the effect of corruption. In column (4) we therefore run the regression using a simpler specification where these two coefficients are assumed to be equal.

Column (5) then uses a binary version of corruption to replace the continuous version previously used. The 'High corruption' dummy takes a value of 1 if the firm is in an environment with above average corruption (i.e. a positive value of corruption) and a value of 0 if the firm is in an environment with below average corruption (i.e. a negative value). We can see that using such a binary value does not change our results

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<sup>15</sup>The 30/70 split was chosen as it maximises the difference between the coefficients on the two linear terms. The difference between the two coefficients however remains strongly significant for a range of other ways of splitting the sample of regulators by ERGI.

qualitatively. Moreover, we can also use this column to consider the net effect of creating an IRA under various scenarios. From the significantly negative coefficient on the High Corruption \* Good IRA term, this suggests that creating a well-governed IRA in a high corrupt environment will increase efficiency. On the other hand, it appears that creating a badly governed IRA in a low corrupt environment may significantly worsen efficiency. This emphasises the importance that governance and corruption have on the performance of a newly created IRA.

Let us consider the size of these described effects by studying the coefficients on the variables in column (5). Focusing on the coefficient on corruption, the value of .21 suggests that an increase in measured corruption of one standard deviation (.82) produces a 19% increase in the amount of labour employed for a given amount of outputs. This effect is slightly larger than that found by Dal Bó and Rossi (2007). However, this assumes that the firm is publicly owned and not subject to regulation by an IRA. If the firm was private, then this effect is reduced by about 40%. Alternatively, if the firm was public but subject to regulation by an IRA, then the effect is reduced by about two thirds. Our average effect across all firms is therefore slightly smaller than that found by Dal Bó and Rossi (2007), which is consistent with the fact that our later sample contains a greater proportion of private firms and firms regulated by an IRA. The importance of governance is also substantial - being regulated by a 'Good IRA' rather than a 'Bad IRA' reduces the number of employees by about 10 %.

Of course, all of these empirical estimates should be taken with caution, since the point values are not precisely estimated and in reality the interaction effects are likely to be much more complex.<sup>16</sup> Nonetheless, they do suggest that the factors considered in the analysis each have a very strong economic importance, and that the impact of institutional reforms can be large. Indeed, the empirical results indicate that corruption significantly reduces the efficiency of firms, but that this effect can be significantly mitigated by the creation of an IRA and private ownership. In addition, the effect on efficiency of an independent regulator appears to be dependent on its

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<sup>16</sup>Moreover, as pointed out by Dal Bó and Rossi (2007) and Mauro (1995), it is not clear that perception indices such as that of corruption truly form a cardinal measure. If instead we interpret the index as ordinal, it is clear that we would not expect the same effects from a jump in corruption from 0.1 to 0.2 as an increase from 0.7 to 0.8, for example.

governance, with better governed IRAs regulating more efficient firms. Let us now consider the robustness of these results by running a series of further regressions.

In Table 6 we take the specification given in column (4) of Table 5 and introduce a number of other controls. In particular, in columns (2)-(4), we include a range of dummies which we interact with our variables of interest.<sup>17</sup> In column (2), we allow for firms to react differently to corruption by interacting corruption with firm dummies, whilst in column (3) we allow for the effect of corruption to change over time by including corruption multiplied by year dummies. In column (4) we allow for the effect of a creation of an IRA to vary across provinces (and hence we can no longer estimate the effect of governance, since this only varies across provinces and not across time once an IRA has been created). In column (5) we allow for the effect of privatisation to vary across countries, and finally in column (6) we allow for country-specific trends in efficiency.

In general, we can see that most of the coefficients remain significant when the regression is generalised in these various ways. In column (2), for example, the fact that there is no reduction in the size of the corruption \* Private or corruption \* IRA coefficients shows that these results are being driven by firms who change ownership or regulation over the period. Similarly, in column (3), we see that our results are not being driven by sample-wide changes over time in the relationship between corruption and efficiency.

Notably however, the corruption \* IRA term becomes insignificant when the IRA dummy is interacted with province dummies, which suggests that a significant part of this result is driven by differences in corruption between countries. In other words, the time variation in corruption is not sufficient to give significance to this coefficient, although the coefficient does not change significantly. Given that corruption is only measured at the country level, and differences in measured corruption between countries are generally greater than those over time within countries, this is not surprising. Within the sample, the standard deviation of corruption between countries is .73,

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<sup>17</sup>In these columns, the coefficients reported in the space of the interacted terms are the 'average effect'. For example, in column (2), the corruption coefficient is the average affect of corruption across all firms, with the appropriate standard deviation.

Table 6: **Baseline Regression with Extra Control Variables**

	(1)	(2)	(3)	(4)	(5)	(6)
Corruption	0.21*** (0.028)	0.34*** (.017)	0.21*** (0.015)	0.18** (0.081)	0.20*** (0.026)	0.15*** (0.038)
Corruption * Private	-0.084*** (0.023)	-0.26*** (0.057)	-0.10*** (0.026)	-0.077*** (0.023)	-0.054** (0.021)	-0.062** (0.024)
Corruption * IRA	-0.14*** (0.027)	-0.14*** (0.027)	-0.13** (0.051)	-0.10 (0.084)	-0.15*** (0.023)	-0.10*** (0.030)
Private dummy	-0.27*** (0.035)	-0.28*** (0.038)	-0.27*** (0.035)	-0.27*** (0.043)	-0.25*** (0.026)	-0.21*** (0.037)
Bad IRA dummy	0.11*** (0.036)	0.12*** (0.041)	0.12*** (0.042)		0.14*** (0.038)	0.057 (0.038)
Good IRA dummy	-0.12*** (0.039)	-0.14*** (0.041)	-0.12*** (0.038)		-0.15*** (0.031)	-0.12*** (0.042)
Corruption * firm dummies		Y				
Corruption * year dummies			Y			
IRA * province dummies				Y		
Private * country dummies					Y	
Country trends						Y
Observations	1359	1359	1359	1359	1359	1359
Number of firmcode	153	153	153	153	153	153
Adjusted $R^2$	0.37	0.45	0.37	0.40	0.41	0.38

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

whereas within countries it is .5.

Finally, when we allow for country specific time trends in efficiency, we see that the coefficient on the 'Bad IRA' dummy loses significance. However, since this coefficient is still significantly different from that on the 'Good IRA' dummy, we can still conclude that regulatory governance is an important determinant of efficiency.

Overall therefore, three main conclusions arise from this econometric analysis. First, corruption appears to significantly reduce labour efficiency. Second, this effect is mitigated if the firm is either privately owned or there exists an Independent Regulatory Agency. Third, firms operating under an IRA with a higher level of regulatory governance operate more efficiently. In the next section, we aim to consider whether these results are robust to changes in the assumptions or methodologies.

## 5 Robustness Checks

### 5.1 Extra Control Variables

One concern of the results above may be that the variables included are correlated with other omitted variables that affect firm efficiency. In order to check for this problem, one can introduce other variables into the equation and observe whether the coefficients on the original variables are affected.

In order to test for omitted variable bias, we need to check that neither the IRA dummies, private ownership nor corruption are proxying for omitted variables. Since in our baseline regression we include IRA dummies linearly and interacted with corruption, to test for omitted variable bias in these coefficients we include a range of country-level control variables along with a term interacting the control variable with corruption.<sup>18</sup> This includes variables such as GDP per capita, national wage levels and urbanisation. A selection of these variables and their sources are given in Appendix B. Since private ownership is also included linearly and interacted with corruption, this also tests for omitted variable bias in the coefficients on the terms involving ownership.

Running the baseline regression with interactions (column (6) in Table 6) we find that many of these variables and their interactions are significant when introduced. However the corruption \* IRA and corruption \* Private terms always remains significant, and we can therefore conclude that these interaction terms are not proxying for any other country level variable. Moreover, the difference between the 'Bad IRA' dummy and the 'Good IRA' dummy always remains significant, and hence we conclude that governance is not proxying for an alternative country-level variable.

To test whether corruption is proxying for an alternative variable, I next include each control variable with its interaction with both private ownership and the IRA dummy. Again, many of the variables and their interactions are significant. It is also the case that on occasion one of the three corruption terms (i.e. either corruption, corruption

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<sup>18</sup>We do not include other regulatory-level variables as these will be investigated further in future work we explore in more detail what aspects of regulation are driving the results.

x ERGI or corruption X private ownership) become insignificant, particularly when the sample size is substantially reduced. However, of most concern to us is whether one or more of the of the corruption terms become insignificant at the same time as the relevant control term becomes significant. For example, if corruption x IRA were to become insignificant but retain a similar coefficient when GDP per capita and its interactions were introduced, we would only be really concerned if the GDP per capita x ERGI term was significant. If this were not the case, then it is likely just to be that the introduction of other highly correlated variables are reducing the significance of corruption x IRA term. If the GDP per capita x IRA term was significant, however, then we may worry that the significance of the corruption x IRA term in the baseline regression was being driven by the correlation between GDP per capita and corruption.

For almost all of our control variables, this is not the case. On the few occasions where one of the corruption terms becomes insignificant, the corresponding control variable term is also insignificant. Overall therefore, we can conclude that our results are likely to be being driven by omitted variable bias.

## **5.2 Instrumental Variables**

One way to control for any potential endogeneity of the key explanatory variables is to use an instrumental variable approach. Although I believe that problems of reverse causality and omitted variables are not likely to affect the corruption or regulatory governance terms, such possibilities cannot be ruled out. In this section we therefore instrument separately for corruption, regulatory governance and ownership using a variety of instruments.

In terms of corruption, Dal Bó and Rossi (2007) find no evidence that corruption is endogenous, and indeed reverse causality seems unlikely since I am looking at the performance of firms in just one sector and corruption in the entire country. Shocks that affect the whole economy of a country in a specific year are likely to be captured by the use of control variables such as GDP per capita. However, since we cannot

rule out the possibility of endogeneity, I check for robustness by instrumenting the measure of corruption.

Regulatory governance is perhaps more prone to problems of reverse causality since it may be that a firm's performance influences decisions about regulatory governance. However, I do not believe that this is likely to be responsible for the positive effect of regulatory governance on efficiency. Partly, this is because such a reverse influence is likely to occur over the longer-term and will hence be captured by firm fixed effects. I also believe that the effect of omitted variables is likely to be picked up by the country-level controls used in the previous subsection. Nonetheless, I check for robustness by instrumenting for regulatory governance since I can not completely rule out endogeneity.

Ownership is perhaps the variable most likely to suffer from problems of reverse causality. It may well be that only the most efficient firms are privatized, which would produce a negative coefficient on the private ownership term. Moreover, it may be that this is felt particularly in corrupt environments if, for example, corrupt governments are most interested in taking a cut from large sales revenues. This, in turn, would produce a negative coefficient on the (Corruption \* Private Ownership) term, as we have found above. It is therefore particularly important to attempt to instrument for ownership.

In order to instrument for corruption, I require variables that are correlated with corruption but not directly correlated with firm efficiency. I use two variables to instrument for corruption, since this is useful to test for the validity of each one. The first is the number of years remaining in the government's term, taken from the Database of Political Institutions constructed by Beck et al. (2001). I find this variable to be negatively correlated with corruption, presumably reflecting the tendency of governments to become more corrupt the longer they remain in power. The second variable I use is the average years of higher education amongst the population, which I also find to be negatively correlated with corruption. Both of these variables should not have any direct effect on firm performance, and indeed when entered into the regression along with the appropriate interaction terms (e.g. term remaining x IRA dummy, term

remaining x ownership) we find that they are all insignificant, which suggests that they are valid instruments.

In order to instrument for regulatory governance I require two instruments since I am simultaneously instrumenting for the existence of a regulator and the governance index. I therefore use measures of regulatory governance in two other sectors, telecoms and water, since I believe the governance of these sectors is likely to be related to that of the electricity sector.<sup>19</sup> Moreover, firm performance in the electricity sector will almost certainly not influence regulatory governance in other sectors, at least in the short term. For the telecoms sector, I use an index of regulatory governance constructed by Gutiérrez (2003b). For water, I use a simple dummy which indicates whether an IRA exists regulating the water sector, as well as the number of years ago that the regulator was created, which I take from Estache and Goicoechea (2005). Each of these two variables, and their interactions with corruption, are insignificant when included as controls in the baseline regression, supporting the belief that they are exogenous.

Finding valid and informative instruments for private ownership is unfortunately the most difficult, since this is a firm level variable, and the other firm-level variables we have are themselves likely to be endogenous with respect to efficiency or affect efficiency directly. We therefore have to use instruments that are measured at the province or country level. At the province level, we use the number of years since Private Participation in Infrastructure (PPI) has existed in the country/province, excluding the energy sector. This is constructed from the World Bank's PPI Project Database, with the six potential sectors being water, telecoms, roads, airlines, sea ports and railways. This gives us an indication of a province or country's tendency to privatize network infrastructure generally, which should not be affected particularly by the performance of the electricity distribution sector. As a second variable, we use a measure of economic globalisation constructed by Dreher (2006a). This is likely to be positively correlated with privatization since countries that are more open to international finance will find privatization more profitable. Again, both variables and their

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<sup>19</sup>I am very grateful to Antonio Estache and Luis H. Gutierrez for providing me with access to their data.

interaction terms are insignificant when entered as controls into the regression, which reassures us they are valid.

The results of the two-stage least squares regressions are presented in Table 7, where the variables included are the same as in column (1) of Table 6. In column (2), I instrument for the three corruption terms, in column (3) for the two regulator dummies and the corruption x IRA term and in column (4) for private ownership and the corruption x ownership term. In each case, the instruments are interacted with the appropriate variable(s) and these new variables are also included as instruments. For example, in column (4) we instrument for both the private ownership term and the (private ownership \* corruption) term, with the instruments being the two described above along with these variables multiplied by corruption. To make this clear, the coefficients of instrumented for terms are displayed in bold. The results of the first stage regressions are reported in the Appendix C.

From Table 7 we can see that the coefficients generally keep the same sign as in the baseline equation, with most of them remaining significant. The exception is the Corruption \* Private ownership term, which is insignificant in columns (1) and (3), when corruption and ownership are being instrumented for respectively. Though this is likely to mainly stem from the weakness of the instruments, it does perhaps suggests that we should be less confident of the positive results of privatization in mitigating the adverse impact of corruption on efficiency than those of good regulatory governance. Overall however, the coefficients suggest that treating the variables as endogenous does not change things substantially.

In the lower rows of Table 7 are the results of various tests of the validity of various assumptions. In order to test whether the instruments are sufficiently strong, the Kleibergen-Paap Wald rank F statistic is calculated. One advantage of instrumenting with more instruments than endogenous explanatory variables is that we can test the validity of the instruments using the Sargan-Hansen test. The joint null hypothesis under this test is that the instruments are valid, i.e., uncorrelated with the error term. The p-statistic for this test is displayed in the table, and we can see that in none of

Table 7: Instrumenting for Corruption and Regulatory Governance

	Instrumenting for:			
	(1)	Corruption (2)	Regulator & ERGI (3)	Ownership (4)
Corruption	0.21*** (0.028)	<b>0.47***</b> (0.15)	0.23*** (0.076)	0.14** (0.061)
Corruption * Private	-0.084*** (0.023)	<b>-0.12</b> (0.083)	-0.073*** (0.020)	<b>0.0060</b> (0.075)
Corruption * IRA	-0.14*** (0.027)	<b>-0.30**</b> (0.13)	<b>-0.17**</b> (0.077)	-0.12*** (0.046)
Private dummy	-0.27*** (0.035)	-0.25*** (0.030)	-0.26*** (0.044)	<b>-0.40***</b> (0.12)
Bad IRA dummy	0.11*** (0.036)	0.029 (0.064)	<b>0.29***</b> (0.10)	0.15*** (0.046)
Good IRA dummy	-0.12*** (0.039)	-0.19*** (0.059)	<b>-0.15</b> (0.15)	-0.054 (0.062)
Observations	1359	1347	1359	1359
Number of firms	153	151	153	153
$R^2$	0.3776	0.2097	0.2548	0.2417
Kleibergen-Paap Wald rank F statistic		5.31	7.92	14.1
Endogeneity test p-value		0.27	0.16	0.23
Hansen J instrument exogeneity test p-value		0.75	0.25	0.43
p-value of underidentification LM statistic		2.2e-06	1.7e-09	0

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

the three cases do we have grounds to reject the assumption that the instruments are valid.

Finally, I would like to test whether corruption, regulatory governance and private ownership index are indeed exogenous. To do so, the difference of two Sargan-Hansen statistics is calculated, one for the equation where the variables are instrumented, and one for the non-instrumented equation. The p-value resulting from the associated test is above 0.1 in all the equations, and hence we cannot reject the null hypothesis that corruption and regulatory governance can be treated as exogenous. Alternatively, we can test for the endogeneity of the variables by running Hausman tests comparing the baseline regression with each of the IV regressions. In each case, there is not sufficient evidence to reject the null hypothesis of non-systematic

differences in the coefficient. I therefore conclude that it is reasonable to treat all of the variables as exogenous.

### 5.3 Ownership differences

A further question of robustness is whether the results above apply to firms in both the public and private sectors. Table 8 shows the result of the regressions where we split the sample by ownership. The first of the three columns contains all firms, whilst the second contains private firms and the third public firms. Firms whose ownership changes over the period are split appropriately - those years in which they are privately owned are included in the second column, whilst those years during which they were publicly owned are included in the third column.

Table 8: **Ownership differences**

	(1) All	(2) Public	(3) Private
Corruption	0.21*** (0.036)	0.13** (0.064)	0.19*** (0.028)
Corruption * IRA	-0.19*** (0.035)	-0.11 (0.069)	-0.14*** (0.026)
Bad IRA dummy	0.10** (0.049)	-0.024 (0.100)	0.051 (0.047)
Good IRA dummy	-0.23*** (0.036)	0.071 (0.044)	-0.16*** (0.053)
Observations	1359	668	691
Number of firmcode	153	93	113
Adjusted $R^2$	0.30	0.22	0.35

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Looking at columns (1) to (3), we can see that corruption appears to significantly worsen efficiency for both types of firm. The effect is of a smaller magnitude for private firms, which is consistent with the previously found significantly negative coefficient on the corruption \* private term. The corruption \* regulator term is similar across both types of firms, suggesting that it is reasonable to assume the effect is common between the two. The lack of significance within the private firm sample most probably

reflects the lack of private firms that are not regulated by an IRA. It is also worth noting that the importance of regulatory governance appears to be driven by public firms. Again, this is likely to be partly a result of the difficulty in identifying the effect of regulation on private firms when there is little time variation.

#### 5.4 Serial correlation

The model above is static, in that it only allows for variables at the current moment in time to affect current efficiency. If variables are correlated over time, then such a model may be inappropriate. To consider whether serial correlation in the residuals affects the results, we can cluster standard errors at the firm level, which allows for the error term to be correlated within these clusters. Table 9 presents the results of clustering by firm in the second column, with the first column repeating the results of column (1) in Table 6 for comparison.

Table 9: **Serial correlation**

Clustering:	(1) Country-year	(2) Firm
Corruption	0.21*** (0.028)	0.21*** (0.039)
Corruption * Private	-0.084*** (0.023)	-0.084*** (0.022)
Corruption * IRA	-0.14*** (0.027)	-0.14*** (0.036)
Private dummy	-0.27*** (0.035)	-0.27*** (0.044)
Bad IRA dummy	0.11*** (0.036)	0.11* (0.063)
Good IRA dummy	-0.12*** (0.039)	-0.12** (0.047)
Observations	1359	1359
Number of firms	153	153
Adjusted $R^2$	0.37	0.16

Robust standard errors in parentheses

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

Clearly, allowing for serial correlation only affects the estimated standard errors, and not the values of the coefficients. From Table 9, we can see that the significance

of most of the coefficients do not change substantially. Though the significance of the two IRA dummies is reduced, the difference between them is still highly significant. We can therefore infer that our result is robust to the presence of serial correlation in the residuals.

### **5.5 Alternative estimation techniques**

To help understand the results further, I carry out the baseline regression using alternative estimation techniques. Table 10 presents four regressions. Column (1) is the baseline equation estimated using the fixed effects estimator (i.e. as column (1) in Table 6), column (2) uses the random effect estimator and column (3) considers between effects. Finally, column (4) runs the regression as a pooled ordinary least squares (OLS).

From Table 10, we can see that under the random effects model all the reported coefficients remain significant, as they are using pooled OLS. Indeed, the coefficients shown in Table 10 are very similar in the fixed effects and the random effects models. However, this is not the case with the coefficients on the translog function. Given the large variation in firm size, this is not surprising. As a result, a Breusch-Pagan Lagrangian multiplier test for random effects therefore rejects the null hypothesis that the random effects model is consistent and hence supports our decision to use a fixed effects approach.

In the between effects model in column (3), all the reported coefficients (bseare insignificant. This suggests that our previous results are driven by changes within firm's efficiency levels more than differences in efficiency between firms.

### **5.6 Alternative LHS variables**

In the baseline regression, we have measured efficiency by estimating a labour requirement function. A simpler method would be to use a LHS variable that itself proxies efficiency. Two potential variables are the number of MWh sold per employee and the number of residential connections per employee. Using these measures has

Table 10: **Alternative estimation techniques**

	(1)	(2)	(3)	(4)
	FE	RE	BE	OLS
Corruption	0.19*** (0.027)	0.19*** (0.032)	-1.83 (1.27)	0.33*** (0.050)
Corruption * Private	-0.081*** (0.023)	-0.079*** (0.024)	-0.23 (0.28)	-0.14** (0.051)
Corruption * IRA	-0.12*** (0.025)	-0.13*** (0.030)	2.17 (1.41)	-0.15** (0.057)
Private dummy	-0.26*** (0.035)	-0.28*** (0.037)	-0.74*** (0.14)	-0.54*** (0.041)
Bad IRA dummy	0.13*** (0.040)	0.16*** (0.044)	0.069 (0.40)	0.022 (0.098)
Good IRA dummy	-0.11*** (0.037)	-0.12*** (0.038)	-0.023 (0.38)	-0.32*** (0.066)
y_1	-1.71** (0.68)	-1.15* (0.68)	-1.80 (1.71)	0.097 (0.82)
y_2	4.52*** (1.10)	2.89*** (0.84)	2.46 (2.13)	0.36 (1.10)
y_1Xy_2	0.22** (0.100)	0.17* (0.099)	0.36 (0.26)	0.082 (0.12)
y_1SQ	-0.067 (0.046)	-0.055 (0.045)	-0.18 (0.12)	-0.059 (0.060)
y_2SQ	-0.21*** (0.067)	-0.14** (0.059)	-0.18 (0.15)	-0.016 (0.071)
Observations	1346	1346	1355	1355
Number of firms	150	152	152	

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

the disadvantage that we are essentially assuming a more restrictive functional form for the labour requirement function, but may be a useful robustness check if we are concerned about the potential endogeneity of the output variables.<sup>20</sup> The results of using this approach can be seen in columns (1) and (2) of Table 11.

Columns (3)-(8) then explore the impact of our variables of interest on other performance variables. Columns (3) and (4) put residential and industrial tariffs on the LHS respectively to attempt to gage whether the impact of corruption and regulation on efficiency translate through to prices. Columns (5) - (7) then consider various measures of quality, looking at the frequency and duration of interruptions as well as the

<sup>20</sup>This approach is closer to that used in Andres et al. (2008).

percentage of electricity that is lost through distribution. Finally, column (8) considers a measure of capital expenditure to investigate whether corruption, ownership or regulation appear to impact upon investment. In these regressions, we no longer include a translog function on the RHS - hence the only variables included are those reported along with year dummies.

Table 11: Alternative LHS variables

LHS:	(1) MWh / Employees	(2) Connections / Employees	(3) Residential Tariffs	(4) Industrial Tariffs	(5) Interruption Frequency	(6) Interruption Duration	(7) Losses	(8) ln(CAPEX)
Corruption	-0.17*** (0.049)	-0.22*** (0.042)	14.5** (6.66)	40.4** (16.1)	-5.92 (15.0)	-7.34 (17.6)	0.031 (0.97)	0.30 (0.26)
Corruption * Private	0.024 (0.023)	0.089*** (0.020)	-1.37 (1.87)	-7.15** (2.85)	1.68 (4.45)	1.37 (4.97)	1.11** (0.46)	-0.19** (0.087)
Corruption * IRA	0.15*** (0.047)	0.15*** (0.041)	-13.2** (6.59)	-35.6** (16.2)	1.31 (14.6)	1.31 (17.2)	-0.52 (0.93)	-0.058 (0.25)
Private dummy	0.32*** (0.029)	0.29*** (0.025)	-6.80*** (2.26)	-3.25 (4.67)	-11.6* (6.40)	-16.2** (7.03)	-1.20** (0.60)	0.0072 (0.17)
Bad IRA dummy	-0.23*** (0.047)	-0.100** (0.040)	14.3*** (4.34)	6.04 (8.89)	-14.9 (10.7)	-21.0* (12.5)	6.28*** (0.93)	0.51* (0.29)
Good IRA dummy	0.090** (0.041)	0.13*** (0.035)	-19.0*** (3.51)	-13.7* (7.18)	-21.8*** (8.08)	-20.5** (9.40)	-0.069 (0.84)	0.64*** (0.18)
Observations	1373	1373	979	571	777	810	1218	535
Number of firmcode	160	160	130	78	119	120	149	101
Adjusted $R^2$	0.39	0.50	0.25	0.096	-0.12	-0.14	-0.019	0.055

Standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

When looking at columns (1) and (2) of Table 11, we should note that we would expect the signs on the coefficients to be reversed compared to our earlier regressions. This is because earlier we were measuring the effect of these variables on labour given various outputs (i.e. inefficiency) whereas here we are measuring their effects on the amount of output produced per worker (i.e. efficiency). Looking at these columns, we see that this is indeed generally the case. In both regressions, corruption has a significant negative effect on the efficiency measure, and this effect is significantly reduced by the presence of an IRA. We also find, as before, that private ownership and better regulatory governance significantly improves efficiency. These regressions therefore suggest our results are in general robust to the precise way we have measured labour efficiency.

Columns (3) and (4) clearly suggest that the effect of corruption on efficiency feeds through directly into prices. Both residential and industrial prices are significantly higher in more corrupt environments, though this effect is reduced by the presence of an IRA. The effect of governance also appears to follow through, with the creation of good IRAs resulting in significantly lower prices when compared to 'bad' IRAs. We can therefore interpret this as hinting that consumers are reaping some of the gains of efficiency improvements noted previously. This may also suggest a mechanism for the effect of good governance, since it may be that price decreases enforced by the regulator are the driver behind the firm deciding to operate more efficiently.

One concern that we may have had previously was that our dependent variable, 'excess labour', might not have been 'excess', but instead employed to raise quality or investment that we did not control for. The results presented in columns (5)-(8) go some way to alleviating this concern. Coefficients involving corruption are only significant in columns (7) and (8), where they suggest that private firms in corrupt environments lose more electricity and invest less. Moreover, the introduction of a well governed regulator appears to significantly increase quality as well as increase capital expenditure. Indeed, even a badly governed regulator appears to increase investment and decrease the duration of interruptions, suggesting that the previously

found positive effect on labour employed may not be entirely an 'efficiency effect'. However, there is a significant difference between the two types of IRA when it comes to losses (column (7)), which suggests that it is still reasonable to infer that better governance leads to greater efficiency.

## 5.7 Other robustness checks

I have carried out various other permutations of the baseline equation, including:

- Carrying out the regressions without individual years or countries in the sample, to check that the results are not being driven by a particular country or year
- Shifting forward the year in which the regulator comes into existence, to consider the fact that a regulatory may become operational only sometime after its official creation
- Replacing the variable MWh sold with (MWh sold + losses), to reflect the fact that the amount of electricity lost varies between firms
- Using a Cobb-Douglas function rather than the translog used above
- Including the length of the distribution network in the translog function
- Weighting by firm size and splitting sample into firms that are small (i.e. below median amount of electricity sold) and firms that are large (i.e. above median amount of electricity sold)

In each of these permutations, the Corruption, Corruption \* ERGI and Corruption \* Private terms remain significant with the expected signs.

## 6 Conclusions and Future Work

In conclusion, the empirical analysis has delivered four main results.

First, corruption at the national level appears to have a significantly negative effect on the efficiency of the electricity distribution firms in the sample. The results suggest

that an increase in the level of country-wide corruption by one standard deviation may lead to a 19 % increase in the number of employees needed for a given level of outputs, if the firm is public and not regulated by an IRA. This result confirms that of Dal Bó and Rossi (2007) and adds to the increasing evidence that corruption can be detrimental for the performance of utilities.

Second, the effect of corruption on efficiency is smaller for private firms than public ones by about 40%. Though this suggests that privatization may be a way to reduce the negative effect of corruption, we should be cautious when making this prediction, since the significance of this result disappears when we attempt to control for the possible endogeneity of private ownership.

Third, the introduction of an Independent Regulatory Agency may reduce the effect of corruption by about 65 %. This result is robust to controlling for firm specific corruption effects and instrumenting for both corruption and the existence of an IRA.

Fourth, the efficiency of firms appears to depend directly on the quality of regulatory governance. Indeed, the results suggest that the creation of an IRA that is badly governed may even damage efficiency relative to direct government regulation. This emphasizes the need to go beyond focusing solely on the existence of an agency when measuring the effect of reform.

These results are interesting as they demonstrate the importance of the institutional environment on firm performance. Moreover, they show that negative effects of the general macro institutional context (in this case corruption) can be significantly reduced with well-designed micro-level institutions (in this case electricity regulators). This is a promising result because it adds hope that there are effective ways that the problems caused by corruption can be reduced.

## Appendix A: Estimating the translog function

Table 12: **Translog function**

	(1) Full sample	(2) Public firms	(3) Private firms
y_1	-1.93** (0.77)	-2.68*** (0.85)	-2.03** (0.96)
y_2	5.80*** (1.31)	4.61*** (1.17)	4.08*** (1.48)
y_1Xy_2	0.21** (0.11)	0.32** (0.13)	0.35*** (0.13)
y_1SQ	-0.047 (0.047)	-0.096 (0.067)	-0.15*** (0.051)
y_2SQ	-0.26*** (0.076)	-0.26*** (0.076)	-0.22** (0.093)
Observations	1353	662	691
Number of firms	152	92	113
Adjusted $R^2$	0.25	0.20	0.31

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## Appendix B: Selection of additional country control variables

Control variable	Description	Source
GDP per capita	Constant 2000 US\$	World Bank (2009)
Workers compensation	Employees compensation / GDP	World Bank (2009)
Population density	People per square km	World Bank (2009)
Fuel Exports	% of merchandise exports	World Bank (2009)
Urbanisation	Urban population / total	World Bank (2009)
Trade	Imports & Exports / GDP	World Bank (2009)
Shadow Economy	Share of total GDP	Schneider (2007)
Length of office	Yrs ruling party in power	Beck et al. (2001)
Executive orientation	Left-wing/central/right-wing	Beck et al. (2001)
Separation of powers	Does the party of the executive control legislature?	Beck et al. (2001)
Elections	Dummy for election year	Beck et al. (2001)
World Bank presence	Number of WB projects	Boockmann and Dreher (2003)
IMF presence	IMF agreement dummy	Dreher (2006b)
Legislative effectiveness	Index	Norris (2009)
General strikes	Number of strikes	Norris (2009)
Workers Rights	Index	Cingranelli and Richards (2009); Teorell et al. (2009)
Government deficit	% of GDP	Easterly (2001); Teorell et al. (2009)
Accountability	Index	Kaufmann et al. (2009); ICRG
Political Stability	Index	Kaufmann et al. (2009); ICRG
Regulatory Quality	Index	Kaufmann et al. (2009); ICRG
Rule of Law	Index	Kaufmann et al. (2009); ICRG
Judicial independence	Index	Gwartney and Lawson (2009)
Property rights	Index	Gwartney and Lawson (2009)
Credit market regulation	Index	Gwartney and Lawson (2009)
Labour market regulation	Index	Gwartney and Lawson (2009)
Business regulation	Index	Gwartney and Lawson (2009)
Financial development	Various measures	Beck et al. (2000)
Employment Elasticity	$\Delta$ Employment / $\Delta$ GDP	ILO (2009)
Unemployment	% of population	ILO (2009)
Aid	Total aid / GDP	Roodman (2005)
Education	Various measures	Barro and Lee (2001)
Inflation		ECLAC (2009)
Legal Origin		Porta et al. (2008)
Economic Freedom	Various indices	Holmes et al. (2008)
Political Rights	Index	Freedom House
Civil Liberties	Index	Freedom House
Freedom of the Press	Index	Freedom House
Globalisation	Various Indices	Dreher (2006a)
Democracy	Various indices	Marshall and Jagggers (2007)
Government spending	Government share of real GDP	Heston et al. (2009)

## Appendix C: First stage regressions for instrumenting

Regression: LHS:	(1)	(2)	(3)	(4)				
	Corruption	Corruption * Private	Corruption * IRA	Bad IRA	Good IRA	Corruption * IRA	Private	Corruption * Private
Term years left	-0.020 (0.041)	-0.020 (0.031)	0.074* (0.041)					
Average Years of Higher Education	-2.44 (1.54)	-1.19 (1.18)	-0.31 (1.56)					
Term years left * Private	0.00082 (0.025)	-0.10*** (0.019)	0.0042 (0.025)					
Years of Higher Ed * Private	0.62* (0.38)	1.09*** (0.29)	0.76** (0.38)					
Term years left * IRA	-0.054 (0.044)	0.053 (0.033)	-0.15*** (0.044)					
Years of Higher Ed * IRA	0.14 (0.42)	-0.26 (0.32)	-0.82* (0.43)					
Ingut_indexV				-0.12*** (0.028)	0.18*** (0.035)	0.076*** (0.025)		
Water IRA Age				-0.039*** (0.0028)	-0.017*** (0.0035)	0.018*** (0.0025)		
Water IRA				0.11*** (0.041)	0.031 (0.051)	-0.40*** (0.036)		
corXIngut_indexV				0.090*** (0.022)	-0.089*** (0.028)	0.22*** (0.020)		
Corruption * Water IRA Age				0.0060** (0.0025)	0.0077** (0.0032)	-0.013*** (0.0022)		
Corruption * Water IRA				-0.062** (0.026)	-0.096*** (0.033)	0.27*** (0.023)		
Years since first PPI							-0.0077*** (0.0011)	0.0028* (0.0014)
Economic Globalisation							0.0069*** (0.0020)	0.0069*** (0.0026)
Corruption * Years since PPI							0.00014 (0.00060)	0.0030*** (0.00077)
Corruption * Globalisation							0.0023* (0.0014)	0.0067*** (0.0018)
Observations	1347	1347	1347	1359	1359	1359	1368	1368
Number of firms	151	151	151	153	153	153	155	155
R <sup>2</sup>	0.0437	0.0446	0.0491	0.2034	0.1872	0.9512	0.1909	0.5769

Standard errors in parentheses  
 \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

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## Chapter 5

### Exploring further the effect of regulation on efficiency

#### 1 Introduction

The previous chapter established some significant results relating a firm's efficiency to its operating environment in the context of electricity distribution in Latin America. A key part of these results was the effect of the creation of an Independent Regulatory Agency (IRA). In particular, I found that the existence of an IRA appeared to mitigate the effect of corruption on the number of employees required to produce a given function of outputs. Moreover, the chapter showed that the level of governance of the IRA, as measured by the Electricity Regulatory Governance Index (ERGI), significantly affected efficiency, with less well governed IRAs regulating less efficient firms.

This chapter serves as an extension to the previous chapter, using the same data and methodology to explore the previous chapter's results further in a number of ways. First, in Section 2, I allow for the effect of an IRA to change depending on the number of years since it was created. Second, I break up our measure of regulatory governance (the ERGI) into its constituent components in Section 3 in order to understand further which aspects of governance are important in determining performance. Finally, Section 4 considers whether other properties of the firm or IRA are important in determining performance.

## 2 Timing

In the previous chapter, I essentially assumed a very static model of the effect of regulation and therefore ignored the possibility of the effect of regulatory governance changing over time. However, there are various reasons why we might expect the effect of an IRA to change over time. For example, as the regulator builds up interactions with the firm over time, regulatory capture may be facilitated. Martimort (1999) shows that this may, for example, lead to an increasing bureaucratisation of the regulator over the course of its life, as the threat of capture is warded off through the removal of discretion. On the other hand, Cubbin and Stern (2006) find that electricity generation firms invest more as a regulator ages, and argue that this is the effect of increasing experience and reputation within the regulator.

To explore the possibility of the effect of an IRA changing over time, I split our IRA dummy variables according to the age of the IRA. For example, rather than including a 'good regulator dummy' (which takes the value 1 iff there exists an IRA with a relatively good ERGI score), I include nine separate dummies - i.e. a dummy indicating the existence of a good IRA created this year, a dummy indicating the existence of a good IRA created one year ago, etc.<sup>1</sup> Since I have relatively few observations of regulators that have been created more than eight years ago, I include a single dummy for regulators with an age of eight years or greater. I then run our baseline regression (i.e. Column (1) of Table 2 in the previous chapter) with these new dummy variables both entered linearly and in the interaction with corruption. In order to allow for differences between private and public firms, I split the sample into two and run the regression separately on firms of each ownership type.

Figure 1 plots the coefficient on the corruption \* IRA dummy term by the age of the IRA. From the graph, we can see that there does not appear to be any significant change over time in the corruption mitigating effect of having an IRA. For both public and private firms, the coefficient generally remains between -.1 and -.15 - regulators created seven years ago are an exception, but these coefficients are imprecisely es-

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<sup>1</sup>As in the previous chapter, I define a 'good IRA' to be one with an ERGI in the top 70 %, since this appears to be the split that maximises the difference in effects. Nonetheless, our results are robust to using alternative splits.

estimated due to there being relatively few observations. Indeed, all of the coefficients are within two standard deviations of the previously estimated  $-.14$  coefficient, and a Wald test does not reject the hypothesis that all the coefficients are equal. Moreover, we can clearly see that there does not appear to be a difference in the corruption mitigating effect on private and public firms, and hence it is reasonable to assume that this coefficient does not vary by ownership type.

Figure 1: **Corruption \* IRA dummy by IRA age**

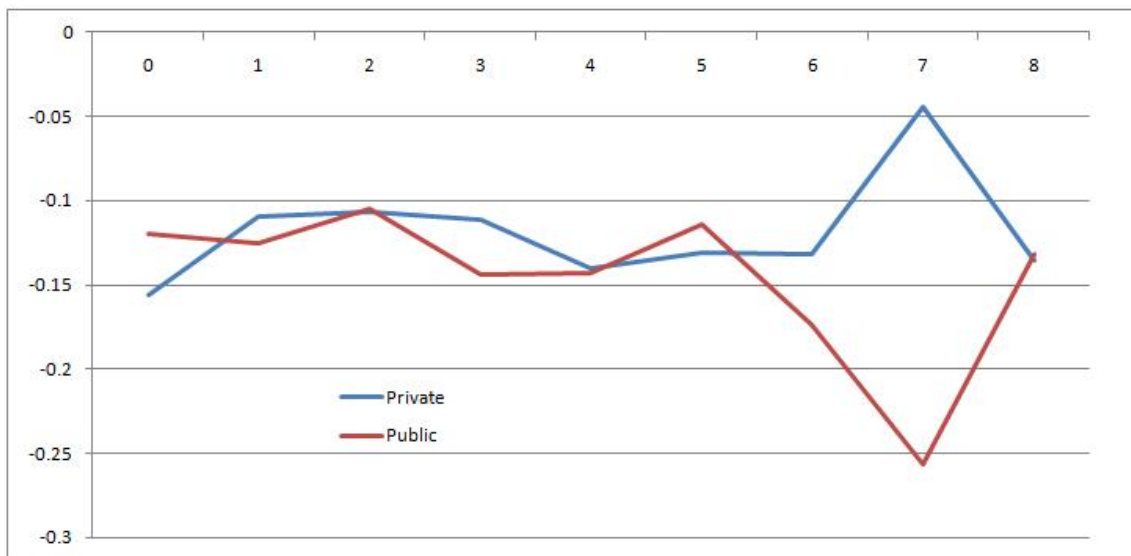
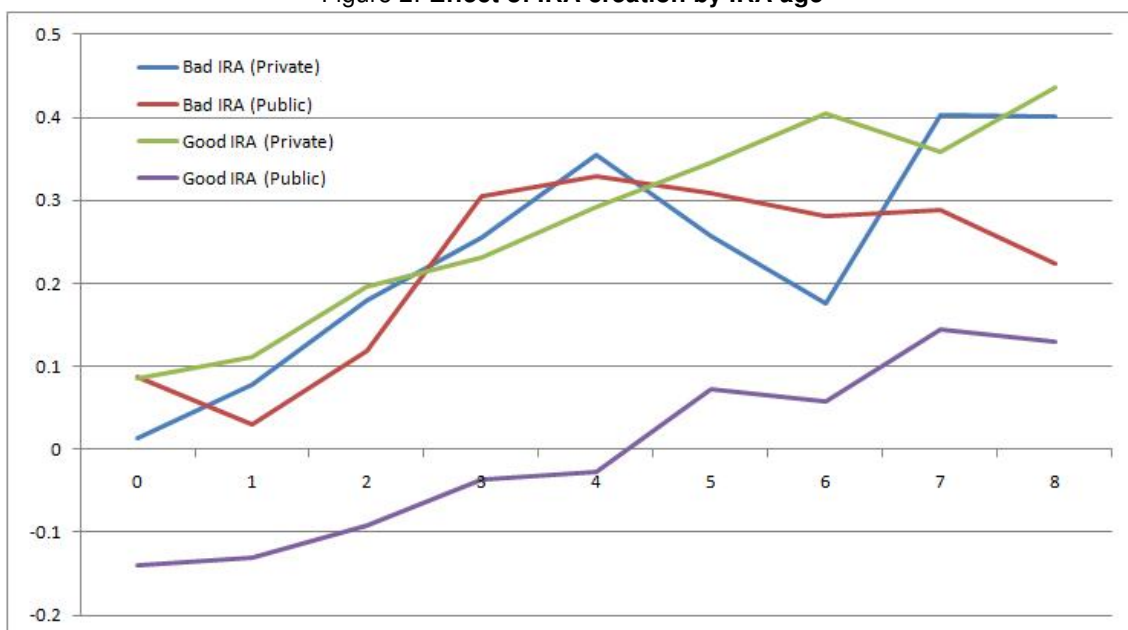


Figure 2 then plots the coefficients on both the 'Good IRA' and 'Bad IRA' terms that enter linearly. Here we can see that there appears to be a clear trend for both types of regulator on firms of both ownership types. In particular, as an IRA gets older, firms appear to become less efficient. Furthermore, for both types of regulators in both samples, a Wald test strongly rejects the assumption that the coefficients are the same over time.

Since the regressions include year dummies, this result is not driven by general trends in efficiency over time, though this does not rule out country or province specific trends. However, when we re-run the regression with province-specific trends included, we still find the same trend remaining, suggesting this is not being driven by an alternative omitted variable. Moreover, when we include dummies for the years before an IRA is created (e.g. a dummy if a good IRA will be created in a years

Figure 2: Effect of IRA creation by IRA age



time, a dummy if a good IRA will be created in two years time, etc.), there appears to be no trend in these dummies, and a Wald test does not reject the hypothesis that they are equal. This serves as further evidence that the results are not picking up a province-specific trend that is unrelated to the creation of an IRA.

It therefore appears that firms become increasingly inefficient after an IRA has been introduced. This appears to be true for both public and private firms and for 'good' as well as 'bad' IRAs, and the effect appears to be independent of the level of corruption in the country. One interpretation of this result is evidence for the capture or life-cycle model previously discussed. If the IRAs are become increasingly captured over time, they may become less effective at enforcing firms to be efficient. Alternatively, in line with the model of Martimort (1999), the IRA may be becoming more bureaucratic over time, which may result in less efficient firms. It is also consistent with Leaver (2009), who finds evidence that individual regulators become less effective over time as they approach the end of their term and hence face increasing career concerns.<sup>2</sup> However, we should be cautious in concluding that this trend is necessarily a negative one, since in the previous chapter we found some evidence

<sup>2</sup>Of course, this would suggest that the trend should reset once a new individual regulator had been appointed. However, given our limited observations for IRAs that are older than the average term limit of individual regulators, we cannot test for this.

that the creation of an IRA increased capital expenditures and quality. An alternative story explaining the effect might be, for example, that as a regulator gains in reputation, firms feel more comfortable investing, and hence employ extra people to increase future capacity. Unfortunately, we do not have the data to test between these various explanations of the discovered trend.

### **3 Governance**

In the previous chapter (and in the previous section) we have split firms into being 'good' and 'bad' depending on the Electricity Regulatory Governance Index constructed by Andres et al. (2007). We found that this was an informative measure of the effect of an IRA's creation on efficiency, but that it did not appear significant when interacted with corruption. In this section, we attempt to probe these results further by deconstructing the ERGI into its component parts.

The ERGI is constructed by Andres et al. (2007) in several stages. At its base is a questionnaire of about seventy questions related to regulatory governance. Most of these questions are then coded in a way that gives them a value between 0 and 1, with 0 representing 'badly governed' and 1 representing 'well governed'. Each of these coded questions is then labelled as measuring one of four aspects of regulatory governance: Autonomy, accountability, transparency or tools.<sup>3</sup>

Autonomy is defined as 'the procedures, mechanisms, and instruments aimed at guaranteeing the independence of the agency from political authorities, the autonomous management of its resources, and the regulation of the sector'. This includes questions such as whether the agency's independence is stated in legislation and where the agency receives its funding from.

Accountability is defined as 'the procedures, mechanisms, and instruments aimed at guaranteeing an adequate level of control of the agency's budget and performance

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<sup>3</sup>In the analysis of Andres et al. (2007), autonomy, accountability and transparency are each divided into formal and informal aspects, which roughly distinguishes between the existence of laws or statutes and their implementation. For example, formal autonomy includes whether any authority has the right to intervene in the agency, whilst informal includes whether or not any such intervention has taken place within the last five years. However, we do not use the split between formal and informal autonomy here, since we found it generally to be uninformative when entered into our regressions.

by political authorities, namely the Parliament'. This includes questions such as whether there is a mechanism for appeals and whether the agency's reports must be approved by the parliament.

Transparency is defined as 'the procedures, mechanisms, and instruments aimed at guaranteeing the disclosure and publication of relevant regulatory and institutional information, the participation of stakeholders in the agency's regulatory decisions and decision-making, and the application of rules aimed at governing the integrity and behavior of agency officials'. This includes questions such as whether there is a procedure for stakeholder participation and whether data is published publicly.

Finally, tools is defined as 'the instruments and mechanisms that contribute to the strengthening of different aspects of an agency's functioning and the quality of its regulations'. This includes questions such as whether the firm uses a benchmarking analysis and whether employees receive training.

Once questions have been assigned to one of these groups, Andres et al. (2007) construct an index for each aspect of governance by taking the average value of the coded questions in this category. Hence each IRA has a score between 0 and 1 for each aspect of governance - autonomy, accountability, transparency and tools. The ERGI is then calculated by taking an average across these four aspects of governance.

In this section, we move down a layer of aggregation to input each of these four components of ERGI into our regression directly. As with the ERGI term, these variables range between zero and one, taking a value of zero for all years where no IRA exists. We carry out this analysis separately for public and private firms, since we believe that aspects of governance may have differing effects depending on the ownership of the firm.

Table 1 considers the effect of entering various aspects of ERGI when considering public firms. Column (1) presents the baseline regression, whilst columns (2)-(5) enter each of the components of ERGI in turn together with them interacted with the corruption term. In these columns, two coefficients stand out as being highly significant.

When tools are entered into the regression in column (5), the coefficient on the linear term is highly significant, whilst the difference between the 'Good IRA' dummy and the 'Bad IRA' dummy becomes insignificant.<sup>4</sup> Furthermore, in column (2), the corruption x autonomy term is highly significant whilst the corruption x IRA dummy term becomes insignificant. Column (6) shows that these results are somewhat orthogonal when we introduce the two terms simultaneously, whilst column (7) shows the result does not depend on the inclusion of any of the insignificant terms. Finally, column (8) creates dummies for IRAs that have above or below average levels of tools/autonomy, and shows that the result also holds when we use these binary variables rather than the continuous indices, suggesting the results are not driven by IRAs with extreme values.

The significance of these two terms suggest that tools is the most significant factor in explaining the importance of governance on efficiency for public firms taking the level of corruption as given, whilst autonomy is important in mitigating the effect of corruption. The importance of tools for public firms may reflect the extent to which commercial incentives have been introduced in the sector, since without tools such as benchmarking analysis or performance based payments, public firms may face limited incentives to behave efficiently. The importance of autonomy in mitigating the effect of corruption may indicate that, the greater the separation between the IRA and the state, the less corruption in the government as a whole effects the IRA, and hence the weaker its effect on the firms performance.

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<sup>4</sup>Though not shown here, this is also occurs if we include the continuous ERGI term along with an IRA dummy rather than the two IRA dummies.

Table 1: Components of ERGI: Public firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Corruption	0.19*** (0.028)	0.16*** (0.032)	0.17*** (0.032)	0.18*** (0.026)	0.14*** (0.029)	0.11*** (0.032)	0.15*** (0.025)	0.086*** (0.016)
Bad IRA dummy	0.057 (0.047)	0.19 (0.35)	-0.18 (0.24)	0.34 (0.29)	0.44*** (0.13)	0.39 (0.38)		
Good IRA dummy	-0.16*** (0.052)	0.0055 (0.39)	-0.41 (0.27)	0.22 (0.37)	0.50*** (0.18)	0.43 (0.48)		
Corruption * IRA	-0.14*** (0.026)	0.14 (0.14)	-0.19** (0.089)	-0.12 (0.10)	-0.10 (0.081)	0.18 (0.14)		
Autonomy		-0.20 (0.48)				0.014 (0.47)		
Corruption * Autonomy		-0.34** (0.16)				-0.43** (0.17)	-0.13*** (0.028)	
Accountability			0.37 (0.37)					
Corruption * Accountability			0.089 (0.12)					
Transparency				-0.48 (0.48)				
Corruption * Transparency				-0.023 (0.13)				
Tools					-0.87*** (0.25)	-0.79*** (0.24)	-0.71*** (0.19)	
Corruption * Tools					0.024 (0.12)	0.14 (0.12)		
IRA dummy							0.37*** (0.11)	
Bad Tools IRA								0.051 (0.041)
Good Tools IRA								-0.15*** (0.052)
Corruption * Good Autonomy IRA								-0.079*** (0.022)
Observations	691	691	691	691	691	691	691	691
Number of firms	113	113	113	113	113	113	113	113
Adjusted $R^2$	0.35	0.36	0.36	0.35	0.36	0.36	0.36	0.36

Table 2 then carries out the same analysis for private firms. We include the singly IRA dummy, rather than separate 'Good' and 'Bad' IRA dummies, since previous analysis of the private firms suggested there was not a significant difference between the two dummies. Column (1) contains the ERGI index along with its interaction, whilst columns (2)-(5) include each of the various components. From column (2), we see that when the autonomy index is included, it is negative and highly significant, whilst the IRA dummy term becomes significantly positive. On the other hand, in columns (4) and (5) transparency and tools appear to increase inefficiency, particularly when interacted with corruption. In column (5) we include all of these variables together. Though individually the terms related to transparency and tools are insignificant, a Wald test rejects the hypothesis that they are all equal to zero. However, a test the coefficients on the 'transparency' and 'tools' terms are the same, along with the coefficients on the respective corruption interactions, is not rejected. We therefore construct a measure which takes the average value of the transparency and tools index, which we include in column (7) both linearly and interacted with corruption. Finally, in column (8), we again construct various dummies that take a value of one when an IRA has above or below average of autonomy / (transparency+tools).

Table 2: Components of ERGI: Private firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Corruption	0.14** (0.063)	0.14*** (0.054)	0.13** (0.065)	0.14* (0.071)	0.14** (0.065)	0.14* (0.073)	0.14* (0.072)	0.14** (0.062)
IRA dummy	-0.21 (0.29)	1.24*** (0.19)	-0.13 (0.20)	-0.33* (0.20)	-0.12 (0.15)	1.16*** (0.37)	0.99*** (0.20)	0.012 (0.067)
Corruption * IRA	-0.24*** (0.088)	-0.18** (0.087)	-0.16* (0.084)	-0.27*** (0.089)	-0.26*** (0.067)	-0.26*** (0.092)	-0.28*** (0.085)	-0.15** (0.065)
ERGI	0.38 (0.38)							
Corruption * ERGI	0.18* (0.094)							
Autonomy		-1.49*** (0.24)				-1.85*** (0.31)	-1.70*** (0.22)	
Corruption * Autonomy		0.089 (0.11)						
Accountability			0.29 (0.27)					
Corruption * Accountability			0.079 (0.055)					
Transparency				0.51** (0.25)		0.10 (0.53)		
Corruption * Transparency				0.22** (0.10)		0.021 (0.13)		
Tools					0.29 (0.23)	0.46 (0.38)		
Corruption * Tools					0.22** (0.097)	0.20 (0.14)		
Transparency + Tools							0.58*** (0.22)	
Corruption * (Transparency + Tools)							0.23** (0.11)	
Good Autonomy IRA								-0.17*** (0.041)
Good Trans + Tools IRA								0.18** (0.081)
Corruption * Good Trans + Tools								0.070*** (0.023)
Observations	668	668	668	668	668	668	668	668
Number of firmcode	93	93	93	93	93	93	93	93
Adjusted $R^2$	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.23

The significance of the coefficients in Table 2 suggest is that an IRA with greater autonomy leads to more efficient firms, whilst an IRA with greater transparency and tools leads to less efficient firms. Furthermore, an IRA with a greater level of transparency and tools appears to worsen the effect of corruption on efficiency. The importance of regulatory autonomy in determining the efficiency of private firms is consistent with the previous literature on the effect of regulatory governance, which has generally focused on various measures of autonomy, rather than issues of transparency or tools.<sup>5</sup> Autonomy may improve performance if the firm feels that it is therefore more likely to be able to keep the rewards from any efficiency gains it enacts. The negative effect on performance of tools and transparency is perhaps surprising, though it may reflect tensions between the private sector which seeks to fire expensive employees and other actors (including the government) who wish to enforce other objectives, such as connecting particular groups or raising quality. Alternatively, transparency in the regulatory process may make it easier for the firm to capture the regulator, along with tools such as whether the IRA performs public consultations. The positive and significant interaction coefficient with the level of corruption in the country may give evidence towards this interpretation.

#### **4 Other properties of regulation and ownership**

In the previous section we have analysed the effect of various components of regulatory governance on efficiency, whilst in the previous chapter we tested whether our results were robust to the inclusion of other country level control variables. In this section, we consider some other aspects of regulation and ownership that may impact upon performance.

In Table 3, we consider four aspects of regulation besides governance: Whether the regulator is a multi-sector agency, the power of incentives given to the firm, whether the sector is vertically disintegrated and whether the sector is liberalised. In column (1), the multi-sector agency dummy reflects the fact that some IRAs are

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<sup>5</sup>See, for example, the analyses of Andres et al. (2008); Cubbin and Stern (2006); Gutiérrez (2003); Gutiérrez and Berg (2000); Pargal (2003); Zhang et al. (2008)

responsible for sectors outside of electricity such as water or gas. We might expect a multi-sector agency to be more effective since they tend to have access to greater resources, or alternatively the lack of focus may lead to less effective regulation. The dummy variable in Table 3 takes a value of 1 if an IRA exists and regulates several sectors. The 'power of incentives' variable in column (2) represents the type of incentives given to the firm, with 1 representing the most powerful incentives and -1 representing the least powerful. In particular, a revenue cap, price cap or efficient company model is given a value of 1, rate of return is given a value of -1 and a combination of the two categories is given a value of 0. For this, along with the variable measuring the extent to which the market is liberalised in column (4), I only have data on the system in 2007, and hence the variable takes a value of 0 for years when there exists no IRA, and its 2007 value for all years where the IRA exists. Finally, the disintegration dummy in column (3) takes a value of 1 if distribution firms have been separated from power generation firms.

In Table 3, we also consider whether the type of private ownership is important in driving the significance of the ownership terms previously found. Using data from the World Bank's PPI Project Database we create a dummy in column (5) that takes a value 1 if part of the private investment in the company comes from abroad. In column (6), we then split this up into foreign investment from other Latin American countries and foreign investment from other continents (namely North America and Europe).

From columns (1) and (4) in Table 3, we can see that the multi-sector nature of an IRA along with whether the sector is liberalised do not appear to significantly affect efficiency. In column (3), we see that disintegration appears to significantly worsen efficiency. This may result from efficiency gains from firms being vertically integrated, but may also reflect the difficulty of measuring exactly how many people are employed in the distribution part of an integrated firm. None of these three variables significantly affects the importance of governance on efficiency (i.e. the difference between the 'Bad IRA' dummy and the 'Good IRA' dummy). The power of incentives in column (2), on the other hand, appears strongly significant and significantly reduces the ef-

Table 3: **Other properties of regulation and ownership**

	(1)	(2)	(3)	(4)	(5)	(6)
Corruption	0.21*** (0.028)	0.16*** (0.034)	0.22*** (0.025)	0.24*** (0.049)	0.21*** (0.028)	0.21*** (0.028)
Corruption * Private	-0.079*** (0.022)	-0.078*** (0.030)	-0.076*** (0.024)	-0.081*** (0.030)	-0.067*** (0.022)	-0.068*** (0.022)
Corruption * IRA	-0.13*** (0.030)	-0.094*** (0.035)	-0.15*** (0.028)	-0.18*** (0.063)	-0.14*** (0.027)	-0.14*** (0.027)
Private dummy	-0.26*** (0.035)	-0.25*** (0.037)	-0.27*** (0.035)	-0.27*** (0.038)	-0.18*** (0.041)	-0.19*** (0.041)
Good IRA dummy	-0.10** (0.049)	-0.030 (0.039)	-0.13*** (0.038)	-0.050 (0.086)	-0.11*** (0.039)	-0.100** (0.039)
Bad IRA dummy	0.12*** (0.036)	0.11*** (0.030)	0.091*** (0.033)	0.18*** (0.064)	0.11*** (0.040)	0.11*** (0.039)
Multi-sector agency dummy	-0.010 (0.030)					
Corruption * Multit-sector	-0.017 (0.011)					
Power of incentives		-0.083*** (0.021)				
Corruption * Power		-0.0045 (0.013)				
Disintegration dummy			0.077** (0.034)			
Corruption * Disintegration			-0.017 (0.026)			
Liberalization				-0.14 (0.16)		
Corruption * Liberalization				0.015 (0.046)		
Foreign owned dummy					-0.15** (0.062)	
Corruption * Foreign					-0.036 (0.024)	
Foreign owned - LA						0.21*** (0.068)
Corruption * LA						0.057 (0.041)
Foreign owned - non-LA						-0.17*** (0.059)
Corruption * non-LA						-0.045* (0.025)
Observations	1359	1359	1359	1359	1359	1359
Number of firms	153	153	153	153	153	153
Adjusted $R^2$	0.37	0.37	0.37	0.37	0.37	0.38

Robust standard errors in parentheses

\*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1

fect of governance on efficiency. Indeed, it appears that higher powered incentives significantly increase efficiency (as would be expected), and that this explains a significant portion of the positive effect on efficiency of creating a well governed IRA. Further investigation (not reported here) suggests that the power of incentives is most important in determining the efficiency of public firms, and when included the 'tools' measure of governance previously included becomes insignificant.<sup>6</sup> This is consistent with our previous interpretation that tools were an important aspect of regulatory governance for public firms since they introduced further incentives for public firms to behave efficiently.

In terms of ownership, column (5) suggests that firms that are partly foreign owned are more efficient than those owned by the domestic private sector. However, column (6) shows that this result is being driven by those firms that are partly owned by a company based outside of Latin America, with those owned by foreign Latin American firms proving significantly less efficient than those owned domestically. These results appear to affect a firm's efficiency linearly, with the standard private ownership dummy remaining the most significant when interacted with corruption.

## **5 Conclusions**

This chapter has explored further the effects of regulation on firms efficiency found in the previous chapter. By allowing for changes over time in the effect of an IRAs creation, we found that firms' efficiency fell as regulators aged. This effect existed for both badly and well governed IRAs regulating both private and public firms, but the corruption mitigating effect of an IRA existence did not appear to be affected by its age.

The chapter also investigated which aspects of governance might be driving the results of the previous chapter. For public firms, we found a regulator's degree of autonomy and tools were the most important aspects in reducing efficiency, with autonomy mitigating the effect of corruption. For private firms, autonomy was also found

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<sup>6</sup>On the contrary, autonomy remains significant in its interaction with corruption for public firms, and there is little change in the coefficients for private firms.

to be important, though its affect did not interact significantly with corruption, whilst we also found some evidence that tools and transparency reduced firms efficiency.

Finally, when we considered other aspects of regulation, we found that firms regulated with more powerful incentive schemes were more efficient, and this explained a significant part of the previously identified direct effect of regulatory governance. Moreover, firms that were partly owned by companies based outside of Latin America appear to operate more efficiently than other private firms.

Overall, we can conclude that the effect of creating an IRA does not have a straightforward effect on regulated firms' efficiency. The effect appears to change over time, and also depend on the level of corruption in the country, the power of the incentive scheme and various aspects of regulatory governance. Further research should therefore be undertaken to understand the various impacts of these different components of regulation, and care should be taken when recommending the creation of an IRA.

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