Implementing Incentive Regulation with Imperfect Regulators

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Abstract

It is puzzling today to explain the diversity and the imperfection of regulation applied to the 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 endowment of the regulators set by the governments and the legislators determines their abilities (staff, budget, judicial powers) to implement any of the regulatory tools. Ranging them from the easiest to the most complex tools to implement for a regulator, there are cost plus, price/revenue cap, output regulation, menu of contracts or yardstick competition. Besides, the regulator must take into account that the network monopolies perform multiple tasks with heterogeneous characteristics in terms of controllability, predictability and observability. These characteristics determine the type of optimal regulatory tool to implement to regulate each network monopoly's tasks. In particular, incentive schemes can be implemented when the criteria of controllability and predictability are satisfied. The level of observability then sets the precise regulatory tool to implement. Some conclusions for regulatory issues of network monopolies are then derived from the study of real power regulators and the tools they implement using the above described analysis framework.

Keywords: incentive regulation, regulator, endowment, network operator, 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 and 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 therefore been attempting to put in place regulatory tools that could alleviate the information advantage the network company holds regarding the real cost of his activities – i.e. solve the adverse selection problem – and the effort he 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*, he pays the network operator his expenses plus a rate of return. The network operator is then incentivized to declare his costs but not to optimize his processes (Joskow, 2008). In *price cap regulation*, the regulator sets a price for the service provided by monopoly which then has an incentive to optimize his process because he will then keep the associated informational rent. The regulator however gains no information about the network operator’s cost (Joskow, 2008). Rather than focusing on optimizing inputs, the regulator can implement *output regulation* where he evaluates the monopoly’s performance in terms of quantity and quality of the produced outputs and incentivizes him 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 then self-selects the most appropriate regulatory schemes. The trade-off is then between minimizing information asymmetry and maximizing incentives (Laffont and Tirole, 1993). At last, the regulator can use *yardstick competition* when he regulates several comparable monopolies. He can then compare the cost and efficiency of one monopoly to the performance of the others. They are then all the more remunerated that they are efficient, which incentivizes them to improve their processes (Scheiffer, 1985).

Until now, the theoretical studies of regulation, whatever the considered regulatory tools, present two shortfalls. First, the textbook model of regulation assumes that the regulator is endowed with all desired cognitive, computational and judicial abilities that enable him to perfectly propose and build the regulatory tool needed to regulate monopoly under its control. The reality however is that the regulators have limited and heterogeneous abilities. In practice, the regulators (among the 200 of them created to deal with infrastructure regulation worldwide[6]) seem rather flawed 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 the local regulatory agency should then be taken into account when considering the tools they should use to perform supervision.

Another weak assumption of the textbook model of regulation is that the regulator is supposed to control the network operator's costs as a whole (Laffont and Tirole, 1993). However, in reality the regulated companies perform multiple regulated services[7] with heterogeneous characteristics requiring 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 quality should be regulated with performance-based regulation and investment is hard to tackle with classical regulatory tools.

Considering these two discrepancies between the theory of regulation and its reality, we aim at investigating the right alignment between the regulatory tools, the regulator's abilities and the targeted network costs 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 they are not applied by an efficient regulator, but by an imperfect regulator. Beside its own abilities, the regulator should then take into account that the regulation of a network monopoly implies to regulate a diversity of services with distinct characteristics requiring adapted regulatory tools (cost-pass-through, input-, output- or benchmarking-based). For instance, in the electricity sector, the networks are interconnected and a TSO may not control all the aspects of a task (e.g. losses or congestion management). Different

[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.

tasks may also suffer from different level of uncertainty and inversely of predictability. At last, the regulator may suffer information asymmetry to different degrees depending on the tasks. Considering these three characteristics (controllability, predictability and observability), the different tasks performed by a regulated company may then require differentiated regulatory tools. To illustrate our arguments, we will focus on the case of European power regulators and transmission and system operators. The IERN database is for this of great help[8]. Nevertheless, the properties we highlight are not sector-specific and can be generalized to the regulation of any other network industries (gas, railway, telecom, and possibly water – Glachant and Perez, 2009).

The paper is organized as follow. In the first section, we demonstrate the discrepancy between the reality and the textbook model of regulators and why any regulatory tools may not be always possible for a given regulator. We discuss next the main characteristics of network operators' tasks and we end up by suggesting a decision tree to choose the appropriate regulatory tool, adapted to the characteristics of the network operator's tasks and costs and to the regulators' abilities. We also exemplified how our analysis framework could be used in theory and practice to determine the most appropriate tools to regulate a monopoly task. At last, we test the robustness of our analysis framework applying it to real regulators, showing that smarter regulators implement smarter regulatory tools and have more abilities to fine tune their tools and to recognize the characteristics of the 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 it has all the required abilities to perfectly design and implement the appropriate regulatory regime. Consequently, lowly endowed regulators may not be able 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 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 his job. In particular, he knows *ex nihilo* how to choose the most efficient regulatory tool and he has all the desirable abilities to implement it. In reality, the regulators were endowed with only limited resources, which is likely to hamper their abilities to do their job efficiently. And 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.

Since Laffont and Tirole and even before, the economic literature does not assume anymore that the regulator is omniscient and omnipotent. He faces two major difficulties while pursuing efficiency. First, the regulator is facing information asymmetry that the regulatory tools should help him to decrease. Second, the regulator (like the network operators) is facing uncertainty for two reasons. There may be an important lag between the network operator action (in particular its investment) and its effect on productive and dynamic efficiency (that even the network operator is 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 he does so on an *ex ante* basis[9]. He is also able to collect the needed data. Obviously, he 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 he 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 1 Evaluation of the regulator's power in Europe before the implementation of the 3rd Energy Directive (Source: DG TREN, 2004[10])

	Ex ante vs ex post 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 ex post 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 permitted 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 difficulty in implementing any of the regulatory tools. This implies different conditions. The regulator must have a sufficient task force to deal efficiently with his 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 his task force and competences, the regulator can alternatively bridge the gap delegating a part of his work to external parties if he 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 them with sometimes tight resources, which they largely perpetuated (see table 2). These limitations are likely to constrain their 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 abrogeant la 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, the CREG, 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 unable to enter uncertain and complex regulatory innovation. Other said, the more the regulator has resources and powers, the more he 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 and regulator's abilities

The regulator's abilities in terms of resources and skills will limit its 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 coupled with the regulator's endowment it determined the tools he is able to implement.

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[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. He 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 auditing costs are smaller because the regulator requires information about the firm's costs only at the beginning of the regulatory period. However, the regulator must spend here resources to set the reference price and the level of the efficient factor, in order to avoid a risk of error about setting initial prices (leading to windfall profits or losses for the network operator disconnected from his performances), because of modifications in demand evolution expectations and main parameters of the allowed revenue formula. In its practical form, the regulator must mix price cap regulation with cost plus regulation, sharing losses and gains between the network operators and consumers. He can then include adjustment mechanism to incentive regulation, protecting consumers' surplus as well as providing firms incentives for cost reduction. Learning effect has a potential positive repercussion on the regulator to adjust correctly the revenue formula when moving from one regulatory period to the next one.

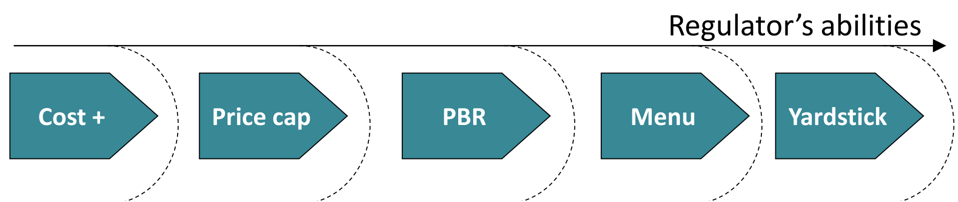
"Performance-based" regulation represents a new degree of difficulty for the regulator. While cost-plus regulation and price cap regulation focus on cost only, performance-based regulation relies on an explicit definition of a performance target on output coupled with a financial incentive to reach it. This would necessitate that the regulator recognizes that the network operator produces different outputs and identify them. He should then find the gains any improvement of these outputs may have for the system as a whole so that he reflect it in the financial incentive. Only to this condition, the network operator will be able to make the efficient arbitrage between his costs and the benefits his efforts generate for the system. A high level of expertise is consequently needed to propose this scheme. The cost of regulation could also be high because the regulator needs to collect data to estimate the benefits to the system of improving the network operator's performances and the network operator's costs to realize 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 new degree of abilities from the regulator. While he was previously not interested in the intrinsic efficiency of the network operator, he must integrate it in the menu of contracts, proposing low-powered incentive schemes to network operators with low potential efficiency gains and high-powered incentive schemes to network operators with high potential efficiency gains. The regulator can apply this rationale to both input and output regulation. The required expertise would condition the construction of the proposed contracts and consequently the effectiveness of the tool while receiving the right signals about network operators' types.

Finally, *yardstick competition tool* is again one step further in terms of difficulties. The regulator would have to collect a huge amount of information from the network operator. He then has to perform an analysis, costly both in terms of time, skills and budget. Collecting, standardizing data and ensuring a trivial quality of data is a complicated issue that any regulator may not succeed in managing efficiently (Brophy Haney and Pollitt, 2009). In particular, a considerable effort has to be made by the regulator to improve data standardization and accuracy to ease his computation and increase the comparability of 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 requires increasing resources and abilities implementing, cost plus, price cap, performance-based regulation, menu of contracts and yardstick competition.

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



3 *The most appropriate regulatory tool for 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 whether the company performs a single task and delivers a single product, or performs multiple tasks and delivers multiple products possibly in an aggregated manner[16]. This implicitly implies that the regulatory characteristics of these products

[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).

and tasks are homogeneous. In practice, the characteristics of the network operator's tasks are heterogeneous and require different and adapted regulatory tools to incentivize the regulated firms efficiently.

3.1 The network operators' tasks

To our knowledge, the question about how to choose a regulatory tool among the five theoretical ones from the knowledge of the characteristics of the network operators' tasks has never been treated in the literature. However there are practical and theoretical recognition that the network operators performs 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 classically 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, he manages the customer relationship with the network users (generators and consumers), metering and billing energy and power, and possibly providing complementary services to the network users. Lastly, he connects new users, plans and expands the grid when excessive congestions appear[17].

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, they must adapt his process 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]. At last, for both of these sectors, the Europeanization of market building 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 supply that 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 Identifying the 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 concerned time horizons. System operation deals with the short term network management. Nevertheless, it encompasses uncertainty because it is highly dependent on the day-to-day behavior of the market participants. 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 concerns very long term decisions[20]. Despite, the recurring process of building lines, the future use of the infrastructure is highly uncertain at the time of planning[21]. At last, uncertainty reaches its highest 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 unknown.

Controlling the TSO's costs as a whole would then be inefficient given the heterogeneous nature of his tasks. Encouraging companies to reduce operational expenditures could lead sooner or later to a lower quality of the provided service. On the opposite, innovation is inevitably costly in the short term and its expected benefits can only be obtained on a longer period of time. The regulator should then find a proper balance between, on the one hand, the incentive given to the regulated firm and the reduction of his information asymmetry and, on the other hand, the uncertainty he and the network operators face.

Our claim is that a hybrid approach relying on the simultaneous use of various regulatory arrangements should then be implemented to address more specifically the different characteristics of the various tasks performed by the network operators. As a consequence of the heterogeneity of the network operator's task, when searching for the most appropriate regulatory tools, the regulator should not only consider his real abilities resulting from his endowment but also evaluate three characteristics of the targeted network operator's task. These three characteristics are the controllability, the predictability and the observability of any specific task. Consequently, we develop a decision tree to select the optimal regulatory tool encompassing these three 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 he eventually suffers information asymmetry.

[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.

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 effectively affect the efficiency of the targeted task either increasing the level of outputs for the same quantity of inputs or similarly reducing the quantity of inputs without modifying the level of outputs. Other said the network operator can control the efficiency of this task through his effort.

If this assumption is always 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. He then has little discretion in minimizing the level on losses on his network. Whatever the action he may decide, it may be countered by the actions of neighboring TSOs. This is for instance what may occur 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 can also imagine that the network operator planned an investment to relieve a structural congestion but cannot implement because of fierce local opposition. He cannot then impact the level of congestion cost.

In such real situations, it would not be efficient to impose him an incentive scheme because it would result in no efficiency improvement, only in regulatory costs and profit shortfall for the regulated company. Consequently only a cost plus regulation should then be implemented to this precise task.

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

3.2.2 Predictability

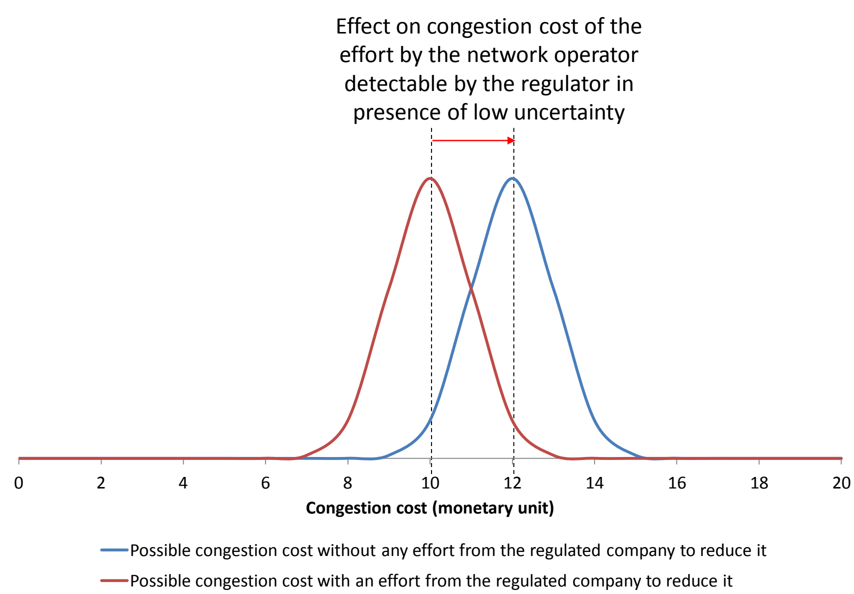
We now consider the situation where the regulator faces no information asymmetry (once again) but both the regulator and the network operator faces uncertainty about the environment of the system management (future demand level, technology, etc.). In this situation, a regulator can incentivize the network operator so that he improves his productivity on a given task if

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

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.

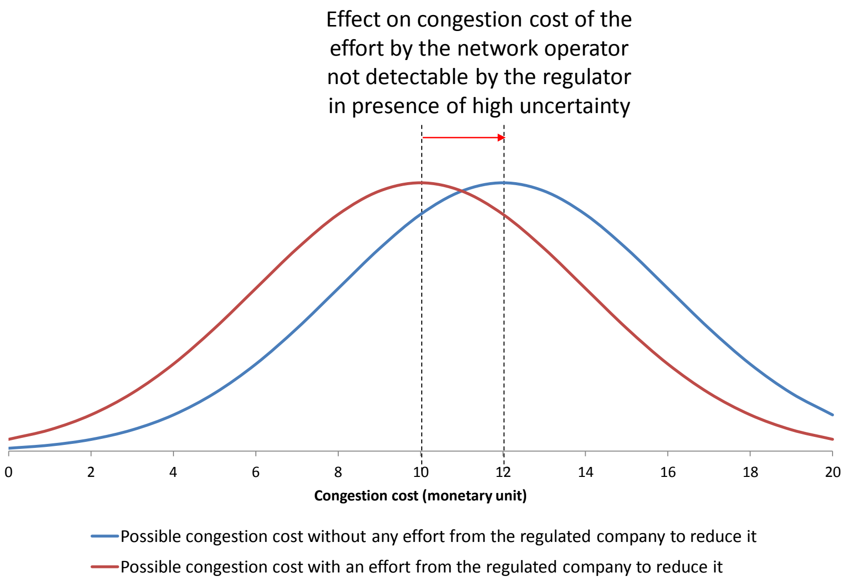
Suppose for instance that the level of demand impacts congestion cost in an unknown manner. Other things equal, the network operator is also supposed to be able to reduce congestion cost thanks to changes in his operation procedures. If the uncertainty about the impact of demand level on congestion cost 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 uncertainty on environment variables on the possibility for the regulator to detect an improvement of the network operator's efficiency (e.g. congestion cost)



Otherwise, if uncertainty about the impact of demand level on congestion cost is too important, it may then be difficult for the regulator and the network operator to distinct the effect of the efficiency improvement realized by the network operator from 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 uncertainty on environment variables on the possibility for the regulator to detect an improvement of the network operator's efficiency (e.g. 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).

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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).

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 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 is able 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 nevertheless reduce 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 a high 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 means performance-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 low observability of tasks (when the regulator has only few historical datasets or that may persist because monitoring is costly), 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. A menu of contracts can be either input- or output-oriented, or both. When the menu of

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

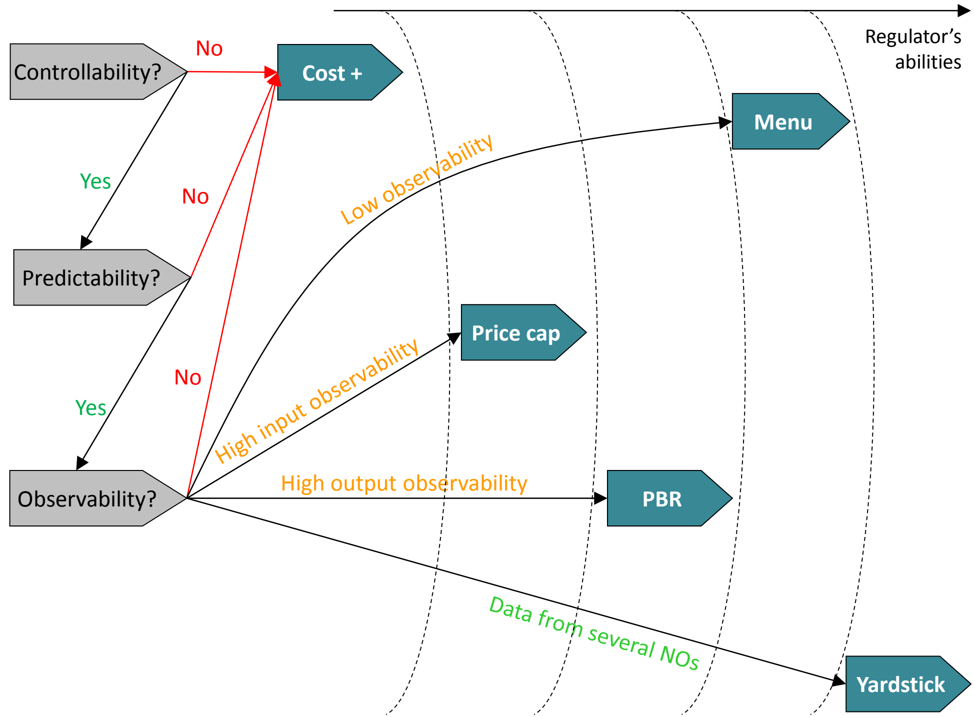
contracts is conveniently constructed, the network company would rationally choose the contract that fits best with its true (while unobservable) characteristics. It nevertheless requires that the regulator be endowed with sufficient abilities to implement such a complex mechanism.

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 depends first 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 during transmission 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. 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 for the 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 a menu of contracts, performance-based regulation and yardstick competition schemes would depend on observability, in particular the regulator's experiences in regulating the cost of losses. In case of low observability, a menu of contracts would be suitable. If the regulator has information from several comparable network operators, he could apply yardstick competition. Otherwise, if he has a historical database of losses volumes for a unique network operator, a performance-based regulation would be appropriate.

[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 tasks that 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 high observability, maintenance costs could be regulated within the price cap regime, if the regulator's abilities allow it. In case of low 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 of contracts 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 innovation process 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 predictability because 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, observability depends 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 analyse 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 Great Britain, in Spain and in Germany. The reason why we choose each of

[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).

these countries will be explained in the following subsections. 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.

4.1 Electricity transmission regulation in Great Britain

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). This was and still is possible because OFGEM is rather well endowed in terms of budget and staff (he is in the middle of the range – see table 2).

Back in the yearly nineties, OFFER (before he merges with OFGAS, the British regulator of gas) was the first power regulator to apply price cap regulation in 1990[30]. However, OFFER then OFGEM has never applied price cap regulation in a blind manner. Indeed, he has used 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. Price cap regulation was then first applied to maintenance because this task has all the desired and easily detectable characteristics to be regulated with this tool. It has also been extended to other tasks, for instance on capital expenditures[31]. Besides, during the first years of implementation, OFGEM realized that the price cap regulation alone leads to inefficient behaviors by the TSO (and the DSOs). A company may let costs of some tasks increased when he was not incentivized[32]. Similarly, OFGEM realized that the network company may choose to decrease the level of some outputs, in particular outputs related to environmental policy or reliability, in order to reach its cost reduction targets. Rustines of output regulation (PBR) were so added to price cap regulation to avoid these effects. Several output incentives mechanisms have then been developed on a case by case basis. For instance, distinct incentive regulation schemes were then imposed to the TSO so that he reduces congestion cost[33], losses[34], reliability level[34] (Joskow, 2008 and Rious et al., 2008)[35]. The

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

[31] 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).

[32] It was the case for instance of congestion in the mid-nineties. Its cost had jumped from less than 100 million pounds in 1991 to more than 500 million pounds in 1995. 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] Either through contracts with some generators or through well located low cost investment in the grid infrastructure.

[34] Through appropriate operation standards and investments.

[35] Other incentive regulation mechanisms were also implemented targeting mainly the distribution companies so that they provide innovative investments and network management schemes (Low Carbon Network fund, Innovation Fund Incentive and Registered

regulation of electricity transmission in Great Britain has then be regularly updated and improved to overcome the difficulties. It had nevertheless been done without great concerns about, harmonization of or study of possible interactions between the different schemes and only to compensate failures of RPI-X cost incentive regulation. 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 he receives a rate of return on the infrastructure investments but not on the "infostructure" operational investments[36]. After 20 years of incentive regulation, OFGEM decided in 2009 to initiate a rethinking, recognizing both achievement and difficulties. It was then noticed that focusing on cost reduction has led to forget the outputs of transmission network and its utility to network users. Besides, it was reminded that regulation was only a shortfall in absence of competition and should then mimic competition pressure on monopoly as much as possible (Jenkins, 2010). 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[37] 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. This whole regulatory project requires obviously a very smart regulator.

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 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 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

Power Zones, see for instance, OFGEM 2004 and 2010a). And menus of contracts (called Information Quality Incentive) and benchmarking were also used to regulate distribution (but not applied to transmission).

[36] 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.

[37] Revenue = Innovation + Incentive + Output.

menu of contracts will be generalized to the more difficult situation of transmission (because of the small number of companies to compare)[38].

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 analysed 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. 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.

4.2 Electricity transmission regulation in Spain

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). Consequently and with no surprise compared to the conclusion our analysis framework could lead, the regulation applied by the CNE is very straightforward with few evolutions.

Of course, the CNE has always been aware that the different tasks performed by the network companies have distinct characteristics requiring distinct regulatory tools and treatments. In particular, the regulatory tools respectively used for CAPEX, OPEX for transmission ownership and OPEX for system operation (i.e the balancing cost and the cost of ancillary services) are clearly different[39]. Nevertheless, the Spanish transmission regulation has historically focused on standard unit cost, both for maintenance and investment costs. A revenue cap in form of standard

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

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

unit cost was then introduced as soon as 1998, targeting the cost of maintenance and the cost of planned investments[40]. 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.

Beside price cap regulation, some elements of output regulation are also implemented. Performance-based regulation was then 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)[41].

The other activities performed by REE (balancing and reserves management, congestion and losses management) 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].

4.3 Electricity transmission regulation in Germany

Germany was the last country to create a gas and electricity regulator in 2006 following the 2003 directive making mandatory for each country to have an energy regulator[43]. He has a medium endowment. He has a staff number close to the OFGEM's one. The budget dedicated to electricity is however among the smallest one in relative terms (see table 2). Consequently, the

[40] A standard unit cost defines a cost level to be added in the tariff when the TSO performs a certain task. If he betters off this cost, he keeps the associated rent. (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* ; *Real Decreto 58/2007, de 10 de abril, por el que se regula el procedimiento de control de la continuidad en el suministro eléctrico y las consecuencias derivadas de su incumplimiento*).

[41] 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 authorised 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.

[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] 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 transmission monopoly and generation competition activities. It has nevertheless made these progresses slow (Glachant et al., 2008).

BNA should be quite careful because he may not have enough resources to implement some of the regulatory tools.

From his very creation, the BNA was nevertheless very ambitious (Brunekreeft, 2006). He was willing to implement yardstick competition not only on distribution but also on transmission as soon as 2006. He was also willing to implement a TOTEX regulation. Beside price cap regulation, some elements of output regulation were also quickly implemented. Regulation in Germany then grounds mainly on price cap on TOTEX, completed by yardstick competition and output regulation on reliability.

Of course, TOTEX regulation is recognized as the most efficient way to regulate a monopoly in theory if the tasks have homogeneous characteristics because he then can optimize his cost arbitrating between CAPEX and OPEX (Laffont and Tirole, 1993). This also avoids the regulator to be forced to detail the different types of tasks and search for their characteristics. Nevertheless, the regulator has then a more important error risk both in setting a too high or too low tariff level but also in choosing the wrong regulatory tools (Brunekreeft, 2006), because he ignores the heterogeneity of the different tasks. As for yardstick competition, it requires a sufficient number of comparable companies. Nevertheless, the BNA was willing to implement it on the 4 TSOs, possibly extending the comparison to other non-German TSOs. This last possibility does not solve the problem at all because the institutional framework of every national TSO is still quite unique in Europe and is so difficult to be filtered out. Besides, considering the risk surrounding the implementation of yardstick competition, 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).

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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