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Abstract

It is puzzling today to explain both the diversity and the rationale of regulators' practice vis-à-vis network monopolies. We argue that two fundamental characteristics should be considered when defining the most appropriate regulatory tools. First, it is the bounded endowment of regulators set by governments and legislators which determines their abilities (staff, budget, administrative powers) to implement any of the regulatory tools. Ranked from the easiest to the most demanding to implement, these various tools are: a- cost plus, b- price/revenue cap, c- output or performance-based regulation, d- menu of contracts and e- yardstick competition. Second, the regulators also have to take into account that the network monopolies perform multiple tasks with heterogeneous regulatory characteristics (in terms of controllability, ex ante predictability and ex post observability). These characteristics of tasks determine what type of regulatory tool is more likely to better regulate each task. The regulatory tools then perform well only when they are implemented for tasks that are controllable and predictable enough. It is the kind of observability of these tasks which determines the best incentive tool to implement. Lastly, conclusions for the regulation of networks are derived. A workable regulation of network relies on a reasonable alignment of the regulatory tools with the regulatory characteristics of tasks and the regulators resource endowment.

Keywords

Incentive regulation, bounded regulator, regulatory endowment, network tasks, regulatory alignment

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 the activity of monopolies through high powered incentive schemes (Laffont and Tirole, 1993). This was illustrated in particular in liberalized electricity and gas industries with the regulation of Transmission System Operators (TSOs) and Distribution System Operators (DSOs), respectively, in charge of transmission and distribution networks operation (see Newbery, 2000 for power transmission and Jamasb and Pollitt, 2007 for power distribution). The economic literature has then mainly focused on looking for tools that help in decreasing information asymmetry that the regulator suffers from and/or in incentivizing the network operator to minimize inputs and/or maximize outputs, assessing the different incentive regulation tools that have been proposed and implemented (Decker, 2009; Jamasb and Pollitt, 2007; Saguan et al., 2008). In this approach, the regulator is supposed 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).

Reviewing the literature and the practice we can find five main regulatory tools. With *cost plus regulation*, the regulator allows the network operator to recover its expenses plus a rate of return. The network operator is then incentivized to declare its costs but not to optimize its processes (Joskow, 2008). In *price cap regulation*, the regulator sets *ex ante* a fixed price for the service provided by the monopoly which then has an incentive to optimize its process because it 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 for a given output, the regulator can implement an *output regulation* which evaluates the monopoly's performance in terms of quantity and quality of delivered outputs and gives incentivizes to improve these levels (Vogelsang, 2006). Besides, rather than proposing a unique performance target (either 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 types or levels of incentives. Monopoly can then self-select the most appropriate regulatory scheme from its own point of view. The trade-off is then between minimizing information asymmetry and maximizing incentives (Laffont and Tirole, 1993). Lastly, the regulator can use *yardstick competition* when it regulates several comparable monopolies operating in similar franchised businesses. It can then compare the cost and efficiency of each monopoly to the performance of the others and fix company revenues based on the average or best practice sector performances. Each monopoly can be more remunerated if it is more efficient than the average level, which incentivizes most –if not all- of them to improve their processes (Shleifer, 1985).

For us, the theoretical analyses of regulation, whatever the considered regulatory tools, still present today two shortfalls. First, the "classic" end of the XXth Century model of regulation assumes that the regulator is endowed with all desired cognitive, computational and administrative abilities that enable him to build the best regulatory tool for the monopoly under its jurisdiction. The reality however is that regulators have limited and heterogeneous abilities which make them "resource bounded regulators" like in the Herbert Simon or Oliver Williamson "bounded rationality" world. In practice,

[*] We thank numerous people for valuable comments received at the FSR annual conference in May 2011, the TU Berlin infrastructure conference in October 2011, the FSR executive seminar in January 2012, the ESNIE workshop in May 2012, the ISNIE annual conference in June 2012, the FSR infrastructure workshop in June 2012 and several other meetings in Florence, Italy or Paris, France. We particularly thank the various regulators and TSOs having gently cooperated in 2011 and 2012.
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the regulators (among the 200 of them created to deal with infrastructure regulation worldwide[1]) seem rather constrained by limits and imperfections, endowed with only limited skilled human resources, limited budgets and limited administrative abilities to investigate the actual behavior or operation processes of regulated companies. Our point is then that the relative strengths and weaknesses of each regulatory agency should be taken into account when considering the more appropriate tools it should use to perform its supervision.

Another too strong assumption of the contemporary 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 practice the regulated companies perform several tasks[2] with heterogeneous regulatory 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 network maintenance while congestion, losses or service quality are better regulated with output or performance-based regulation. Investments in network development or in innovations are themselves hard to tackle with any of these two classical regulatory tools.

Considering the two big discrepancies between the theory of regulation and its practice, we aim at investigating the right "regulatory alignment" between the regulatory tools, the regulator's abilities and the targeted network tasks. It does seem to be the only way to go ahead towards a workable regulatory efficiency. We then raise a new perspective on the relationship between regulators and regulated networks and look at feasible efficient regulation choices which are not made by a quite perfect regulator, but a quite bounded regulator. Knowing its ability or not to manage efficiently each regulatory tool, the regulator also has to take into account that the regulation of a network addresses a diversity of tasks with distinct regulatory characteristics. The characteristics of tasks call themselves for adapted and finely tuned regulatory tool (like cost plus, price cap, output performance-based regulation or yardstick-based regulation). For instance, when transmission electricity networks are strongly interconnected, a TSO cannot control all the performance factors of all transmission tasks (e.g. losses or congestion volume and costs). Obviously, different network tasks may also suffer from different levels of uncertainty and thus of predictability. As a result, depending on the tasks to perform, the regulator shall himself suffer different degrees of bounded rationality. The various network tasks have then three key regulatory characteristics, being: a-their controllability (by the operator), b- their *ex ante* predictability (by the operator and by the regulator) and c- their *ex post* observability (by the operator and by the regulator). As a consequence, the different tasks being performed by a regulated network may require differentiated regulatory tools as we could illustrate in this paper with European electricity regulators and TSOs (Transmission System Operators)[3]. Nevertheless, the properties we highlight are not sector-specific and could 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 follows. In the first section, we highlight the discrepancy between the practice in the field and the theoretical model of well-endowed regulators. We next identify the key regulatory characteristics of the various network operators' tasks. We end by suggesting a decision tree to better align the chosen regulatory tool with the regulatory characteristics of the network operator's tasks and with the costs of this regulatory alignment born for the resource bounded regulators.

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1 Source: http://rru.worldbank.org/Toolkits/InfrastructureRegulation/

2 For instance for the power Transmission and System Operators: operation, maintenance, investment, R&D, 'climate change and European energy market building' actions, etc.

3 The IERN database managed by the Florence School of Regulation is of great help to provide an overview of regulators' abilities and bounded actions around the world.
Source: http://www.iern.net/portal/page/portal/IERN_HOME/REGIONAL_ASSOC?pId=3070021

2. Discrepancy between practice of regulation and the textbook model of regulators

The practice of regulation is significantly different from its theoretical frame. Notably, the textbook model of regulators is always assuming that they have all the required abilities to design and implement the theoretically most efficient regulatory regime. However in practice, lowly or badly endowed regulators may not be inclined or able to apply the most complex or most innovative regulatory tools to the network operators under their jurisdiction.

In this section, we will first assert that real regulators are endowed by governments and legislators within straight limits which end with heterogeneous regulatory resources. This may hamper their capability to implement the most difficult regulatory tools, and may oblige them to focus on the less demanding tools rather than considering the whole range of possible regulatory tools.

2.1 The actual endowment of regulators

In the economic literature conceiving regulatory tools, the regulator is generally thought to have all the desired cognitive, computational and administrative abilities to do its job. In particular, it knows *ex nihilo* how to choose the most efficient regulatory tool and it has all the desirable abilities to implement it. In practice, regulators are endowed with only limited resources, which is likely to hamper their abilities to perfectly do their job. In practice, regulators also learn by doing and they are still learning how to use the different regulatory tools provided by theory in order to respond to their endowment gap and to adapt their actual regulatory practice to incurred risk and uncertainty.

Of course, since the Laffont and Tirole main contributions, the economic literature does not assume anymore that the regulator is omniscient and omnipotent. It is supposed to already face two major difficulties while pursuing either perfect efficiency or its second best. First, the regulator is facing information asymmetry while the regulatory tools could help him to decrease this. Second, the regulator is facing uncertainty of network operation for two reasons. There may be an important lag between a network operator action (notably an investment) and its effect on productive and dynamic efficiency (even the network operator may be unable to anticipate this perfectly). Beside this, demand for network services is always uncertain to a certain extent because of general economic conditions and potential novelties. All these elements are now included in recent works about regulatory tools (Evans and Guthrie, 2006).

This economic literature nevertheless makes still stringent explicit or implicit assumptions. A first one is that the regulator sets the tariff paid to the network operator on an *ex ante* basis[4]. It is assumed to be able to collect the corresponding data. It is also independent from the government so as to avoid that any political disturbances could modify the tariff structure or level, which would otherwise make the regulatory incentive far less credible. Lastly, the regulator has the administrative abilities to implement the regulatory tool it targets. When considering the actual regulators' powers, one realizes that practice is quite far from what theory supposes as the real powers of a regulator. From table 1, one can notice that some of the national regulators in Europe were far from reaching the set of supposedly "normal" regulatory powers. Some regulators were setting the tariff *ex post*, which prevents them from setting any *ex ante* incentive. And some regulators actions were still undermined by ministries' involvement.

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

Table 1 Evaluation of the regulator's power in Europe before the implementation of the 3rd Energy Directive (Source: DG TREN, 2004[5])

	***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
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

[5] 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**
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

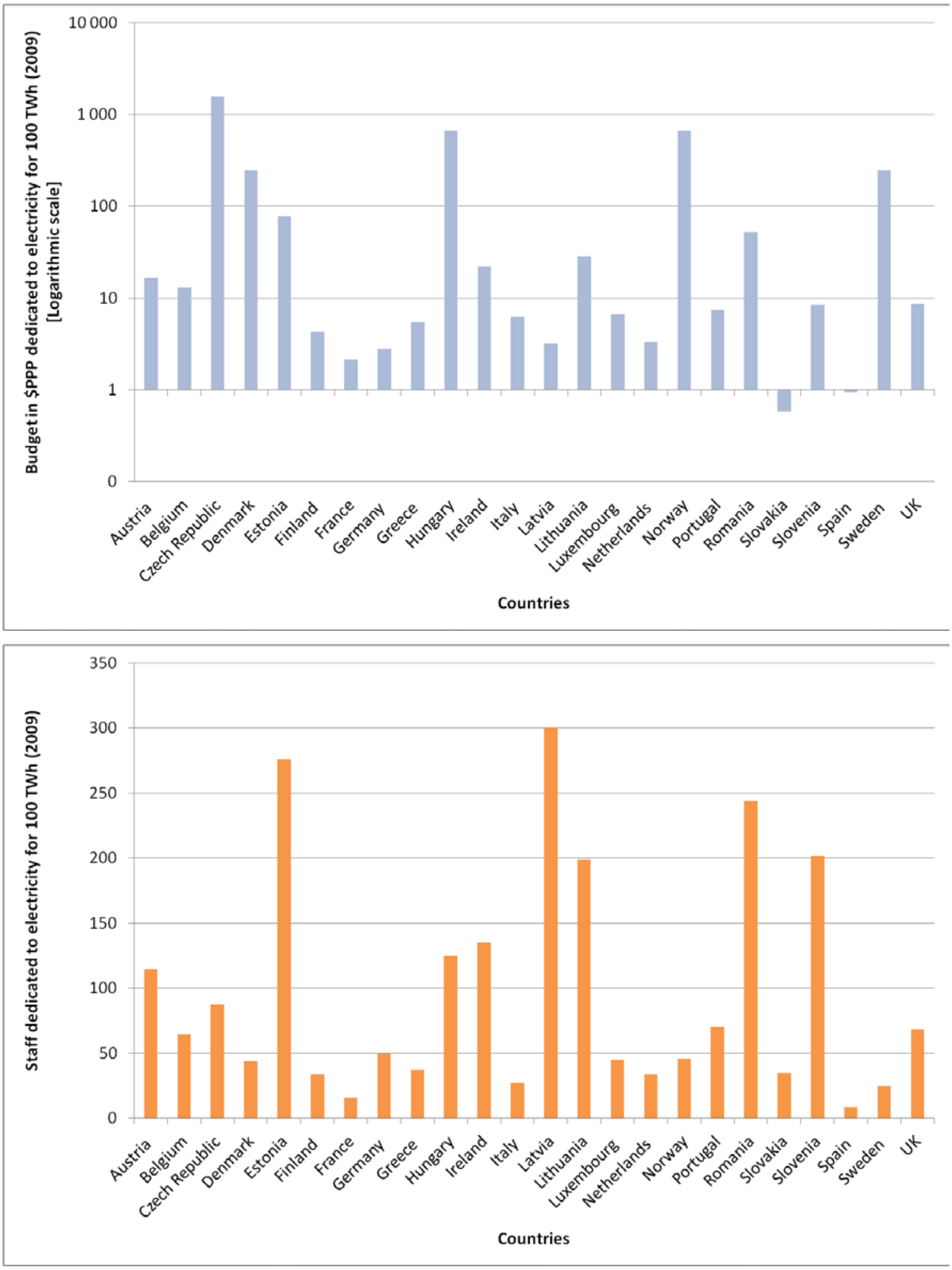
Of course, the third European energy directive has recently pushed for a convergence of the national regulatory agencies' powers toward a set closer to the assumptions of regulatory theory[6]. Meanwhile, it would not solve the entire issue. Beside the assumption about regulatory powers, the economic literature also assumes that the regulator will never face key difficulty in implementing any of the efficient regulatory tools. This requires that the regulator must always have a sufficient staff to deal efficiently with its numerous duties. The staff dedicated to the building and operationalization of regulatory tools should always have enough industrial and computational skills. Of course the regulator can alternatively bridge the gap by delegating a part of its work to external parties… as it is supposed to have the budget to do so.

When looking at existing regulators, the staff and budget implicit assumptions in theory seem rather optimistic. The governments were not so generous that all the regulators fit the rosy description of their theoretical counterpart. When creating regulatory offices, some governments and some legislators endowed some of them with quite tight resources, which they largely perpetuated (see figure 1[7]). Since the worsening of the financial crisis in the EU budget constraints on regulators are only worsening too. These limitations are likely to prohibit most of the regulators from always tapping the best and sophisticated tool to frame the network operation.

[6] Article 36 of the Directive 2009/72/CE of the European Parliament and the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.

[7] 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 (Purchasing Power Parity – Source: PPP conversion factor, private consumption (LCU per international $) from Worldbank, http://data.worldbank.org/indicator/PA.NUS.PRVT.PP). At last, this set of data should be carefully analyzed because, for instance, there are certainly economies of scale in regulation requiring a minimum budget and staff whatever the size of the power system (e.g. Estonia and Latvia).

Figure 1 Budget and staff resources of European regulators



In practice, most of regulators undergo a limitation of their abilities either in terms of administrative powers or in terms of resources, which strongly deviate from what the textbook model assumes. Such regulators may have to be conservative with regulation so as to avoid negative judicial review or, being small administrative units of 10-15 people, to avoid entering into demanding and uncertain regulatory innovation. Put another way, the more resources and powers the regulator has, the more adapted, innovative and sophisticated regulatory regimes it might put in place and the lower the risk of consequential error *ceteris paribus*[8].

2.2 The alignment of regulatory tools with the regulator's abilities

The regulator's abilities in terms of resources (powers, budget and skills) will limit its choice of regulatory tools because different tools stand for different kinds of regulator's implementation difficulties. We propose in this section a simple scale of "implementation complexity" for the various types of regulatory tools and we suggest how these tools could be matched with the actual regulator's endowment.

Cost plus regulation is the simplest regulatory tool. It requires that the regulator can audit the network operator's accounts and would be able to justify and defend its audit at a court. It then sets the network tariffs according to the audited costs.

Price cap regulation appears to have a higher degree in terms of regulation complexity. Of course, the burden of detailed auditing is smaller because the regulator needs information about the firm's costs only at the beginning (or the end) of each regulatory period. However, the regulator must spend highly qualified resources to correctly set the reference price and the level of the efficiency factor, in order to avoid a significant error about tariffs being disconnected from the actual network performance potential (leading to windfall profits or direct losses for the network operator). Note that whereas "cost plus" regulation is more a backward looking way of regulation, price cap regulation is forward looking and needs to forecast the trajectory of efficient costs for the whole regulatory period. Consequential errors may also happen because of unexpected changes of demand, and other main parameters of the allowed revenue formula. In practice, to avoid the worst cases, the regulator might want to mix price cap regulation with cost plus regulation, and share losses and gains between the network operator and the consumers. It could then include an adjustment mechanism to incentive regulation, protecting consumers' surplus as well as providing the firm incentives for cost reduction. Learning effects on the regulator's side may have a likely positive influence on the regulator who might be able to better adjust the revenue formula when moving from one regulatory period to the next.

Output regulation (also known as *performance-based regulation*) represents a new degree of sophistication for the regulator. While cost-plus regulation and price cap regulation focus on input costs only, performance-based regulation relies on an explicit definition of a performance target for a given output to be coupled with a financial incentive to reach it. This would necessitate from the regulator a definition of how the network operator already produces the various outputs and how it should be done better. It should also weigh the gains that any improvement of these outputs may have for the society as a whole vis-à-vis the value left to the operator in the financial incentive. Only under these conditions might the network operator be able to make an efficient arbitrage between the costs and the benefits that an operational effort for output performance will generate for the society. A high level of expertise is needed there. The regulator's implementation cost of this regulatory tool could also come from the costs of measurement of the benefits for the society as well as the measurement of the network operator's actual performances and the following up of proxies associated to network operator's costs to deliver the associated efforts. Meanwhile, network companies are given a significant liberty in how they achieve their output driven efficiency goals.

The implementation of a *menu of contracts* requires sharper abilities from the regulator. While it was not previously interested in the intrinsic efficiency improvement profile of each individual network operator, it now must integrate it in the menu of contracts. It must now offer at least several

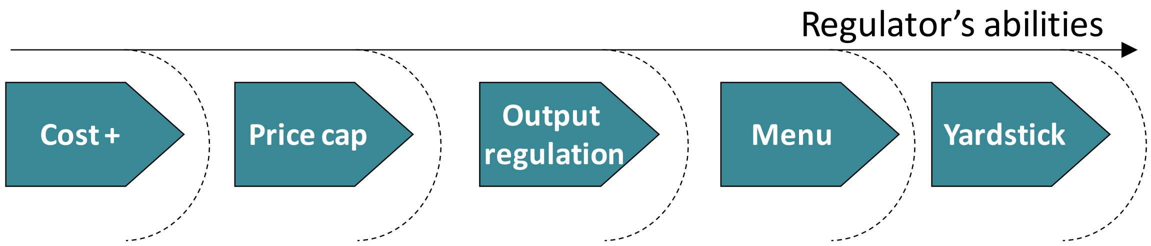
[8] Meanwhile, it should not be forgotten that the shortfalls of regulator's abilities could be partially overcome thanks to the experiences that the regulators individually accumulate or commonly share among each other (Brophy Haney and Pollitt, 2010; Brousseau and Glachant, 2011).

low-powered incentive schemes to network operators with low potential efficiency gains (or low appetite for risks or efforts) and at least several high-powered incentive schemes to network operators with high potential efficiency gains (or high appetite for risks or efforts). The regulator can apply this to both input and output regulation. An actual sharp expertise is the key condition there to construct fine-tuned appealing menus of contracts. This conditions the effectiveness of the tool and the appropriate separation among the several network operators' types of management and of shareholders.

Finally, regulation with *yardstick competition* is one more step further in terms of difficulties. The regulator would have to collect an important and coherent amount of information from the network operator(s). It then has to perform a careful analysis, costly both in terms of time, skills and budget. As seen previously with "output performance-based" and "menu of contracts" regulation, the regulator cannot assume that all regulated companies simply perform the same tasks in the very same conditions. The identification of the particular environment in which each operator operates as well as its individual type of company management matters as much as crude data collected and blind calculations (if not more than these later ones). Collecting and standardizing data and ensuring a robust quality of data comparison is therefore a complicated issue that all regulators may not succeed in managing efficiently (Brophy Haney and Pollitt, 2009). A high level of data standardization and accuracy is needed to run a significant computation and permit the comparison of various network operators[9]. Beside data, well implemented econometric models need specific skills that normally regulators do not have (or are expensive to externalize). The benchmarking computation itself is then more a piece of art than a matter of hard science.

The various and crescent difficulties faced by the regulator in the implementation of different regulatory tools are ranked in the following figure. We then assume that the regulator needs increasingly qualified resources and higher abilities to implement cost plus, price cap, output performance-based regulation, menu of contracts and yardstick competition.

Figure 2 Alignment of the regulatory tools with the regulator' abilities[10]



3. The matching of the various regulatory tools with the network operator's tasks characteristics

Beside the discrepancy between the reality of regulators' abilities and the assumption of the textbook model, it is also frequently assumed that the regulator frames a company performing a single task with a single regulatory tool (or multiple tasks with homogeneous characteristics). In practice it should

[9] 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.

[10] 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 tools.

highly matter whether the operator performs a single task and delivers a single service, or performs several tasks and delivers several services[11]. Textbook assumes at least that the regulatory characteristics of the regulated task(s) are homogeneous (enough). In practice, the characteristics of the network operator's tasks are significantly heterogeneous and may require adapted regulatory tools to give consistent enough incentives to the regulated firm.

3.1 The heterogeneity of network operators' tasks

To our knowledge, economic literature has never treated the question of how to choose a regulatory tool among the set of theoretical ones considering the heterogeneity of the regulatory characteristics of the actual network operators' tasks. However, there are already practical and theoretical recognitions that the network operators perform heterogeneous tasks requiring distinct regulatory tools (See Rious et al., 2008 and Khalfallah and Glachant, 2012 for electricity transmission; Glachant et al, 2005 and 2006 and Saplacan, 2008 for electricity distribution). We may operationalize this network reality by distinguishing four main network tasks. The three first deal with short term issues and the last one with long term issues.

In the electricity industry, a Transmission System Operator (TSO) firstly operates the energy system on a day-to-day basis, ensuring the balance between injections and withdrawals, managing congestion and contingencies. Second, this network operator maintains the assets of the grid. Third, it 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. Fourth and last, it connects new users, plans and expands the grid when excessive congestions appear[12]. A further distinction could be made between "isolated" TSOs and interconnected TSOs. Isolated TSOs have no foreign and uncontrollable flows that might disturb its management, whereas interconnected TSOs must cope with the interaction from outside flows that they cannot easily control.

Today new TSOs goals, like regulated levels of security of supply or environmental targets (translated into higher renewable integration, higher energy efficiency or higher demand response), may also trigger new or renewed tasks[13]. In the electricity sector, because of the European "20-20-20" climate change policy, TSOs must adapt their operation processes to the integration of new classes of assets and processes, to innovation both on the supply side (intermittent generation from wind and photovoltaic producers) and on the demand side (smart meters, demand response, and possibly electric vehicles)[14]. Moreover, a wider and deeper integration of European markets requires the TSOs to act as market architects (see "Market Coupling" as a key to the European electricity target model), in liaison with the power exchanges (Glachant, 2010). All these changes also require a revival of TSOs' RD&D to better address the business and operational shift of transmission infrastructures and services. TSOs' actual work is going out of "pure network monopoly area regulation" as we knew it in the energy sector and is making a first step closer to the communication and media sector (Brousseau and Glachant, 2011).

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11 See for instance Laffont and Tirole (1993).

12 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).

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

14 In the gas sector, this is mainly the concerns about security of supply that drive 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 a workable matching of regulatory tools from the characteristics of network operators' tasks

The different tasks performed by the network operators are actually heterogeneous, including in terms of uncertainty and of delivery time horizons. The tasks that TSOs themselves call, "system operation", deal with the short term network operation. They encompass uncertainty because they are highly dependent on the day-to-day behavior of the market participants (generators, traders, suppliers, consumers). However other tasks corresponding to grid maintenance and customer relationship management are recurrent in the mid-term horizon and present few uncertainties, unless innovation appears (like the maintenance of offshore grids would bring). Oppositely, the grid connection and expansion are activities bordering on very long term decisions[15]. Despite the recurring process of conceiving and building lines, the future use of infrastructure is always uncertain at the time of planning[16]. Lastly, a higher level of uncertainty is reached when undertaking TSO RD&D. This is because the actual outcome of developing new technologies today for the network may be especially fuzzy.

One sees why controlling the TSO's costs and outputs as a whole with a unique regulatory tool would then be rather inefficient given the heterogeneous nature of its tasks. Only encouraging companies to reduce their operational expenditures (Opex) may work as long as it would not lead to an undesired level of quality or of volume of any service provided. Inversely, undertaking innovation is by nature an unproductive expense in the short term and its expected benefits would only be obtained after a longer period of time. The regulator should then look for the proper balance between, on the one hand, the incentives that are known as influential for certain classical tasks of the regulated firm and, on the other hand, more appropriate incentives for new tasks or new processes that the network operators are already undertaking.

In practice, this mixture of tasks pleads for a hybrid regulatory approach consisting in the simultaneous use of various regulatory tools able to deliver the various desired results. To seriously match its regulatory tools with the industry operation, the regulator has to closely address the different regulatory characteristics of the various tasks performed by the network operators. These key regulatory characteristics are first the "controllability" (the regulator knows that the operator can control how to perform the task), second, the "predictability" (the regulator and the operator can reasonably foresee ex ante the future outcome of a task) and third, the "observability" (the regulator can check ex post the actual outcome) of the regulated task. For the purpose of simplicity, we express this in a binary way (yes/no) to create a decision tree suggesting how to match the regulatory tools with the key regulatory characteristics of the tasks. We present these regulatory characteristics both when the regulator is working with consistent information and when it eventually suffers from a consequential information gap.

3.2.1 Controllability of operator tasks

Let's assume that both the regulator and the network operator face no significant uncertainty with regard to the network operation and that the regulator faces no consequential information gap. In this situation, a regulator can think of incentivizing the network operator if the latter can enhance the efficiency of a targeted task either by increasing the level of output for the same quantity of inputs or similarly by reducing the quantity of inputs without modifying the level of output. Put differently, the network operator is able to control its task efficiency.

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[15] The practical lifetime of a power line can reach up to 80 years while their economic and accounting lifetime is generally estimated at 40 years.

[16] For a discussion on the role of TSOs for planning the network development see Rious et al. (2011).

While this assumption is mundane in theory, it is not always obvious in practice. Let's take this hypothetical case: a network operator whose zone has its very small own injection and withdrawal and is mainly transited by cross-border flows. It then has little control in minimizing the electrical losses in its network. Whatever the action may be decided, it may be countered by the independent actions of neighboring TSOs[17].

In such situations, it would not be efficient to submit the TSO to a strong incentive scheme because it would not result in a predictable efficiency improvement, only in regulatory costs or profit hazards for the regulated company. Consequently, a cost plus regulation could be preferred for the losses of an interconnected grid.

When a task is controllable, the regulated company can undertake actions to reach an efficient level of operation. That is why there is room for an appropriate incentive regulatory scheme which may make sense. For instance some cost-related losses may be controllable in the medium or long term with dedicated investments while not in the short term, upon the condition that this task is also predictable (*ex ante*) and observable (*ex post*).

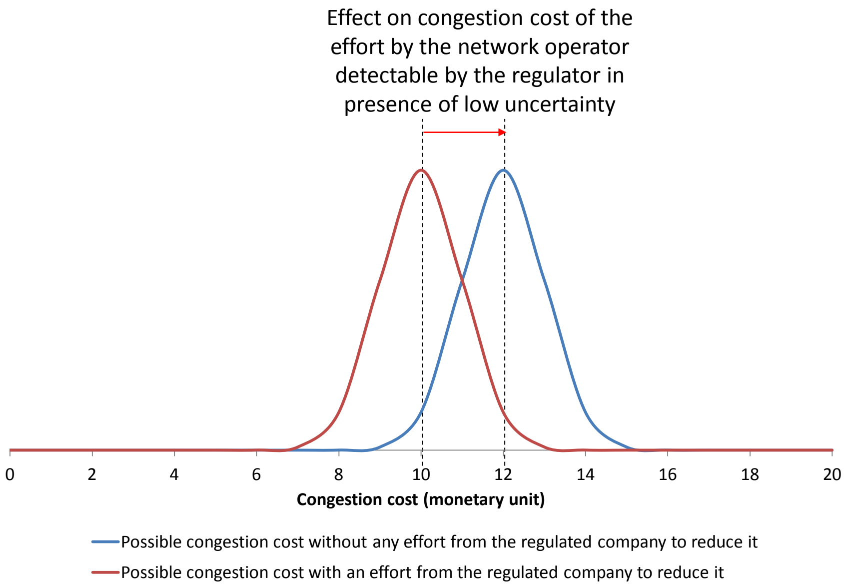
3.2.2 Predictability of operator tasks

We again consider a situation where the regulator faces no consequential information gap while both the regulator and the network operator face some uncertainty about the future of the energy system (demand level, generation or consumption technology, etc.). In this situation, a regulator can nevertheless incentivize the network operator so that it improves its productivity in a given task if the related uncertainty is not too high. That is to say that both the regulator and the network operator should be able enough to distinguish the effect of TSO's effort on its efficiency from the action of uncertain and uncontrollable variables.

Let assume now that the level of demand impacts congestion costs in an unknown manner. Other things being equal, the network operator is also supposed to be able to reduce congestion costs thanks to changes in its operation procedures. If the uncertainty about the impact of demand level on congestion costs is quite limited, it is then possible to use a proxy to evaluate the effect of the network operator's effort to reduce congestion costs (see the illustration of figure **3**). An incentive scheme can then be adequately implemented.

[17] This is for instance what occurs if the use of phase shifters are not coordinated, one tap shift by a TSO being potentially countered by another tap shift by a neighboring TSO (Verboomen et al., 2006). The TSOs use phase-shifters in particular to control power flow and possibly repulse them outside their networks.

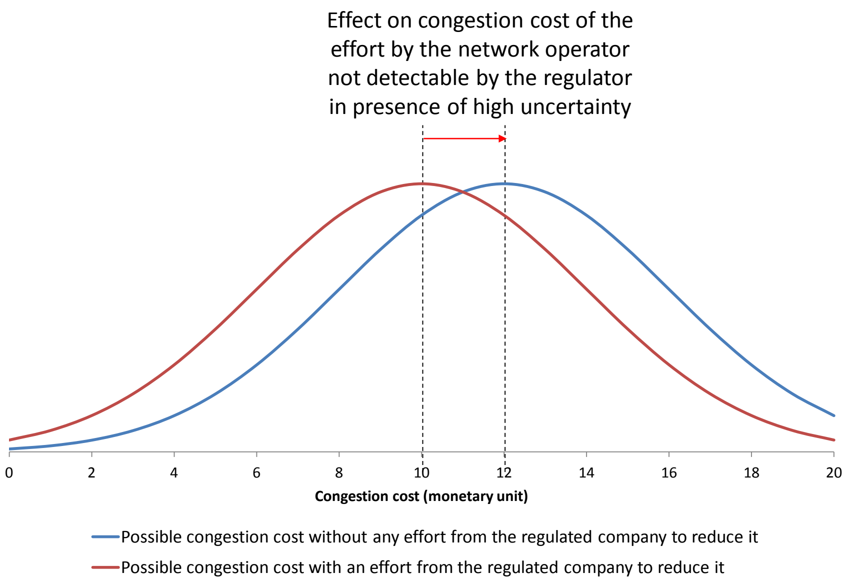
Figure 3 Effect of a low environment uncertainty on the regulator's ability to detect an improvement of operator's efficiency (e.g. congestion costs)



Otherwise, if uncertainty about the impact of the demand level on congestion costs is too important, it may be difficult for the regulator and the network operator to distinguish the effects of the efficiency improvement from the negative impact of demand level (see the illustration of figure 4). In such an uncertain situation, unless the regulator is able to properly filter the impact of uncertain variables on the network operator's tasks, it would not be effective to impose on the latter an incentive regulation[18]. The regulator would not be able to differentiate the effect from real efforts by the network operator from windfall improvements due to the uncertain environment.

18 If the regulator has a sufficient experience, set of competences and budget (as for the TSO), it 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).

Figure 4 Effect of a high environment uncertainty on the regulator's ability to detect an improvement of operator's efficiency (e.g. congestion costs)



3.2.3 Observability of operator tasks

We now consider a more realistic situation where the regulator and the network operator face an ex ante uncertainty and the regulator also suffers from a significant information gap. In this more realistic case, a regulator can nevertheless incentivize the network operator so that it improves its efficiency. It works with a task that can be monitored. That is to say that the outcome of an effort by the network operator can be observed *ex post*: firstly by the network operator and secondly by the regulator.

While this assumption about the observability of a task outcome may easily be made in theory, it is not always the case in practice. An example is when the monitoring of the customer relationship management requires indicators about the speed and the quality of answers given to the users' demands. The observability criterion requires that *ex ante* adequate Key Performance Indicators (also called KPIs) exist in the network operation process (like the indicator for "undelivered energy"). To avoid that the operator is able to easily manipulate this data, the regulator has to define and ask for the implementation of key performance indicators in a robust manner while keeping the faculty of auditing their measurement. Without accurate monitoring (an accurate measurement), it would be impossible to implement any effective incentive scheme. Observability can either target inputs or outputs. It may then determine the regulatory tools (either input- or on output-oriented) that can be implemented. Besides, the regulator may face different forms or degrees of observability, ranging from a small historical set of data from one network operator only to a large set of data from several comparable network operators (operators themselves use private benchmarking to compare their own business with the performance of their colleagues). When the regulation frame is still in its infancy, it can then happen that observability is still out of reach for the regulator for certain tasks. Consequently the regulator may prefer the "safeguard" of a cost plus scheme. However, the regulator can also reduce its information gap *vis-à-vis* the network operator from one regulatory period to the other by conceiving some new indicators paving the way for future incentive schemes.

Inversely, with a high observability of a task, more sophisticated regulatory tools could be implemented. We may however distinguish two types of observability. When only inputs are easily observable, the regulator should privilege an input-oriented regulatory tool, that is to say, a price cap[19]. Otherwise, if outputs (like quantity or quality of the provided service) are easily observable, the regulator may privilege 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 any observed deviation (either positive or negative). Any gap with the target will be treated under a predefined reward-penalty function so that the network operator may react and maximize social welfare.

After several periods of regulation the regulators may have a reasonable set of information about the process of operation and the likely behavior of the operator. Regulators could then start conceiving several possible output functions of reaction to the behavior of the operator. Improving predictability then becomes the key of the next step of regulatory building. If regulators can observe the outcome but not predict it, they cannot use the most sophisticated forms of incentives because they cannot foresee how the operator produces its output (its "performances") from its behavior being already driven by the regulator sophisticated "incentives". Sophisticated strong incentives may only result there in giving too much or too little rent to the operator through an output regulation scheme.

When regulators know enough about how the operator could react to output incentives, they may envisage investing into a more advanced regulatory tool like a menu of contracts where the company is pulled into a voluntary "efficiency type" revelation scheme. 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 particular contract that fits best with its true (while not yet observed) nature as a company (= productivity slack, innovation capability, risk appetite etc. of the staff, of the management, and of the shareholders). It nevertheless requires that the regulator be endowed with sufficiently high level and well trained abilities to implement such a complex regulatory mechanism.

Lastly, the regulator can also reduce its information gap by creating a "virtual competition environment" relying on benchmarking techniques. Regulation with a "yardstick competition" scheme can be either input- and/or output-oriented. Nevertheless, this regulatory tool requires that the regulator get enough relevant information from several comparable network operators. It is therefore generally limited to distribution networks and not applied much to transmission[20]. It is also the most complex regulatory tool to deal with. Yardstick reveals differences among companies but leaves open the explanation. If companies' performances differ because they do not operate in the same environment, or with the same technology, or for the same mix of outputs or if the various benchmarked companies cannot and do not react in the same way to the already existing set of incentives, then Yardstick misleads regulators' reaction to its results. Only a regulator with a high level of ability can easily regulate several network operators through yardstick competition. Of course, a much weaker version of regulation through benchmarking is to use it as an open "bargaining" platform between the regulator and the companies when setting price caps.

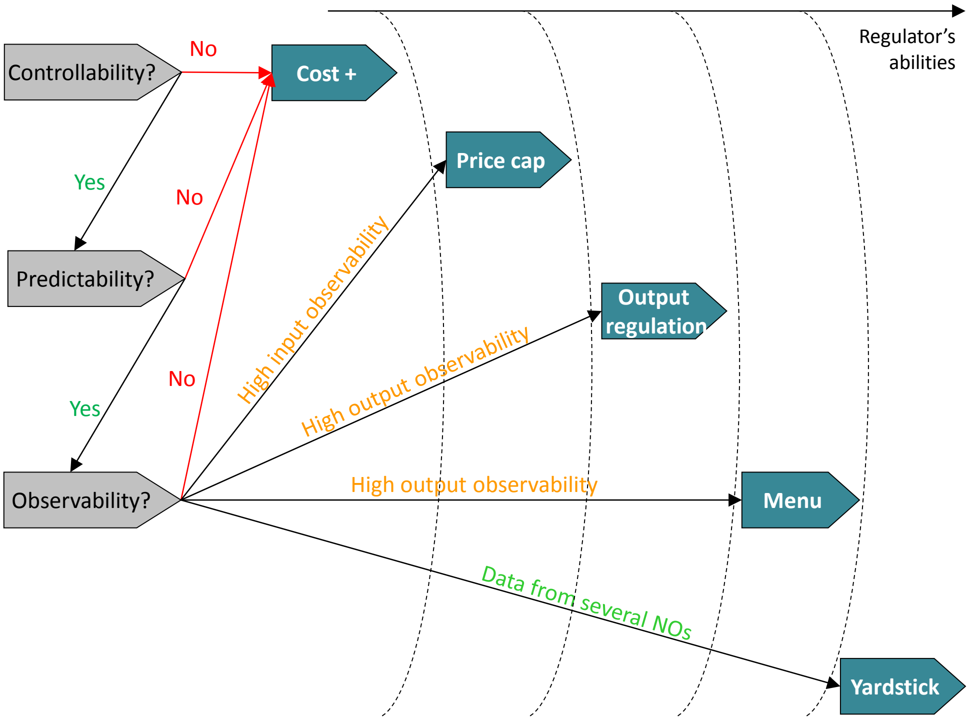
Figure 5 summarizes the decision tree: how to choose the appropriate regulatory tool taking into account on the one hand the characteristics of the network operator's tasks in terms of controllability, predictability and observability, and on the other hand the regulator's abilities. To sum up, if a 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 an

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

[20] Since there is generally only one TSO per country, applying yardstick competition to transmission would imply that benchmarking allows filtering for the different energy system and institutional contexts the national power and gas TSOs are evolving in.

incentive regulatory tool depends first on the degree of observability and second on particular regulator's abilities.

Figure 5 Decision tree to align tasks, regulatory tools and regulator's abilities



Beside this, it should not be forgotten that the regulator does not have an *ex nihilo* knowledge of the best regulatory tool for each of the network operator's tasks. Even a well-endowed regulator will have to learn from applying regulatory tools to counterbalance itshis information or knowledge gap, to adapt the tools to actual uncertainty and to increase its computational abilities. The regulator may find how the regulatory tools match with its goals and the targeted network tasks through a trial and error process that our framework may help to organize. As a consequence, our analysis suggests carefully considering any change in the regulatory goals or/and in the characteristics of the network operator tasks that may modify this workable alignment between tools, tasks and resource endowment.

3.3 Practical examples of "regulatory alignment"

This section illustrates the above framework to show how it may help in choosing the most appropriate regulatory tool, depending on controllability, predictability and observability of the targeted tasks. We consider there several tasks of an electricity TSO with different time horizons going from short term (grid losses), to long term ("hardware" or "software" innovation), passing by medium term (grid maintenance).

3.3.1 A short term task: the management of transmission losses

Losses refer to physical energy losses during transmission through a network. Their management is generally conceived of as a part of the system operation[21]. The degree of interconnection of a network

[21] 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

with neighboring networks would strongly determine the choice of the appropriate regulatory tool to incentivize a TSO to reduce its losses[22]. In an interconnected system where a given TSO network is widely used for transit from abroad, the network operator is not easily able to influence the volume of losses on its network (because the actions it may engage in may also be countered by actions from the neighboring TSOs). Energy losses are then, in this case, not really controllable. There is then little to be gained by making the TSO primarily responsible for the incurred volume of losses and to bear the risk of their occurrence. A cost plus scheme is more suitable.

However in an isolated power system where the network itself is isolated (say an electrical island), the TSO is actually able to influence the energy transmission losses. The volume of losses there 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 himself may suffer a substantial information gap regarding how the regulated firm manages its transmission losses. The choice between an output regulation, a menu of contracts and some yardstick competition schemes would crucially depend on the observability, in particular on the cumulated regulator's experience in regulating the cost of losses. If it has a historical database of loss volumes for an isolated network operator, an output regulation would be tempting. In the case of high observability for the regulator, a menu of contracts would be suitable. If the regulator has information from several comparable network operators, it could go to yardstick competition.

3.3.2 A medium term task: the grid maintenance

Grid maintenance is a basic task that the network operator undertakes to guarantee the operational reliability of its grid. The incurred costs are not frequently affected by uncertainty and unexpected events and rely much more on the company's productivity potential, which means that these costs respect both controllability and predictability criteria. The degree of observability of maintenance would depend on the regulator's own evaluation of both productivity improvement and the relative cost of (worst to best) practices to maintain a reliable grid. Consequently, a network operator could be incentivized to minimize the maintenance costs. However, the choice of the most appropriate regulatory tool should consider the regulator's abilities. In the case of sufficient observability for the regulator and if the regulator's abilities allow it, maintenance costs could be regulated within the price cap regime. In the case of high observability and of the regulator's sufficient abilities, a menu of contracts or yardstick techniques could be used to target optimal efficiency levels.

Meanwhile, incentivizing a network operator on the cost of maintenance may have adverse effects on the quality of the services it provides. It is indeed easy for it to decrease the cost of maintenance by reducing the maintenance actions, which may eventually endanger the network services quality. It is widely argued that quality has then to be regulated complementarily to cost regulation (Jamasb and Pollitt, 2008). The regulation of maintenance cost is generally completed with an output regulation whose metrics refer to quality indicators (Joskow, 2008). Quality is indeed controllable for the operator, predictable to some extent and observable for the regulator (if adequate key performance indicators are implemented). Quality is controllable in the medium term because the network operator knows how to influence it by investment and maintenance. Quality is also predictable under the condition that the extreme events are filtered out from the quality indicators[23]. This can possibly be done using econometric tools (Yu et al., 2009). Lastly, the observability of quality may depend on the

(Contd.)

prompt it 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.

22 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).

23 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).

set of indicators that the regulators would ask the network company to implement. The regulator can then implement an output regulation, either on a stand-alone basis, or inserted in a menu of contracts or integrated in a yardstick competition scheme.

3.3.3 A long term task: Innovation

For a few years the business of electrical networks literally has rung with innovation buzz words like: smart metering, smart grids, offshore grids, demand response, integration of massive renewable, energy storage, achievement of the internal market through market coupling, etc. The 20-20-20 European climate change policy has also led several regulators to consider new regulatory objectives beyond the classical ones of cost efficiency and system security. It comprehends, among others, incentivizing network operators to undertake RD&D spending and to invest in new technologies, to connect large-scale renewable sources (like offshore wind) and distributed generation (like photovoltaic power), and to foster responsive demand to be equipped with smart meters (ENTSOE & EDSO, 2010).

Smartening up the grid industry would necessitate important and repeated innovation investments from network operators. Similarly to classical transmission investments, innovation investments are characterized by high short term expenditures while the benefits are uncertain and mainly generated over a long lead time. To better reach these new regulatory objectives, the network operators have to consider these activities as new or renewed tasks. On the other hand, the regulator wonders how to conceive a fair regulatory scheme to efficiently frame these new network tasks and their incurred costs.

The innovation process is controllable in the sense that the management provided by the network operator influences the quantity and quality of innovation that it will produce. Of course, the innovation outcome has itself a low degree of predictability because the outcome of an innovation and its tradeoff between cost and benefit is by definition uncertain. However, the predictability of innovation is increasing with its technological and managerial maturity, i.e. technologies and processes that are closer to the market suffer less uncertainty and bring more identified benefits than innovation in their infancy. Similarly, the observability crucially depends on the proper definition of relevant key performance indicators. A more mature innovation will anyway allow the network operator to better foresee first hand, and the regulator second hand, the usefulness and probable outputs of the deemed innovation.

It is obviously more difficult for the regulator to conceive the appropriate regulatory tools. Indeed, the level of predictability and observability depend significantly on the innovation maturity. In case of low maturity, the TSOs could only guess the possible interactions between the innovation and the rest of the power system. It could then be inappropriate to put in place an incentive regulation tool where neither the regulator nor the network operator are able to seriously predict the thereof innovation’s cost and benefit, whatever the regulator’s abilities[24]. An innovation fund (filled by grid tariff) may then provide a “cost of service” frame to trigger an early innovation favored by the regulator’s own new objectives. However the regulator may also choose to align certain key operator revenues parameters (e.g. the rate of return; the speed of amortization) with the risk increase born by more innovation from the network. By doing so the regulator eases the innovation process while letting the operator undertake what it deems attractive in the innovation field covered by the new rules. Regulatory help to innovation can go up to exemption of certain basic regulatory rules (e.g. Third Party Access or use of congestion rents for certain audacious interconnections). When innovation maturity is increasing and the once very innovative services or processes are integrated on a more

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

business-as-usual basis, another incentive tool that may be considered is a rule of risk sharing between the network operator and the grid users (Bauknecht, 2010).

4. Conclusion

Our analysis focuses on the fact that incentive regulation works better within a certain regulatory alignment. Such alignment is welcome because different monopoly's tasks may require different regulatory tools following a decision tree based on their characteristics of controllability, predictability and observability. While previous theoretical works focused on the intrinsic efficiency of the various regulatory tools (to deal with the information asymmetry problem with or without uncertainty), literature had until now not paid much attention to their extrinsic efficiency conditions. Consequently, it delivered no practical method for regulators to choose among the various regulatory tools.

In our regulatory alignment framework, cost plus regulation still appears to be a very useful tool when a task is uncontrollable for the TSO, or unpredictable and unobservable for the regulator. If another task is controllable and predictable by the TSO, its degree of predictability and observability by the regulator helps determine the most efficient regulatory tool to be used. In case of a high predictability, the regulator may give a high incentive choice to the monopoly among a menu of contracts which will reveal to the regulator the actual risk / reward profile of the operator. With a minimum of observability, the regulator can always implement a price cap regulation (if observability targets the inputs) or an output regulation (if observability targets the outputs). Finally, if the regulator can "easily" compare different operators, it can implement a yardstick competition scheme in order to incentivize all of them to a higher efficiency (assuming no collusion and no strong heterogeneity of profiles among them). Of course, the regulator would only implement these regulatory tools if its endowment gives him the required cognitive, computational and administrative abilities.

We think that this framework could reasonably be applied to electricity regulators in the European Union. It could of course be applied anywhere else. It could also be applied in other network industries (like with gas) because they all share two chracteristics. First, regulators always have limited abilities being bounded by their resource endowment (Glachant and Perez, 2009). Second, all network industries and network monopolies are "task modular", that is to say that the industry and its networks perform various tasks that can be analyzed and considered separately (i.e. detachable from each other) vis-à-vis the regulatory process. In many network industries we would find what we saw for electricity transmission: market operation and customer relationship management; proper system operation; network asset maintenance; network asset investment; RD&D. This applies to several other liberalised industries like railways, and possibly the water sector (Pollitt, 2011)

While the third European energy package really aims at reducing the gap of regulatory powers among regulators, a significant resource gap is always striking in the EU. The European financial crisis may even push this gap to never before seen and regretable extremes. In a context of subsidiarity, the lower endowment and abilities of certain regulators vis-à-vis the others will persist in the EU if not be deepened (Glachant and Perez, 2009). It may then be of the highest importance that all European regulators keep sharing (through their dedicated cooperation institutions: CEER and ACER) their renewed experience with the design and implementation of the various regulatory tools (Brousseau and Glachant, 2011; Brophy Haney and Pollitt, 2010).

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