Stanford Center for International Development

Working Paper No. 218

INCENTIVE STRUCTURES IN THE PRESENCE OF SUBSIDIES: OPTIMAL CONTRACTS IN INFRASTRUCTURE UTILITIES

by

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June 2004

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Key words: subsidy, contracts, incentives.
JEL Classification: D82, H25, L51.

1. INTRODUCTION

The decade of the nineties witnessed an increased emphasis on enhancing accountability and increasing efficiency in public infrastructure utilities, which despite technological progress, remain predominantly monopolistic in nature. Utility regulators, moreover, share a common feature that they seek to control the conditions of provision of services in an environment characterised by marked information asymmetry, when they can neither observe utilities' private information, nor control their decisions.

The consequent shortcomings of rate of return regulation in general, and its inability to stimulate efficiency gains in particular, led to a search for alternative methods of regulation in order to simulate some of the effects of market forces. There has concomitantly been a gradual transition in regulatory contracts – which define the relationship between the regulators and the regulated utilities with the objective of increasing efficiency – to a Performance Based Ratemaking (PBR) / RPI-X type of regulation across countries in many utilities, with the intention of moving to less heavy-handed, information intensive procedures.

This transition to incentive regulation was also spurred by a deeper theoretical understanding of contracts (see Armstrong and Sappington [2003]), with a burgeoning literature on effective regulatory oversight suggesting newer designs of regulatory contracts using revelation mechanisms in an environment of marked asymmetric information between regulators and utilities (see Crew and Kleindorfer [2002]). An associated empirical corpus, both within the matrix of the theoretical literature and as independent research, has investigated the performance of actual contracts of private investors and of incumbent utilities (Shirley [1995], Shirley and Xu [1997]). The advances in incentive regulation have, however, focused predominantly on two uncertainties – demand and cost – that together served to alter the design of contracts studied in the much more extensive literature on single variable uncertainty in many important respects (Sappington [1991]).

There are three shortcomings of this focus for regulating utilities in developing countries. First, the degree of uncertainty and information asymmetry is aggravated, as a result of both poor data availability and institutional features, specific to these countries, of both publicly owned utilities as well as the emerging private providers of utility services[1]. For instance, in the case of publicly owned utilities – which remain the dominant providers of utility services – by the inadequate accounts and balance sheets which more than offsets their slightly weaker incentive to overstate profits. For private utilities, there is an inadequate track record and lack of experience in matters relating to cost structures, arising from the nascent exercise of independent regulation. Second, the uncertainties usually studied relate to different variables and regulated activities than those which are the focus of regulation of utilities in developed countries. For example, utilities have much lower flexibility in commercial pricing, given the political and social constraints, including a hysteresis engendered by a historical divergence of costs and prices charged to most users and the social reality of users' inability to pay full prices for these utility services. The extent of demand uncertainty in many utility sectors in developing countries is also much lower, since there is a large unmet demand, especially at the stringently controlled prices that are charged to most users, and the low levels of access that have been achieved so far.

[1] An account of these shortcomings in the case of India is provided in Bhattacharya and Patel [2003].

Third, subsidies are a reality in most developing countries; affordability and access considerations require significant subsidy transfers from the government to utilities, especially for universal service provision. In fact, it is the compulsion (as well as the convention) to price these services below cost that enhances the need for subsidies; default service obligations are also larger. Given the distressed fiscal condition of these countries, the actual magnitude of these transfers is variable. Many developing countries are moreover trying to attract private investment in these utilities, with the aim of extracting efficiencies in their operations. Government subsidies are then necessary to cover (at least for a while) the loss-making operations of these privately owned utilities.

Apart from the problems for the regulator by introducing another "control" variable, there is an additional aspect of subsidies that has not been investigated. This relates to the effect on the performance of the utilities of the very provision of the subsidies themselves. Subsidies have the same effect as that of a wealth endowment of an economic agent in influencing his production or consumption decisions. The distortive effects of endowed wealth on the optimisation behaviour of economic agents are well documented in the areas of incentives and labour and financial economics (Lewis and Sappington [2000]). It is noteworthy that that there is virtually no formal literature on optimal regulation in the presence of explicit government subsidies that skew the output and investment decisions of utilities.

This paper borrows from the literature on incentives, contracts and mechanism design to extend the scope of current models of utility regulation in the face of multiple sources of information asymmetry and the distortive effects of transfers from the government. We adopt a mechanism-design view of regulation espoused by Laffont and

Tirole [1993][2]. A strong criticism of this view of regulation is that it is based, in one way or another, on assumptions like common knowledge that "endow the regulator with information that he cannot have without a contested discovery process that always leaves him in a state far short of the level of information assumed in these theories" (Crew and Kleindorfer [2000]). The "third-best" distortions induced by these multiple asymmetry sources may lead to a collapse of the incentive system through the impossibility of separating different types of utilities. Possibly in recognition of this reality in utility regulation, the centre-piece of the X-efficiency theories of incentive regulation was the requirement of the regulator to cede some "information rents" to a utility.

The paper is partially motivated by the discussion in Bhattacharya and Patel [2001] on the behaviour of utilities in India vis-à-vis regulators in the face of asymmetric information which have the common feature of inducing inefficiencies in operations and investments, high costs, sub-optimal quality of service and other monopolistic practices. It seeks to impart greater reality to the general corpus of work on incentive contracts in regulation by incorporating an aspect of regulation – accounting for subsidy transfers – that is not normally investigated, but which is critical for understanding incentives for utilities in developing countries. It explores the nature of incentive contracts that a regulator may offer a utility, who has access to subsidy transfers from the government, with the objective of maximising its expected surplus. The model incorporates an environment of information asymmetry with the presence of adverse selection – arising from asymmetry in the knowledge of costs and subsidies – as well as moral hazard from the unobservability of the levels of investment made by the utility. The main contribution of the paper is to provide a

[2] In other words, we abstract from the kinds of regulated monopolies where competitive entry is a reality.

theoretical basis for introducing a cautionary note on the effectiveness of the increasing advocacy (and actual use) of “menus of contracts” and incentive options by regulators in many countries and sectors (Sappington and Weisman [1996]), by highlighting the limitations of these contracts under conditions of multiple information asymmetries such as those that prevail in developing countries.

The structure of the paper is as follows. Section 2 briefly surveys the existing literature on incentives and contracts in regulation of utilities, elaborating the motivation provided in the introduction. Section 3 provides an overview of the scope, nature and extent of subsidies to various utilities globally and briefly touches on the problems that have arisen between regulatory authorities, incumbent utilities and new entrants on tariff structures and associated commitments and license fees required of the utilities. Section 4 presents the formal model of the incentive properties of contracts offered to utilities by regulators in an environment characterised by multiple sources of uncertainty. Section 5 provides some illustrations of the analytical framework, one of them specific to utility regulation in India. It also highlights the shortcomings of the regulatory incentives that have been (and are being) used. Section 6 concludes by drawing some policy conclusions arising out of the theoretical framework.

2. INCENTIVE REGULATION OF UTILITIES

Regulation is viewed as a “bargaining” process between the regulated utility (the agent) and the consumer (the principal, represented by the regulator)[3] that seeks to

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Weisman [2000] provides a discussion of the regulator’s role under competitive entry.

[3] This interpretation remains valid even if contracts are awarded through competitive bidding, since properties of these contracts would need to be translated to the bidding process and structure to elicit the desired efficiencies.

negotiate a contract that (i) provides utilities with incentives to invest and operate efficiently and (ii) simultaneously protect the social and economic interests of consumers (i.e., maximises social surplus through (full) rent extraction). The utility has private information about its costs which are only imperfectly observed by the regulator. The divergence of interest created by this asymmetry and imperfect observability gives rise to strategic behaviour for both the principal and the agent.

In this scenario, the regulator's problem is to induce the utility to divulge its information correctly. An incentive structure that endogenously elicits information from utilities is preferable under these circumstances. If an information asymmetry persists, the regulator's second task is to devise an incentive scheme to restrict the utility's rent and induce it to operate efficiently.

2.1 A review of the theory

An extensive literature has accumulated on incentive theory in a principal-agent (PA) framework when principals can neither observe the private information of agents nor control their decisions (see Laffont and Martimort [2001] for reviews). Much of the theoretical literature on regulation in the face of information uncertainty and asymmetry has extensively used this body of results. As shown by Laffont and Tirole [1986], optimal contracts in a regulatory environment with imperfect information are designed to solve a trade-off between efficiency and rents that is needed to induce a truthful revelation of the relevant information.

Models with just one dimension of information asymmetry – either demand or cost uncertainty – have been extensively analysed (since the seminal papers of Baron and

Myerson [1981] and Sappington [1983]). The commonest form of incentive regulation is price cap regulation. Other techniques such as the revenue cap, the sliding scale (earnings sharing), the discounted cost pass-through, yardstick regulation, performance target schemes, rate freezes and rate case moratorium, have since been used.

Optimal regulation in a more general and "realistic" environment of asymmetries is less well understood. There have been many attempts to model multi-dimensional private information and a lesser (or single) number of contractible variable(s) (McAfee and McMillan [1988], Lewis and Sappington [1988], Armstrong [1999]). While the effects of adverse selection (AS) and moral hazard (MH) individually on contract design is relatively well understood, the interactions between AS and MH is a more intractable problem. This class of models, where output is a function of both the characteristic and input variables, neither of which can be observed by the principal, and consequently the effects of each individually on output cannot be distinguished, were studied by Guesnerie *et al.* [1989] and Picard [1987]. They show that if the effort demanded of agents is not decreasing in the output parameter, then the optimal contract is a menu of (distortionary) deductibles designed to separate the agents. However, when the AS component is such that the most efficient agents prefer to sign the deductible contracts of the least efficient, then fines for unexpected deviations are needed so that agents honestly reveal their characteristics. In this case a linear contract menu is not optimal, but quadratic contracts are. The introduction of risk aversion in combined MH-AS models makes these models more difficult to solve (although the conditions for the existence of solutions are known (Page [1992])).

2.1.1 The Revelation Principle, incentive compatibility and separating equilibria

Mechanism design relates to the contract structure that will be offered by the regulator to implement a particular objective despite the self-interest of individual agents. The premise of the Revelation Principle is that agents will voluntarily reveal their private information if lying does them no good in the situation addressed by this particular mechanism-design exercise. Under fairly stringent assumptions, if multiple contracts are offered by the regulator, a revelation mechanism will result in a separating equilibrium. Private information leads to inefficiency because it is effectively a form of monopoly power (of information). Sometimes it is possible to introduce competition (such as auctions) as a method of reducing informational rents. If competition is not a possibility, mechanism design can still effectively minimise the rents of the privately informed, provided that there are more dimensions in control variables than in the information problem.

Menu contracts

Revelation mechanisms can be decentralised through a menu of contracts. A conventional contract consisting of one incentive scheme, referred to as a "singleton" contract, might be designed to avoid excessive rent retention. One prediction of the standard theoretical model is that the high-type agents (the more productive type) will get "efficient" contracts and informational rents, whereas low-type agents will opt out of the system. A menu contract, on the other hand, is defined as a collection of incentive schemes. When a menu contract incorporating a mix of low and high power incentives[4] is

[4] A high-powered incentive is defined as one in which the utility bears a high fraction of its cost at the margin. A fixed price procurement contract is an example of a high-powered incentive scheme. A cost-plus

offered, the agent has to choose one element, i.e., one incentive scheme, before taking an action[5]. Each utility facing such a menu chooses the contract that corresponds to its own efficiency level, with the most efficient utility choosing the highest power scheme (usually a fixed price contract) and the least efficient one a cost-plus contract.

Examples of the use of such mechanisms abound in the housing finance sector (for example, through screening for the risk of pre-payment of housing loans by offering combinations of "points" and interest rates) or in banking regulation and deposit insurance pricing (through a mix of insurance rates and capital adequacy). If a manager, for instance, knows workers care both about wages and the number of hours worked, he can devise a contract menu of hours and wages that induces more truthful revelation of own characteristics. Boitani and Cambini [2002] have recently investigated the optimality properties of a "subsidy cap" mechanism based on a menu of contracts and find that this possesses some properties that have been identified as desirable in the incentive literature.

2.2 Why "menu contracts" when competitive bidding can address the problem?

An objection that is likely to be raised to the contracts-based approach of this paper is the increasing use of competitive bidding to award concessions for utilities; most current concessions being competitively bid, the process should both extract rents and allocate projects to the utility that can most efficiently provide the service. The answer is that competitive bidding is relevant only in the case of transfer of ownership. Utilities in many

procurement contract is an example of a low-powered incentive scheme because the utility is not made accountable for cost overruns or savings.

[5] Menu contracts are becoming increasingly popular, especially in the area of compensation. In many high-tech firms, a typical compensation scheme includes a salary and an option to spend a fixed percent of salary

developing countries continue to cover many segments that are natural monopolies (and hence need to be regulated), but have not, nor are likely to be in the near future, put up for sale or concessions. The role of the regulator *vis-à-vis* these incumbent utilities is primarily the extraction of operating efficiencies.[6] The degree of information asymmetry between the regulator and the utility regarding the magnitude of subsidy becomes even more marked in this scenario.

Another reason that revelation mechanism design for separating contracts remain relevant even in the presence of competitive bidding is that The concessions themselves have various degrees of regulation-based contracts built in. Even well designed concessions might encourage the use of efficient operators in inefficient agglomerations, in other words, inefficient investment decisions. Design Build Finance Operate (DBFO) contracts, for example, are an approximation, though weak, of such leeway in structuring contracts. Aggregation of projects through simultaneous auctions is another example of exercising choice. An example of a bidding process replicating separating contracts was the tender of the state of Virginia in 1996 that set out a requirement for 5000 MW of power. Bidders were required to quote a single tariff for supplying this power. They were free to use any technology, fuel, location, etc., subject to availability norms.

3. IMPORTANCE OF SUBSIDIES IN UTILITY INVESTMENT DECISIONS

Utilities in developing countries serve large numbers of consumers who either need to be subsidised (i.e., utility revenues are lower than the costs of service provision), or who

to purchase the firm's stock at a discount. To participate in this plan, an employee has to choose the percentage of salary allocated to stock purchases in advance and commit to it for a fixed period.

[6] Although the rationale for incentive contracts are naturally mitigated due to the (presumed) absence of explicit financial rent seeking in the case of publicly owned utilities, incentive contracts are still useful for

simply do not pay for its services (in the absence of credible deterrent action from the utility). Consequently, either the utilities are loss-making (electricity, water supply and urban transport), or else do not have the ability to expand their services to large numbers of consumers (rural telephony and electricity). This deters financial closure of many private projects, inhibiting optimal levels of investment.[7] Although utilities are increasingly becoming more commercially oriented, continuing operations of these utilities, or their investment plans, are then largely dependent on subsidies that are granted to them by governments.

Apart from the recognised effects of subsidies on utilities' operations, subsidy considerations can also complicate many of the utility's investment decisions in an indirect fashion. The changes in a network utility's marginal incentives that accompany changes in wealth can arise from non-negativity constraints on income. For example, a telephone network might benefit from greater economies of scale and scope from extension of networks to remote areas and sections of users that are not a commercially viable proposition. A transfer of subsidies from the government might enable it to exploit these economies. In the case of transfer of utility ownership from public to private operators, moreover, the inherent loss-making nature of utilities makes subsidy transfers critical. For instance, phased subsidy transfers from the government to private electricity distribution companies upon their takeover of erstwhile publicly owned companies is often claimed to be a necessary condition for a successful privatisation exercise.

benchmarking purposes as well as the mitigation of other "rents" typically associated with the public sector in developing countries, viz., monitoring waste, checking corruption, poor service quality, etc.

[7] Moreover, the loss-making nature of utilities in developing countries is a further hurdle for them from making adequate investment in their distribution and supply networks.

Government subsidies to state-owned enterprises (SOEs) are difficult to quantify, in part because they are often hidden; loans are given by governments at below market interest rates; principal and interest payments are repeatedly rolled over or even wiped off the books and loans are converted into direct transfers, etc. Similarly, arrears of utilities on their taxes or on payments to other SOEs are sometimes forgiven. In addition, state-owned enterprises may have special privileges to bid on government contracts, to purchase goods or services from the government or other SOEs at below market prices, or to use government land or buildings rent-free. Finally, a state-owned enterprise may benefit from requirements that government agencies or other SOEs buy its output[8]. Subsidies are also delivered in many indirect ways, which make their measurement more problematic. Many transportation project bonds are offered federal tax credits to subscribers in the US, for instance, rather than the more usual tax exempt status.

Complicating these problems of measuring the quantum of subsidies is the uncertainty about the levels of government subsidies that is actually transferred, and worse, the degree of asymmetry in knowledge about these levels between the regulator and the utility. The government, as a paymaster of bills (even those that it has committed on), has low credibility in developing countries. At worst, the state declares at the end of the year that it would be unable to transfer the committed amounts owing to its own fiscal difficulties. This implies a higher degree of risk for the investors than is commensurate

[8] Untangling these hidden subsidies to discover the true cost to the government of an inefficient state-owned enterprise is especially difficult when several exist simultaneously, which is very often the case. In Turkey, for example, subsidised electricity prices from the state power company helped the state aluminum company survive competition from imported aluminum. Turkish SOEs received many other implicit subsidies, including lower interest rates on loans, not available to their private counterparts; and if they defaulted on debt service payments for international loans received via the government, the government would make the payment to preserve its credit standing with international investors. Although SOEs were fined for such

with the expected rate of return. It is not entirely surprising, therefore, that it is in the interest of utilities that are promised subsidies by the government to expend effort in obtaining information about the expected levels of payment from the government – especially since some of their own commitments to the government is likely to be upfront, in the form of license fees or other non-monetary covenants.

This uncertainty regarding the magnitudes of subsidy transfers is glaring in India. The two sectors that have received a significant degree of private investment are telecom and power. In the telecom sector, which is by far the most commercially oriented utility sector, the amount of private investment in improving access of remote areas is virtually nil, since private investors have expressed doubts about the certainty of the Universal Service Fund transferring committed grants to these operators were they to roll out remote service. In the power sector, the problems of the private distribution companies in the state of Orissa have raised a big question mark over the entire privatisation exercise. While the troubles of these companies have many origins, including unrealistic commitments expected of the investors, a basic problem right from the beginning was the refusal of the state government to provide (a limited and phased) subsidy to the private distribution companies. The subsidy earmarked for a period of 5 years after the privatisation of electricity distribution in Delhi may be exhausted after only a couple of years of private operation; there is no commitment for the following three years.

Although the knowledge of the probable levels of subsidies from the government is best known to government owned utilities due to the close links between the management

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behavior, the penalty interest rate was only 30 percent, until 1990, compared with a 50 percent rate for commercial loans.

of these institutions and the government executives, it is likely that even private service providers would have a better feel than regulators due to their extensive interactions with government officials in both the investment process, as well as the routine operations of their utilities[9]. The regulator has recourse only to (usually, annual) *ex-post* information about the level of subsidy, whereas the utility has many more informal channels of interaction with the government which enables them to acquire better information about the level of subsidy that it would actually receive in the course of the year.

With independent economic regulation becoming increasingly important for utility supervision even in developing countries, in the current environment when utility services are increasingly being provided by private operators (see Bhattacharya and Patel [2003] for recent developments), the role of the regulator is explicitly wider in ensuring that the subsidy does not accrue to the utility in the form of rent, especially given the asymmetry of information between the regulator and the utility. The environment in which utilities operate in developing countries and the limitations on regulators that we discussed above provides the context for the application in this paper of these theories to utility regulation.

It might be worth clarifying that the provider of subsidies is different from the regulator (the principal). Given the key importance of transfer of subsidies in the paper, as well as the information asymmetries about the extent of subsidies, there is scope for confusion on the mantle donned by the principal – the government or the regulator – and the consequent nature of its relationship with the agent, i.e., the utility. This separation is

[9] Surprisingly, a common observation, if not complaint, of public sector executives is the untrammeled access of private operators to the decision making bodies of the government. This leads to the somewhat contradictory situation where each accuses the other of unduly influencing the formation of policies to provide them an unfair advantage.

supported by the observation that the question of subsidies is decided primarily by the Treasury or the Ministry of Finance, which is usually an autonomous body relative to regulators.

3.1 The magnitude of subsidies in infrastructure sectors

Subsidies continue to play an important role in the operations of basic infrastructure providers in most countries, particularly in the energy, transport and water sectors. Global energy subsidies are estimated to have been about $600 bn in 1997. The largest part of these is for fossil fuels; $100 – 200 billion (bn) are spent annually on subsidies to conventional energy worldwide[10]. In the developed countries, the subsidies are mostly for generation of electricity; in the developing countries, on the other hand, energy *consumption* is often subsidised more than production. For instance, Kay [2003] argues persuasively that the dilapidated transmission systems of many developed countries requires significant government fund transfusions if the breakdowns witnessed in the Northeastern US in 2003 are to be avoided. In Chile, subsidies to rural electrification were about $1.5 bn in 1999. Water and sanitation services are the most severely underpriced infrastructure services in the world, both in developing and developed countries. Water subsidies vary greatly within the OECD, but are generally higher in the US, Australia, Japan and Turkey. Cost recovery for drinking water services in developing countries is about 35 percent on average, and subsidies (including for irrigation), amounted to $45 bn in 1996 (DeMoor [1997]). According to FCC figures, about 70% of local residential lines in the US are still subsidised by long-distance services, in amounts varying from $3 – 15

[10] UNDP World Energy Assessment, 2002.

per month. The total subsidy amounts are currently estimated to be $25 – 30 bn per annum[11]. Table 1 below gives an estimate of subsidies delivered globally.

Table 1: Estimates of sectoral subsidies globally (in US $ bn)

	global estimates		partial estimates	
	non OECD	**OECD**	**non OECD**	**OECD**
energy	150-200	70-80	--	--
road transport	15	--	--	85-200[a]
water use	42-47[b]	--	--	(30%-50%)[c]
agriculture	10[d]	335	--	--

Source: DeMoor [1998]
a Includes USA, Japan and Germany.
b Includes subsidies to drinking water and irrigation.
c Subsidies as a percentage of total costs.
d Includes food and input subsidies but not irrigation.

Subsidy magnitudes in India are large. Just non-merit subsidies, i.e., those where users can pay for the services, have averaged over 10 percent of GDP annually in the nineties. Of these, power, water and transport accounted for over half. The power sector in India continues to operate at huge deficits in its revenue (or current) accounts, both due to dilapidated networks, inefficient operations and (misplaced) considerations of equity, which mandate electricity as an entitlement for farmers and other low income segments. Though not as dramatic as the power sector, and not as well documented, the extent of direct subsidies in the water and sanitation and transport sectors are reported to have assumed alarming proportions as well[12]. Table 2 below gives an estimate of subsidies that have been given to various infrastructure segments in India.

[11] Business Week, August 13, 2001, pp. 42-49.
[12] This is in addition to the extensive prevalence of cross-subsidies, which are detrimental to production efficiencies.

Table 2: Estimated subsidies to utilities / infrastructure sectors in India (Rupees billions)

	Centre	States / Local bodies	Total	Cost of supply	% of Cost
Electricity Distribution	--	407[13]	407	1,765@	23.1
Telecom	130	--	130	257^^	50.5
Transport (State Transport Undertakings)[14]	15*	8*	23*	132**	14.9
Railways	7	--	7		
Roads and Bridges	17	43	60		
Urban Municipal functions^	--	285	285	1,634	17.2
Irrigation			52	229&	22.8

Sources: Govt. of India Discussion Paper on Subsidies and (*) Report of the Eleventh Finance Commission.

** Indian Journal of Transport Management, 2000, 24(7), cited in S. Sriram, "State Road Transport (SRT) Undertakings in India: Issues, constraints and options", India Infrastructure Report 2002, ch. 10.3, pg. 300.

^ Mathur, O. P., P. Sengupta and A. Bhaduri, 2000, "Option for closing the revenue gap of municipalities", NIPFP, from India Infrastructure Report 2001. Municipalities have to statutorily establish a balanced budget and subsidies are in the form of transfers from the centre and states.

^^ Telecom Regulatory Authority of India (TRAI) Interconnection Usage Charge Regulation, January 2003, Table 1 (including capital and operating expenditures).

@ Planning Commission [2002], Tab 3.6. Subsidy is total uncovered gap (Tab. 4.7).

& Water Conservation Mission, Andhra Pradesh, Draft Water Vision, 2003, Vol. 2, Chapter 4. (http://www.wcmap.com/).

4. A MODEL OF INCENTIVE CONTRACTS IN THE PRESENCE OF SUBSIDIES

We investigate the properties of the design of an optimal contract in a one-period setting between a principal (regulator) and agent (utility), say, in awarding a concession to a project. We start with the setting where cost structures are common knowledge, but the amount of subsidy provided is private information.

4.1 Structure of the model[15]

The problem that we model is the following. A regulator awards a license to a utility (which is a monopoly in the license areas and is (partially) financed through government subsidies) and oversees it. The regulator is the principal (acting on behalf of the utility's consumers) and the utility is the agent. The utility's cost structures, investment

[13] Planning Commission [2000]. Another Rs 10,120 crores is estimated to have been transferred as cross-subsidies.

[14] As in 1994-95.

plans[16] and subsidy receipts from the government are unknown to the regulator. In the face of these multiple sources of information asymmetry, the regulator's objective is to design a contract that optimises the trade-off between the efficiency incentive to the utility and the rent that thereby accrues to him.

The two players – the principal (regulator) and the agent (the utility monopoly producer) – are both risk neutral. The utility has the objective of profit maximisation, while the regulator aims to maximise a welfare function that includes revenue[17] from the utility and the overall consumer surplus. There are three characteristics of the utility that the regulator might not be able to observe perfectly:

1. The *subsidy* received by a utility from the government, S. S is bounded by $[S_L,S_H]$. S_L might be 0. This subsidy can skew the utility's incentive to make the optimal level of investments.[18] It also enhances its liquidity.[19] The regulator assumes that the utility's subsidy (S) will be drawn from a probability distribution, g(S), with a distribution function G(S).
2. The efficiency of the utility, encapsulated by its *cost* structure, C. This is to say that a service may be provided by either a low- or a high-cost operator. The cost structure needs to be distinguished from the capital costs (investment) of the operator. At any given level of investment, the operating efficiency of the utility determines its cost structure.
3. The utility's level of *investment*, I. A contract for electricity supply, for example, would require conditions not only on the amount the utility would invest for generation

[15] The analytical framework is analogous to that of Lewis and Sappington [1999], who investigated the properties of similar contract structures in the labour market.
[16] A proxy for the unobservable effort put in by the licensee.
[17] Including commitments that might be broadly construed as deemed revenues.
[18] This is akin to a wealth effect in the literature on investment.

[19] In practice, it is common for utilities to have better information about the amount of subsidies that will be given by the government, especially if the utility is a public sector organisation or incumbent.

capacity, but also its timing, its reliability, the mix between peak and base load capacity, its impact on the environment, etc. The cost of investment is normalised at one.

The "outcome" at end of contract period is observed. The outcome has two states:

A High state, with gross value H

A Low state with value L (which may be normalised to 0).

The probability of outcome is p(I).

Characteristics of the probability function p(.):

p(0) = 0 for all S. This implies that with no investment, the outcome will be the low state.

$p_I(I) > 0$, $p_{II}(I) < 0$. i.e., the probability of the High state being the outcome increases with the level of investment, but at a diminishing rate.

The probability function is a known schedule, as a function of the level of investment, I. The causality in the model is from the level of subsidy to the level of investment, which determines the probability of outcome H.

Also assume that the level of subsidy is small relative to the outcome of the project.

Contract structure

The regulator promises to pay the utility a **reward**, T(S) according to the outcome:

$$T() > 0 \text{ if outcome} = H, \quad \text{and}$$
$$T() = 0 \text{ if outcome} = 0. \qquad (1)$$

The reward T is the revenue of the utility from its production and investment decisions, and should be distinguished from the transfer (the subsidy) from the government. The reward actually depends on the subsidy received by the utility. Since the level of the subsidy (which is assumed to be unknown to the regulator) determines the level of investment by the utility, and thereby, the probability of outcome H, the regulator will try to maximise p, which in turn maximises its surplus. He will thus link the reward offered to the utility with the level of subsidy the latter is expected to receive. Since this level is *ex-ante* unknown to the regulator, he will try to extract this information through the commitment level promised by the utility, which is a signal of the level of subsidy that the latter expects to receive.

The reward can be thought of as incentive payments, e.g., tariff levels in electricity distribution or interconnection charges in telecom, if a utility attains (or exceeds) a certain level of pre-specified performance or a prior commitment, or if the efficiency level of the utility increases beyond a specified level[20]. These incentive payments can also be linked to the fulfillment by the utility of universal service obligations. Rewards can also be thought of as profit sharing arrangements[21]. The regulator can offer the utility a higher share of profits if certain conditions, like traffic flow, are met[22]. The performance level is assumed to be a function of the level of investment I, made by the utility.

The regulator often requires the utility to make a commitment, B, upfront, designed to increase the chances that the project will be credibly completed.[23] This commitment

[20] This is observed in both the generation and distribution segments of electricity, where the performance parameters are Plant Load Factor (PLF) and availability for the former, or loss reduction targets and collection efficiencies for the latter. Kay [2003] also points out the relevance of flexibility in rewards in the case of electricity transmission, given the experience of the US North-East grid collapse in 2003. The essence of the argument is that larger returns might be necessary for higher investments.

[21] Profit sharing incorporates elements of both rewards and penalties, since it is predicated on sharing the risks associated with production. The model separates these components explicitly into rewards for and commitments required of utilities.

[22] This was observed recently in the concession for container terminals at the Chennai port. The mechanism was different from a negotiated contract, having been awarded through competitive bidding.

[23] Regulators, for instance, often impose or recommend the use of license fees for a utility in return for the right to provide a specific service. In Peru, firms awarded licenses for rural telecom services were required to provide three financial guarantees: one, to ensure the seriousness of the offer, two, an installation guarantee and third, a guarantee against default on their contractual obligations.

entails a cost for the utility, which is in addition to its investment in the project. Commitment costs (broadly the charges, either paid upfront or over the period of the utility's franchise, that extract the rents derived from monopoly operations), therefore, need to be segregated from investment costs.

Recently, the Indian government required that new entrants in the National Long Distance (NLD) telephony sector provide a (refundable) bond of Rs 4 bn, together with a license fee of Rs 1 bn, when applying for a license. In cases where existing utilities come under a regulatory purview, the regulator forces the utility to concede its monopoly position, which leads to an immediate loss in revenues for the utility. In other cases, the regulator forces the utility to commit to pre-specified roll-out plans for remote and uneconomic areas (as part of its Universal Service Obligations) that leads to a loss for the utility, which needs to be made good by a subsidy from the government. The utility will only agree to such remote and universal access if it is certain that the losses it incurs over the course of these obligations will be met by the subsidy component.

Commitments can also be seen as a mechanism to restrict monopoly behaviour of incumbents. Public sector incumbents have the capacity of using their links with government to extract higher (and often disguised) subsidies and then use the subsidies to price out competition. The greater the level of subsidies, then, the higher the penalties that will be imposed. To motivate such an incumbent to deliver, a high commitment can be combined with a high reward.

The regulator has to ensure a truthful revelation of the level of government support that will be given to the utility. The utility often has an incentive to understate its expected subsidy, demanding a higher reward structure to make up for losses that will be claimed as uncovered due to various obligations not connected with its production decisions[24]. We postulate that the amount (equivalent to the cost of the utility's commitment) is a function of the subsidy that is declared to the regulator by the utility, i.e., B = B(S).

A **contract** is then a pair {B(),π()} (or equivalently {B(),T()}). The regulator offers the utility a contract from a menu based on the declared levels of S. Table 3 below indicates such pairs that have been used (or are proposed to be used) in various utility sectors[25].

Table 3: Reward-Commitment structures in selected utility segments

	Rewards	Commitments
Electricity		
Generation		
Existing plants	Tariffs	Performance parameters.
New plants	Dispatch incentives	License fees.
Distribution	Larger regulatory base; "regulatory assets"	Reduction of commercial losses; penalty clauses on appropriate Quality of Service parameters.
Transmission	Higher tariffs / relaxed revenue caps	Higher investments for system redundancy and spare capacity.
Telecom		
Fixed services	Lower revenue shares	Universal Service commitments.
Cellular services	Spectrum allocation, profit	Net worth declarations; earnest money requirements.
Water / Sanitation	Similar to Electricity	

[24] There is a downside to subsidies. The government's intention to provide a high subsidy may act as a disincentive for the licensee to reduce his cost and increase his investment. The regulator then must penalise higher subsidy levels and impose more stringent conditions for rollout and other performance parameters.

[25] A different form of calibrating such contracts is manifest in recent attempts to allow service providers to deviate from a stringent and uniform standard for providing access to the poor, which had the effect of pushing up costs and increasing the exclusion of the poor. Customers under such schemes receive service at a lower cost at the expense of quality, or for a reduced number of hours every day. Examples are a dual mode water and sewerage system in Buenos Aires, Argentina and pre-paid electricity and gas cards in the UK which permit consumption at certain periods during the day (Baker and Tremolet [2000]).

Table 4 below is an illustration of the risk profile of infrastructure investments that might be associated with different menus of respective regulatory contracts and the power of the incentive contract that is likely to be adopted by different categories of utilities.

Table 4: Matrix of return – risk characteristics of selected infrastructure segments

Commitment (Risk)			
High		Electricity distribution (guaranteed return on equity but rewards predicated on performance)	High Frequency Spectrum Bandwidth Toll road contracts
Medium	Electricity Generation	Toll road contracts with LPVR bids	
Low	Low Frequency Spectrum Bandwidth Annuity road contracts Management contracts in water utilities		
	Low	**Medium**	**High** **Reward**

<u>The nature of uncertainty in the model is limited</u>. The probability function in the production technology, whereby the amount of investment by the utility determines the level of output, is known to both parties. The uncertainty for the principal (the regulator) arises through (a) its inability to observe the actions and characteristics of the utility and (b) a probability function of output that has the utility's effort (investment) as an argument.

The regulator's maximisation function is:

$$W^R = \{p(I(.))[H - T] + B\} \qquad (2)$$

Therefore, $dW^R = 0$ implies the following shape of the regulator's iso-return loci:

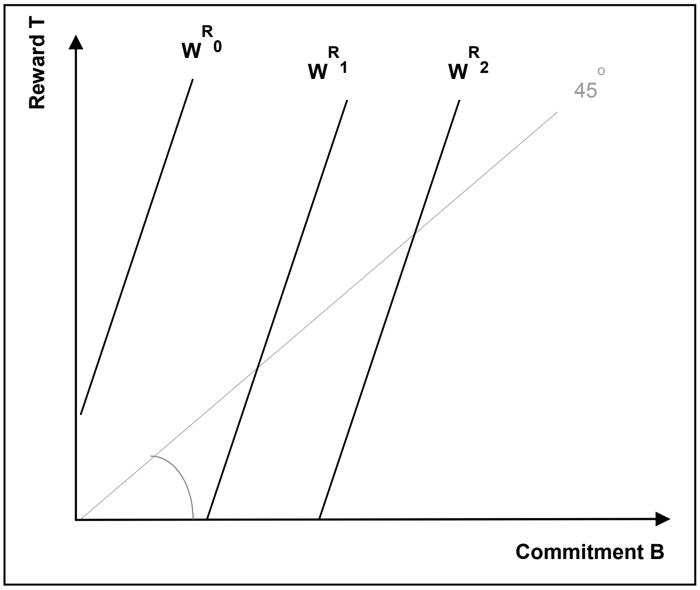
$-p(I(.))\, dT = -dB$[26]

$$\frac{dT}{dB} = [p(.)]^{-1}$$

[26] Note that the probability function p(.) is a given for the regulator, with each iso-rent locus defined for a specific level of investment.

Since p(.) < 1, the slopes of the iso-return loci are positive and greater than one, as depicted in Figure 1 below.

Figure 1



Note, moreover, that the levels of return for the regulator increase as we move right in Figure 1; for any specified level of commitment demanded by the regulator, the rewards needed to be given to the utility is lower.

Production technology

The utility's expected **rent** with investment level I, after receiving a reward T for success, and making a commitment B is:

$$\rho(.) = p(I)T - I - B \qquad (3)$$

Consequently, its expected **profit** from production is

$$\pi(.) = p(I(.))T(.) - I(.) \qquad (4)$$

$$= \rho + B$$

The utility's maximisation exercise is defined as follows:

$\text{Max}_I \{p(I)T - I\}$.

The utility's optimum investment level is then determined by:

$$p'(I^*)T - 1 = 0 \tag{5}$$

where

$$I^*(T) = \text{argmax}_{I}\ \{p(I)T - I\} \tag{6}$$

Therefore, at the utility's optimum investment,

$$T^* = \frac{1}{p'(I^*)} \tag{7}$$

Consider the profit level of the utility at the optimum level of investment, from equation (4). This relation, together with the optimum reward T*, determines the relation between the utility's profit level and its chosen level of investment (from equation (5)) and can be considered the production technology of the utility.

$$\pi(.) = \frac{p(I^*)}{p'(I^*)} - I^*(.) \tag{8}$$

Expressing the level of investment in terms of profit in the above equation determines a proxy for the utility's production function, i.e., $I = I(\pi)$, the level of investment made by the utility when he is promised a profit level π.

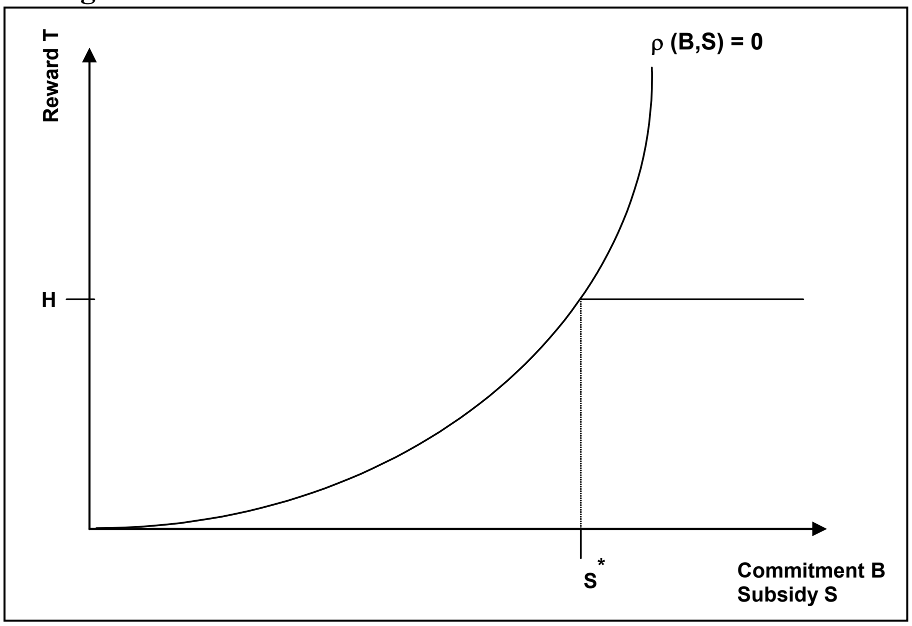
Define h(I) as the rate at which the utility's investment levels increase with its expected profits. From the utility's maximisation exercise and equations (6) & (7),

$$h(I) = -\left[(p'(I))^2 / \{p''(I)p(I)\}\right] \tag{9}$$

Assumption 1. Assume that $h'(I) < 0$ for all $I > 0$. This implies diminishing returns to profit sharing, i.e., the rate at which the utility's investments increase as expected profits from production increases is non-increasing in the level of investment (and, therefore, profits).

This contract structure may be illustrated by Figure 2 below.

Figure 2



The $\rho(B,S) = 0$ line is the iso-rent locus of the menu of contracts (reward-commitment pairs) that a regulator can offer a utility. The locus is convex in S given Assumption 1 and equation (9) above, through its interaction between p(.) and T(.), both of which are functions of S.

4.2 The optimisation exercise

The optimisation exercise can be decomposed into two parts. In the first, the utility chooses an investment rule that maps its optimal level of investment to the contract option offered by the regulator (as outlined through its production function above). The second part is the regulator's optimisation exercise, where he incorporates this rule in its surplus function, and offers a commitment-reward contract that optimises the total expected (utility and regulator) surplus.

4.2.1 Case 1: Symmetric information

4.2.1.1 Case 1a: Perfect information

In the first case, with perfect information, the regulator's decision problem has the following characteristics. There is no adverse selection problem, as the regulator and utility both know the level of subsidy that will be provided. The moral hazard problem still remains, since the level of investment of the utility remains unknown to the regulator.

The regulator can calculate the level of investment that maximises total expected surplus (the regulator's and utility's)[27], which is:

$$I^*(T) = \text{argmax}_{I} \; \{p(I)H - I\} \tag{10}$$

The regulator then announces a reward T = I*, if the utility delivers I*, and 0 otherwise. The utility also (weakly) prefers to deliver I*, so that the regulator's optimal outcome is ensured.

Substituting the utility's chosen investment level (from (6) above) into (2),

$$T^{**} = \text{argmax}_{T} \; \{p(I^*(T))[H - T] + B\} \tag{11}$$

This means that for a utility that has limited amounts of expected subsidy, the regulator can cap the rent to the utility by offering a reward T** that maximises the regulator's expected net return from production.

[27] The regulator's objective function is {p(I)[H-T] +B]; the licensee's is {p(I)T – I – B}.

If the utility has an unlimited subsidy, then the optimal solution for the regulator (that solves its moral hazard problem) is to give the utility the full residual proceeds from the project.

The optimal level of subsidy for the utility will then be

$$S^* = p(I^*)H - I^* \tag{12}$$

Referring to Figure 2 above, the regulator will pay the utility a reward structure that moves along the locus till the level of subsidy, S*, derived from equation (12) above. Beyond that level, he caps the reward at T*, determined by equation (7) above (note that $T^* \leq H$, which is the outcome in the high state).

4.2.1.2 Case 1b: Imperfect information

Consider the case where the utility too does not know of its subsidy transfer before he commits to a contract, i.e., the regulator and the utility both share the same imperfect knowledge on the level of subsidy. Let the utility's expected subsidy be denoted by:

$$E(S) = \int_{\underline{S}}^{\bar{S}} Sg(S)ds \tag{13}$$

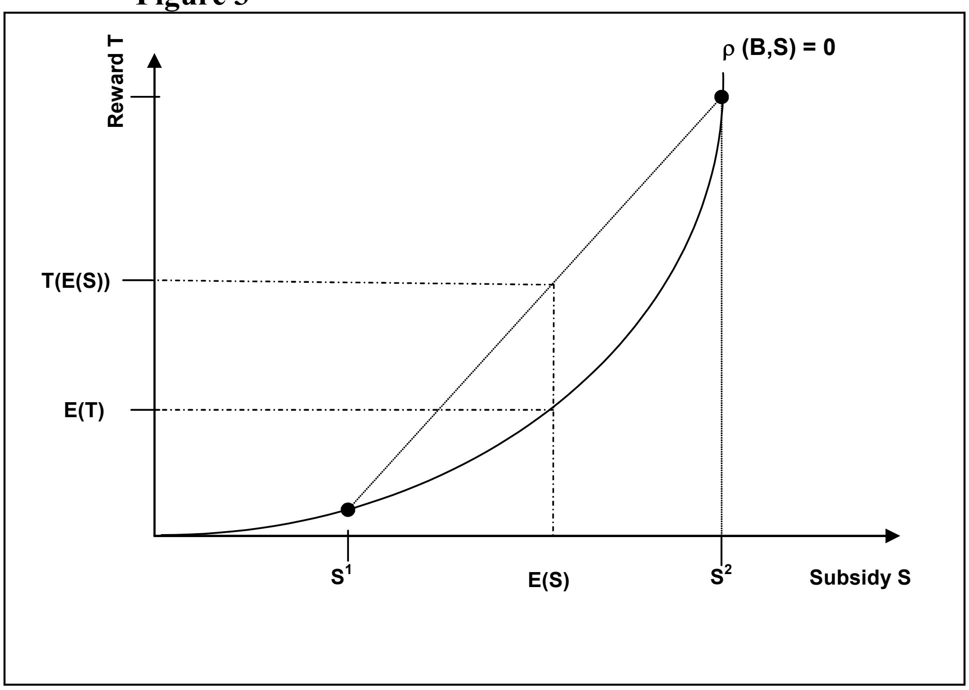
By Jensen's inequality[28], the concavity of the utility's production function (Assumption 1 above) implies that among all reward options that deliver the same rent to

[28] If f(X) is a continuous concave function in a random variable X with expected value EX, i.e., $f'(X) > 0$ and $f''(X) < 0$, then $f(EX) > Ef(X)$.

the utility, the regulator will prefer that which induces the same level of investment for all realisations of the level of subsidy, i.e., at the expected level of the utility's subsidy.

This is an even better outcome for the regulator than the symmetric perfect information case. The regulator will only need to guarantee the utility an expected profit of zero, rather than for each realisation of the level of subsidy. This allows the regulator to implement a reward T that varies only with the utility's expected subsidy, not with actual realisations. This is a counter-intuitive result, since increased uncertainty actually results in a better outcome for the regulator. This can be represented by Figure 3 below.

Figure 3



4.2.2 Case 2: Asymmetric information

4.2.2.1 Case 2a: Utility's costs are known to regulator.

Consider the setting where the regulator cannot observe the level of subsidy. He offers the utility the reward-commitment pair {B(S), T(S)}. The regulator's optimisation problem is as follows[29]:

$$\text{Max}_{B(S),T(S)} \int_{\underline{S}}^{\bar{S}} \Big[\; p\{I(T(S))[H - T(S)] + B(S) \; \Big] g(S)dS \tag{14}$$

Subject to

$$\rho\,(S) = T(S) - B(S) > 0 \tag{14a}$$

Denote the integrand in Equation (10) as

$$W^R(S) \equiv p[I(\pi\,(S))H - I(S)] - \pi(S) + B(S)$$

This is the regulator's expected welfare when the utility's realised subsidy is S.

Proposition 1: The solution to (14) has the following properties:

(i) $B(S) = S$, $\pi'(S) > 0$ and $W^{R'}(S) > 0$ for all $\pi(S) < S^*$.

(ii) $\rho'(S) = 0$, for all $S \in [\underline{S}, \bar{S}]$, i.e., $\rho = \rho^c$, a constant.

[29] This is the standard regulatory problem of maximising expected consumer surplus.

(iii) $$\int_{\underline{S}}^{\bar{S}} \left[\{p'(I)H - 1\} \frac{dI}{d\pi} - 1 \right] g(S)ds \leq 0 \text{ if } \rho^c = 0, \text{ and } = 0 \text{ if } \rho^c > 0$$

Proof: See Appendix

Property (i) says that the regulator optimally induces the utility to deliver its entire subsidy as a commitment whenever the investment level is below the surplus maximising level, I*. If the regulator did not do this, the outcome would be Pareto inferior, since the more generous the profit share that the utility could be rewarded with to compensate for its larger commitment, the larger the expected surplus as a result of increased investment and a larger expected payoff for the regulator.

To prevent the utility from concealing some of the subsidies that he gets, the regulator must reduce the share of profits the utility is awarded when he makes a smaller commitment. The utility might wish to understate the extent of his subsidy, hoping to convince the regulator of the need to earn higher profit shares to offset the losses that he would incur. The regulator responds by demanding a lower commitment level and promising lower reward for success, the higher the utility claims the cost to be. This is a counterintuitive result that is not usually a part of the regulatory toolkit. At the same time, limiting profit shares as rewards is a conflicting requirement for the regulator: with both players being risk neutral, pronounced profit sharing can alleviate the regulator's moral hazard concerns, but can simultaneously aggravate risk sharing concerns.

Property (ii) says that the regulator maintains a constant level of rent by increasing the utility's reward (share of profit). The selected rent level then determines the menu of profit sharing arrangements, one for each level of realised subsidy. Why would the regulator try to keep the utility on a constant rent loci? As seen from property (i) above, the regulator induces the utility to part with his entire subsidy to realise the gains from higher investments induced by higher rewards. But diminishing returns to profit sharing (Equation (9) above) implies that increases in the utility's share of realised profit induce larger investment the smaller the initial share of profit. In other words, the regulator will implement a more generous reward scheme than one required to compensate the utility for making a larger commitment, only at low levels of rent of the latter.

How is this level of rent chosen? Property (iii) determines the level by balancing the expected benefits and costs associated with any particular level of rent. A higher threshold rent increases the level of investment put in by the utility, but also increases the rent level afforded to it.

4.2.2.2 Case 2b: Utility's costs are not known to regulator

The regulator's optimisation problem in (14) is now:

$$\text{Max}_{B(.,C),T(.,C)} \int_{C} \Big[\ p\{I(T(.,C))\}[H - T(.,C)] + B(.,C)\ \Big]\ f(C)dC \qquad (15)$$

Subject to the standard set of constraints. (15a)

Proposition 2: The solution to (15) has the following properties:

(i) $T_C(C,S) > 0$ for all $C \in [\overline{C}, \underline{C}]$.

(ii) $T(\overline{C},S) = H$.

(iii) If S < $\overline{B}$, then their exists a $\hat{C} \in [\overline{C}, \underline{C}]$ such that T_C(C,S) > 0 for all C $\in [\underline{C}, \hat{C}]$ and T(C,S) = T(C',S) for all C $\in [\hat{C}, \overline{C}]$.

(iv) If $S^1 < S^2$, and $S^1, S^2 \in [\underline{S}, \overline{B}]$, then $T(C,S^1) > T(C,S^2) > T(C, \overline{B})$ for all C $\in [\hat{C}, \overline{C}]$.

Proof: See Appendix

Property (i) and (ii) state that the utility's rewards will strictly increase the lower his costs, at all levels of subsidies. Property (iii) implies that if the utility has access to only limited amounts of subsidy, the regulator will never reward him the full value of the project. Doing this would afford the more efficient utilities' super-normal rents[30].

The regulator cannot ensure the ideal outcome of Case 1a, since any attempt to do so would induce the low-cost utility to overstate his costs to secure the franchise for a lower price (or demand a higher profit share). To prevent this, the regulator would award him a lower reward, but correspondingly ask a lower level of commitment. A utility would thereby secure a higher profit share, the lower his costs.

To induce the utility to provide the maximum effort, however, the utilities are still provided a reward that is relatively large compared to the level of commitment. This enables lower cost providers to enjoy rents, and because of these rents, low cost utilities would have lesser incentives to overstate costs. Consequently, when the regulator does not know the utility's cost, he may forego full extraction of subsidies when the utility's cost structures are high in order to limit the rent to utilities when their cost levels are low.

[30] The broad features of such contracts can be discerned in the regulation of private electricity distribution companies of the Orissa state in India. Despite the small subsidy amounts relative to the total turnover of the

4.2.2.3 Case 2c: Both the costs and subsidy amounts are not known to the regulator.

The regulator's optimisation problem is as follows:

$$\text{Max}_{B(C,S),T(C,S)} \int_C \int_S \{p[I(T(C,S))\,[H - T(C,S)] + B(C,S)\}\, f(S)g(C)\, dCdS \quad (16)$$

This is the standard regulatory problem of maximising expected consumer surplus.
Subject to:

$$\rho(S) = T(S) - B(S) \geq 0 \quad (16a)$$

$$B(C,S) \geq 0 \quad (16b)$$

Proposition 3: When a solution to (16) exists[31], it can be implemented by a set of contracts that have the following properties:

(i) For each $C \in [\underline{C}, \overline{C}]$, there exists an $\hat{S}(C)$ such that $B(C,S) = S$ for all $S \leq \hat{S}(C)$ for which the utility operates and $B(C,S) < S$ for all $S \in [\hat{S}(C), \overline{S}]$.

(ii) (Cost pooling) For each $S \in [\underline{S}, \overline{S}]$, there exists some $\hat{C}(S)$ such that $\langle B(C,S), T(C,S)\rangle = \langle B(C',S), T(C',S)\rangle$ for all $C, C' \in [\hat{C}(S), \overline{C}]$.

(iii) (Subsidy pooling) For each $C \in [\underline{C}, \overline{C}]$, $\langle B(C,S), T(C,S)\rangle = \langle B(C,S'), T(C,S')\rangle$ for all $S, S' \in [\hat{S}(C), \overline{S}]$.

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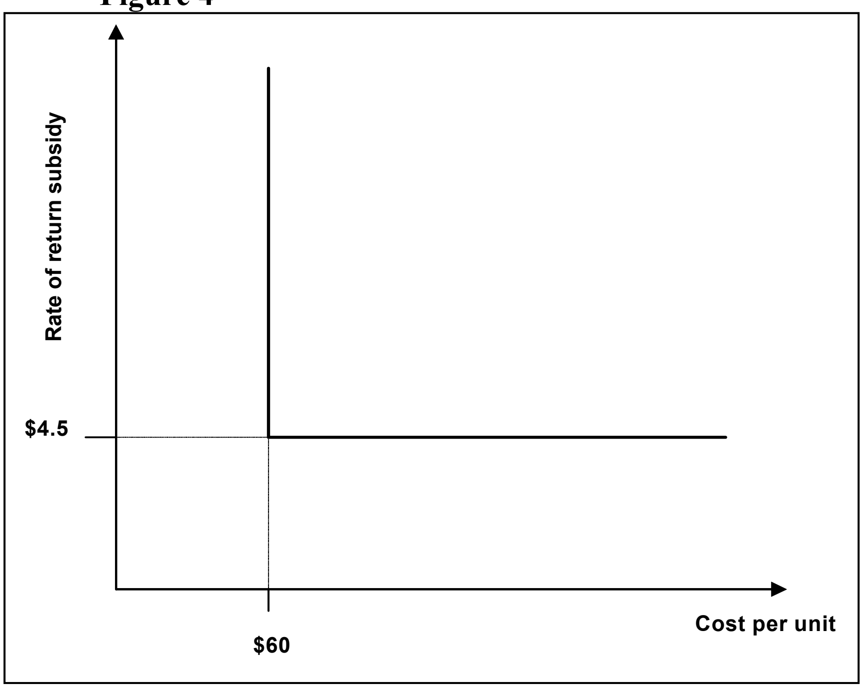
companies (and to be provided only indirectly through World Bank support), the regulator imposed stringent loss reduction and other revenue collection targets.

[31] Lewis and Sappington [2000] state that it can be shown that a solution to Proposition 3 exists when Assumption 2 holds and f(.) and g(.) are both uniform densities.

Figure 4 below shows **iso-contract loci**, which are pairs of costs and subsidies for which the utility operates under the contract identified in the solution to Proposition 3. These loci are characterised by a Leontief nature: the L shaped loci indicate that subsidies and costs are perfectly complementary in determining the power of the incentive scheme under which the utility operates. This implies that a more powerful reward structure will be acceptable only to those utilities with both access to higher levels of subsidies and a lower cost structure, but this will not be true generally of larger subsidies or lower costs alone. The intuition for this becomes clearer with the help of an example, delineated below.

Figure 4



Suppose that the vertex of Figure 4 above corresponds to a cost level of $60 and a subsidy level of $4.5 (the numbers are to be seen in conjunction with Table 5 below). The kinked locus implies that at a cost of $60, the power of any scheme associated with subsidy over $4.5 remains the same and will fail to separate utilities with different cost characteristics.

The pooling outcome – leading to the failure of incentive options – can be demonstrated by a modification of a reward scheme formulated in Pfeifenberger *et al.* [2001], with the options presented in Table 5 below:

Table 5: Options for rewards in different instances of project completion ($)

Realised cost	Reward offered after project completion				
	A	**B**	**C**	**D**	**E**
50	17	15.5	13	9.5	5
60	**12**	11.5	10	7.5	4
70	7	**7.5**	7	5.5	3
80	2	3.5	**4**	3.5	2
90	-3	-0.5	1	**1.5**	1
100	-8	-4.5	-2	-0.5	**0**
110	-13	-8.5	-5	-2.5	-1

Note: Boldface indicates highest expected rewards for each level of expected costs.

Option A offers the maximum reward for expected costs of $60, option D, that for $90, and so on. If a utility expects to complete a project for a total cost of $80, then option C offers the highest reward, equal to $4, if the project is actually completed for $80. These rewards (or penalties, if negative) are provided to the utility in addition to the full recovery of actual project costs.

Consider now the effect of a subsidy transfer to the utility, the expected value of which is unknown to the regulator. An expected subsidy of $4.5 will make an operator who expects to complete the project for $70 migrate from his previously chosen option B to option A. Therefore, a menu of options A and B, with a subsidy transfer, will be unable to distinguish between utilities with expected costs of $60 and $70 for completing the project.

The larger the subsidy transfer, the less the power of the incentive scheme. An expected subsidy of $8, for instance, will render options A, B and C unable to separate utilities with expected cost levels of $60, $70 and $80. This can be depicted in Figure 4 above: for any given level of cost, a larger subsidy will reduce the power of the incentive scheme. In other words, an iso-contract locus – i.e., a combination of rewards and commitments – above and to the right of the one depicted in the figure will have lower power.

The regulatory response to this specific environment involving multiple uncertainty needs to be highlighted. Conventional theory argues that in this situation, full extraction of the subsidy is not always optimal; "something" needs to be kept on the table for an efficient utility. In the case investigated in this paper, however, this conclusion may be reversed. When the levels of investment and the cost structure of the utility, together with subsidy levels, are unknown to the regulator, it might not be optimal for the regulator to allow the efficient utility rents. Higher levels of subsidies will be sought by the utility from the government on the basis of higher stated costs. To discourage this, the regulator's response, for higher levels of (observed) subsidy would be to offer a smaller reward, with a corresponding lower level of required commitment (implicitly to reduce costs). This is a counter-intuitive outcome, since at first sight, it would seem better to offer the utility a higher reward with a higher required commitment, in order to incentivise him to increase investments. That, in fact, would have been a superior outcome in the absence of a subsidy transfer. With subsidies and an inability of the regulator to distinguish between high and low cost utilities, increases in up-front payments and rewards for success will generate rent for the low-cost utility, given any specified level of subsidy. It is then rational for the regulator to prohibit the utility from using the higher subsidy to secure a more powerful reward structure, in order to limit its rents. Subsidies, then, are used as a signal by the regulator to distinguish between high and low cost utilities, based on the assumption that low-cost utilities will have less incentive to seek higher levels of subsidies and consequently rewarded more.

The underlying intuitions of the rather lengthy and involved proof of Proposition 3 can be illustrated by a simple algebraic formulation. The following example also demonstrates that the separating outcomes arising out of the contracts offered by regulators under the previous cases with one degree of adverse selection asymmetry, breaks down when there are two sources of information uncertainty. Consider an example of an incentive scheme with linear reward and commitment structures:

$$\text{Max}_{\{C,S,I\}}\ C^* I^{\gamma} (\alpha_0 C + \beta S) - I - (a_0 C + b S) \ , 0 \le \gamma \le 1$$

Where C* is the actual cost and C and S are the declared cost and subsidy levels, respectively. The first order conditions are as follows:

$$C^* I^{\gamma} (\alpha_0) - a_0 = 0 \text{ and } C^* I^{\gamma} (\beta) = 0$$

The solution being independent of C and S implies pooling. In other words, any agent, whatever their declared C and S type, will choose the same I and opt for identical incentive schemes. On the other hand, a quadratic reward commitment structure, of the following form:

$$\text{Max}_{\{C,S,I\}}\ C^* I^{\gamma} (½) (\alpha_0 C^2 + \beta S^2) - I - (½)(a_0 C^2 + a_1 C + b S^2)$$

will have as the first order conditions

$$C^* I^{\gamma}(\alpha_0)C - a_0 C + a_1 = 0 \text{ and } C^* I^{\gamma}(\beta S) = 0$$

Since the investment decision of the agent is a function of both C and S, the solution implies a separating equilibrium. Different C and S types will choose an incentive scheme that most closely corresponds to their optimal investment levels. Notice, though, that this is the result of the simplistic objective function chosen, separable in the arguments for commitments and subsidies. Pooling and separating outcomes will be more ambiguous in more general objective functions.

Table 6 below summarises the incentive contracts associated with different classes of information asymmetry discussed in this section, and also attempts to situate the contracts in the economic environments associated with the specific asymmetries. It furthermore points out the improvements likely to be derived from the modified contracts in relation to the existing structure.

Table 6
Summary of incentive contracts associated with different types of information asymmetry in the presence of subsidies

Symmetric Information
(Both regulator and utility have common knowledge of cost, subsidy or both)

Case	Known to both	Unknown to both*	Context of use	Recommended structure of contract	Comments on outcomes, improvements over existing contracts and limitations
Ia	Subsidy and cost	--	The amount of subsidy available to the utility is known if, for instance, a dedicated fund is in place. Subsidies provided through the telecom Universal Service Fund; each Village Public Telephone (VPT) point gets an amount from the USF.	**Case for standard price cap regulation.** The regulator calculates the level of investment that maximises total expected surplus. He then offers the utility a reward that matches this level of investment, at all levels of subsidy. The utility also maximises his surplus by providing this level of investment.	Menus are unlikely to improve performance.
Ib	Cost	Subsidy	Subsidies are not earmarked. Telecom operators compete for subsidies per subscriber (e.g., in the case of US rural subscribers), instead of a lump-sum subsidy amount, i.e., subsidies are budgeted on an expected basis.	**Case for a price / revenue cap regulation.** Among all reward options that deliver the same rent to the utility, the regulator will prefer that which guarantees the utility an expected zero rent, rather than a zero rent for each level of subsidy.	**The "average contract" is a superior outcome for the regulator, given the concavity of his objective function (based on diminishing returns to investment for the utility).**

* Investment is unknown to the utility in the sense that it is a decision variable for the utility. The regulator is always, *ex ante*, unaware of investment by the utility.

Asymmetric Information
(Utility has private knowledge on cost, investment and subsidy)

Case	Known to regulator	Unknown to regulator	Context of use	Recommended structure of contract	Comments on outcomes, improvements over existing contracts and limitations
IIa	Cost	Subsidy and investment	Investments and subsidies are likely to be correlated. The utility has an incentive to understate the level of subsidy that he gets. This has implications for dealing with utilities whose political capabilities may be	**Case for a menu price-cap / revenue-cap mechanism.** To induce the utility to deliver his entire subsidy, the regulator offers him a larger reward, the higher the level of commitment that he makes, but in a	The constant rent level implies full wealth (subsidy) extraction. In particular, the high-cost utility's rewards may be capped more severely, irrespective of his level of subsidy.

Case	Known to regulator	Unknown to regulator	Context of use	Recommended structure of contract	Comments on outcomes, improvements over existing contracts and limitations
			higher than commercial ones. A situation here might be the case of power distribution subsidies. The utility, by disguising theft as agricultural consumption, can ask for larger subsidies.	manner that keeps his rent constant. Revelation about true subsidy levels can be incentivised through commitment levels, so that utility does not lose through higher subsidies.	To ensure that subsidies are used only for covering the tariff gap and not commercial losses, the regulator might insist on a commitment to meter agriculture consumption while allowing higher tariffs / lower loss reduction targets.
IIb	Subsidy	Cost and investment	Since the utility will have an incentive to overstate costs, to convince the regulator that project success is costly, the regulator's optimal response will be to offer a smaller reward, and demanding a correspondingly smaller commitment, the larger the level of subsidy. This is particularly true of higher cost utilities. When the subsidy is limited, the regulator will not reward the utility the full value of the project.	**Case for a menu subsidy cap.** A commitment by the utility to a faster reduction in commercial losses will be matched by the regulator permitting a larger increase in tariffs. Full extraction of subsidy is not always optimal in this case, especially in the case of a high cost utility, in order to limit the rent that would accrue to a low-cost utility if he declares his costs to be high.	This case is especially relevant for case where the utility has access to an earmarked fund, but many contracts are being given to different utilities with widely varying cost structures.
IIc	--	Investment, subsidy and cost	Multiple degrees of uncertainty leading to a regulator being unable to offer high / low power incentive contracts to different utilities.	Assuming that subsidies mimic the revenue realisation gap, a non-linear schedule of incentives that disallows a higher reward for higher commitment levels is the optimal response for the regulator.	The regulator will be unable to distinguish between operators of different efficiencies, and the incentive structures will result in pooling of utilities of varying efficiencies. A price or revenue cap type of incentive regulation is unlikely to be effective.

5. APPLICATION TO UTILITY REGULATION

This section assesses the relevance of the theoretical model presented in the paper for evaluating the contracts that have hitherto been awarded, are being considered for award or are likely to be awarded in the future, for utility services in India. Thus far, the most numbers of contracts to private companies have been awarded in the power sector, and consequently, most of our examples will be drawn from this sector[32]. Table 7 below is a schematic classification of characteristics of infrastructure sectors designed to facilitate the customisation of menu contracts.

Table 7: Classification of sectors in congruence with model variables

Investment \ Subsidy	Low	Medium	High
Low		• Water & waste management contracts	• Power distribution
Medium	• Industrial Water Supply	• Rural telecom and IT networks	• Public road transport
High	• Power generation • Ports		• Urban transport

5.1 An application to contracts for power projects

Power generation projects in emerging markets offer the best illustration of the adherence to (or deviation from) the principles of an optimal menu of contracts delineated in the previous section. Most power projects in developing countries operate under long term Power Purchase Agreements (PPAs) signed with the conceding authorities and not as merchant power plants (i.e, selling directly into spot markets for electricity). Although many of these contracts have been awarded through competitive bidding (that were designed to extract the rents inherent in negotiated PPAs), the structure of the bids and associated informational asymmetries have been thought to have left the conceding authorities at a disadvantage.

Information asymmetries are considerably aggravated when a project is large. There is a bias in many developing countries towards "mega" power projects deriving from an instinctive desire of attracting large amounts of private capital. This has led to a series of problems with large IPPs in many developing and transitional countries ranging from Central Europe to Pakistan, India, Indonesia and the Philippines.

The award of a contract to the Enron sponsored Dabhol Power Corporation (DPC) in India is illustrative of the problems caused by a contract that is uniform and allows the agent to extract a significant rent by leveraging on information asymmetries. The 2,184 MW, $2.8 bn project has an overwhelmingly large take-or-pay structure[33], which takes most of the risks away from the project. The rate of return on equity that is factored into the tariff is approximately 30 percent, far too high for the commensurate levels of risk that were to be borne by the sponsors. Although there are commitments for DPC built into the 30 year Power Purchase Agreement (PPA), for instance on heat rates, availability, ramp-up time to maximum power, etc., these are technical requirements. It is now obvious that the excessively high rate of return – far beyond those justifiable by the extent of risks normal in a developing nation – was *ipso facto* a subsidy given to the project[34].

Contrast the problems with the instances of successful concessioning and commissioning of gas operated power plants in many other emerging markets. The marked differences in these

[32] The telecom sector is, of course, the most commercial, but, other than concessions for rural telephony, competition precluded the license award mechanisms that we deal with in this paper.
[33] The variable cost per unit of power from the Dabhol plant operating at 90% PLF is 0.2 cents.
[34] This is another example of implicit subsidies mentioned earlier in section 2.

experiences indicate a problem with not only the size of these projects, but also the degree of implicit subsidy (in the form of revenue and other guarantees) that have been given.

The DPC contract also illustrates the other aspect of commitment that we have not addressed in this paper – that of the principal's[35]. Despite the signing of an "iron-clad" contract, there have been continuing defaults by the contractual purchaser of the power, the Electricity Board of the State of Maharashtra (MSEB). DPC was expected to sell to a bankrupt utility (ninety percent of whose customers are subsidised), and the gap between the receipts of MSEB and the contracted payments was to have been made up by the state and central government. Only a fraction of these payments have materialised. Therefore, ex post, DPC, may feel justified in having ex ante demanded a high risk premium!

The main lesson here is that the risks of setting up large projects in developing countries often offset the occasional economies resulting from size. In sharp contrast to DPC is the case of a 216 MW gas-based power plant set up in Andhra Pradesh. The capital cost of this project is Rs 474 million per MW.

5.2 An illustration of a separating contract for a power distribution license

Penalties and incentives necessarily go together: if there are incentives to perform, there must also be penalties for non-performance. However, instead of penalties, asymmetric incentives, involving a financial downside as well as an upside is also likely to result in certain performance characteristics. In some incentive schemes, such as the Kanpur Electricity Supply

[35] The approach of our paper is, of course, different to that of the standard commitment literature. Our paper is a one-period contract without the dynamics of credibility of commitments inherent in a multi-period model.

Company's (KESCO) privatisation bid in 1999-2000, the downside risk was greater than the upside benefit in beating designated performance targets (Tadimalla [2000]).

A simple illustration of a separating contract may be a licensing exercise for a power distribution company, where the utilities have a choice of opting for a concentrated (urban) zone versus a consolidated (urban and rural combined) one. Assume that there are two types of utilities, with the more efficient type (Utility 2) dominating the other. The figures in Tables 8a and 8b below indicate the payoffs to these utilities from operating the distribution license for specially configured zones. The figures in brackets represent the payoffs from the rural zones, which are measures of subsidies provided to the utilities for operating in the rural areas (and which are a component of the total payoffs of the utilities). Note that the payoff to utilities from the consolidated zone is less than that from the concentrated zone and the subsidy combined, due to the additional cost of integration of two different kinds of systems. It is this loss that makes it optimal to separate the utilities in service provision in the concentrated and rural areas.

Table 8a: Payoffs to a utility from a distribution license (Case IIb)

	Consolidated zone (concentrated + rural)	Concentrated zone
Utility 1	700 (**300**)	500
Utility 2	1200 (300)	**1000**

Consider the simple case where the regulator knows the payoffs of the utility, but cannot distinguish the efficiencies of the two utilities (corresponding to case IIb of Table 6 above). Let a reserve price of 300 be set for the rural zone. Bidding in this structure ensures that Utility 2 gets the license for the concentrated zone and Utility 1 will (as a residue) bid for the rural zone (having to pay only as much of its supernormal profits). The payoff to the regulator increases in the case where the utilities segregate themselves in serving the two zones, i.e., (i) if Utility 2 bids for the consolidated zone (payoff to regulator is 1200) or (ii) Utility 2 bids for the concentrated zone and Utility 1 for the rural zone, respectively (payoff to regulator is 1300).

Now consider the case (corresponding to case IIc) where the regulator is uncertain about the subsidy transfer (Table 8b shows the regulator's expectations of payoffs).

Table 8b: Expectations of regulator about payoffs to a utility (Case IIc)

	(a): E(S) > S			(b): E(S) < S	
	Consolidated zone	Concentrated zone		Consolidated zone	Concentrated zone
Utility 1	800 (400)	500	Utility 1	600 (200)	500
Utility 2	1300 (400)	1000	Utility 2	1100 (200)	1000

If the regulator believes the expected subsidy is 400, and sets a reserve price of 400 for the rural zone, neither utility will bid for the rural zone. If, on the other hand, he expects the subsidy to be 200, and sets this as the reserve price, Utility 2 will be indifferent between the zones (since he obtains the same payoffs in both the zones) and a pooling equilibrium emerges (with the regulator unable to separate the two utilities into the two zones), with Utility 1 being shut out and the payoff to the regulator consequently less than under a separating equilibrium.

6. CONCLUSION

In an environment of multiple information asymmetry, regulatory contracts that give rise to separating equilibria are a critical component in any exercise to simultaneously incentivise efficient provision of services and extract rents from efficient service providers. A suitably designed menu of contracts has been considered an incentive compatible means of achieving separating equilibria. This paper investigates the properties of an optimal contract between a regulator and utility in the context of utility investment, where the utility receives subsidies from the government.

Subsidy transfers, besides increasing the information asymmetries, also serve to create a distortion in utilities' investment decisions through a "wealth" effect. This paper has attempted to provide an analytical framework to formulate a mechanism of regulatory oversight of utilities when large and uncertain subsidy transfers to the utilities from the government induces multiple uncertainties between utilities and regulators. We show that in this situation of multiple adverse selection and moral hazard, many of the standard menus of contracts designed as means of information disclosure in an environment of more limited asymmetry results in nullifying much of the power of standard incentive regulation and the ability of the offered contract to distinguish between utilities. When the levels of subsidies, furthermore, are observed only imperfectly by the regulator, this creates an incentive for the utility to demand higher rewards (larger revenue shares or higher tariffs, etc.) from regulators.

The regulator can best motivate a utility, under these conditions, to make the optimal level of investment by structuring a menu of rewards and commitments that are contingent on the relevant source of uncertainty and will vary depending on the variable(s) that is (are) private information to the utility. This implies that each individual utility concession has to be tailored, and a "one size fits all" concession is not likely to be optimal, as a consequence, raising the transaction costs of regulation.

There are three main conclusions from the paper. One, contract menus are the optimal revelation mechanism in this environment. Two, many menus of the types that have been offered by regulators to utilities are likely to fail in this objective under circumstances investigated in the paper. Third, menus need to be tailored to address the relevant source of uncertainty.

These conclusions have significant implications for regulatory pricing in developing countries, where tariff setting for utilities is done predominantly on a cost-plus basis. One is the generally accepted conclusion that the mode of regulation needs to move away towards an incentive based system like RPI-X. Second, and more importantly, in the particular case, when multiple asymmetries are present, even the standard incentive regulatory schemes are unlikely to achieve the desired results; regulatory schemes need to be tailored according to the specific uncertainties that characterise the system. Since low-cost utilities would have an incentive to overstate costs and thereby extract rents, the regulator should optimally devise a sliding scale where lower cost utilities are allowed higher rents. In other words, higher declared cost structures are penalised by being offered lower rewards. The Private Finance Initiative (PFI) contracts in the UK broadly bears this out, since each contract (defining the investment and subsidy components involved) has had to be tailored. Finally, in an environment when the information uncertainty is symmetric, the model suggests that, by making an expected (in probability terms) reward scheme deliver a superior outcome to individual schemes, that regulators not micro-manage decisions, thereby buttressing the often heard recommendation for regulators to focus on “doable” actions.

References

Armstrong, M., 1999, "Optimal Regulation with unknown demand and cost functions", Journal of Economic Theory, vol. 84, pp. 196-215.

Armstrong, M. and D. E. M. Sappington, 2003, "Towards a unified treatment of adverse selection problems", Discussion Paper, Nuffield College, November.

Baker, B. and S. Tremolet, 2000, "Utility reform: Regulating quality standards to improve access for the poor", World Bank Note No. 219, October.

Baron, D. and R. Myerson, 1981, "Regulating a monopolist with unknown costs", Econometrica, vol. 50(4), pp. 911-930.

Bhattacharya, S. and U. R. Patel, 2001, "New regulatory institutions in India: White Knights or Trojan Horses?", also forthcoming in volume of Conference Proceedings on *Public Institutions in India: Performance and Design*, Harvard University (revised May 2003).

Bhattacharya, S. and U. R. Patel, 2003, "Markets, Regulatory Institutions, Competitiveness, and Reforms," SCID, Stanford University, Working Paper No. 184, September.

Boitani, A. and C. Cambini, 2002, "Incentive regulation of local public transport: The subsidy cap mechanism", Working Paper, Universita Cattolica del Sacro Cuore, Milan, March.

Crew, M. A. and P. R. Kleindorfer, 2000, "A critique of the theory of incentive regulation: Implications for the design of performance based regulation for postal service", paper prepared for *Rutgers University 13th Annual Western Conference on Competitive Challenge for Network Industries*, Monterey, California, July.

Crew, M. A. and P. R. Kleindorfer, 2002, "Regulatory economics: Twenty years of progress?", Working Paper, University of Pennsylvania.

de Moor, A. P. G., 1997, "Key issues in subsidy policies and strategies for reform", UN Fourth Expert Group Meeting on Financial Issues.

de Moor, A. P. G., 1998 "Perverse incentives: Subsidies and sustainable development", Mimeo., Institute for Research on Public Expenditure, the Netherlands.

Green, J. and J. Laffont, 1986, "Partially verifiable information and mechanism design", Review of Economic Studies, vol. 53, 447-456.

Guesnerie, R., P. Picard and P. Rey, 1989, "Adverse selection and moral hazard with risk-neutral agents", European Economic Review, vol. 33(4), pp. 807-823.

Kay, J., 2003, “Are the increasingly frequent failures in electricity supply the result of privatisation and deregulation?”, Financial Times, October 1.

Laffont, J-J. and J. Tirole, 1986, “Using cost observations to regulate firms”, Journal of Political Economy, vol. 94, pp. 614- .

Laffont, J-J. and Tirole, J, 1993, *Theory of incentives in procurement and regulation*, MIT Press.

Laffont, J-J. and D. Martimort, 2001, “The theory of incentives: The principal-agent model”, Princeton University Press.

Lewis, T. and D. Sappington, 1988, “Regulating a monopolist with unknown demand and cost functions”, Rand Journal of Economics, vol. 19(3), pp. 438-457.

Lewis, T. and D. E. M. Sappington, 1999, “Optimal contracting with private knowledge of wealth and ability”, Rand Journal of Economics, vol. 19, pp. 438-457.

Lewis, T. and D. E. M. Sappington, 2000, “Motivating wealth-constrained actors”, American Economic Review, vol. 90(4), pp. 944-960.

McAfee, R. P. and J. McMillan, 1988, “Multidimensional incentive compatibility and mechanism design”, Journal of Economic Theory, December, vol. 46, pp. 335-354.

Page, F. H., Jr., 1992, “Optimal contracting mechanisms for principal agent problems with moral hazard and adverse selection”, Economic Theory, vol. 1, pp. 323-338.

Pfeifenberger, J. P., P. R. Carpenter and P. C.Liu, 2001, “REx incentives: PBR choices that reflect firm’s performance expectations”, The Electricity Journal, November, vol. , pp. 44-51.

Picard, P., 1987, “On the design of incentive schemes under moral hazard and adverse selection”, Journal of Public Economics, vol. 33, pp. 305-331.

Planning Commission (India), 2002, “Annual Report on the working of State Electricity Boards and Electricity Departments”, April. (Also see earlier issues).

Sappington, D. E. M., 1983, “Optimal regulation of a multi-product monopoly with unknown technological capabilities”, The Bell Journal of Economics, vol. 14(2), Autumn, pp. 453-463.

Sappington, D. E. M., 1991, “Incentives in principal-agent Relationships”, Journal of Economic Perspectives, vol. 5 (2), pp. 45-66.

Sappington, D. E. M. and D. Weisman, 1996, “Designing options in incentive regulation plans”, in *Designing Incentive Regulation for the Telecommunications Industry*, MIT Press.

Shirley, M., 1995, "Contracting: What works, what doesn't and why", from *Bureaucrats in Business: the Economics and politics of Government Ownership*, Oxford University Press for the World Bank.

Shirley, M. and L. Colin Xu, 1997, "Information, incentives and commitment: An empirical analysis of contracts between government and state enterprises", Discussion Draft, The World Bank.

Tadimalla, S., 2000, "Privatisation of Kanpur Electricity Supply Company (KESCO): A case study", *Mimeo*., Infrastructure Development Finance Company Limited, Mumbai.

Weisman, D., 2000, "Regulatory moral hazard: Price caps and endogenous entry under the 1996 Telecommunications Act", in *Expanding competition in regulated industries*, M. A. Crew (ed.), Kluwer.

APPENDIX

Proof of Proposition 1.

The regulator's optimisation problem is as follows:

$$\text{Max}_{\,B(S),T(S)} \int_S \{p[I(T(S))*[H - T(S)] + B(S)\} \; g(S) \, dS \tag{14}$$

This is the standard regulatory problem of maximising expected consumer surplus.

Subject to

$$\rho\,(S) = T(S) - B(S) > 0 \tag{15}$$

Denote the integrand in Equation (10) as

$$W^R(S) \equiv p[I(\pi\,(S))H - I(S) - \pi(S) + B(S)$$

Set up the Hamiltonian

$$\Lambda = [W^R(S)]g(S) + \lambda(S)\,\rho'(S) + \mu(S)[S - B(S)]$$

where $\rho(S) = \pi(S) - B(S)$ is the state variable, $\lambda(S)$ is the co-state variable. $\rho'(S)$ and $B(S)$ are control variables.

Assume that the regulator's objective function is concave in T() and B().

<u>Necessary Conditions:</u>

$$p'\,[I(S)H - I(S)]\,\frac{dI}{dB}\,g(S) - \mu(S) = 0 \tag{A.2}$$

$$\lambda'(S) = [1 - \{p'(I)H - 1\}\frac{dI}{d\rho}]\,g(S) \tag{A.3}$$

$$\lambda(S)\,\rho'(S) = 0 \tag{A.4}$$

$$\mu(S)[S - B(S)] = 0 \tag{A.5}$$

$$[S - B(S)] \geq 0 \tag{A.6}$$

Proof of Property (i)

(A.2) implies that $\mu(S) > 0$ when $\pi(S) < S^*$.

Together with this, (A.5) implies that <u>$B(S) = S$ for all S for which $\pi(S) < S^*$</u>

Proof of Property (ii)

Note that S^* has been defined previously in (12) as that level of subsidy for which the regulator maximises his surplus.

$$\lambda(\underline{S})\rho(\underline{S}) = \lambda(S)\rho(S) = 0; \quad \lambda(\underline{S}), \lambda(S) \geq 0 \qquad (A.7)$$

Proof by contradiction:

Suppose $\rho'(S) > 0$ for all S.

Then (A.4) implies that $\lambda(S) = 0$ for all S. (A.1a)

Using (A.3),

$$[p'(I)H - 1] \frac{dI}{d\rho} - 1 \equiv \Phi(S) = 0, \text{ for all } S \qquad (A.8)$$

$$\Phi'(S) = p''(I)H[\frac{dI}{d\rho}\rho'(S) + \frac{dI}{dB} B'(S)]$$

$$+ [p'(I)H - 1] \frac{d^2I}{d\rho^2} [\rho'(S) + B'(S)] \qquad (A.9)$$

Recalling that $p'(I) > 0$ and $p''(I) < 0$,

Property (i) then implies that $B'(S) = 1$.

From the definition of h, (also see (2)),

$$h = \frac{dI}{d\rho} = \frac{dI}{dB} \qquad (A.10)$$

Therefore (A.9) implies

$$\Phi'(S) = p''(I)H[h\{\rho'(S) + 1\}] + (p'(I)H - 1)[h'\{\rho'(S) + 1\}] \qquad (A.11)$$

From (A.2), $p'(I)H - 1 > 0$. Also from (1), $\rho' + 1 > 0$.

Therefore, if $h' \leq 0$, then $\Phi'(S) < 0$.

This contradicts (A.8), since $\Phi(S) = 0$, for all S.

Therefore, $\rho'(S) = 0$ for all S.

In other words, the optimal contract for the regulator is to maintain a constant level of rent by increasing the utility's reward just enough to offset the larger commitment that he makes. Each selected rent level determines a menu of rewards and commitments, which will be exactly the subsidy obtained by the utility, from (11).

Property (iii)

The optimal level of rent selected by the regulator is determined at the level that exactly balances the benefits and costs associated with the level of rent.

Recall from (A.1b) that $\int_{\underline{S}}^{\bar{S}} \lambda'(S) = 0$ when $\rho(S) > 0$ for all $S \in [\underline{S}, S]$.

(A.3) then implies

$$\int_{\underline{S}}^{\bar{S}} [1 - \{p'(I)H - 1\} \frac{dI}{d\rho}]\, g(S)ds = 0$$

The Proof of Proposition 2 follows on similar lines.