Implementing Incentive Regulation with Bounded Regulators

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Abstract

It is puzzling today to explain the diversity and imperfection of regulation applied to network monopolies. We argue that two sets of fundamental characteristics should be deemed when searching for the most appropriate regulatory tools to implement. First, the bounded endowment of regulators set by the governments and the legislators determines their abilities (staff, budget, judicial powers) to implement any of the regulatory tools. Ranging these tools from the easiest to the most complex to implement, they are: a- cost plus, b- price/revenue cap, c- output regulation, d- yardstick competition or e- menu of contracts. Besides, the regulator must take into account that the network monopolies perform multiple tasks with heterogeneous regulatory characteristics in terms of controllability, predictability and observability. These tasks characteristics determine what type of regulatory tool is more likely to better regulate each network monopoly's tasks. In general, incentive schemes should be implemented with tasks responding well to the criteria of controllability and predictability. It is then the level of observability of these tasks which should set the particular incentive tool to implement. Conclusions for the regulation of network monopolies' tasks are then derived from the actual regulatory capability of regulators.

Keywords: incentive regulation, bounded regulator, regulatory endowment, network tasks, regulation alignment

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1 Introduction

A lot of insights have already been drawn from the principal agent theory to highlight the role of an efficient regulator to control, through high powered incentive schemes, the activity of the monopolies (Laffont and Tirole, 1993). This was illustrated in particular in the liberalized electricity and gas industries with the regulation of the Transmission System Operators (TSOs) and the Distribution System Operators (DSOs) respectively in charge of the transmission and distribution networks management (see Newbery, 2000 for power transmission and Jamasb and Pollitt, 2007 for power distribution). The economic literature has then mainly focused on searching for tools that help in decreasing the information asymmetry that the regulator suffers and/or in incentivizing the network operator to minimize inputs and maximize outputs, assessing the different incentive regulation tools that have been proposed and implemented (Decker, 2009; Jamasb and Pollitt, 2007; Saguan et al., 2008). Other said, the regulator has been attempting to put in place regulatory tools that could alleviate the information advantage the network company holds regarding the real cost of its activities –i.e. solve the adverse selection problem – and the effort it made to perform them – i.e. solve the moral hazard problem (Joskow, 2008).

We can find five main regulatory tools widely used reviewing the literature and the practices. When the regulator applies *cost plus regulation*, she pays the network operator her expenses plus a rate of return. The network operator is then incentivized to declare her costs but not to optimize her processes (Joskow, 2008). In *price cap regulation*, the regulator sets a price for the service provided by the monopoly which then has an incentive to optimize her process because she will then keep the associated informational rent. The regulator however gains no information about the network operator's cost function (Joskow, 2008). Rather than focusing on optimizing inputs, the regulator can implement *output regulation* where she evaluates the monopoly's performance in terms of quantity and quality of the produced outputs and incentivizes her to improve it (Volgelsang, 2006). Besides, rather than proposing a unique performance target (either in terms of input- or output-oriented) that may not be optimal compared to the potential of improvement that monopoly can reach, the regulator can propose a *menu of contracts* with different levels of incentives. Monopoly can self-select the most appropriate regulatory schemes. The trade-off is then between minimizing information asymmetry and maximizing incentives (Laffont and Tirole, 1993). Last, the regulator can use *yardstick competition* when she regulates several comparable monopolies. She can then compare the cost and efficiency of one monopoly to the performance of the others. Each can be more remunerated if it is more efficient, which incentivizes most of them to improve their processes (Scheiffer, 1985).

Until now, the theoretical studies of regulation, whatever the considered regulatory tools, present two shortfalls. First, the “classic” model of regulation assumes that the regulator is endowed with all desired perfect cognitive, computational and judicial abilities that enable her to perfectly propose and build the regulatory tool needed to regulate monopoly under her control. The reality however is that the regulators have limited and heterogeneous abilities (which make them "bounded regulators" as in the Herbert Simon or Oliver Williamson "bounded rationality" world). In practice, the regulators (among the 200 of them created to deal with infrastructure regulation worldwide[6]) seem rather constrained by imperfections, endowed specially with only limited human skilled resources, limited budgets and limited judicial abilities to investigate the real behavior of companies. The relative strengths and weaknesses of every regulatory agency should then be taken into account when considering the tools it should use to perform supervision.

Another weak assumption of the contemporary model of regulation is that the regulator is supposed to control the network operator’s costs as a whole-as for a single task (Laffont and Tirole, 1993). However, in reality the regulated companies perform multiple regulated tasks[7] with heterogeneous characteristics which actually require distinct regulatory tools (See Rious et al., 2008 and Saguan et al. 2008 for electricity transmission and Saplacan 2008 for electricity distribution). For instance, price cap regulation is known to be an efficient tool for maintenance while congestion, losses or service quality should be regulated with performance-based regulation. Investment is itself hard to tackle with these classical regulatory tools.

Considering the two big discrepancies between the theory of regulation and its reality, we aim at investigating the right "regulation alignment" between the regulatory tools, the regulator’s abilities and the targeted network tasks to make the global regulatory system efficient. In the present paper, we raise a new perspective on the relationship between regulator and network monopoly and look at the efficient regulation choices when being not made by a perfect regulator, but a bounded regulator. Beside her own abilities, the regulator should then take into account that the regulation of a network monopoly addresses a diversity of tasks with distinct characteristics requiring finely tuned regulatory tools (as: cost-pass-through, input-, output- or benchmarking-based). For instance, in the electricity sector, when networks are interconnected a TSO cannot control all the performance factors of all tasks (e.g. losses or congestion management). Different network tasks may also suffer from different levels of uncertainty and then of predictability. As a

[6] Source: http://rru.worldbank.org/Toolkits/InfrastructureRegulation/

[7] For instance for the power Transmission and System Operators: operation, maintenance, investment, R&D, ‘climate change and European energy market building’ actions, etc.

result depending on the tasks to perform, the regulator shall suffer different degrees of information asymmetry. Network tasks have there three key regulatory characteristics being a- their controllability, b- their predictability and c- their observability. As a consequence the different tasks performed by a regulated network may then require differentiated regulatory tools. To illustrate our arguments, we will focus on the case of European electricity regulators and TSOs (transmission and system operators). The IERN database managed by the Florence School of Regulation is there of great help[8]. Nevertheless, the properties we highlight are not sector-specific and can be generalized to the regulation of all other network industries (gas, railway, telecom, and possibly water – Glachant and Perez, 2009).

Our paper is organized as follow. In the first section, we demonstrate the discrepancy between the field reality and the theoretical model of perfectly endowed regulators. We discuss next the main regulatory characteristics of network operators' tasks. We end up by suggesting a decision tree to choose the appropriate regulatory tool, adapted to the regulatory characteristics of the network operator's tasks and to the regulatory costs born for the bounded regulators. We also exemplified how our frame of analysis could be used to define the most appropriate tools to regulate a certain monopoly task. We then test the robustness of our frame by applying it to real regulators, showing that "better endowed" regulators implement "more demanding" regulatory tools as they have more abilities to refine the regulatory tools and to monitor the actual regulatory characteristics of the various network companies' tasks.

2 Discrepancy between the reality and the textbook model of the regulators

The reality of regulation is fundamentally different from its theoretical framework. While a regulatory tool would require specific regulator's abilities to implement it, the textbook model of a regulator is always assuming that she has all the required abilities to perfectly design and implement the appropriate regulatory regime. Consequently, lowly endowed regulators may not be able in practice to apply some of the complex regulatory tools to network operator.

In this section, we first show that the real regulators are endowed with heterogeneous abilities by governments and legislators. This may hamper their abilities to implement the most complex regulatory tools, obliging them to focus on some basic tools rather than considering all of them.

[8]Source: http://www.iern.net/portal/page/portal/IERN_HOME/REGIONAL_ASSOC?pId=3070021

2.1 The endowment of regulator

In the economic literature proposing and building regulatory tools, the regulator is always thought to have all the desired cognitive, computational and judicial abilities to do her job. In particular, she knows *ex nihilo* how to choose the most efficient regulatory tool and she has all the desirable abilities to implement it. In reality, the regulators are endowed with only limited resources, which is likely to hamper their abilities to do their job perfectly. In practice the regulators have learned and are still learning how to use the different regulatory tools provided by theory in order to reduce their information asymmetry and to adapt the regulation to uncertainty and risk.

However since Laffont and Tirole, the economic literature does not assume anymore that the regulator is omniscient and omnipotent. She faces two major difficulties while pursuing perfect efficiency. First, the regulator is facing information asymmetry while the regulatory tools could help her to decrease. Second, the regulator (like the network operators) is facing uncertainty for two reasons. There may be an important lag between a network operator action (in particular an investment) and its effect on productive and dynamic efficiency (even the network operator may be unable to anticipate perfectly). Besides, demand for network services is always uncertain to an extent (because of general economic conditions and potential innovations). These elements are now included in the most recent work about regulatory tools (Evans and Guthrie, 2006).

The economic literature nevertheless makes stringent implicit assumptions. The first one is that the regulator sets the tariff paid to the network operator. And she does so on an *ex ante* basis[9]. She is also able to collect the needed data. Obviously, she is independent to avoid that any political disturbances modify the tariff level, which would otherwise make the incentive far less credible. At last, the regulator must have the judicial abilities to implement the regulatory tool she targets. When considering the regulators' powers, one realizes that reality is quite far from what theory supposed as the embedded powers of a regulator. From table 1, one can notice that some of the national regulators in Europe are far from reaching the set of normal regulatory powers. Some regulators set the tariff *ex post*, which prevents them from setting any incentive unless they credibly threat to cut the tariff if they judge the expenses by the network operators were unreasonable. And some regulators'actions are still undermined by ministries involvement.

[9] Otherwise he would be unable to provide incentive to foster the efficiency of the network operators.

Table 1Evaluation of the regulator's power in Europe

before the implementation of the 3rd Energy Directive(Source: DG TREN, 2004[10])

	Ex ante vs expost regulation	Network access conditions	Dispute settlement	Ministry Involvement	Information powers
Austria	Ex ante	Regulator	Regulator	General guidelines	Strong
Belgium	Ex ante	Regulator	Regulator	No	Strong
Denmark	Ex post	Regulator	Regulator	Yes	Strong
Finland	Ex post	Regulator	Regulator	No	Strong
France	Ex ante	Regulator	Regulator	Tariff approval	Strong
Germany	Ex ante	Regulator	Competition Authority	No	Strong
Greece	Ex ante	Ministry	Regulator	Tariff approval	Strong
Ireland	Ex ante	Regulator	Regulator	No	Strong
Italy	Ex ante	Regulator	Regulator	General guidelines	Strong
Luxembourg	Ex ante	Hybrid	Regulator	N.A.	Strong
Netherlands	Ex ante	Regulator	Competition Authority	Issues instructions	Strong
Portugal	Ex ante	Regulator	Regulator	No	Strong
Spain	Ex ante	Ministry	Regulator	Yes	Strong
Sweden	Ex post	Regulator	Regulator	No	Strong
UK	Ex ante	Regulator	Regulator	No	Strong

[10]To our knowledge,no more recent source exists on this topic. The set of information about Germany is completed from the regulator's website. N.A. means "Not Available".

	Ex ante vs expost regulation	Network access conditions	Dispute settlement	Ministry Involvement	Information powers
Norway	Ex ante	Regulator	Regulator	No	Strong
Estonia	Ex ante	Regulator	Regulator	N.A.	Strong
Latvia	Ex ante	Regulator	Regulator	No	Strong
Lithuania	Ex ante	Regulator	Regulator	Instruction supervision	Strong
Poland	Ex ante	Regulator	Regulator	No	Strong
Czech R	Ex ante	Regulator	Regulator	No	Strong
Slovakia	Ex ante	Regulator	Regulator	Tariff approval	Limited
Hungary	Ex ante	Ministry	Regulator	Non-eligible	Strong
Slovenia	Ex ante	Regulator	Regulator	Instruction supervision	Strong
Cyprus	Ex ante	Regulator	Regulator	N.A.	Strong
Malta	Ex ante	Regulator	Regulator	No	Strong
Romania	Ex ante	Regulator	Regulator	No	Strong
Bulgaria	Ex ante	Regulator	Regulator	No	Strong

Of course, the third energy directive has recently pushed for a convergence of the national regulatory agencies' powers toward a set closer to the assumptions of regulatory theory[11]. Meanwhile, it would not solve the entire problem. Beside the assumption about the regulatory powers, the economic literature also implicitly assumes that the regulator will never face key difficulty in implementing any of the regulatory tools. This implies different conditions. The regulator must have a sufficient task force to deal efficiently with her different duties, related to the competitive and regulated areas. The task force dedicated to the building and operationalisation of the regulatory tools should have enough technical and computational competences. With regards to her task force and competences, the regulator can alternatively bridge the gap by delegating a part of her work to external parties if she has the budget to do so.

When looking at real regulators, the above-mentioned implicit assumptions seem rather optimistic. The governments were not so generous that all the regulators fit the description of their theoretical counterpart. When creating the regulators, some governments and some legislators endowed some of them with tight resources, which they largely perpetuated (see table 2). These limitations are likely to constrain the regulators abilities to regulate efficiently the network operators.

Table 2 Budget and employee resources of the European regulators[12]

	Staff dedicated to electricity for 100 TWh	Budget in $PPP dedicated to electricity for 100 TWh
Austria	114,68	16,67
Belgium	64,57	13,10
Czech Republic	87,41	1574,16
Denmark	43,89	244,82
Estonia	275,69	77,00
Finland	33,54	4,30

[11] Article 36 de la directive 2009/72/CE du parlement européen et du Conseil du 13 juillet 2009concernant des règles communes pour le marché intérieur de l'électricité et abrogeantla directive 2003/54/CE.

[12] These figures are the results of the following calculations. The original set of data is from the budget and staff information provided by the CEER regulators on the IERN website for year 2009 most of the time (2010 otherwise). This set of data was accessed the 1st October 2011. There is nevertheless an exception for the Belgian regulator, theCREG, whose IERN website gives no information about the budget. The CREG budget data then comes from the *Arrêté royal fixant les montants destinés au financement des frais de fonctionnement de la Commission de Régulation de l'Electricité et du Gaz pour l'année 2011*. When the IERN website provides any information about the percentage of the staff that is dedicated to the electricity sector, we use it to scale the total regulator's budget and so find an approximation of the budget dedicated to electricity only and we apply the same rationale to staff. When no information is provided, we scaled the regulator's budget and staff by the number of sectors the regulator is managing to obtain a rough approximation of the budget and staff dedicated to electricity. We also scaled these two factors by the national electricity consumption in 2009 (Source: Consumption of electricity by industry, transport activities and households/services from EUROSTAT, http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables#) and we scaled their budget dedicated to electricity in order to make them comparable in $PPP 2010 (Puchaing Power Parity – Source: PPP conversion factor, private consumption (LCU per international $) from Wordbank, http://data.worldbank.org/indicator/PA.NUS.PRVT.PP). At last, this set of data should be carefully analyzed because there are certainly economies of scale in regulation requiring a minimum budget and staff whatever the size of the power system. The colors indicate their relative values: the red color stands for low values and the green color stands for high values.

	Staff dedicated to electricity for 100 TWh	Budget in $PPP dedicated to electricity for 100 TWh
France	15,47	2,15
Germany	49,49	2,79
Greece	37,16	5,42
Hungary	124,90	661,52
Ireland	135,37	22,13
Italy	27,24	6,22
Latvia	300,40	3,18
Lithuania	199,10	28,44
Luxembourg	44,69	6,63
Netherlands	33,67	3,31
Norway	45,57	658,82
Portugal	70,00	7,42
Romania	243,75	52,52
Slovakia	34,60	0,58
Slovenia	201,91	8,44
Spain	8,57	0,95
Sweden	24,59	243,45
UK	68,39	8,58

In brief, most of regulators undergo in reality a limitation of their abilities either in terms of powers or in terms of resources, which strongly deviate from what the textbook model assumes. They may have to be conservative to avoid negative judicial review or, being small administrative units of 10-15 people, to avoid entering uncertain and complex regulatory innovation. Other said, the more the regulator has resources and powers, the more she can put in place innovative and sophisticated regulatory regimes and the lower is the risk of error *ceteris paribus*[13].

2.2 The alignment of regulatory tools with regulator's abilities

The regulator's abilities in terms of resources and skills will limit her choice of regulatory tools because they stand for different levels of implementation difficulties. We present in this section the complexity of the different regulatory tools and how it determined the tools to implement when coupled with the actual regulator's endowment.

[13] Meanwhile, it should not be forgotten that the shortfalls of regulator's abilities could be partially overcome thanks to the experiences that the regulators individually accumulate or commonly share among each other (Brophy Haney and Pollitt, 2010; Brousseau and Glachant, 2011).

Cost plus regulation is obviously the simplest regulatory tool. It only requires that the regulator audits the network operator's account. She then sets the network tariffs according to the observed costs.

Price cap regulation is then just a degree higher in terms of complexity. Of course, the burden of auditing is smaller because the regulator requires information about the firm's costs only at the beginning (or end) of the regulatory period. However, the regulator must spend here resources to set the reference price and the level of the efficiency factor, in order to avoid a risk of error about initial tariffs (leading to windfall profits or losses for the network operator being disconnected from her performances). Errors may also happen because of modifications in demand evolution expectations and other main parameters of the allowed revenue formula. In practice, the regulator must mix price cap regulation with cost plus regulation, and share losses and gains between the network operator and the consumers. She then can include an adjustment mechanism to incentive regulation, protecting consumers' surplus as well as providing to the firm incentives for cost reduction. Learning effect has a potential positive repercussion on the regulator to better adjust the revenue formula when moving from one regulatory period to the next.

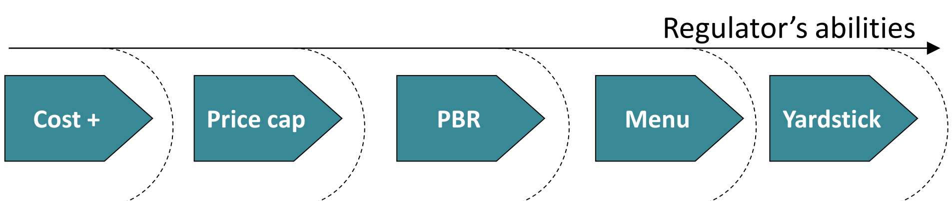
"Performance-based" regulation represents a new degree of difficulty for the regulator. While cost-plus regulation and price cap regulation focus on costs only, performance-based regulation relies on an explicit definition of a performance target for an output to be coupled with a financial incentive to reach it. This would necessitate from the regulator to recognize that the network operator produces different outputs and to define each. She should also weight the gains that any improvement of these outputs may have for the system as a whole as to value it in the financial incentive. Only to these conditions, the network operator will be able to make the efficient arbitrage between the costs and the benefits that an operator effort generates for the system. A high level of expertise is needed there. The cost of this regulatory tool could also be high because the regulator needs to collect data valuating the benefits to the system of improving the network operator's performances and the associated network operator's costs to deliver the associated efforts. Meanwhile, network companies are given a significant discretion in how they achieve the efficiency goals. Besides, no cost observations are required within the regulatory period.

The implementation of a *menu of contracts* requires a supplementary degree of abilities from the regulator. While previously she was not interested in the intrinsic efficiency of each network operator, she now must integrate it in the menu of contracts, offering at least several low-powered incentive schemes to network operators with low potential efficiency gains and at least several high-powered incentive schemes to network operators with high potential efficiency gains. The regulator can apply this to both input and output regulation. The actual expertise is there the key condition to construct fine-tuned appealing contracts. It conditions the effectiveness of the tool and the right separation among network operators' types.

Finally, *yardstick competition tool* is one more step further in terms of difficulties. The regulator would have to collect a huge amount of information from the network operator(s). She then has to perform a careful analysis, costly both in terms of time, skills and budget. Collecting, standardizing data and ensuring a robust quality of data is a complicated issue that any regulator may not succeed in managing efficiently (Brophy Haney and Pollitt, 2009). In particular a high level of data standardization and accuracy is needed to run her computation and permit the comparison of various network operators[14].

The difficulties faced by the regulator in implementing the different regulatory tools can be summed up in the following figure. The regulator needs increasing resources and abilities to implement cost plus, price cap, performance-based regulation, menu of contracts and yardstick competition.

Figure 1 Alignment of the regulatory tools with the regulators' abilities[15]



3 *The matching of regulatory tools with the network operator's tasks*

Beside the discrepancy between the reality of regulators' abilities and the assumption of the textbook model, it is generally assumed that the regulator frames a company performing a unique task with a single regulatory tool. In practice it should highly matters whether the operator performs a single task and delivers a single product, or performs multiple tasks and delivers multiple products possibly in an aggregated manner[16]. Textbook assumes that the regulatory characteristics of the regulated tasks are homogeneous. In practice, the characteristics of the

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[14] The regulator should also be able to alleviate the risk of strategic behavior or gaming by firms that could sometimes produce illusory efficiency improvements (Jamasb et al., 2003). The risk of tacit collusion would materialize if the network operators collectively limit their effort in one regulatory period in order to be able to display efficiency gains in the next regulatory period. However in practice, no gaming situation was observed when yardstick competition is implemented in some electricity networks.

[15] The amount of additional abilities required from the regulator to implement a more complex regulatory tool is not necessarily the same one for any of the regulatory tool.

[16] See for instance Laffont and Tirole (1993).

network operator's tasks are highly heterogeneous and therefore require different regulatory tools to match enough to give enough efficient incentives to the regulated firm.

3.1 The heterogeneity of network operators' tasks

To our knowledge, economic literature never treated the question about how to choose a regulatory tool among the five theoretical ones *considering the heterogeneity of* the regulatory characteristics of the network operators' tasks. There are however practical and theoretical recognition that the network operators perform heterogeneous tasks requiring distinct regulatory tools (See Rious et al., 2008 for electricity transmission and Saplacan 2008 for electricity distribution). The power and gas network operators basically perform four main tasks, the three first ones dealing with short term issues and the last one dealing with long term issues.

In the case of the electricity industry, a Transmission System Operator (TSO) operates the system on a day-to-day basis, ensuring the balance between injections and withdrawals, managing congestion and contingencies. Second, the network operator maintains the grid. Third, she manages a customer relationship with the network users (generators, suppliers and consumers), metering and billing energy and power, and possibly providing complementary services to some network users. Lastly, she connects new users; plans and expands the grid when excessive congestions appear[17]. A further distinction could be made between interconnected TSOs and "isolated island" TSOs.

The TSOs may also have to grasp new or renewed tasks because of new regulatory objectives or new environmental constraints[18]. In the electricity sector, because of climate change policy, TSOs must adapt their operation processes to the integration of innovation both on the supply side (intermittent generation from wind power and photovoltaic power) and on the demand side (smart meters, demand response, and possibly electric vehicles)[19]. On the top of this, the wider integration of European markets emphasizes the role of the TSOs as market architects, jointly with the power exchanges (Glachant and Rious, 2010). All these changes require a revival of RD&D in the electricity sectors in both the domains of infrastructures and of services.

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[17] It is possible that System Operation and Transmission Ownership are unbundled activities. In this case, the Transmission Owner maintains and builds the network while the System Operator performs all the other tasks (system management and planning).

[18] In the case of unbundling between System Operator and Transmission Owner, this statement applies to both of them.

[19] In the gas sector, that is mainly the concerns about security of supplythat drives organizational and technological innovation with the increase of supply through LNG and the implementation of reverse flows in case of disruption to ensure solidarity at the European scale.

3.2 Predicting the matching of regulatory tools from the characteristics of the network operators' tasks

The different tasks performed by the network operators are obviously heterogeneous, in particular in terms of uncertainty and of delivery time horizons. The tasks that TSOs call "system operation" deals with the short term network management. They encompass uncertainty because they are highly dependent on the day-to-day behavior of the market participants (generators, traders, suppliers, consumers). Maintenance and the customer relationship management are recurrent mid-term activities presenting few uncertainties, unless innovation appears. The grid connection and expansion are recurrent activities but touches to very long term decisions[20]. Despite, the recurring process of building lines, the future use of the infrastructure is still highly uncertain at the time of planning[21]. Last, uncertainty reaches its highest possible level when considering RD&D because it concerns the use of the network infrastructure in the very long term with developing technologies whose outcome is partially unknown.

Controlling the TSO's costs as a whole with a unique regulatory tool would then be inefficient given the heterogeneous nature of her tasks. Encouraging companies to reduce operational expenditures may work as long as it would not lead later to an unexpected lower quality of the service provided. On the opposite, innovation is inevitably an unproductive cost in the short term and its expected benefits would only be obtained on a long period of time. The regulator should then find a proper balance between, on the one hand, the incentives being influential for certain tasks of the regulated firm and, on the other hand, the uncertainty she and the network operators always face.

In practice only a hybrid approach relying on the simultaneous use of various regulatory tools could deliver more appropriate results. To intensively match with the industry operation the regulation has to address more specifically the different characteristics of the various tasks performed by the network operators. As a consequence of the heterogeneity of tasks the regulator looking for a better matching should evaluate three characteristics of the targeted network operator's tasks. These characteristics are the controllability (the regulator knows that the operator can control how she performs the task), the predictability (the regulator and the operator can foresee ex ante the future outcome) and the observability (the regulator can check ex post the actual outcome) of the regulated task. We express it with a decision tree suggesting how to match

[20] The practical lifetime of a power line can reach up to 80 years while their economic lifetime is generally estimated to 40 years.
[21] For a discussion on the role of TSOs for planning the network development see Rious, Perez, Glachant 2011.

the regulatory tools with these tasks characteristics. We present these three cost characteristics considering first that the regulator is working in an ideal situation of perfect and certain information and then in situations where information encloses risk and where the regulator eventually suffers information asymmetry.

3.2.1 Controllability

We first consider the situation where both the regulator and the network operator face no uncertainty with regard to the system management and where the regulator faces no information asymmetry. In this situation, a regulator can incentivize the network operator if the latter can enhance the efficiency of a targeted task either increasing the level of output for the same quantity of inputs or similarly reducing the quantity of inputs without modifying the level of output. Other said the network operator control the efficiency of this task through her effort.

If this assumption is satisfied in theory, in reality it is not so obvious. Imagine a network operator whose zone has neither injection nor withdrawal and is only transited by cross-border flows. She then has little discretion in minimizing the level on losses on her network. Whatever the action she may decide, it may be countered by the independent actions of neighboring TSOs. This is for instance what occurs if the use of phase shifters [22]are not coordinated, one tap shift by a TSO being potentially countered by another tap shift by a neighboring TSO (Verboomen et al., 2006). We also can imagine that the network operator is planning an investment to relieve a structural congestion but cannot implement it because of fierce local opposition. She cannot then lower the congestion cost.

In such real situations, it would not be efficient to submit her to a strong incentive scheme because it would not result in a predictable efficiency improvement, only in regulatory costs and profit shortfall for the regulated company. Consequently a cost plus regulation could be preferred for the losses of an interconnected grid or –under conditions- the cost of a “structural but internal” congestion.

When a task is controllable, the company can undertake actions to reach an efficient level of operation, and appropriate incentive regulatory scheme may make sense (some congestions costs for instance maybe controllable in the medium term while not in the short term), upon the condition that task is also predictable and observable.

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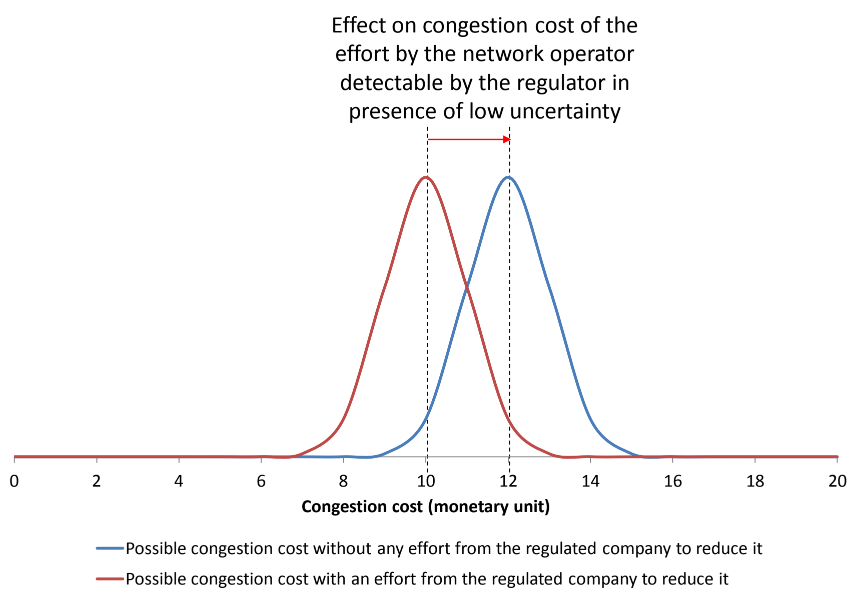
[22] The TSOs use phase-shifters in particular to control power flow and possibly repulse them outside their networks.

3.2.2 *Predictability*

We now consider the situation where the regulator faces no information asymmetry (once again) but both the regulator and the network operator faces uncertainty about the environment of the system management (future demand level, technology, etc.). In this situation, a regulator can incentivize the network operator so that she improves her productivity on a given task if uncertainty is not too high, that is to say that the network operator can distinct the effect of his effort on his efficiency from the interaction of uncertain (and uncontrollable) variables from the environment.

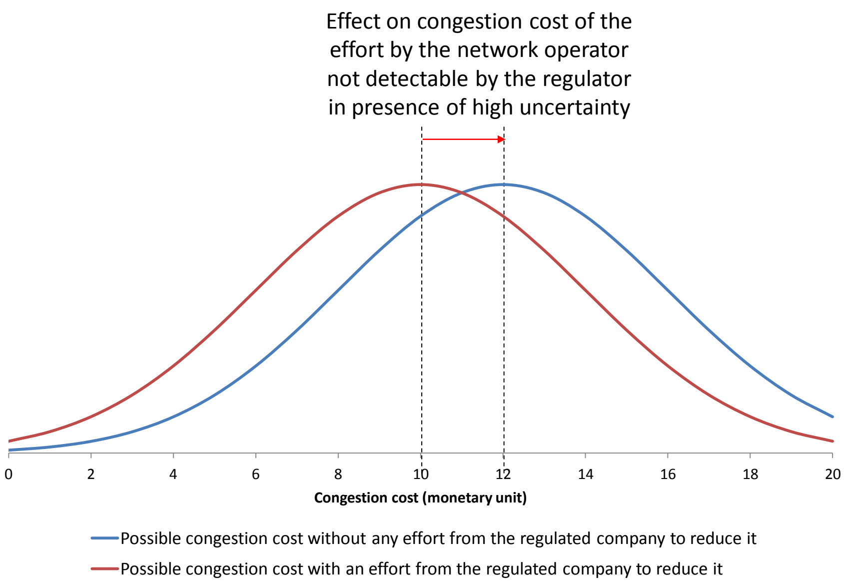
Suppose for instance that the level of demand impacts congestion cost in an unknown manner. Other things equal, the network operator is also supposed to be able to reduce congestion cost thanks to changes in his operation procedures. If the uncertainty about the impact of demand level on congestion cost is quite limited, it is then possible to identify the effect of the network operator's effort to reduce congestion cost (figure 2). An incentive scheme can then be efficiently implemented.

Figure 2 Effect of low environment uncertainty on the regulator's ability to detect an improvement of operator's efficiency (like for congestion cost)



Otherwise, if uncertainty about the impact of demand level on congestion cost is too important and radical, it may then be difficult for the regulator and the network operator to distinguish the effect of the efficiency improvement realized by the network operatorfrom the impact of demand level (figure 3). In such an uncertain situation, unless the regulator is able to filter the impact of uncertain variables on the network operator's tasks[23], it would not be efficient to impose the latter an incentive regulation because the regulator would not be able to differentiate the effect from real efforts by the network operators from windfall improvements due to the system environment.

Figure 3 Effect of high environment uncertainty on the regulator's ability to detect an improvement of operator's efficiency (like for congestion cost)



3.2.3 Observability

We now consider the most realistic situation where the regulator and the network operator face uncertain information and the regulator also suffers from asymmetry of information. In this situation, the most realistic one, a regulator can incentivize the network operator so that he improves his efficiency on a given task only if it is monitored, that is to say the effect of an effort by the network operator can be observe first by the network operator and second by the regulator (if he is interested in regulating it).

If this assumption about the observability of a task is always satisfied in theory, it is not always valid in reality.For instance, before liberalization, losses were generally not monitored. In such situation, it is not possible to implement any incentive scheme. Another example can be found in

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[23]If the regulator has a sufficient experience, set of competences and budget (as for the TSO), he can filter the noise from environment variables and extract the effect of the effort by the network operator with an error margin. If the regulator and the network operator are risk takers, an incentive scheme can then be implemented even in this uncertain situation (possibly combined with a cost plus scheme to take into any residual unfiltered uncertainty). Nevertheless, the regulators are generally conservative and risk adverse (Brousseau and Glachant, 2010).

distribution where the monitoring of the customer relationship management requires indicators about the speed and the quality to answer the network users' solicitations. The task observability needs that related indicators exist in the network operator's process in a natural manner or that the regulator asks, standardizes and imposes them so that he isable to audit them. Without accurate monitoring, it is impossible to implement any incentive scheme. Observability can either concern inputs or outputs and may so determine the regulatory tools (either input- or on output-oriented) that can be implemented. Besides, the regulator may face different degrees of observability, ranging from a small historical set of data from one network operator only to a large set of data from several possibly comparable network operators.

In the first moment of regulation, it can then happen that observability is really out of reach of the regulator. Consequently the regulator may prefer the safeguard of a cost plus scheme. The regulator can neverthelessreduce his information asymmetry from the network operator for the next regulatory periods imposing the latter to monitor some indicators that may serve as vectors for future incentive schemes.

Inversely, with higher observability of a task, more sophisticated tools can be implemented. We must however distinguish between two types of observability. When only inputs are observable, the regulator should obviously implement an input-oriented regulatory tool, that is to say a price cap[24]. Otherwise, if only outputs (quantity or quality of the provided service) are observable, the regulator should implement an output-oriented regulatory scheme, which meansperformance-based regulation. The regulator then sets the output targets that the network operator should meet as well as the economic schemes to settle the observed deviations. Any gap with the target will be treated under a predefined reward-penalty function so that the network operator behaves maximizing social welfare.

In case of high observability of tasks, in particular when the regulator has historical datasets, it makes sense to invest in more advanced regulatory tools like a menu of contract where the company is pulled into a voluntary efficiency revelation scheme. The regulator can then build up the menu of contracts on historical results of the company, wondering whether she can still improve efficiency. A menu of contracts can be either input- or output-oriented, or both. When the menu of contracts is conveniently constructed, the network company would rationally choose the contract that fits best with its true (while unobservable) characteristics. It nevertheless

[24]Under this regime, the network operator could undertake efficient actions to reduce cost and then benefit from this improvement extracting rent

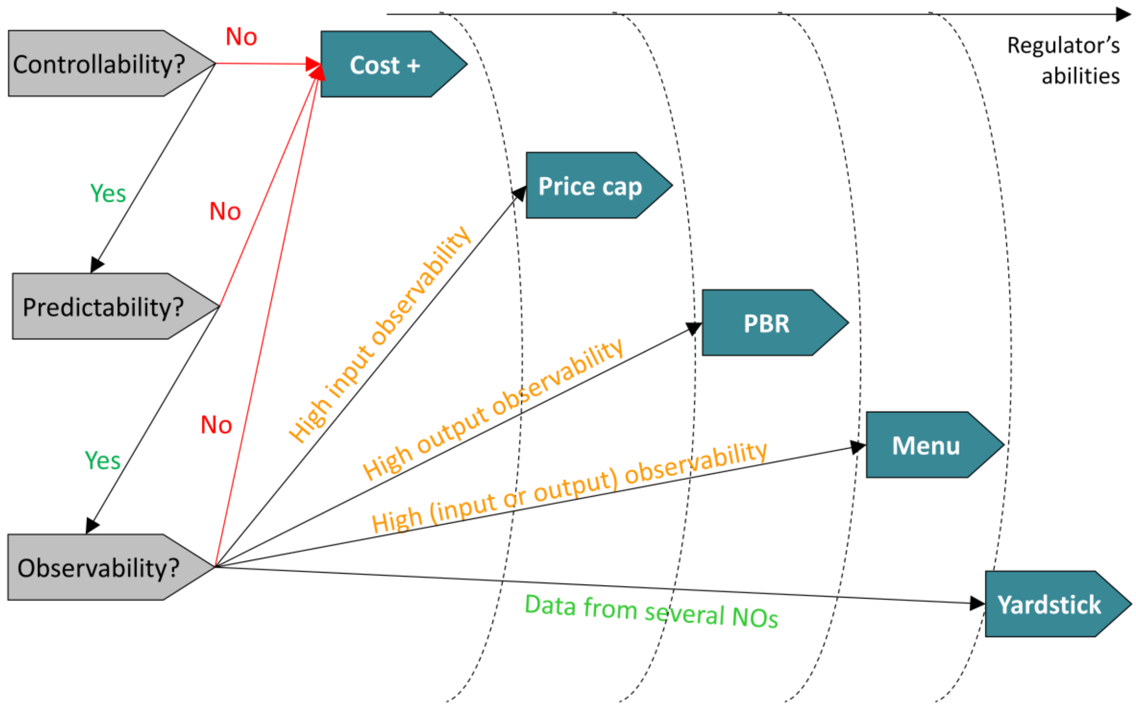
requires that the regulator be endowed with sufficient abilities to implement such a complex mechanism.

At last, he can also reduce his information asymmetry creating a "virtual competition environment" relying on benchmarking techniques. Yardstick competition can be either input- and/or output-oriented.Nevertheless, this regulatory tool requires that the regulator gets enough relevant information from several and comparable network operators. It is generally limited to distribution and not applied to transmission[25]. It is also the most complex regulatory tools to deal with. Only the regulator with a higher level of abilities can efficiently regulate several network operators with yardstick competition.

Figure 4 summarizes the decision tree to choose the appropriate regulatory tool taking into account on the one hand the characteristics of the network operator’s tasks in terms of controllability, predictability and observability, and on the other hand the regulator’s abilities. To sum up, if a task does not satisfy any of the controllability, predictability and observability criteria, the cost plus scheme is the most appropriate tool to recover the incurred cost. Otherwise, the efficiency of implementing another regulatory tool dependsfirst on the degree of observability and second on the very particular regulator’s abilities.

[25] Applying yardstick competition to transmission would imply that benchmarking allows to filter for the different institutional contexts the national power and gas TSOs are evolving in.

Figure 4 Decision tree to choose the appropriate regulatory tool



Besides, it should not be forgotten that in practice, the regulator does not have an *ex nihilo* knowledge of the best adapted regulatory tools to the goal he pursue for the network operator's task he targets. And even the best endowed regulators are learning with experience how to use regulatory tools to reduce asymmetry of information, to adapt these tools to uncertainty and to increase their computational abilities. The regulator may find how the regulatory tools should be matched with his goals and the targeted network operator tasks through a try and error process. As a consequence, our analysis should always be carefully considered since a change in the goals and in the characteristics of the network operator costs/tasks may modify this alignment.

3.3 Practical examples to choose appropriate regulatory tools

We dedicate this section to the illustration of the above framework to show how it may help a regulator in choosing the most appropriate regulatory tool, depending on his abilities and on controllability, predictability and observability of the targeted task. We consider tasks of an electricity TSO with different time horizons going from short term (losses), to very long term (innovation), passing by medium term (maintenance).

3.3.1 A short term task: the management of transmission losses

Energy losses refer to physical losses duringtransmission through a network. Their management is generally part of system operation[26]. The degree of interconnection of a network with cross-border systems would determine the choice of the regulatory tool to incentivize a TSO to reduce their volume[27]. In an interconnected system where the considered TSO's network is only used for transit from abroad, the network operator is not able to influence the volume of losses that occur on his network (because whatever action he may engage in, it may be countered by actions from the neighboring TSOs). Energy losses are then uncontrollable unless it is possible to filter the influence of external factors from the TSO's decision. There is then little to be gained by making the company responsible for the incurred costs of losses and to bear the total risk of their occurrence. Cost plus scheme is so suitable.

In an isolated power system, the TSO is the only one responsible forthe energy transmission losses on his network (given its use by the connected market participants). We can argue here that the volume of losses is controllable.It is also predictable if the network operator can anticipate how the market participants will use the network (i.e. the future load level and the future generators' dispatch). However, the regulator faces a substantial information asymmetry regarding how the regulated firm is managing transmission losses. If losses are included in a more global price/revenue cap regulation, the company may be incentivized to choose for instance more conventional technologies rather than low-losses one in order to reduce global costs. Otherwise, if the regulator is interested in minimizing the losses cost even if it may increase the global network costs through higher investment (for instance pursuing energy efficiency targets), he may prefer other regulatory tools. The choice between performance-based regulation, a menu of contracts and yardstick competition schemes would depend on observability, in particular the regulator's experiences in regulating the cost of losses. If few historical data is available, a performance-based scheme should be implemented. If a bigger historical dataset is available, a menu of contracts could be built and would be suitable. If the regulator has information from several comparable network operators, he could apply yardstick competition.

[26] The TSOs are not always in charge of buying losses, which does not prevent the TSOs from being incentivized in order to reduce their volume. For instance in Great Britain, the consumers must include their share of losses in their energy purchases. Meanwhile, the System Operator National Grid (like the distributors) also faces an incentive mechanism to prompt him to act in order to reduce their amount (Joskow, 2006). In other power systems like in France, the TSO and the DSOs are in charge of purchasing losses.

[27] It is also possible to implement an incentive scheme focusing on the purchase cost of losses if the TSO is in charge of buying them. It is for instance the case in France (CRE, 2010).

3.3.2 A medium term task: maintenance

Grid maintenance is part of the regular tasksthat the network operator undertakes to guarantee the reliability of his services. Its incurred costs are weakly affected by uncertainty and unexpected events and rely much more on the company's productivity potential, which means that they respect controllability and predictability criteria. The degree of observability of maintenance would depend on the regulator's correct evaluation of productivity improvement and of the cost of best practices needed to maintain a reliable grid. Consequently, a network operator should be incentivized on maintenance to minimize these costs and the choice of the most appropriate regulatory tool should consider the regulator's abilities. In case of emerging observability, maintenance costs could be regulated within the price cap regime, if the regulator's abilities allow it. In case of high observability and of a regulator with sufficient abilities, a menu of contracts and benchmarking techniques could be more appropriate to target optimal efficiency levels.

Meanwhile, incentivizing a network operator on the cost of maintenance may have adverse effects on the quality of the service he provides. It is indeed easy for him to decrease the cost of maintenance reducing globally the number of maintenance interventions, which may eventually endanger the network quality. It is then widely argued that quality has to be regulated complementarily to cost regulation (Jamasb and Pollitt, 2008). The regulation of maintenance cost is generally completed with a performance-based regulation whose metrics refer to quality indicators (Joskow, 2008). Quality is indeed controllable, predictable to some extent and observable for the regulator. Quality is controllable because the network operator determines it by his investment and maintenance. Quality is also predictable under the condition that the effects of extreme events are filtered out from the quality indicators[28]. This can possibly be done using econometric tools (Yu et al., 2009). At last, the observability of quality will depend on the set of indicators the regulators may impose on the network company to monitor. The regulator can then implement a performance-based regulation, either on a stand-alone basis, in a menu ofcontracts or integrated in a benchmark.

3.3.3 Innovation expenditures

The climate change policy in EU has led the regulators to consider new regulatory objectives beyond the ones of cost efficiency and system security. It consists, among others, of pushing network operators to undertake RD&D spending and to invest in new technologies to connect

[28]The quality indicators should not be filtered out from the whole weather conditions because the networks are supposed to withstand a given reliability standard (generally such that there is no more than one day interruption of the service in 10 years).

large-scale renewable sources and distributed generation with responsive demand to be equipped with smart meters (ENTSOE & EDSO, 2010).

Smartening up the grid would necessitate huge and continuous innovation investments from the side of network operators. Similarly to classical transmission investments, innovation investments are characterized by high short term expenditures while their benefits are uncertain all the more that they are potentially generated over a long lead time. With regard to the new regulatory objectives, the network operator should consider these activities as new or renewed tasks. On the other hand, the regulator should propose the right regulatory scheme to regulate these new tasks and their incurred costs.

The innovationprocess is a controllable one in the sense that the effort endured by the network operator will determine the quantity of innovation he is able to produce. Inversely, it has a very low degree of predictabilitybecause the usefulness of the innovative product and so its benefits are by definition unknown. The predictability of innovation is however simultaneously increasing with technological maturity. Similarly, observabilitydepends on technological maturity since a more mature technology allows the network operator in a first hand and the regulator in a second hand to have a better knowledge about the usefulness and outputs of the deemed innovation.

It is obviously the most complex TSO's task when the regulator has to figure out its optimal regulatory tool. Indeed, the level of predictability and observability would depend on the technology maturity. In case of low maturity, the TSOs could not foresee the possible interaction between the innovative product with the other components of the power system. It would so be inappropriate to put in place an incentive regulation tool where neither the regulator nor the network operator are able to consider the thereof innovation's cost and benefit, whatever the regulator's abilities[29]. When maturity is increasing and the once innovative products or services are integrated on a business-as-usual basis,an incentive tool that considers a sharing rule of risk between the network operator and grid users is suitable (Bauknecht, 2010).

4 Application to the analysis of some European regulations

We now test our framework to analyze real regulators and the tools they implement. We verify that the smarter ones implement the most complex tools and have the abilities to fine tune their regulation. We accordingly study regulation of the power network monopolies, mainly the transmission one in Spain (section 4.3), in Germany (section 4.4) and in Great Britain with the

[29] However, the regulator can rely on open fora where the market participants can display their expectations about innovative products (whether their own ones or those of others') and their interactions with the rest of the power system (Brousseau and Glachant, 2011).

two regulatory paradigms of RPI-X[30] (section 4.1) and RIIO[31] (section 4.2). We make these choices because their challenges and their ways of regulating network companies are quite different. Meanwhile, we welcome any further work willing to apply our analysis framework to other countries in order to propose new tools to regulators in adequacy with their abilities and with the characteristics of the network operators' tasks or to complete our analysis framework.

All the following sections are organized as follows. First the regulatory used by the regulator are presented. Then their match with the regulator's endowment is checked. At last, external factors affecting the controllability, predictability and observability criteria are also integrated to complete the matching analysis.

4.1 Electricity transmission regulation in Great Britain with RPI-X

The five standard regulatory tools have been implemented in Great Britain. Price cap was hence first applied to maintenance from 1991 (NGT, 2005). Otherwise, all other tasks were then regulated with a cost-of-service scheme. PBR schemes were then progressively introduced on losses and other system operation tasks like balancing and congestion management from 1993 (Rossignoli et al., 2005, Rious et al. 2008)[32]. A specific PBR scheme was also introduced for the achievement of reliability level from 2004 both to avoid that network companies decrease quality to achieve their cost objectives and to incentivize them to improve reliability when it is worth it(OFGEM, 2004b). And investment is regulated thanks to a combination of tools. First, the regulator reviews the investment planning by the companies at the beginning of the regulatory period. She relies on these results to set the transmission investment cap in a PBR scheme[33]. This scheme has the particularity of adapting to the investment allowances to changes in the location of generators, consumers and flow patterns during the regulatory period. Once decided and built, the assets are included in the Regulated Asset Value at their construction cost to be remunerated at the Weighted Average Cost of Capital (WACC) during their lifetime. No incentive scheme was then applied to the TSO's performances with regard her customer relationship management. At

[30] Retail Price Index minus the X efficiency factor.
[31] Revenue = Innovation + Incentives + Outputs
[32] Operation system costs had indeed dramatically increased in the mid-nineties. They had jumped from less than 100 million pounds in 1991 to more than 500 million pounds in 1994. It was due to generators located in load pockets gaming congestion management scheme to receive high rent. The TSO was then not incentivized to control this cost because it was passed through to the final consumer.
[33] Different profit-sharing rules are applied on OPEX and CAPEX in the last regulatory period (TPCR 4). The transmission monopoly retains 100% of efficiency gains for OPEX and 25% of efficiency gains for CAPEX (OFGEM, 2011).

last, RD&D has been tackled only recently, with the Innovation Funding Incentive from 2007[34] and the Low Carbon Network Fund from 2010[35].

The regulation of electricity transmission in Great Britain has then be regularly updated and improved to overcome the difficulties. The table below sums up the implementation of regulatory tools on transmission under the RPI-X framework.

The British regulator for gas and electricity, OFGEM, is considered as a pioneer in Europe and even worldwide in the application of the most advanced theoretical tools to regulate power and gas network operators (Joskow, 2008). OFFER (before she merges with OFGAS[36], the British regulator of gas) was the first power regulator to apply price cap regulation in 1990. OFFER then OFGEM has applied price cap regulation using a building-block approach and several types of regulatory tools recognizing in this way that the different network operator’ tasks require distinct regulatory tools. OFGEM also perfected the match between tasks and regulatory tools through practices and feedback analysis. This was possible because OFGEM is rather well endowed in terms of staff and budget expressed in power purchase parity (she is in the upper middle of the range of the European countries – see table 2).

The improvement of regulation was quite easily in Great Britain, (at least easier there than in other countries) because, at that time, it benefited from an adapted situation in terms of controllability, predictability and observability. First, Great Britain is lowly interconnected with other countries with dispatchable links. Network management is then highly controllable and its regulation is easier because the influence of cross-border flows on the internal network can be easily measured. Besides, until recently, the generation mix was made of conventional power plants almost exclusively. System management and network development have then not experienced the effects of production volatility from massive renewable sources at that time. The network operator and the regulator then face rather predictable flow patterns. At last the observability of each network operator (National Grid, Scottish Power Transmission and Scottish Hydro Electricity Transmission) for the regulator has increased with her experience in regulation but it is only recently (see next section) that OFGEM has been able to consider benchmarking these three companies altogether because it is only since the BETTA implementation that they face the same regulatory framework.

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[34] The Innovation Funding Incentive where applied to distribution from 2004 and was extended to transmission in 2007. The distribution companies also benefit from the Registered Power Zones where they are authorized to experiment innovative technologies (OFGEM 2004a and 2010a).

[35] Benchmarking and menu of contracts (called Information Quality Incentive) were also introduced to regulate system operation, maintenance and investment of distribution companies comparing their relative efficiencies (from 2005).

[36] OFGAS, the British regulator of gas was then the first gas regulator worldwide to apply price cap regulation in 1988.

4.2 Electricity transmission regulation in Great Britain with RIIO

The successive improvement of British regulation had been done without great concerns about harmonization of or a study of possible interactions between the different schemes. The idea was only to compensate failures of RPI-X cost-cutting incentive regulation, on a case by case basis when they progressively appear. In particular, one of the biggest shortfall of the RPI-X regulation that has never been dealt with until recently in Great Britain (and were never dealt with elsewhere in the world to our knowledge) is that monopoly has a far higher incentive to invest than to improve his operational efficiency (i.e. "invest in OPEX") because she receives a rate of return on the infrastructure investments but not on the "infostructure" operational investments[37].

After 20 years of incentive regulation, OFGEM decided in 2009 to initiate a rethinking, recognizing both achievement and difficulties. The wide consultation process then concludes that focus in the RPI-X regulatory framework was mainly on short term and cost reduction, which has led to forget the outputs of transmission network and its usefulness to network users (Jenkins, 2010, Crouch, 2012). That is why the activity of the regulated company should be consumer-oriented and so focused on first outputs to improve services to consumers/users, innovation to provide new services & cost reduction in the long run and only at last incentives for cost reduction in itself.

The idea of the brand-new RIIO[38] regulation is that the prescription of a set of outputs to be delivered, rather than a set of inputs, provides powerful incentives for companies to innovate and seek least cost ways to provide network services. The earned return will then vary with output delivery performance.

The RIIO regulation was then discussed by the stakeholders and is now on the way to be implemented. While the RPI-X regulation primarily relied on price cap regulation, the RIIO regulation will primarily rely on output regulation. Besides, while the interactions between the regulatory mechanisms were initially taken into account only on a case-by-case basis in the RPI-X regulation, it is now considered in the core of regulation. A part of OPEX (maintenance) will then be included in the Regulated Asset Base and so be remunerated through the rate of return. Besides, the profit-sharing rules for OPEX and CAPEX will be harmonized. At last, the use of benchmarking and menu of contracts will be generalized to the more difficult situation of

[37] Another big shortfall is that the profit-sharing rules are different for OPEX and CAPEX (the monopoly retaining 100% of efficiency gains for OPEX and 25% of efficiency gains for CAPEX), implying that the company will focus his efforts for efficiency improvements on OPEX rather than on CAPEX.

[38] Revenue = Innovation + Incentive + Output.

transmission (because of the small number of companies to compare)[39]. The regulation of system operation costs (losses, congestion, balancing, system operation actions on reliability, etc.) are currently discusses among the regulator, the SO and the stakeholders, the main stake being about the bundling of these tasks in a single incentive scheme (OFGEM, 2011). This whole regulatory project requires obviously a very smart regulator.

The promise of the RIIO regulation is to increase efficiency of the network company and to make their activities more user-oriented. Nevertheless, the forthcoming implementation shall be analyzed to see potential difficulties and its real efficiency. The regulatory process itself raises a lot of questions. While the RIIO regulation requires the implementation of the most complex regulatory tools, the regulatory process rather implies a disengagement of the regulator relying on a less transparent regulation with a kind of beauty contest. The network operators are indeed required to submit their business model for the regulatory period. The regulator then builds the price control reviews on these business plans using a so-called “proportionate treatment”. This means that there is a possibility for fast track and less scrutiny for well-justified business plan. The regulation is then less intrusive if the regulated company justifies the adequacy of its business plan to research cost reductions, the needed outputs and the usefulness of innovation through the stakeholders consultation process she relied on to build it. The cost assessment can then go from a light-handed one to more and more intrusive analyses (e.g. unit cost benchmarking, random inspections, full engineering reassessment of asset replacement strategy, etc. –OFGEM, 2010b). The practical way all these different processes will be implemented is still an open question but may be determinant for the effectiveness and efficiency of regulation.

4.3 Electricity transmission regulation in Spain

Only three of the five standard regulatory tools have been implemented in Spain, revenue cap, performance-based regulation and cost plus. Revenue cap was implemented in the form of “standard unit cost”.[40] A standard unit cost defines a cost level to be included in the tariff calculation when the TSO performs a certain task. If she betters off this cost, she keeps the associated rent. A revenue cap in form of standard unit cost was then introduced as soon as 1998,

[39]It is noticeable that the European integration is almost completely absent from the OFGEM considerations.

[40] See *Ordén ITC/368/2011, de 21 de febrero, por la que se aprueban los valores unitarios de referencia para los costes de inversión y de operación y mantenimiento para las instalaciones de transporte, por elemento de inmovilizado, que serán aplicables a las instalaciones puestas en servicio a partir del 1 de enero de 2008 ; Ordén ITC/688/2011, de 30 de marzo, por la que se establecen los peajes de acceso a partir de 1 de abril de 2011 y determinadas tarifas y primas de las instalaciones del régimen especial*. and also *Real Decreto 2819/1998 de 23 diciembre, por el que se regulan las actividades de transporte y distribución de energía eléctrica* ; *Real Decreto 1955/2000, de 1 de diciembre, por el que se regulan las actividades de transporte, distribución, comercialización, suministro y procedimientos de autorización de instalaciones de energía eléctrica* ; *Real Decreto 1164/2001, de 26 de octubre, por el que se establecen tarifas de acceso a las redes de transporte y distribución de energía eléctrica*.

targeting the cost of maintenance and the cost of planned investments. Until 2008, the TSO REE kept the whole efficiency rent both for OPEX and CAPEX for transmission ownership. After 2008, the profit sharing rule was changed and now REE only keeps 50% of cost reduction compared to standard unit cost. Transmission planning is also submitted to a kind of ex ante output, though highly political, regulation. REE establishes a network development plan every 4 years that then follows a long and complex administrative process before being approved in order to be authorized to be included in the RAB when built. The plan detailing each investment in a precise manner (this is possible because REE owns and operated only EHV lines) is indeed analyzed by the regulator, then transmitted to the Ministry and presented to the Parliament. Performance-based regulation was also quickly added to price cap regulation in 2000 to avoid a potential decrease in reliability. It focuses on 3 reliability indicators (availability, ENS, average downtime). The other activities performed by REE (balancing and reserves management, congestion and losses management[41]) remain completely passed through. And their implicit status of uncontrollable costs has never been questioned to our knowledge. Besides, innovation like the dispatching centers dedicated to the management of wind power seems to have been passed through to the consumers[42]. The regulation of electricity transmission in Spain has been only recently updated but feedbacks lack to know the difficulties and further room for improvement. The table below sums up the implementation of regulatory tools on transmission in Spain. With regard the TSO's performances in terms of customer relationship management and RD&D[43], No incentive scheme was applied.

The CNE is the Spanish regulator of energy, i.e. for electricity, gas and petroleum since 1998. It can be given to the CNE' credit that she has quickly applied revenue cap regulation using a building-block approach and several types of regulatory tools recognizing in this way that the different network operator' tasks require distinct regulatory tools. Nevertheless, to the authors' knowledge, the CNE has not tested whether the cost components under cost-of-service regulation could have been not submitted to incentive regulation. It is likely that it is because the CNE is known to suffer from a major ministry intervention undermining his credibility (see table 1 and Crampes & Fabra, 2005). This is confirmed when one evaluates his resources. The CNE is then among the least endowed regulator in the European Union (see table 2). Besides, the Spanish

[41] The losses are directly paid by the consumers in their energy purchases

[42] A particularity of the Spanish regulation is that the regulator uses a simulation tool mimicking the development of each distribution network taking into account uncertainty and legacy to define a reference distribution network whose cost is used to set the distribution companies' allowed revenue. In other words, the regulator does its own planning of each distribution network. Besides, to our knowledge, a menu of contracts is not used in Spain.

[43] Despite REE has a dedicated development plan dedicated to innovation (Source: http://www.ree.es/sala_prensa/web/notas_detalle.aspx?id_nota=255)

government suffers from a conflict of interests as he sets the regulatory rules and the regulator's resources for a company it is one of the major shareholders, detaining 20% of REE's capital.

The improvement of regulation may not have been a great concern in the Spanish case because the focus was then on the integration of massive amount of intermittent wind production. This can be explained not only by the development of massive wind production but also by the isolated geographical situation of Spain.

Spain is indeed lowly interconnected with other countries namely with France, Morocco and France. However, interconnections are made with AC lines. Flows are then non controllable and result from the balance of the different countries. The Spanish network may then suffer from loop flows close to the borders. Network management may then depend on decisions by neighboring TSOs and not only by REE. Nevertheless, considering the quasi-radial nature of these interconnections, the influences of cross-border flows on the internal Spanish network might be measured and distinguished from actions by the national TSO, opening new possibilities of implementing incentive regulatory tools with regard the predictability and controllability criteria.

Besides, there was a high increase in wind production with less than 1 GW installed in 1998 and more than 20 GW installed now (AEE, 2011). With a low level of interconnection, Spain was then forced to manage wind production variability and volatility alone. System management and network development have then experienced the effects of production volatility from massive renewable sources (REF). The network operator then developed specific dispatching centers at the regional scale to supervise and control wind power production (the CEGRE). Besides, major network investments were and are still needed to bring wind power energy from the North East, East and South regions toward the main load centers in the Center (Madrid) and toward the West coast (Pitarma, 2011). At last, observability is not neglectable because the regulator has now a decade of results of the TSO's performance. However, considering that REE is the single Spanish TSO, observability obviously does not allow benchmarking, at least on a national basis only.

4.4 Electricity transmission regulation in Germany

Four of the five standard regulatory tools are applied in Germany. From his very creation, the BNA was nevertheless very ambitious (Brunekreeft, 2006). She was willing to implement yardstick competition not only on distribution but also on transmission as soon as 2006. Finally, yardstick competition was applied on the 4 German TSOs in the framework of the European e3grid project in 2009 (Agrell & Bogetoft, 2009). Besides, she uses a TOTEX approach instead of a building block approach to set the allowed revenue and define the efficiency target. More precisely, the BNA distinguishes between the non-controllable and the controllable costs (Petrov

& Nunes, 2009). The first ones are passed through to the consumer while the TSOs are incentivized on the second ones with a single regulatory scheme, whether the tasks they originate (system operation, maintenance, investment, etc.). The non-controllable costs mainly include: costs from legal obligation for instance the connection of renewable generators, concession levy for instance the use of public domain settle cables, taxes, specific network investment once they are validated by the regulator (Groebel, 2011)[44]. These investments are new lines to connect offshore power plants, new underground cables and investment to ensure and maintain the network security. The controllable costs are the costs not considered as non controllable ones, that is to say, the costs of losses, congestion, balancing, and the investments excluded from the set of non controllable costs. The efficiency improvements of controllable costs are set with an international benchmarking. The inefficient part of TSOs' controllable costs is hence evaluated and the efficiency targets are set so that these inefficiencies are assumed to disappear in ten years. To the authors' knowledge, no output regulation seems to be applied to TSOs[45]. Nonetheless, they have legal reliability obligations. No specific incentive schemes seem to be applied to customer relationship management and RD&D.

The BNA was the last gas and electricity regulator created in Europe in 2006, as a result of the 2003 directive making mandatory for each country to have an energy regulator[46]. Nevertheless, as mentioned before, the BNA is very ambitious in the regulatory tools she has implemented or forecast to implement and in the efficiency improvement she is expecting. One should remind that she asked a tariff decrease from 6 to 28% to some TSOs after her creation (IEA, 2007). This is despite she has a medium endowment. She has a staff number close to the OFGEM's one. Nevertheless, the budget dedicated to electricity is however among the smallest one in relative terms (see table 2). With this regard, one should not forget that the BNA is a multi-commodity regulator dealing with electricity, gas, post and railway and telecommunications. BNA may then experience important economies of scale in her endowment among the different industries she is in charge of.

The very implementation and improvement of regulation is a real challenge for the BNA because the German regulation is faced with a very complicated situation in terms of predictability and

[44] Investment is considered as a controllable cost in distribution. Besides, the upstream network charges for distributors add to the other non-controllable charges.

[45] Nevertheless, an output regulation is applied to distribution, including a quality term in the global regulatory formula.

[46] The electricity and gas network monopolies were previously regulated through the application of the antitrust policy by the Competition Authority, Bundeskartellamt. This way of regulation has proved efficient to progressively open the network access despite the bundling of monopoly transmission activities and competitive generation activities. It has nevertheless made these progresses slow (Glachant et al., 2008).

controllability. Nevertheless, the German regulator wants also to rely on the high observability she benefits from the regulation of several national operators.

Germany is indeed highly interconnected with other countries namely with France, the Netherlands, Denmark, Poland, Czech Republic, Austria, Switzerland. Besides, the interconnections are made with AC lines. Flows are then non controllable and result from the balance and generation patterns of all the countries of continental Europe. The German TSOs' network may then suffer from loop flows close to their borders from neighboring areas (being other German or foreign TSOs) and generate loop flows through these areas too. Network management may then depend on decisions by neighboring TSOs and not only by the German TSOs. Distinguishing between German TSOs actions on the national network and influences from the rest of continental Europe would require a large-scale econometric analysis. Only under this condition, incentive regulatory schemes could be applied on German network operators with the greatest efficiency.

Beside the cross-border situation of the German power system, it has the characteristics of accommodating a massive amount of intermittent renewable production. There was indeed a high increase in wind production in Germany, with less than 300 MW installed in 1993 and more than 27 000 MW installed now[47] and a dramatic increase in photovoltaic production, with less than 1 GW in 2005 and almost 25 GW now[48]. Thanks to a high level of interconnection, these huge amounts of intermittent production have been integrated without major operational changes. Nevertheless, it has highlighted the weaknesses of the European continental power system. For instance, it has conducted to major disturbances, for instance the blackout of 4th November 2006 (Bialek, 2007). A higher operational coordination between the TSOs of continental Europe is then fundamental. Some of them (one of them is a German TSO, 50Hz, now a subsidiary of the Belgian TSO Elia) have then decided to build the joint venture Coreso to monitor several hours ahead and in real time the flows on the network of continental Europe. Besides, major network investments were and are still needed to bring wind power energy from the Northern regions toward the main load centers in the Southern regions (ENTSOE, 2011). The willingness to rely on benchmarking may then be a way for the regulator to overcome the difficulties in establishing the levels of controllability and predictability. Even if there are only 4 TSOs in Germany, which is a number insufficient to perform a robust econometric analysis, the German regulator has relied

[47] Source: http://www.wind-energie.de/sites/default/files/download/publication/jahresbilanz-facts-go/jahresbilanz_facts-to-go-2011.pdf

[48] Souces: http://www.epia.org/fileadmin/EPIA_docs/public/Global_Market_Outlook_for_Photovoltaics_until_2014.pdf and http://en.wikipedia.org/wiki/Solar_power_in_Germany

on international benchmarking of TSOs. It may indeed be an interesting idea to detect major discrepancies in the performance of some TSOs. It is generally used as a basis of the negotiations between the regulator and the utilities, not to blindly set the regulated tariff (Kraus, 2006). It is then useful under the condition that the benchmarking process is not a black box and is transparent enough so that the regulated companies and the other stakeholders can propose improvements (Kindler, 2012).

5 Conclusion

Our analysis has demonstrated that the different monopoly's tasks require different regulatory tools following a decision tree based on their intrisic characteristics of controllability, predictability and observability. While previous theoretical works had focused on the efficiency of the different tools to deal with the information asymmetry problem with or without uncertainty, literature had until now given no solution for the regulators to choose among the regulatory tools in practice.

Cost plus regulation can then be a useful regulatory tool when a task is uncontrollable, unpredictable or unobservable. If it is controllable and predictable, its degree of observability determines the most efficient regulatory tool to be used. In case of low observability, the choice of the monopoly among a menu of contracts will give the regulator information about his costs. With a medium observability, the regulator can implement a price cap regulation if the targeted inputs are observable or an output regulation if the targeted outputs are observable. At last, if the regulator can compare different monopolies, he can implement yardstick competition in order to incentivize them to a higher efficiency and to decrease his information asymmetry. Of course, the regulator should only implement these regulatory tools if his endowment gives him the required cognitive, computational and judicial abilities.

We showed that this framework could be applied to electricity regulators looking at the European ones. It can of course be applied anywhere else. It can also be applied in other network industries because they all share two chracteristics. The regulators may have limited abilities determined by their institutional endowment (Glachant and Perez, 2009). Besides, the network industries and the network monopolies are modular, that is to say that the market participants and the network monopolies perform a set of tasks that are almost interdependent. And their distincts tasks are close to the one we presented for the transmission monopoly, i.e. system and market operation, maintenance, investment, RD&D. In particular, it can be applied in recently liberalised industries like railways, and possibly in water sector (Pollitt, 2011)

Naturally, implementing the most incentive regulatory tools remain a goal to strive toward when the institutional endowment of the regulator allow it, since they ensures that the monopoly behaves efficiently.Nonetheless, in a context of subsidiarity, unless a future European directive sets a budget targets that the States should allocate to their regualtors, their low endowment and limited abilities will persist (Glachant and Perez, 2009).It is then of importance that they gather and share their experience in international fora since there are some clues that it may help then to overcome their limited endowment gaining further competences (Glachant and Brousseau, 2011; Brophy Haney and Pollitt, 2010).

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