The regulation of electricity transmission networks and its impact on governance[1]

Laurens J. De Vries(*)

Faculty of Technology, Policy and Management, Delft University of Technology, the Netherlands

Jeroen De Joode(**)

Faculty of Technology, Policy and Management, Delft University of Technology, the Netherlands
Energy research Centre of the Netherlands (ECN), the Netherlands

Rudi Hakvoort(***)

Faculty of Technology, Policy and Management, Delft University of Technology, the Netherlands
D-Cision B.V., Zwolle, the Netherlands

Key words: electricity, transmission, network, regulation, governance, investment

---

[1] An earlier version of this paper was presented at the 31st IAEE International conference in Istanbul. The authors would like to thank session participants at this conference for their comments. In addition we thank the anonymous reviewer for constructive comments. Responsibility for any remaining errors or omissions lies with the authors.

(*) **Laurens de Vries** (1967) holds a M.Sc. degree in Mechanical Engineering, a Master of Environmental Studies Degree and obtained his Ph.D. degree in 2004 from the Faculty of Technology, Policy and Management of Delft University of Technology. He currently is an Assistant Professor in Delft, researching and teaching in the field of electricity market design.
Contact details: l.j.devries@tudelft.nl

(**) **Jeroen de Joode** is a researcher with the Policy Studies unit of the Energy research Centre of the Netherlands (ECN) and also has a Ph.D. position at the Faculty of Technology, Policy and Management at Delft University of Technology. His research focuses on energy market economics and in particular the development and governance of energy infrastructures.

(***) **Rudi Hakvoort** (1966) holds an M.Sc. in Applied Physics and a Ph.D. in Materials Science. Dr. Hakvoort is currently associate professor at the Faculty of Technology, Policy and Management of Delft University of Technology and furthermore active as consultant for the energy industry.

1. Introduction

The current institutional and regulatory arrangements with respect to electricity transmission vary significantly across the EU. The EU only requires legal unbundling, which makes joint ownership of electricity transmission and generation assets by holding companies possible. The Energy Sector Enquiry of DG Competition (EC, 2007) concluded that the vertically integrated structure that currently exists in many countries is an obstacle to competition both in the short run (through discriminatory access to networks) and in the long run (insufficient incentives for infrastructure investment). Therefore, in its third legislative energy package for internal energy markets, the European Commission (EC) proposed full ownership unbundling of electricity transmission and generation, or, if this option would prove practically (read: politically) infeasible, at least the creation of independent system operators (ISO). In the heated debate that followed, alternative institutional designs were proposed such as the creation of regional transmission operators (RTOs) or continuing vertical integration, but with stronger regulatory and institutional controls.

In liberalized European electricity markets, nearly all aspects of electricity transmission are regulated as natural monopolies. This is due to the economic and technical characteristics of transmission: the load flow patterns cause significant network externalities (due to which, for instance, the cost of a specific electricity transmission transaction cannot be established unambiguously), electricity network investments are lumpy and exhibit substantial economies of scale, and multiplication of networks is technically unattractive, too costly and, most importantly, largely unfeasible due to land use and permitting considerations. An exception can be made for direct current (DC) network links, which can in principle be developed under competition (cf. Brunekreeft, 2004; De Jong *et al.*, 2006). In this paper we will focus exclusively on the network of alternating current (AC) transmission lines, which form the bulk of the European transmission network. We will review the impact of the governance framework upon transmission, especially investment.

2. Policy goals

While continuing to be regulated as a natural monopoly, the role of the transmission networks has changed with liberalization. In addition to providing a reliable conduit for electricity between producers and consumers, transmission networks now also need to facilitate competition in the (wholesale) electricity market, which also includes large flows of power from one system to another. For this reason, the integration of national electricity markets into 'regional' markets is being promoted, for which new transmission capacity, mostly between countries, is needed.

As liberalization was motivated by a desire to improve the economic efficiency of the electricity industry, the regulation of transmission networks focused on improving their economic efficiency. The current regulatory focus on short-term efficiency makes it difficult for TSOs to facilitate market integration and the integration of increasingly large amounts of renewable energy (a.o. wind-based electricity production). Therefore, a new regulatory approach that balances short-term and long-term interest is needed.

In the first period after restructuring, the regulation of transmission in Europe was focused was on static economic efficiency. A number of countries implemented a form of performance regulation, which provides TSOs with incentives to reduce their costs. Gradually, however, the focus shifted to investment and dynamic efficiency. A first reason is that while the overall demand for electricity has been growing at a modest rate, the transmission of electricity appears to have been growing much more quickly. The sum of electricity exchanges between UCTE members and with third countries can be considered an indicator for the use of the transmission network. The share of these exchanges relative to total electricity consumption has been growing steadily from about 6% in 1975 to nearly 14% in 2006 (UCTE, 2008). As there is no trend break around the time of liberalization, this appears to be an autonomous trend.

A second reason for the shift to long-term efficiency is that sufficient network capacity is a precondition for the development of competition in the electricity market. As the limited number of generating companies in many EU member states limits the prospects for competition inside these countries, much attention is devoted to interconnectors as means for facilitating competition between member states. Facilitating competition may require significantly more network capacity than is necessary for security of supply: while network congestion is not necessarily a risk to security of supply – as long as there is enough generation capacity available 'downstream' of the congestion to meet reliability standards – congestion tends to divide the European electricity market into different price zones, in each of which market power may increase substantially, as compared to a situation without congestion.

The three general policy goals for the electricity transmission are – in line with the general goals for the electricity sector – (1) reliability, (2) economic efficiency (one aspect of which is the facilitating competition) and (3) contributing to the sustainable development of the energy system. The goal of reliability can be divided into operational aspects (which we will not focus on) and the adequacy of the transmission network. The goal of facilitating competition can be subdivided into the goal of achieving a 'level playing field' for competition, which is generally interpreted as removing anti-competitive advantages *within states*, and 'regional integration', which refers to the integration of neighbouring electricity markets. With respect to economic efficiency, liberalization caused the central planning paradigm to be replaced with competition in generation (as a means for achieving economic efficiency in that link of the value chain) while a mix of central planning and economic incentive regulation is applied to the transmission networks.

Summarizing, we have identified the following goals for transmission:

- reliability:
    - secure operation (which we will not focus on)
    - adequate investment;
- economic efficiency, which can be subdivided into:
    - efficient network operation (which we will not focus on);
    - efficient investment, for the purpose of:
        - ▪ minimizing system costs, given reliability criteria;
        - ▪ facilitating competition (reducing congestion when the benefits of increased competition outweigh the costs):
            - within states: 'level playing field';
            - between states: 'regional integration'.
- facilitating the sustainable development of the energy system, which

consists of:

- providing sufficient network capacity at locations where power is being produced from renewable generation (mostly wind and solar power),
- facilitating decentralized power generations (including bidirectional flows).

The main trade-off is between minimizing network costs – e.g. investing just enough for meeting reliability standards in the future – and making additional investments for the purpose of facilitating competition and/or the sustainable development of the system.

3. Regulation of transmission networks

3.1. Regulatory framework

While the above policy goals are fairly general, there is no satisfactory regulatory framework for achieving them. At a fundamental level, an important problem is that it is impossible to define an optimal network even in a static situation, let alone in a dynamically changing environment and with construction lead times of a decade or more (cf. Brunekreeft *et al.*, 2005; Ajodhia, 2006). As it is difficult to objectively measure the performance of a network operator, in the absence of an objective benchmark, much regulation is focused on process, rather than output. Such regulation is designed to provide network operators with incentives for making optimal decisions.

However, this approach runs into fundamental obstacles. In theory, economically efficient incentives are based on the cost or market value of the service or product, both of which are difficult to define in the case of transmission due to its specific technical characteristics. However, it is not unambiguously possible to allocate the costs of a specific network transaction (transporting a certain volume of electric energy from A to B at a certain moment in time) to that transaction. The costs of that specific transaction depend in a non-linear way on, among others, which other network transactions take place at the time. Consequently, cross subsidization between network users is inevitable and neither the network service provider nor the network users receive short-term economically efficient incentives. (This causes, among others, the need for a congestion management method.)

A second obstacle is that a limited set of incentives – connection and transmission tariffs, congestion costs or rents – need to provide efficient signals to both the network operators and the network users (generators and consumers). The question of network access costs provides a particular dilemma: for the location of large conventional plants, network access costs provide only very limited incentives, whereas for renewable power generation (especially from wind), full cost pass through of the connection costs may easily render a project uneconomic (notably for offshore wind parks). In addition, the limited set of incentives needs to serve both short-term and long-term goals. Incentives for efficient network operation do not necessarily also provide incentives for the necessary investments and *vice versa*. Overall, the challenge is to design a set of network regulations that provides the best possible set of incentives to both network operators and network users, both for the short and the long term, while taking into account the specific policy goals such as the development of electricity production from renewable sources.

A consequence of the absence of a sound regulatory framework is that in practice, a patchwork of regulations applies to electricity networks, each of which is directed at a subset of the goals that were identified above. Cross-subsidies and other external effects are inevitable. Whenever they give rise to (too strong) undesired consequences, the regulations are adjusted or new ones are added. There are five broad areas of network regulation in which this game unfolds. *Table 1* presents an overview of the main different aspects of transmission regulation, their objectives and examples of the available choices for designing regulation. The first four rows describe aspects of network regulation that are generally not focused on transmission investment, but that do have an impact on investment behaviour of the TSO. The bottom row lists regulations that are explicitly focused on transmission investment.

Table 1: Aspects of network regulation

Regulation aspect	**Objective(s)**	***Examples of options***
Network tariff level	Prevent abuse of network operator's monopoly power	*Two categories: cost of service regulation and incentive regulation*
Network tariff structure	Allocate network costs to network transactions	*Locational variations, variation of tariffs between the voltage level of the connection, distance or non-distance related tariffs.*
Network connection tariffs	Equal access for all network users	*Deep or shallow connection charges; capacity or energy-based tariffs.* *Locational investment incentives for generation.*
Congestion management	Efficient allocation of available network capacity	*Variations of auctions or redispatching. In case of auctions: choice of what to do with the revenues; in case of redispatching there is a choice whether to allow the network operator to pass the costs along to consumers.* *Locational investment incentives or generation.*
Network expansion	To meet demand reliably; to facilitate competition in the market; to facilitate renewable and decentralized generation	*Two extremes are either to subject each capacity increase to a regulatory review process, or to include all investments indiscriminately in the revenue cap (in case of incentive regulation). Another option is to let the network operator bear the costs of congestion, so he has an incentive to increase network capacity when that is cheaper.*

3.2. Network tariff level

The design of network tariff regulation in European liberalized electricity markets is generally targeted at preventing TSOs from charging monopolistic tariffs, and, in the absence of the threat of real competition, at providing incentives for improving economic efficiency. Network tariff regulation affects investment behaviour by the TSO by influencing his ability to recover transmission investment costs. Broadly two types of network regulation are distinguished: rate-of-return regulation and incentive-based regulation.

Before European energy market liberalization, network tariffs were typically determined through a form of so-called rate-of-return regulation (or 'cost-plus' regulation). Regulation was often implicit. The regulator or government sets tariffs in such a manner that network operators can cover their operating and capital expenses plus a guaranteed rate of return on investment. This regulatory approach has several known drawbacks related to (i) asymmetric information, (ii) the difficulty for the regulator to set the 'right' (optimal) rate of return, and (iii) the difficulty of determining a proper evaluation method for rate base assessments ('which investments/costs to include in the rate base'?).

Asymmetric information between the regulator and the regulated firm is a key issue in the regulation of natural monopolies. Baron and Myerson (1982) and Laffont and Tirole (1986) address regulation of monopoly firms in the presence of asymmetric information in the form of unknown costs and unobservable effort to reduce costs. The major weakness of rate-of-return network regulation was pointed out by Averch and Johnson (1962). They found that unregulated monopolistic network operators structurally over invest in network capacity due to their relative favourable risk position (later called the Averch-Johnson effect). The effect was empirically proven by Stigler and Friedland (1962) and Courville (1974).

This type of inefficiency occurs mainly in networks for which there is a limited need for new expansion or replacement. For example, current electricity networks need to accommodate a transition to a more sustainable electricity system, which poses new challenges for network operators. In addition, due to the large network investment boom between the 1950s and 70s, many components of the electricity networks in developed countries need to be replaced in the coming years. Moreover, network operators who are vertically integrated with generation may have a counter incentive, since they may have an interest in protecting their own generation business by limiting the volume of interconnection capacity with neighbouring networks. Incentive regulation, on the other hand, explicitly uses the firm's information advantage and profit motive.

The regulator refrains from setting TSO inputs but steers on desired output, which is efficiency improvement. Incentive regulation decouples the direct link between costs incurred and revenues received by the network operator. For a complete overview of the various forms of incentive regulation we refer to Vogelsang (2002). Both rate-of-return and incentive-based regulatory regimes have implications for network investment. The former may lead to excess investment, while the latter may discourage investment as the investment risk is fully borne by the transmission operator. The certainty of investment cost recovery is the major issue for network operators.

3.3. Network tariff structure

The second aspect of the regulatory framework, the tariff structure, influences the behaviour of network users in both the short and the long term, but also affects the incentives that TSOs experience, especially with respect to investment. There are several design variables. Transmission charges can have both capacity and volume related elements, where capacity can refer to either average or peak capacity use. This distinction is particularly relevant for intermittent sources that show large variation in transmission capacity usage. A second variable is the way in which costs are allocated to the customers connected to different network (voltage) levels.[2] Another variable is the degree to which tariffs are related to the distance between load and generation.

Ideally, each electricity producer or consumer connected to the transmission network is charged full cost-reflective network tariffs, but the general uncontrollability of electrical flows in the network and insufficient real-time metering of flows through the network prevents this. As a result, network charges inevitably involve compromise. For example, strong differentiation between network capacity charges for two different voltage levels could induce a party desiring a network connection to economically prefer the option that causes substantial operational (or even investment) costs for the network operator.

3.4. Network connection tariffs

Network connection tariffs are the one-time charges for realizing new network connections. The main tariff design question here is: which part of the costs caused by the new connection is passed through to the party that initiated the connection? In general, every new connection requires some investments in (local) assets and equipment. But on occasion, a new connection may cause a particular bottleneck elsewhere in the network that

---

[2] This for example affects the integration of distributed energy resources (single wind turbines, small-sized combined heat and power producing (CHP) units, and the like).

gives rise to substantial new investment needs. The choice is between deep and shallow connection charges. Deep connection charges are, in principle, fully cost-reflective since all incurred investment costs are passed n to the party connecting to the network. Shallow charges only reflect the direct investment costs required locally.

For the purpose of efficient network expansion we would wish to confront applicants for new network connections with the full cost of their connection (deep connection charges) since this would provide proper incentives to applicants to choose a location that is optimal for both network operation and expansion. However, there are significant obstacles to implementing fully cost-reflective network charges (cf. Turvey, 2000; Brunekreeft *et al.*, 2005; see also the discussion in Section 3.6). An argument for shallow connection charges is the 'fairness' argument. A situation in which a second or third power plant seeking a connection to the network would need to pay deep connection charges (for capacity increases elsewhere in the network), while earlier connected plants, that were able to use existing 'reserve' capacity in the network, only paid shallow connection costs, is considered to be unfair. Consequently, network connection charges across the EU are typically shallow, or at least 'shallowish', thereby favouring the policy goal of facilitating competition through a 'level playing field'. A final variable in the design of connection tariffs is whether to implement geographical variations in the network charges so as to incentivize the siting decisions of generators. These variations should reflect the cost differences imposed by locational choices of network users. However, these cost differences are average costs, not marginal operating costs, and are difficult to forecast for the life span of the connected asset.

3.5. Congestion management

The choice of congestion management method affects several policy goals: efficient use of the network, price formation and competition in the wholesale market and incentives for investment in the network and generation. We discern three types of congestion management methods: corrective methods, pricing methods and distributive methods. The latter are methods for network capacity allocation use other criteria than willingness tot pay (such as priority and pro-rata assignment). We will not discuss them because they violate the principle that congestion management methods should be based on market principles (EU, 2003). The other two types of method can be considered as market-based (Knops *et al.*, 2001; De

Vries and Hakvoort, 2002), although none of the congestion management methods meet all the goals of providing efficient incentives for network use and network investment (EU, 2003).

A general characteristic of corrective congestion management methods is that market parties are allowed to make transactions without consideration for congestion. As a result, a single price emerges in the market, regardless of network constraints. The TSO then acts 'behind the scenes', through redispatching or counter-trading, to prevent network overload. *Redispatching* involves increasing output 'downstream' of the congested connection and decreasing it 'upstream'. The costs related to this system of redispatching are generally socialized in network tariffs. A slightly more market-based approach is called *counter trading*. Within this system, the TSO creates a secondary market in which it requests bids from generation companies to reduce generation on one side and increase generation on the other side of the congested line. As with redispatching, the costs are socialized in the network tariffs.

Congestion pricing methods allocate access to a congested network through some form of auctioning. Exemplary methods are explicit and implicit auctioning and nodal pricing. In *explicit auctions* the use of transmission capacity is offered to the highest bidders in regularly recurring auctions; often in yearly, monthly and daily auctions. In Europe this is a common method for allocating scarce interconnector capacity. The interconnector price is set equal to the marginal bid, which is the lowest bid that is awarded transmission capacity. All bidders that bid equal or higher than the marginal bid obtain capacity rights against the value of the marginal bid. In principle, the willingness to pay is equal to the price difference over the congested link. In an *implicit auction*, the auction of transmission capacity is integrated with a power exchange. The original design works in one direction and requires the presence of an organized market downstream of the congested link. The transmission capacity is implicitly auctioned: it is allocated to the highest bids in the spot market that make use of the congested link. Thus the energy and capacity bids are combined in a single package (De Vries, 2004). Market splitting and market coupling are extensions of implicit auctions in which the case-by-case method for managing structural congestion makes room for a more 'zonal' approach.

A particular case of congestion pricing is locational marginal pricing. It combines bids for electricity (commodity) with bids for network capacity.

As the management of congestion is integrated in the market clearing method, it can be considered an advanced form of implicit auctioning. The system (market) operator (SMO) matches the bids of producers and consumers to clear the market. Congestion is handled by varying the prices among the different nodes in the network: lower prices will lead to less generation and, perhaps, higher consumption at a node, and vice versa (cf. Hogan, 1992; Kirschen and Strbac, 2005). This method is conceptually elegant, as it is the only congestion management method that fully takes network constraints into account. However, it is also complex and only works in integrated markets (using the classification of Hunt (2002)). Nodal pricing can only be implemented in an integrated market in which the system operator is also is the market operator. As the SMO fully controls market outcomes it is crucial that the SMO is strictly independent from all the other parties.

The two categories of market-based congestion management methods, auctioning and corrective methods, vary widely with respect to efficient use of the network, wholesale competition and efficient investment in network and generation capacity. The only auction-type method that utilizes available network capacity efficiently is locational marginal pricing, but this does not appear to be feasible in Europe in the near future. Other types of auctioning are based on (much) less refined approximations of available network capacity. Given a certain estimate of available network capacity, all auction methods should in principle allocate this capacity efficiently. A practical barrier exists for explicit auctions, in which the coordination between network capacity and traded volumes may lead to sub-optimal outcomes. Implicit auctions (of which market splitting and market coupling are variations) do not have this disadvantage. The corrective methods lead to efficient network use, in theory, as they prompt the TSO to seek the least-cost dispatch of generation capacity.

With respect to competition, in principle there should not be a difference between the two types of congestion management method. With sufficient suppliers and effective price competition, both groups of congestion management methods should work well. Auction-based methods have in practice as a disadvantage that different price zones emerge, which may lead to local market power. However, hiding the fact that there is a pivotal supplier in an area behind a façade of a single price zone does not necessarily work: the supplier may use its market power when it is redispatched, leading to high costs for the TSO. In fact, this is an important vulnerability of corrective methods: even if a supplier is not pivotal, redispatching and counter trading can easily be manipulated by suppliers and wholesale consumers. The advantage of a single price zone appears to be mainly political: political leadership in Sweden, for instance, and Germany oppose the development of different electricity price zones within their countries, even though this could provide a significant economic advantage (cf. Bjørndal and Jörnsten, 2007).

Corrective methods and pricing methods each provide optimal investment incentives, in theory, to one side of the equation. Both counter-trading and redispatching have the advantage that they provide TSOs, in theory, with perfect information about the need for network reinforcements. However, when the costs of congestion are socialized into network tariffs, the incentive may be removed, so the TSO should be fully accountable for congestion costs. Then the TSO can decide between the cost of network investment versus the continuing occurrence of congestion. Initially, auctioning was intended to provide an optimal allocation method for existing capacity, but more recently it has also been viewed as an efficient method to determine and allocate future demand (McCabe *et al.* 1989).

Congestion pricing methods theoretically provide optimal investment signals to network users, but the underlying assumptions are not easy to realize in practice. The following assumptions would need to hold: (i) risk neutral behaviour, (ii) independent private bids, (iii) information-symmetric bidders and (iv) sufficient bidders. This would mean that those bidders with the highest willingness to pay would indeed obtain the auctioned good, thereby providing maximum revenues to the auctioneer (cf. Klemperer, 1999). Yarrow (2003) and Newbery (2003) discuss the application of auctioning principles to network capacity allocation. Congestion management based on nodal prices creates price risks for investors. The means to deal with this risk are hedging instruments in the form of financial transmission rights (FTRs), also called transmission congestion contracts (Hogan *et al.*, 1996, see also Kirchen and Strbac, 2004). These rights entitle their holders to revenues equal to the quantity of electricity times the price differential between two specified nodes (O'Neill *et al.*, 2003). Locational marginal pricing is widely regarded as the most efficient method, but it also is generally agreed that for the time being, institutionally it is not feasible in Europe (Brunekreeft *et al.*, 2005). It would require network operation to be integrated with market operation, which it currently is not, and neighbouring interconnected markets would need to integrate their operations.

Unfortunately, there is no congestion management method that combines efficient investment incentives for market parties and for the TSO. Moreover, in practice these incentives are not as useful as they appear. Because the corrective methods are so easily manipulated, they may as much signal the degree of market power as the need for network capacity. Many other factors affect network investment, such as permitting restrictions and the allowed return on investment for the TSO. Similarly, generating companies may attach little value to short-term congestion price signals when deciding where to locate their power plant as permits and proximity to fuel infrastructures may dominate the decision. Consequently, congestion management methods appear of limited use in providing locational incentives to network users and signalling the need for network investment. Auction-based methods probably provide the most useful incentives, as at the very least they signal the momentary marginal value of a network link, which, if it does not provide optimal incentives directly, can be used to inform regulatory decisions (Newbery, 2003). In the next section this issue will be further analyzed.

3.6. Network expansion

The traditional approach to regulating network investment is the public contest approach, in which sizeable new transmission network expansion projects are subjected to a (social) cost-benefit analysis by an independent (government) agency. Depending on the responsibilities and rights of the actors involved, different variations of this method are possible. For example, the obligation to propose new expansion projects can be placed on the network operator, who may be required to develop a long-term network expansion plan for large bottlenecks. In this case, the regulator would need to check the welfare impact of the investment. This approach, the most traditional, is subject to the Averch and Johnson (1962) effect, which holds that the network operator has an incentive to over invest.

Alternatively, the initiative can be left to network users, who may be given the right to propose network investments based on the congestion effects that they experience (cf. Chisari *et al.*, 2001). In the Argentinean model of the 1990s, the network operator evaluates the welfare implications while the regulator provides oversight on the regulatory procedure. In order to improve the productive efficiency of network expansion, a decision to go ahead with an expansion project may be followed up by a public tender for the realization of the expansion. While this approach would circumvent the

Averch-Johnson effect, Joskow and Tirole (2002) warn that consumer cooperatives face complex governance problems due to conflicting goals among their members. Baldick *et al.* (2007) assess current allocation practices and derive a number of principles to guide the allocation of electricity transmission investment cost for the United States (US) case.

Several types of more sophisticated incentives schemes have been proposed. Vogelsang (2005) notices, however, that during the past decades, the economic literature has drifted farther away from the ideal of optimization due to many practical obstacles. A fundamental issue that he notes is that the non-storability of electricity creates the necessity of very short-term incentives, whereas transmission is characterized by particularly long life cycles. Many theoretical approaches are not feasible in practice due to too high informational requirements, transaction costs and, in some cases, market power issues. This is illustrated by Joskow and Tirole (2002), who identify two theoretical options for providing a TSO (with a two-node network) with optimal investment incentives. The first is to reward the TSO based on the social surplus that is created by its transmission line. The surplus is derived from the supply and demand curves for power on both sides of the link. The second method is essentially the same, except that it is based on an *ex ante* estimate of the social value of a capacity increase. This estimate is derived from the costs of redispatching (or 'congestion uplift', as Léautier and Thelen (2007) call it) that would be avoided by the investment. The problem with the latter is that redispatching can be manipulated easily, as the involved generating companies typically have local market power (the 'inc/dec game' that was pioneered in California, cf. Brunekreeft *et al.*, 2005), while a problem with the former, as the authors themselves note, is the need to know the supply and demand curves.

Theoretically, FTRs can provide optimal incentives for network expansion, but a large number of conditions must hold for this to be true in practice (Joskow and Tirole, 2004). Among them are the absence of returns to scale in network expansion and the inexistence of sunk costs. Particularly these two conditions are not likely to be met in reality in the case of electricity network expansion, as a consequence the usefulness of FTRs for signalling investment expansion is limited in practice.

All things considered, Léautier and Thelen (2007) regard congestion rents ('merchandising surplus') as the best metric of the value of transmission expansion. However, in the practice of the European context even their pragmatic approach is limited for several reasons:

- Congestion rents provide an indication of the marginal value of a link or path, but investment is lumpy. Congestion rents do not signal the full social value of a network upgrade. This would require information regarding demand and supply curves.
- In Europe, congestion pricing is generally limited to national borders (Norway being an important exception). Internally, redispatching or counter trading is typically used; the extent to which this takes place is not clear. This does not necessarily mean, however, that all congested im/export capacity is due to capacity limits on the interconnectors themselves: restrictions on im/exports may actually be motivated by capacity shortages within the connected national networks. So whereas import capacity auction revenues may signal a demand for more capacity, they do not necessarily signal where this capacity should be added.
- In addition, parallel explicit (flow-gate) auctions may distort price signals, as the transaction costs for optimizing between parallel routes may be very high. For instance, there are multiple parallel connections between Scandinavia and the UCTE network. The same is true of, for instance, Germany and the Netherlands, and of France and Italy.
- Another factor is the existence of large parallel flows, which, in the current situation in Europe, do not increase congestion revenues but do contribute to the demand for network capacity.
- Finally, the hybrid structure of the European power market, with many vertically integrated firms combined with cross-border ownership of generation, creates a risk that incentive-based regulation of transmission be manipulated.

An issue that is less frequently touched upon is the fundamental difficulty, even for a TSO with the best available knowledge, to establish what ‘optimal’ network expansion would be – apart from the question of how to provide incentives to a TSO or other parties to achieve it. Ajodhia (2006) shows how difficult it is to determine the least-cost configuration of a simple network, even under static conditions and with full information. It appears to be even more difficult for a large, meshed network where generation can substitute for network capacity. Finally, the dynamic nature of power markets – with changes in the location of generation due to changing fuel price differentials and the development of renewables – has as a consequence that it is impossible to foresee the optimal network configuration over the life cycle of its assets. After all, it takes years to upgrade an existing transmission line and at least a decade to construct a new line, the life span is many decades and, due to permitting restrictions, the geographic path may remain in use for much longer even. Consequently, transmission investment projects must be undertaken based on long-term and therefore uncertain expectations of future demand. Alternatively, they may take place only after the demand for additional network capacity is manifest, but in this case demand will go unmet while the project is under development, which can be many years. Therefore the only alternative to accepting a risk of excess investment appears to accept certain under investment.

The absence of a clear benchmark by which to evaluate investments is a key issue. However, Cazalet *et al.* (1978) already showed that the social costs of excess capacity in the electricity infrastructure are much smaller than the costs of under capacity. Joskow and Tirole (2002) repeat this argument, which holds even stronger for the transmission network, as it is the backbone of the electricity system while it constitutes less than 10% of total cost. Therefore excess capacity may be considered as a cheap social insurance against the much higher costs of too little investment.

4. Regulatory challenges

We will review some of the basic issues for transmission network regulation. Current EU policy (Directive 2003/54/EC) requires legal unbundling of network and system operation from competitive activities. This means that the TSOs must be legally separate entities, but that joint ownership of transmission and commercial activities such as generation, trade and retail is allowed. This type of vertical integration is common and many European TSOs are part of commercial energy companies. Joint ownership may provide uncompetitive advantages to the owners. Firstly, TSOs may be inclined to offer more favourable network access conditions to their competitive affiliates (generators, traders) than to third parties, distorting competition. Secondly, in case of congested links with other networks (in Europe often interconnectors), an integrated network company may have an incentive to maintain the status quo in order to continue its dominant market position in its home market. This disincentive to invest is an obstacle to network expansion, regional and European market integration, and ultimately, the development of a competitive European market (EC, 2007).

4.1. Cross subsidization

A first issue is the opportunity for cross subsidization between the regulated network activities and the competitive activities of a vertically integrated company. The structure of the tariffs and connection charges can easily be regulated, preventing opportunities for a vertically integrated company to favour its own competitive activities. However, it is much more difficult to regulate the level of the network tariffs in such a way that they provide a reasonable return as well as reasonable incentives for improving the efficiency of network management, without allowing anti-competitive advantages. If network tariffs are allowed to be higher than necessary, the vertically integrated company can use the revenues to lower energy prices, thus making it harder for other parties to sell electricity over its network. As a system operator, a vertically integrated company may also have opportunities to favour its own generators with respect to ancillary services, for instance with favourably priced contracts.

4.2. Exchange of sensitive information

A second issue deals with the 'Chinese walls' that should separate the TSO from its commercial affiliates in case of a vertically integrated company. As the main incumbent generator in its area, a vertically integrated company probably already has an advantage, being able to balance internally; combining the knowledge of the system operator with being the main provider of balancing power may provide an opportunity to make balancing substantially more costly for competitors. TSOs control competitively sensitive information about the generators in their area which should not become available to their commercial affiliates. However, Chinese walls often appear to end up as Japanese walls in practice, as it is difficult to enforce that nothing is passed through these paper-thin walls. Ownership unbundling would be a remedy to both of these issues and reduce the need for regulation.

4.3. Discrimination

The situation is more complicated when it comes to congestion management. In Section 3.5, it was pointed out that the corrective congestion management methods are vulnerable to manipulation; they are even more so in case the TSO is part of a vertically integrated company. In this case, the TSO would be able to favour its affiliated generating or trade company by paying above-competitive prices for its redispatching actions, which would provide a way to transfer network revenues to its commercial affiliate. If the redispatching costs are socialized, this would lead to additional revenues for vertically integrated companies at the cost of the network users; if the redispatching costs are not socialized, the vertically integrated company could reduce its overall costs of redispatching by preferentially using its own plant. There is no simple solution to this problem of mixed incentives, which is an important reason for favouring congestion pricing methods in systems with vertically integrated TSOs.

4.4. Perverse incentives

Congestion pricing methods will also vulnerable to manipulation by vertically integrated firms. For instance, the revenues of the explicit auctions of interconnector capacity on the German-Dutch border are split between the two countries. The Dutch set the revenues aside for network investment, but on the German side for the revenues flowed back to the TSOs. This provided a double negative incentive. First, the German TSOs benefited from the presence of congestion. Second, as the German TSOs were vertically integrated, half of the auction payments by their trade affiliates flowed back to their parent companies, providing them in effect with half-price access to the auctions.

The argument is corroborated by Léautier (2001) and Léautier and Thelen (2007). Léautier and Thelen (2007) find from an empirical analysis of 16 jurisdictions that vertical unbundling is conducive to the reduction of congestion. Regardless of the degree of vertical integration, it is clear that TSOs should never be allowed to retain congestion revenues. However, finding a good purpose for the revenues may not be easy. They can be set aside for network investment, but there is no relation between the volume of the auction revenues and the need for investment. If they are given to the shareholder(s) of the TSO, this may still lead to an indirect incentive to maximize congestion revenues, rather than to minimize congestion.

Another option is returning the revenues to network users by lowering the network tariffs.

Regardless of the congestion management method, a vertically integrated company has an incentive to invest sub optimally in interconnections with neighbouring networks in order to protect its generating company from competition. The simplest way to remove this incentive is ownership unbundling. However, a regulatory solution may also be possible.

5. Conclusion

Regulation of transmission networks covers the issues of network tariffs, tariff structure, connection tariff, congestion management and network expansion. A proper governance structure is a *sine qua non* for proper regulation of transmission companies. Most notably, vertical integration may hinder non-discriminatory network access and efficient network operation. Some, but not all negative effects of vertical integration may be controlled through regulation.

With respect to the regulation of network investment, the current level of development of European markets does not appear to support more sophisticated schemes than regulatory approval based on a social cost-benefit analysis. The theoretical proposals for more economically efficient regulatory schemes fall short of true economic efficiency, which means that they can deliver at best a relative improvement, and are currently difficult to implement in Europe. On the other hand, the downside of a regulatory approval process, that it may lead to excess investment, is probably limited. In practice, permitting restrictions limit network expansion, while the social cost of excess investment in transmission is quite limited in comparison to any shortfalls. In fact, excess capacity also has benefits in terms of higher reliability and allowing more competition, and the current challenges to the energy sector – more renewable energy, less CO_2, more remote sources of natural gas – will require substantial investments, both in terms of network capacity and innovation.

6. References

Ajodhia, V.S. (2006). *Regulating beyond price, integrated price-quality regulation for electricity networks*. Doctoral dissertation. Delft University of Technology.

Anderson, K. P. and McCarthy, A. (1999). "Transmission pricing and expansion methodology: lessons from Argentina". *Utilities Policy* 8, pp. 199-211.

Averch, H. and Johnson, L.L. (1962). "Behaviour of the firm under regulatory constraint". *The American Economic Review* 52: 1053-1069.

Baron, D.P. and Myerson, R.B. (1982), "Regulating a Monopolist with Unknown Costs", *Econometrica*, Vol. 50, No. 4 (Jul., 1982), pp. 911-930.

Baldick, R., Brown, A., Bushnell, J., Tierney, S. and Winter,T. (2007). "A national perspective on Allocating the Costs of New Transmission Investment: Practice and Principles". A White Paper Prepared by The Blue Ribbon Panel on Cost Allocation for WIRES (Working group for Investment in Reliable and Economic electric Systems), http://www.hks.harvard.edu/hepg/Papers/Rapp_5-07_v4.pdf.

Bjørndal, M. and Jörnsten, K. (2007). "Benefits from coordinating congestion management – The Nordic power market". *Energy Policy* 35: pp. 1978–1991.

Brunekreeft, G. (2004). "Market-based investment in electricity transmission networks: controllable flow". *Utilities Policy* 12: 269–281.

Brunekreeft, G. (2005). "Regulatory issues in merchant transmission investment". *Utilities Policy* 13 (2), pp. 175-186.

Brunekreeft, G., Neuhoff, K. and Newbery, D. (2005). "Electricity transmission: An overview of the current debate". *Utilities Policy* 13 (2): 73-93.

Cazalet, E.G., Clark, C.E. and Keelin, T.W. (1978). "Costs and Benefits of Over/Under Capacity in Electric Power System Planning." Report Prepared for the Electric Power Research Institute (EPRI) by Decision Focus, Inc.

Chisari, O.O., Dal-Bó, P. and Romero, C.A. (2001). "High-tension electricity network expansions in Argentina: decision mechanisms and willingness-to-pay revelation". *Energy Economics* 23: 697-715.

Courville, L. (1974). "Regulation and Efficiency in the Electric Utility Industry". *Bell Journal of Economics and Management Science*, 5 (1), pp. 53-74.

De Jong, H. and Hakvoort, R. (2006). "Interconnection investment in Europe: Optimizing capacity from a private or a public perspective?". *In: Proceedings, 29th IAEE International Conference "Securing Energy in Insecure Times".* Potsdam (Germany).

De Jong, H. M., Van der Lippe, J. C. and Knops, H. P. A. (2007). "Investment in cross border transmission capacity: Economics or Politics? A European Case Study". In: *Proceedings, 30th Conference of the International Association for Energy Economics.* Wellington (New Zealand).

De Jong, H., Knops, H. and Hakvoort, R. (2006). "Merchant transmission investment in Europe, opportunities for private initiatives in a regulated market segment". In: *Proceedings, 29th IAEE International Conference "Securing Energy in Insecure Times".* Potsdam (Germany).

De Joode, J., De Jong, H.M., and De Vries, L.J. (2006), "Congestion management in meshed gas networks: can the electricity market serve as an example?, In: *Proceedings, 29th IAEE International Conference "Securing Energy in Insecure Times".* Potsdam (Germany).

De Vries, L.J. (2004). "Securing the public interest in electricity generation markets: the myths of the invisible hand and the copper plate". Dissertation, Delft University of Technology.

De Vries, L.J. and Hakvoort, R.A. (2002). "An Economic Assessment of Congestion Management Methods for Electricity Transmission Networks". *Journal of Network Industries* 3 (4): 425-466.

EC (Commission of the European Communities) (2007). *DG Competition Report on Energy Sector Inquiry SEC(2006) 1724.* Available at: http://ec.europa.eu/energy/electricity/package_2007/index_en.htm.

EU (2003). "Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003, concerning common rules for the internal market in electricity and. repealing Directive 96/92/EC". *Official Journal of the European Union* 2003 L 176: 37-55.

EU (2003). "Regulation (EC) No 1228/2003 of the European Parliament and of the Council of 26 June 2003, on conditions for access to the network for cross-border exchanges in electricity". *Official Journal of the European Union* 2003 L 176: 1-10.

Gómez-Acebo & Pombo Abogados, S.L. and Charles Russell LLP (2005). *Unbundling of Electricity and Gas Transmission and Distribution System Operators Final Report*. Report to the European Commission. Available at: http://ec.europa.eu/energy/electricity/publications/doc/2006_03_08_finalcommon_report.pdf.

Hakvoort, R.A. and De Jong, H.M. (2007). "Pushing European Power Transmission: Private Investment in Priority". *European Review of Energy Markets* 2 (1): 109-139.

Hogan, W. (2002) "Financial Transmission Right Incentives: Applications Beyond Hedging," Presentation to HEPG Twenty-Eight Plenary Sessions, May 31, http://www.ksg.harvard.edu/people/whogan.

Hogan, W.W. (1992). "Contract networks for electric power transmission", *Journal of Regulatory Economics* 4 (3): 211-242.

Hunt, S. (2002). *Making competition work in electricity*. New York: John Wiley & Sons, Inc.

Joskow, P. and Tirole, J. (2002). "Transmission Investment: Alternative Institutional Frameworks". Mimeo. Available at: http://idei.fr/doc/conf/wme/tirole.pdf.

Joskow, P. and Tirole, J. (2004). "Merchant Transmission Investment". IDEI Working Papers 263, Institut d'Économie Industrielle (IDEI), Toulouse.

Kirschen, D.S. and Strbac, G. (2004). "Fundamentals of power system economic"s. John Wiley and Sons.

Klemperer P. (1999). "Auction theory: A Guide to the Literature", *Journal of Economic Surveys* 13, 227-286.

Knops, H.P.A., De Vries, L.J. and Hakvoort, R.A. (2001). Congestion management in the European electricity system: an evaluation of the alternatives. *Journal of Network Industries* 2 (3-4): 311-351.

Laffont, Jean-Jacques, and Tirole, J. (1986). "Using Cost Observation to Regulate Firms", *The Journal of Political Economy*, Vol. 94, No. 3, Part 1. (Jun., 1986), pp. 614-641.

Léautier, T.-O. (2000) "Regulation of an Electric Power Transmission Company," *The Energy Journal*, 21: 61-92.

Léautier, T.-O. (2001) "Transmission Constraints and Imperfect Markets for Power." *Journal of Regulatory Economics* 19 (no. 1, January): 27-54.

Léautier, T.-O. and Thelen, V. (2007). *Optimal expansion of the power transmission grid: why not?* Paper presented at the IDEI/Bruegel Conference on Regulation, Competition and Investment in Network Industries. Brussels. Available at: www.bruegel.org/Public/SimplePage.php?ID=5610#networks.

Newbery, D. M. (2003). "Network capacity auctions: promise and problems". *Utilities Policy* 11: 27-32.

Olmos, L. and Pérez-Arriaga, I. J. (2007). "Computation of Transmission Tariffs Based on the Cost Driver Behind Transmission Expansion". In: *Proceedings, 30th Conference of the International Association for Energy Economics.* Wellington (New Zealand).

Pérez-Arriaga, I. J., Perán Montero, F. and Rubio Odériz, F. J. (2002). "Benchmark of Electricity Transmission Tariffs". Report prepared for the Directorate-General for Energy and Transport of the. European Commission. Madrid: Universidad Pontificia Comillas.

Pollitt, M.G. (2008). "The Future of Electricity (and Gas) Regulation". University of Cambridge Electricity Policy Research Group Working Paper 0811, http://www.electricitypolicy.org.uk/pubs/wp/eprg0811.pdf

Rosellón, J. (2003). "Different approaches towards electricity transmission expansion". *Review of network economics* 2 (3): 238-269.

Rosellón, J. and Weigt, H. (2007). "A Combined Merchant-Regulatory Mechanism for Electricity Transmission Expansion in Europe". Paper presented at the IDEI/Bruegel Conference on Regulation, Competition and Investment in Network Industries. Brussels.

Stigler, G. and C. Friedland (1962). "What can regulators regulate? The case of electricity", *Journal of Law and Economics* 5, pp. 1-16.

Turvey, R. (2000). "Infrastructure access pricing and lumpy investments". *Utilities Policy* 9: 207-218.

UCTE (2008). Sum of exchanges of the UCTE 1975 – 2006, UCTE database as of 15 April 2007. Available at: www.ucte.org. Underlying data were provided upon request.

Vogelsang, I. (2001) "Price Regulation for Independent Transmission Companies," *Journal of Regulatory Economics*, 20: 141-165.

Vogelsang, I. (2002). "Incentive Regulation and Competition in Public Utility Markets: A 20 Year Perspective", *Journal of Regulatory Economics* 22 (1), pp. 5-27.

Vogelsang, I. (2005). "Electricity Transmission Pricing and Performance-Based Regulation". CESIFO Working Paper No. 1474. Available from: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=741085.

Yarrow, G. (2003). "Capacity auctions in the UK energy sector", *Utilities Policy* 11, pp. 9-20.