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Vertical Economies and the Costs of Separating Electricity Supply – A Review of Theoretical and Empirical Literature

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Abstract

Motivated by the European movement towards a separation of electricity networks from the competitive functions generation and supply this paper reviews theoretical and empirical literature on vertical synergies in electricity supply. In the analysis a clear distinction is made between four different unbundling options leading to different forms and magnitudes of synergy losses. Apart from *coordination economies* a main source of scope economies seems to result from a *market risk effect* if generation and retail are separated. Accordingly, the European policy of network unbundling (either transmission or distribution) results in synergy losses between 2 and 5 percent due to coordination losses, while an unbundling option that includes a separation between retail and generation, as observed in some U.S. states, may lead to a permanent cost increase of 15 percent and more due to a significant risk increase.

Keywords: ownership unbundling, vertical integration, economies of scope

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1 Introduction

Traditionally, the electricity supply industry (ESI) was dominated by vertically integrated electric utilities, due to large sunk costs in generation and networks and coordination requirements between the supply stages. Both transmission and distribution networks have remained monopolistic up to date, since it would be economically infeasible to duplicate them. For generation, however, the situation has changed. Technological developments lowered the minimum efficient scale of generators (see Christensen and Greene, 1976). In particular, combined cycle gas turbine (CCGT) technology allowed for a larger number of small-scale power producers. In combination with an increase in market demand over time, this supported the idea of competition in generation (see e.g. Joskow, 1998). Furthermore, developments in information technology have improved possibilities to coordinate generation and transmission between separate firms (see e.g. IEA, 1999). Nevertheless, there appears to be a trade-off between enhancing competition and exhausting economies of vertical integration. Accordingly, vertical relations have remained to be in the focus of the liberalisation discussion.

This paper reviews theoretical and empirical literature on sources and magnitudes of vertical synergies in the electricity sector. Section two shortly analyses the structural characteristics and major steps of liberalisation in Europe and the U.S., as these markets reveal fundamentally different philosophies and developments in restructuring and unbundling. Section three analyses the sources of vertical synergies according to theoretical literature. Four basic options of unbundling will be defined that closely reflect implemented and discussed unbundling options in practice. The analysis shows that the precise location of the vertical split along the supply chain determines the resulting synergy losses. Section four reviews empirical studies on scope economies, and relates the numerical results to the four reference scenarios. Section 5 concludes.

2 Liberalisation

2.1 Liberalisation and vertical relations in the European Union

The starting point for liberalisation on the European level was the First Electricity Directive of 1996 (see EC, 1996).[1] This first step of liberalisation aimed to allow independent generators to gain access to the grids required for electricity supply on a fair and non-discriminatory basis. After a period of transition, final customers should be allowed to choose their electricity supplier, so that the protected supply area of the incumbent firms was given up in favour of retail competition. After a promising start of the liberalisation process with market entries of independent suppliers and decreasing retail prices, the development slowed down, and prices started to increase again. The traditionally high market shares of the incumbent supply companies did not decline considerably, and it was questioned whether the playing field for all competitors could be levelled as long as network owners and operators still have own supply interests. Accordingly, the European Commission's Second Electricity Directive in 2003 contained a package of unbundling requirements, referred to as *legal unbundling*. In detail, this package includes the following unbundling rules (see EC, 2003):

- *Legal Separation*: the utility's network section had to be transformed into a separate legal entity with separate bookkeeping (*accounting separation*). This requirement is met, for instance, if the network business is organised as an affiliate within a holding structure.
- *Management Separation*: the management and staff of the network business were no longer allowed to be active or to have financial interests in the competitive businesses.
- *Operational Separation*: this unbundling requirement aimed to increase the independence of the network part with respect to operational decisions. This also included an *informational separation* between network and supply business. By implementing Chinese Walls, it should be prevented that confidential information about competitors, collected for the purpose of network operation, is handed over to the affiliated supply business that could misuse this information to gain a relative advantage.

In 2007, the European Commission criticised the weak development of competition in Europe in its *Sector Inquiry* on the energy markets (see EC, 2007b). Since then, two aspects are in the

[1] England & Wales and Norway were the first countries in Europe that started the restructuring process as early as 1990/91. For an overview of the development of EU Policy in the energy sector, see e.g. Kreis (2004). Joskow (2003) gives a description of the transition processes in the U.S.

focus of discussion, and for both of them vertical integration has been identified as the main source of problems.

First, the Commission argues that even under legal unbundling the incumbents – that mostly have remained vertically integrated – have both incentives and the ability to hinder market entry and competition in favour of their own commercial supply interests. The key point is the dependence of supply on the monopolistic networks that may give their owners the possibility of vertical foreclosure (see e.g. Beard et al., 2001). This could take the form of *price discrimination*, if incumbents are able to charge higher network prices for competitors than for its own affiliates to squeeze their profit margins and render market entry unattractive. Even though a direct discrimination in network access charges is prohibited, vertically integrated firms may cross-subsidise their competitive business by shifting costs into their network part. Given imperfect and cost-based regulation, these costs are passed through to all network users. This leads to a distortion of competition, since for incumbents the increased network charges are a pure cost shift. For independent network users, however, these reflect real costs, leaving them with a relative cost disadvantage (see Joskow, 1996). This practice is known in the literature as *raising rivals' costs*.[2] Furthermore, incumbents may use *non-price discrimination* like delays in network connection or administrative burdens to consumer switching to frustrate the level playing field for competitors.[3]

In a second line of arguments, the Commission is concerned about insufficient incentives for network investments, especially across borders. Electricity markets have largely remained national in scope, as network congestions at most borders indicate. The European Commission argues that incumbents may lack sufficient incentives to invest in cross-border network connections, as a relief of congestion to lower-cost countries intensifies domestic competition and runs counter to their own profit interests.[4]

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[2] A general discussion of discrimination and sabotage is provided by Perry (1978); Krattenmaker and Salop (1986); Beard et al. (2001). For the electricity industry, Brunekreeft (2003) gives an excellent overview.

[3] However, at least for the electricity sector, these problems seem well addressed by regulatory rules after some years of practical experience and may nowadays play a minor role in the discussion (see Brunekreeft, 2008a).

[4] Although this argument holds in principle, it should be noted that cross-border connections involve two network firms, one of which may well have an interest in a capacity increase if supply interests exits; namely the one in the low-cost country that heads for export opportunities in the neighbouring country (see Brunekreeft, 2008a).

As a consequence of these arguments, the Commission regards the current state of legal unbundling as insufficient and considers that "transmission ownership unbundling is the most effective tool to promote investments in infrastructure in a non-discriminatory way, fair access to the grid for new entrants and transparency in the market" (see EC, 2007b).

In September 2007, the European Commission presented an *Impact Assessment* that aimed to measure the expected effects of unbundling on the electricity markets (see EC, 2007a). This study was heavily criticised for methodological reasons by many observers, since it neglects the cost aspects of unbundling, while the assessment of its benefits is based on simple comparisons of market shares and investments between countries with legal and ownership unbundling. Nevertheless, it sufficed the Commission to support and accompany its proposal for a Third Legislative Package that should leave the EU member countries the choice between *ownership unbundling*, a *deep ISO (independent system operator)*, and an *ITO (independent transmission operator)*. Under the ISO option, the ownership structure remains unchanged, while operating and investment decisions are handed over to a company without commercial supply interests. This industry structure is established in many U.S. markets.[5] The ITO solution was added as a third alternative after strong opposition, in particular by France and Germany. This option can be seen as a stricter form of legal unbundling with stronger restrictions with regard to cross-ownership between the network and competitive departments of the incumbents.[6] The Third Legislative Package was adopted in 2009 (see EC, 2009).

All European unbundling options refer to a separation of transmission from the competitive stages generation and retail. Although retail competition is implemented in Europe, the discussion did not yet expand to ownership unbundling of distribution from generation and retail; up to date, only legal unbundling applies. However, given that the Netherlands have recently started to implement distribution unbundling, the extension of the debate to the European distribution level may only be a question of time.

It should be noted that the new unbundling legislative applies to the gas market as well, although this paper will focus on electricity only.[7]

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[5] It should be noted that both ownership unbundling and the deep ISO involve severe constitutional problems if electricity companies are already privatised (see Pielow and Ehlers (2008) and Ehlers (2010)).

[6] The remainder of this paper will focus on strict ownership unbundling. For an analysis of the ISO option see Balmert et al. (2008), and Balmert and Brunekreeft (2009). A discussion of the ITO solution, also known as *Effective and Efficient Unbundling (EEU*), is provided by Säcker (2008).

[7] For a discussion of unbundling and its impacts on the gas industry, see Growitsch et al. (2008).

2.2 Liberalisation and vertical relations in the United States

Many studies on vertical scope economies in electricity supply are based on the U.S. industry. Accordingly, it is advisable to review the main similarities and differences between the U.S. and Europe in terms of the industry structure.[8] Like in Europe, electric utilities in the U.S. have been characterised by a high degree of vertical integration. Prior to liberalisation, regulated retail rates were "bundled" prices for generation, transmission, and distribution.

Compared to Europe, however, the electricity supply industry in the U.S. has been strongly fragmented. Historically, the industry developed from small, local systems that were weakly integrated. In 2000, there were 140 control areas within the three synchronized AC systems. Since most utilities fell under regulation of the states' Public Utility Commissions (PUCs), a consistent and integrated regulatory regime was missing. Hence, incentives for transmission investments to enlarge and integrate control areas were rather low. Interconnections between the transmission networks were mainly constructed for reliability reasons based on cooperative agreements between utilities. Open access to transmission networks was only granted "voluntarily" to allow municipal distributors to gain access to generators outside of the control area they were embedded in (see Joskow, 2005). The weak integration of the U.S. transmission areas may explain why the discussion on deregulation and unbundling has rather been motivated by the aim to strengthen investment incentives to increase supply security than to lower supply costs by granting access to remote generators.

Although open access to transmission networks was already implemented with the *Public Utility Regulatory Policy Act* (PURPA) in 1978, many complaints about discriminatory behaviour remained, for instance due to refusals of transmission capacity by integrated firms in favour of own supply requirements.

This led to the implementation of *Order 888* in 1996 that required a *functional separation* of the transmission stage from generation to prevent discriminatory behaviour of integrated utilities. In detail it involved the separation of administrative units, transparent pricing, and rules of conduct that should reduce the scope for anticompetitive behaviour (see Kwoka et al., 2007). Although this unbundling measure is comparable to the management and operational unbundling that were implemented in Europe within the Second Electricity Directive in 2003,

[8] See Joskow (2005) for a detailed description of the institutional and regulatory developments in the United States.

it seems far less strict, since it neither required the separation of operational decisions nor the installation of firewalls to exclude the exchange of confidential information on competitors.

Possibilities of stricter unbundling measures were limited for at least two reasons. First, most utilities were already under private ownership so that a divestiture policy would have raised serious constitutional problems. Second, the majority of utilities fell under state regulation, while FERC was only responsible for state-crossing companies. In particular, FERC did not have sufficient authority to enforce restructuring measures against the will of the U.S. states. Different attitudes of the states regarding the adequate choice of deregulation measures made it difficult to establish a single coherent regulatory regime (see Joskow, 2005). Some states, for instance, have been reluctant to establish retail competition. In these cases, distributors remain as franchised suppliers in their geographic areas.[9] As a result of this regulatory fragmentation, a general unbundling debate like in the European Union did not emerge in the United States.

The alternative solution was to leave the ownership structure unchanged and separate *ownership* and *operation* of transmission systems. With *Order 2000*, FERC initiated the creation of ISOs that independently operated electricity transmission networks, integrated over large geographic areas. These companies, referred to as RTOs (*regional transmission organizations)* in the official terminology, fall under FERC regulation. According to Joskow (2005) the establishment of these RTOs seemed to be the most ambitious goal that could be achieved by FERC to expand and unify regulatory conditions in the U.S. electricity industry.

Further reaching unbundling policies partly took place on the state level. A couple of U.S. states provided financial incentives for vertically integrated utilities to divest generation assets. These policy measures were motivated by concerns about market power and a lack of liquidity in the wholesale markets. By splitting the generation assets and selling them to a larger number of independent companies, it was intended to create "more agents that would demand wholesale power from independent, competing generation utilities" (see Kwoka et al., 2007, p. 5).

These examples show that the discussion about vertical synergies, investment incentives, and market power has been present in the U.S. as well. However, the diversity of market

[9] As will be discussed below, it makes an important difference for the measurement and interpretation of scope economies, whether the term distribution covers only the *network* function or includes *retail* activities. A lack of retail competition may significantly increase the market risk of vertical splintering of the supply stages.

structures complicates the analysis of scope economies and limits the possibilities to transfer the results of U.S.-based studies to Europe. This refers particularly to the impact of outsourcing operating activities to RTOs on the amount of scope economies that vertically integrated companies are able to realise. Furthermore, as Joskow and Schmalensee (1983) emphasise, electric utilities in the U.S. are characterised by a large number of horizontal and vertical arrangements, ranging from contracts and cooperatives over joint ventures to full integration. Accordingly, it is not possible to draw a precise line between integrated and separate firms; there is rather a continuum of in-betweens.

3 Economies of scope

3.1 Source of vertical synergies

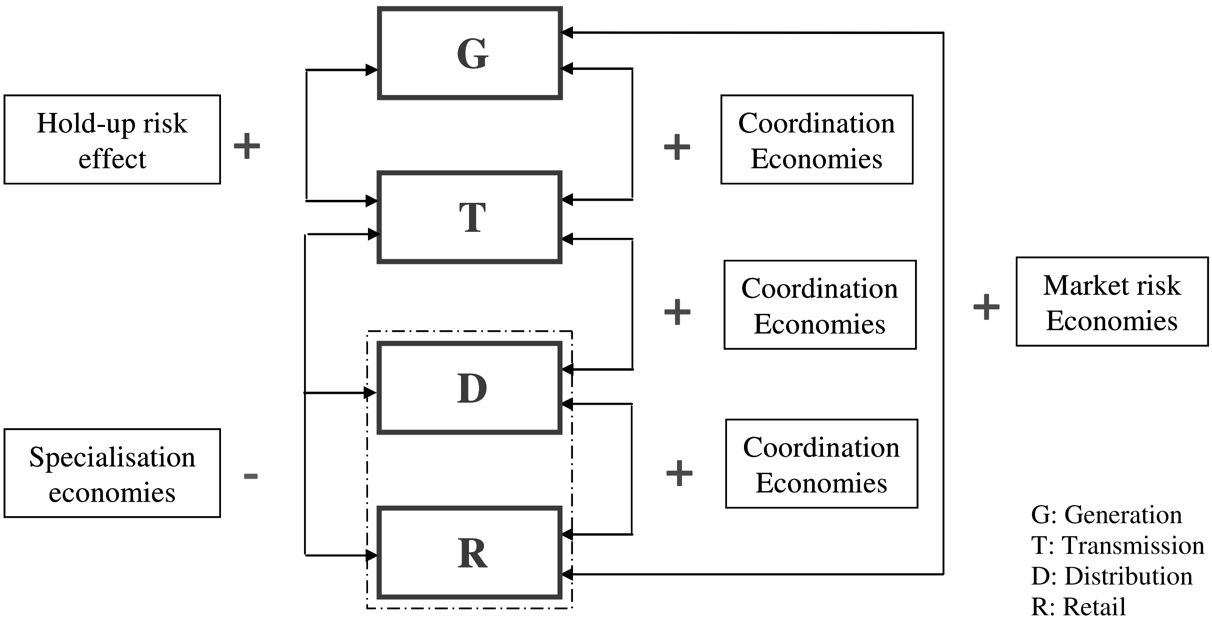
The previous section reviewed the restructuring process in Europe and the U.S. and outlined the main arguments for unbundling. However, there is another side of the story. There are important technological aspects of the ESI that favour vertical integration between the supply stages. The arguments against ownership unbundling arise from the existence of vertical scope economies.

Figure 1 illustrates the vertical stages of electricity supply and shows between which of them scope economies or diseconomies are likely to occur.

Although being interrelated, three main groups of synergies may be distinguished, namely coordination economies, market risk economies (including hold-up risks), and specialisation economies.

Coordination economies result from the technological interdependency of electricity supply. Due to the fact that electricity supply and demand must be balanced in real-time to maintain a constant voltage and frequency in the networks, an instant coordination between all supply stages is of essential importance to keep the system working. Since the strongest interaction occurs between generation and transmission, one would expect the most significant synergies between these stages.

Figure 1. Supply stages and synergy effects



Both information and incentive problems may occur under vertical separation (see Brunekreeft and Meyer, 2009). The necessary exchange of *information* may be organised more efficiently by hierarchical coordination within an integrated utility than between separate companies (see Joskow and Schmalensee, 1983). The restructuring process may lead to a duplication of tasks and, accordingly, increase both operational and capital costs. Furthermore, information flows are more complicated to handle as more market players are involved, and may become available at too short notice for the network operator to efficiently organise flow paths for electricity, in particular in cases of shutdowns of generators for maintenance reasons. As long as only the technical organisation of *information flows* is concerned, the problem is less severe. In these cases, coordination in the form of costless signals by the involved market players may suffice to achieve an efficient outcome. This simple form of coordination is known as “cheap talk” in the literature (see Brunekreeft and Friedrichsen, 2010). However, the central problem arises from diverging *incentives*. This is particularly the case for investment coordination. Competitive firms may for instance hold back information on generation investments plans for strategic reasons or may at least not be truth telling with respect to relevant details needed for efficient long-term network capacity planning. In such cases “cheap talk” may not suffice as an efficient coordination mechanism.[10] Since operation and construction costs of the network clearly depend on the location of generators feeding into the network, a generator being placed at the wrong location or the wrong point in time affects the whole system flows of electricity in a costly way. In an unbundled world, power producers typically do not care about the effects on network costs, as long as these costs are paid by all network users. This is a typical network externality. As a consequence, generators are too often simply connected "one after another", leaving no room for a joint transmission optimisation to minimise overall system costs (see Baldick and Kahn, 1993). Only a vertically integrated company takes overall costs into account and therefore internalises those network externalities by a joint decision making over all supply stages (see Nemoto and Goto, 2004). Furthermore, there is a substitutive relation between building a nearby generator and extending or reinforcing transmission lines to connect to a more distant generator. Vertical integration ensures a coherent investment strategy that is needed to find the most efficient system configuration (see Chao et al., 2005). The degree of synergy losses depends on how efficiently a decentralised market mechanism can replace firm internal coordination.[11] For investment coordination, a market-based solution is to implement locational pricing to send efficient long-term investment signals to generators (see Brunekreeft et al., 2005).

Market risk economies, as a second group of vertical synergies, relate to *transaction cost economics* as developed by Oliver Williamson.[12] Transaction costs can be interpreted as costs of using the market instead of firm-internal command and control mechanisms of an integrated company. The argument is similar to that of coordination economies described above but more directly addresses the costs of vertical arrangements (e.g. contracts or spot market transactions) as well as the resulting incentive problems. A major characteristic of the electricity supply industry is the complexity of its vertical relations and the dependencies on other market players' investment and operational decisions, and – not the least – on the regulatory framework. Both generation and network assets are highly specific and irreversible investments with a long construction and operating duration. The *sunk costs* character of these investments fully exposes an investor to this risk of uncertainty. While this risk is fairly

[10] See Brunekreeft and Friedrichsen (2010) for an analysis of a *cheap talk model* of investment coordination.

[11] See Joskow and Schmalensee (1983) for a discussion of how a decentralised system should optimally behave. From a more technical point of view, Künneke and Fens (2006) and Künneke (2008) investigate the institutional challenges for the electricity sector resulting from deregulation and unbundling.

[12] For the theory of transaction costs see Williamson (1971, 1975, and 1979) and Hart (1995).

manageable under the integrated optimisation of investment decisions within a single utility, separate market players with opposing interests face a small-numbers bargaining problem. Accordingly, vertical arrangements in terms of long-term contracts are necessary to alleviate the investment risk. However, given the complexity of the industry in face of demand fluctuations, network and generator availability, these contracts inevitably remain incomplete. This gives rise to *opportunistic behaviour* of the market players which can be described as "the tendency for people to violate the spirit of agreements in pursuit of self-interest" (Joskow and Schmalensee, 1983, p.27). Anticipating this *hold-up risk,* independent investors may hesitate to invest, as they cannot be sure to recover their investment costs adequately.[13] On the generation level, this may be a serious problem for ancillary services. Peak load generators providing spinning reserves, for instance, may only generate electricity in a small fraction of the day but are important for system stability. For those generators to 'jump in' in cases of emergency or balancing needs, it is particularly important that these services are adequately (and ex-ante credibly) valued. Vertical integration reduces the risk for a generator to be held-up by the transmission system operator as soon as the investment is made. However, the hold-up risk similarly applies to networks. The profitability of building or upgrading transmission lines requires reliable information on generation investment plans. If the realisation of those plans fails (or a generator's capacity exceeds or falls short of the expected capacity), a transmission company may be left with *stranded costs* that cannot be recovered by ordinary network charges.

Market risk economies also play an important role between the retail and generation stage. Lacking the possibility of vertical integration, retailers have to purchase their supply needs from independent generators. If relying on wholesale spot markets, suppliers face the risk of price volatility. Even in the presence of financial hedging instruments in the market, the transaction costs may be significant compared to integrated retailers, who are better capable of predicting their own generation costs. In particular, market power aspects become very important under vertical unbundling. As both Mansur (2007) and Bushnell et al. (2008) argue, integrated firms have reduced incentives to set higher market prices, as long as these were merely transfer prices that shifted profits between their integrated generation and retail stages. By contrast, a separate generator does indeed have incentives to exhaust market power in order to increase its profits relative to retailers.

[13] For an analysis of asset specificity and hold-up problems see the seminal paper of Klein et al. (1978).

If vertical integration is prohibited, there are two alternatives for retailers to alleviate market risks. *Market transactions* as provided by forward markets or financial option markets may help to hedge against price volatility. There is indeed theoretical evidence that these market instruments can increase market efficiency (see Allaz and Vila, 1993; Willems, 2005). However, such hedging instruments involve transaction costs and do not cover all risk aspects, in particular in markets that lack sufficient liquidity. As an alternative, retailer can go directly for (*long-term) contracts* with generators. However, demand fluctuations and opposing interests between market players generally hinder a complete elimination of market risks. As Chao et al. (2005) note, both generators and suppliers have a common interest to fix *prices*, but differ with respect to fixing *volumes*. While generators aim for a constant utilisation of their capacity, retailers prefer contracts with flexible energy volumes due to load fluctuations in order not to rely on spot markets. Accordingly, at least one – if not both – contract parties are left with some remaining market risk. The complexity and dynamics of the ESI make it impossible to foresee all possible future events and environmental conditions. Therefore, contracts necessarily remain incomplete, or it would involve exorbitant transaction costs to negotiate and control the fulfilment of these contracts (see e.g. Landon, 1983). Nevertheless, lacking the possibility to vertically integrate, there is no doubt about the importance of alternative vertical arrangements to alleviate market risks.

However, there are two sides of the coin. In its Sector Inquiry, the European Commission argues in the opposite direction. Long-term contracts are criticised for reducing liquidity in spot markets and therefore causing (instead of reducing the risk of) price volatility and market power issues (see EC, 2007b). Indeed, the only difference between a long-term contract over 20 to 40 years (corresponding to the lifetime of a generator) and vertical integration is that the former lacks "direct investment and operational management and control" (Chao et al., 2005, p12). In both cases, wholesale markets are by-passed and market entry of new competitors may be hampered.

As a third group of scope effects, it is often claimed that there may also be negative synergies due to a *specialisation advantage.* The underlying argument is that a separation of supply stages may lead to efficiency gains due to a better management focus on specific tasks compared to a multi-product company. The European Commission uses this argument and claims that "experiences of full ownership unbundling suggest that it significantly changes the behaviour of the network undertaking: fully unbundled Transmission System Operators (TSOs) and Distribution System Operators (DSOs) will no longer have the incentive to favour affiliated companies – since there are none –, but can focus on optimising the use of the networks" (EC, 2007b, p.160f). The specialisation argument contains two aspects. First, there appear to be significant differences in network and supply operation. Different requirements in personnel skills and organisational structures may thus give rise to specialisation advantages if a company focuses on one group of activities. This argument has also been applied in the discussion on distribution unbundling in the Netherlands (see CPB, 2005). Indeed, it seems quite unlikely that a company after a vertical split would continue to behave as if nothing happened. Instead it would rather seek to compensate for the loss of vertical synergies by organisational restructuring. Empirically, both Ida and Kuwahara (2004) and Meyer (2010) confirm the existence of a specialisation effect in the longer run.

3.2 Reference scenarios of unbundling

Vertical economies of scope are defined as the percentage cost increase of separate production compared to vertical integration (see Baumol et al., 1982). Hence, they provide a measure for the costs of vertical unbundling. Obviously, these costs depend on where exactly the line of separation is drawn along the vertical supply chain. As the liberalisation discussion above showed, there is a large diversity of deregulation policies that have been pursued by different countries and states including the question whether or which kind of unbundling measures should be taken to ensure the most cost efficient and reliable power system.

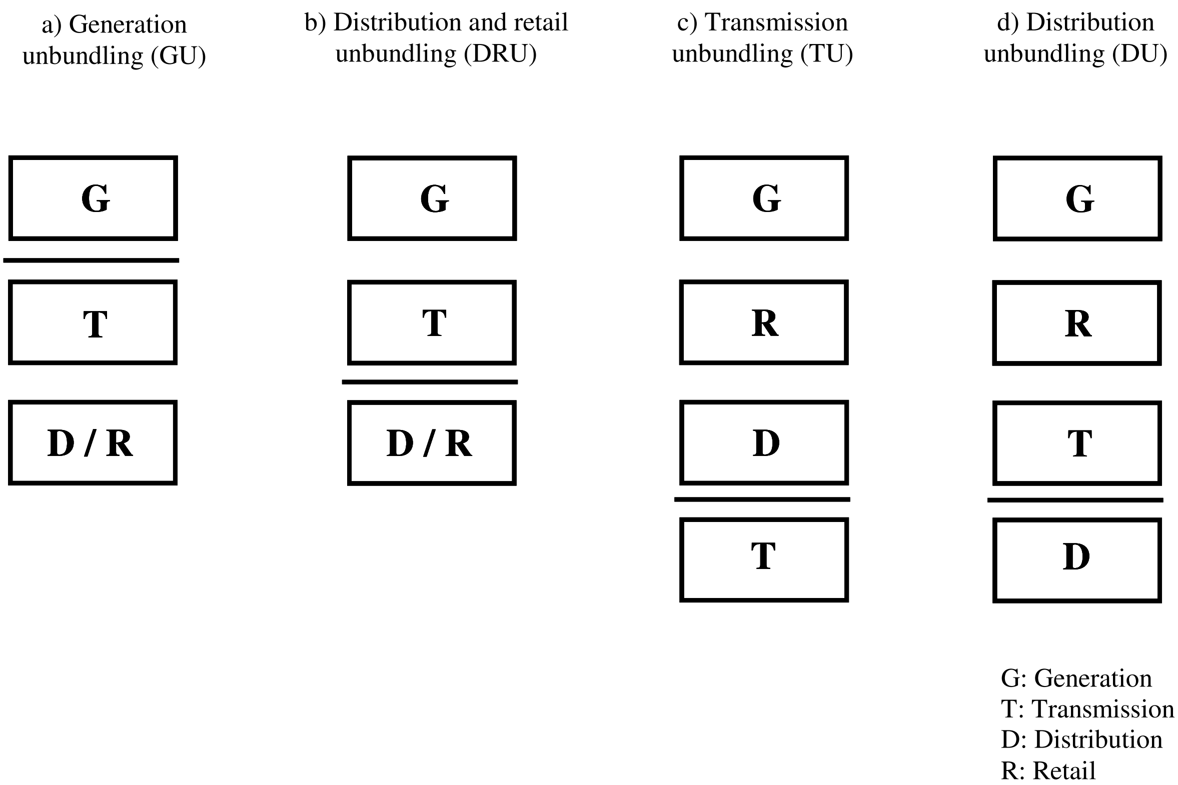
There appear to be four main unbundling scenarios that most closely correspond to unbundling policies that have been or are going to be implemented in electricity markets around the world. Figure 2 illustrates these unbundling options and shows between which of the supply stages the line of separation is drawn.

The first two scenarios correspond to electricity markets that have not introduced retail competition, as is the case for several U.S. states. In other words, the retail function is assumed to remain in the hand of the distributor that is serving its protected franchise area. Accordingly, these unbundling cases include a separation of retail activities from generation. The theoretical implication of this separation has been discussed above. We will fall back on this issue below when discussing the empirical results.

Due to the fact that available data do not allow distinguishing between distribution and retail output, these two stages are combined in most empirical studies. As a consequence, the majority of studies focus on the first two scenarios in figure 2, namely *generation unbundling*

(GU) and *distribution and retail unbundling* (DRU). In case of GU, transmission and distribution are often combined to one "network" stage, although containing retail as well.

Figure 2: Reference scenarios of unbundling



The latter two unbundling options more closely reflect the European discussion focusing on the network businesses excluding retail. The most topical debate is on *transmission unbundling (TU)* pursued by the European Commission. For the case for *distribution unbundling (DU)* two examples can be found in the Netherlands and New Zealand.[14]

[14] It should be noted that both the Netherlands and New Zealand have implemented ownership unbundling on the transmission level as well. Hence, it would be more precise to add another line of separation in figure 2 between retail and transmission. We simplified the graph in order to emphasize that the main focus of the DU scenario is on the single effect of separating distribution.

3.3 Concepts of vertical synergies

There is a broad range of empirical literature on vertical synergies in electricity supply. However, studies differ with respect to the underlying concepts to measure or indicate scope economies. Before turning to empirical results, a short summary of related concepts will be provided.

The most direct concept is that of *economies of scope*. The degree of economies of scope is the relative cost increase if two or more products are produced by separate firms compared to integrated production. Following the general definition of Baumol et al. (1982), economies of scope relative to a product T can be written as

$$SC_T = \frac{\left[C(Y_T) + C(Y_{-T}) - C(Y)\right]}{C(Y)}, \tag{1}$$

where C(Y) gives the costs of integrated production of the complete output vector Y, while $C(Y_T)$ and $C(Y_{-T})$ are the stand alone costs of separately producing product T and all products except for T (i.e. Y_{-T}), respectively. Accordingly, scope economies exist, if the costs of separate production by specialised firms $[C(Y_T)+C(Y_{-T})]$ are higher than the costs of integrated production C(Y). To this end, vertical scope economies measure the costs of separating the production along the vertical supply chain.

Another concept is that of *cost complementarities* between supply stages. If these exist, the marginal costs of serving one supply stage decrease, as the outputs at all other supply stages increase. Cost complementarities are a sufficient condition for the existence of economies of scope, but they are not necessary (see Baumol et al., 1982). Both concepts are empirically implemented by estimating a multi-stage cost function, while only the latter one provides a numerical estimate of synergies.

A third group of studies is based on a single-stage cost function and investigates *cost separability* from the other stages. This is a mathematical concept that tests whether a multi-stage cost function can be divided into separate *independent* cost functions. If cost separability is rejected, the stages cannot be analysed independently from one another due to technological externalities. A lack of separability indicates – but does not proof – the existence of vertical economies of scope.

Finally, *subadditivity* is a more general concept of scope economies. Subadditivity is given if *any* distribution of outputs among separate companies leads to higher costs compared to integrated production. Accordingly, economies of scope are a special case of subadditivity where orthogonal output vectors, i.e. a full specialisation of companies, is assumed (see Baumol et al., 1982). Subadditivity is a much stricter concept than scope economies, since it renders the whole industry a *natural monopoly*. Economies of scope, however, may still exist even in the absence of subadditivity.[15]

4 Empirical studies

Before turning to an analysis of the unbundling scenarios defined above, we shortly review some empirical studies on related concepts of scope economies.

Following a proposal by Evans and Heckman (1984), Gilsdorf (1995) uses a local test for *subadditivity* over the observed range of outputs, based on a multi-stage cost function.[16] He does not find evidence for subadditivity that would render the electricity supply industry a natural monopoly. Also Fraquelli et al. (2005) do not find evidence for a subadditive cost structure of the Italian electricity supply industry. However, as mentioned above, scope economies may exist even in the absence of subadditivity. In an earlier study, Gilsdorf (1994) tests for *cost complementarities* between the electricity supply stages, using a multiproduct translog cost function.[17] His results show that, for the average firm, marginal costs tend to increase slightly with increasing output at related stages, providing evidence against cost complementarity. In contrast, a study by Piacenza and Beccio (2004) does indeed find evidence for cost complementarity for the Italian electricity industry. Also Ida and Kuwahara (2004) confirm cost complementarities for Japan's electric power industry. According to their panel estimation, values tend to decrease over time. This indicates some kind of adjustment process after specialisation that reduces the quantitative importance of scope effects over time.

Roberts (1986) tests and rejects *separability* of the distribution stage from generation and transmission, indicating technological externalities. Thompson (1997) additionally tests for separability of generation from the network parts. Both kinds of separability are strongly rejected. Hayashi et al. (1997) reject separability of the transmission and distribution cost

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[15] For a more formal and more general discussion on these cost concepts see Baumol et al. (1982).

[16] Note that a global test for subadditivity is difficult, as one would have to test for all possible combinations of output quantities to decide whether joint production is more or less cost efficient than separate production.

[17] As a consequence of this specification, a direct test of scope economies is not possible, since a translog function cannot handle zero values necessary for a comparison of orthogonal production vectors.

function from the generation stage. They find that *electricity prices* have an influence on the design of networks, thereby affecting its costs. Nemoto and Goto (2004) find negative externalities of *generation capital* on both network stages that would only be internalised if investment decisions are optimised from an overall perspective within an integrated utility. However, the explanatory power of their approach is limited to verifying the existence of network externalities. The conclusion of Nemoto and Goto (2004) that separating investment decisions leads to an overcapitalisation at the generation stage only holds if other aspects – like market risk effects of unbundling – are left aside, as these would rather argue in favour of a possible under- than overinvestment in generation assets.

Lee (1995) tests for the opposite causality of externalities, and finds that electricity costs depend on *network capital*. This result indicates the effect of network design and investments on generation costs, for instance by influencing the possibilities of capacity utilisation.

To summarise, all studies confirm the interaction between electricity supply stages, showing that these stages cannot be treated separately. Accordingly, centralised decision-making may be more efficient in finding "an optimal substitution between local generation and transmission to access distant generation" (Chao et al., 2005).

Analysing the impact of unbundling on investments, Nardi (2009) does not find a significant effect apart from enlargements at the peripheries. However, his study reveals a negative effect on quality of supply. Reversing this argument, the same level of supply quality would obviously require *more* investments. In this sense, Nardi's finding does indeed confirm a negative effect of vertical separation on network costs and additionally raises questions, whether an adequate level of investments is provided if the vertical supply chain is separated. These concerns are confirmed by Arocena (2008) who finds a negative effect of unbundling on supply security.

Although all of these studies indicate the existence of scope economies, they do not provide a direct measure for the loss of synergies due to unbundling. In the following, direct cost estimations will be presented and categorised according to the four unbundling scenarios defined above.

a) Generation unbundling (GU)

Generation unbundling (GU) shall denote a separation of generation from all remaining supply stages. Since no distinction is made between retail and distribution, this unbundling scenario corresponds to electricity markets that did not introduce retail competition. As discussed above, an important implication is that the generation stage is fully separated from retail leading to a *market risk effect* for distributors, as these have to purchase their supply requirements on the wholesale markets.

The following papers estimate a multi-stage quadratic cost function for U.S. electric utilities and combine transmission and distribution (including retail) to a single supply stage. Kaserman and Mayo (1991) show a cost increase of almost 12 percent due to separate production for the average company with a generation output (G) of 9 million MWh and transmission, distribution and retail output (T=D=R) of 7.3 million MWh. The values appear to increase strongly with the size of firms and are most significant for almost completely integrated companies, where most of the distribution output is self-generated. Kwoka (2002) uses a similar approach and finds a cost increase of almost 37 percent for the median firm (G=8.2 million MWh, and T=D=R=9.6 million MWh).[18] When scaling the outputs to a fully integrated company with 16 million MWh at all output stages, both Kaserman and Mayo (1991) and Kwoka estimate scope economies as high as 72 and 75 percent. However, these values seem way too high to provide a plausible measure of the costs of unbundling. At least the strong increases of synergy effects cast serious doubt on the underlying model specifications. A more recent U.S. study of Arocena et al. (2009) estimates lower vertical synergies ranging from 4.3 to 9.7 percent.

Meyer (2010) further distinguishes transmission and distribution output to calculate scope economies for three different forms of unbundling. Here, the GU scenario shows lower values compared to Kaserman and Mayo (1991) and Kwoka (2002): a fully integrated company with a symmetric output of 16 million MWh reveals synergies of 17 percent.

Fetz (2008) analyses vertical synergies for the Suisse electricity industry. Depending on the estimation model used, the author calculates integration economies between 10 and 26 percent for the average company (G=0.2 million MWh, and T=D=R=0.6 million MWh). Similar to the studies mentioned above, scope values increase with a higher degree of vertical integration. Within his range of outputs, however, synergies first decrease with company size, while they start to increase again for larger utilities.

[18] Precisely, Kwoka (2002) measures the cost *savings* of vertical integration. His average value of 27 percent corresponds to a cost *increase* of 37 percent when moving from integrated to a separate production.

A detailed analysis of the scope effects in Meyer (2010) confirms that both *coordination economies* and *market risk economies* are significant in case of generation unbundling. However, results also indicate that there might be a *specialisation effect* for network companies that divested their generation assets. The existence of this specialisation advantage, which is also confirmed by Ida and Kuwahara (2004), indicates that the costs of unbundling may be significantly lower in the long run, as soon as firms are able to realise efficiency gains from restructuring.

b) Distribution and retail unbundling (DRU)

Scope estimations for the DRU case are obtained when only the distribution and retail stages are separated from generation.[19] There are some examples for studies on European markets. Fraquelli et al. (2005) estimate economies of scope for Italian distribution utilities, excluding the transmission activity. Results for the average firm (G=0.3 million MWh and D=R=0.6 million MWh) show a cost increase of 3 percent. These vertical economies also increase with firm size up to a value of 79 percent (G=2.4 million MWh and D=R=4.8 million MWh).

Jara-Díaz et al. (2004) measure integration economies for the Spanish electricity industry. Since transmission networks in Spain are owned and operated by the independent company REE, only costs of generation and distribution are included in their cost estimation. For an average firm (G= 8.2 million MWh, D=R=11.35 million MWh) vertical synergies make up 8 percent. In a non-parametric DEA approach, Arocena (2008) calculates about 4 percent for a similar firm size. In general, vertical integration economies for the Spanish ESI range from 1.7 percent to 5.3 percent.[20] Applying the DRU scenario on the U.S. cost estimation, Meyer (2010) calculates synergies of 5 percent for a company size comparable to those of the Spanish estimations.

Kwoka et al. (2007) focus on the effect of unbundling on distribution network costs. Using a DEA approach for U.S. distribution companies, an average efficiency loss of 4 percent for the time period of 5 years after unbundling is estimated. Within this time frame, however, efficiency losses appear to increase from 4.1 percent in the second year after divestiture up to

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[19] Empirically, this means that the vertical relation between transmission and the other stages either remains unchanged (as for Fraquelli et al.2005) or transmission costs are not regarded at all (as for the Spanish studies, Arocena (2008) and Jara-Díaz et al. (2004)).

[20] A short description of the DEA approach to calculate scope economies is given in the annex.

15.3 percent in year five. Thus, an adjustment process due to specialisation could not be observed. However, Kwoka et al. (2007) only measure the network cost and do not take account of cost effects that may occur at the generation stage.

Summarizing these studies, it is noticeable that the estimated scope economies differ strongly depending on the specific markets that are analysed and the way the transmission stage is treated. Focusing on the studies that leave the transmission stage aside, synergies between 4 and 8 percent can be expected for a distribution company with an average output of 10 million MWh in generation and distribution.

It should be noted that these studies may overestimate the costs of unbundling for markets with retail competition. Lacking the possibility to empirically separate distribution from retail in cost function estimations ignores the fact that part of the synergies may be preserved if an integration of generation and retail is still possible and only the distribution *networks* are separated from the competitive stages. A more adequate analysis of markets with retail competition is provided by the two following scenarios.

c) Transmission unbundling (TU)

To the best of the author's knowledge, there is only one cost function approach measuring vertical synergies for a pure *transmission unbundling (TU)*. Meyer (2010) calculates vertical integration economies between 3 and 5 five percent for the U.S. industry. The estimated values decrease with company size up to an output of 28 million MWh, and slightly increase with larger outputs.

A couple of further studies investigate *price* and *efficiency effects* of transmission unbundling. Instead of vertical synergies, these studies rather estimate an overall effect, including possible efficiency gains due to an increase in competitive pressure. Steiner (2000) was the first author to provide an international comparison of electricity markets and measures the impact of several regulatory and liberalisation policies, one of which is transmission unbundling. Although results hint towards a price reduction for industrial users, they are statistically not significant. In a re-estimation of Steiner's results, Hattori and Tsutsui (2004) find a price reduction due to ownership unbundling which also lacks statistical significance. A study of Copenhagen Economics (2005a; 2005b) investigates the impact of several indicators of market opening on industrial prices. For transmission unbundling they confirm the results above since they do not find a significant influence on prices. The same holds true for the study of Growitsch et al. (2008) on ownership unbundling in the gas industry. To the author's knowledge, only one study does indeed find a significant price effect: Schober and Weber (2009) apply a regression model similar to Steiner (2002) to nine South American countries. Their results show a price decreasing effect of ownership unbundling amounting to 2 US-cents per kWh.

The fact that most of the market studies do not find significant price effects is not surprising. Due to the large number of different deregulation measures taken by countries, and given the uncertainty about their respective time-lags, an econometrical separation of the individual influences of liberalisation policies is problematic. As Joskow (2006, p73) puts it, "It is difficult to disentangle the effects of privatization, restructuring and incentive regulation".

d) Distribution unbundling (DU)

Finally, *distribution unbundling (DU)* illustrates a scenario where only the distribution wires business is separated from all other supply stages, while retail remains to be integrated with generation. For this scenario, no cost function approach could be found to provide a direct measurement of scope economies. Hence, we have to fall back on a couple of bottom-up studies to get an idea of the costs of distribution unbundling. With the Netherlands and New Zealand we find two examples that have been analysed empirically.

The Netherlands recently decided to implement ownership unbundling of distribution networks until 2011. In an *ex ante* welfare analysis, Deloitte (2005) estimates permanent synergy losses ranging between 350€ and 460€ million. The major part of these costs appears on the holding level and is attributed to IT systems, finance, personnel, and organisation. Roland Berger (2005) calculates somewhat smaller costs between 285€ and 400€ million. The Dutch Minister of Economic Affairs (MEA) estimates permanent restructuring costs of 150€ million, arguing that unbundling would simplify contracts and the billing system, since it would allow for a capacity-based network fee. However, no detailed breakdown of these figures is provided to underpin the argument (see De Nooij and Baarsma, 2009).

CPB (2005) emphasises that most of the synergy losses already result from the step to legal unbundling, which has been implemented on the distribution level in 2005. Accordingly, they expect further losses of an additional step to ownership unbundling to be about 100€ million.

Relating these values to the overall industry costs of the Netherlands of about 10€ billion, scope economies of distribution unbundling can be expected to roughly lie in the range of 2 to 5 percent, which is comparable to the results of transmission unbundling.[21]

For New Zealand, Nillesen and Pollitt (2008) found only temporary effects of distribution unbundling in terms of reduced commercial prices. While generation costs are not directly analysed, a decrease of networks operating costs of about 17 percent was found. However, as the authors note, this effect can not undoubtedly be attributed to unbundling, but could have resulted from other deregulation policies and a so-called "regulatory threat". The latter refers to efficiency increases due to an (implicit) threat of the government that a regulator – that did not exist in New Zealand before 2003 – would be implemented in case the performance was too weak. Indeed, the discussion about establishing a regulation authority was ongoing since 1999. New Zealand's distribution utilities may have had incentives to increase their efficiency to avoid their profits to be regulated away (see Brunekreeft, 2003). Nevertheless, this strong decrease in network costs is surprising, given that it seems to contradict almost all theoretical and empirical findings so far.

Table 1 categorises the estimated scope economies for each unbundling scenario based on the empirical studies discussed above. Results have been transferred to fully integrated companies. However, it should be noted that these numbers can only give a rough approximation, and not all of the studies cover the full output range. Figure 3 compares the first three scenarios according to the cost function estimation of Meyer (2010).

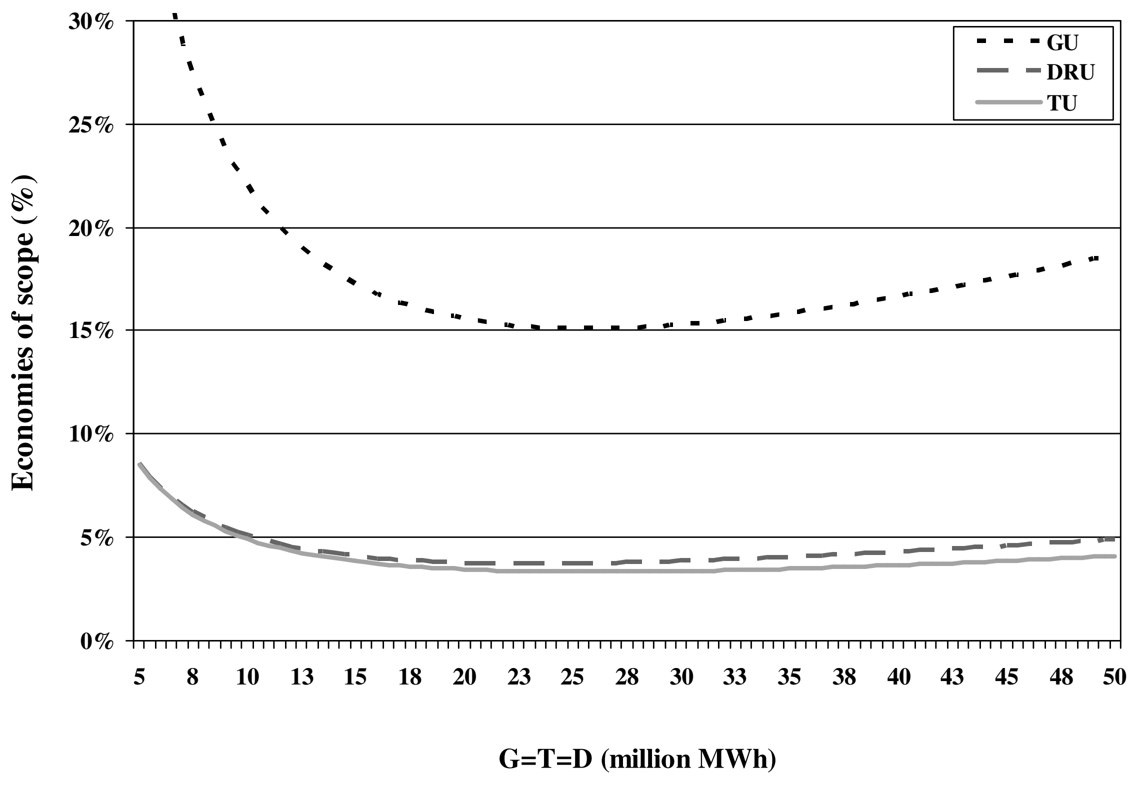
[21] These values are indeed very high. As a consequence, a social cost-benefit analysis of De Nooij and Baarsma (2007) draw a negative conclusion on the welfare effects of distribution unbundling.

Table 1: Economies of scope for fully integrated utilities (in fractions of total costs)

Output all stages (million MWh)	**1 – 10**	**10 – 15**	**15 – 20**	**20 – 40**	**40 – 50**
Generation Unb. (GU)					
Kaserman & Mayo (1991)	<0.19	0.19–0.54	0.54–0.89	-	-
Kwoka (2002)	<0.43	0.43–0.75	0.75–1.04	-	-
Arocena et al. (2008)	-	0.04–0.10	0.04–0.10		
Meyer (2010)	<0.22	0.17–0.22	0.16–0.22	0.16–0.17	0.17–0.19
Dist. & Retail Unb. (DRU)					
Arocena (2008)	<0.04	0.04–0.05	0.04–0.05	0.04–0.05	0.04–0.05
Fraquelli et al. (2005)	>0.16	-	-	-	-
Jara-Díaz (2004)	~0.08	~0.08	-	-	-
Meyer (2010)	<0.09	~0.04	~0.04	~0.04	~0.05
Transmission Unb. (TU)					
Meyer (2010)	<0.09	0.04–0.05	0.03–0.04	0.03–0.04	~0.04
Distribution Unb. (DU)					
Deloitte (2005)[1]	0.04–0.05	0.04–0.05	0.04–0.05	-	-
Roland Berger[1]	0.03–0.04	0.03–0.04	0.03–0.04		
CPB (2005)[1]	~0.01	~0.01	~0.01	-	-

[1] Based on ex-ante welfare analysis

Figure 3: Economies of scope for fully integrated utilities



As table 1 indicates, empirical studies differ widely with respect to the estimated degree of scope economies for all scenarios. While the estimations show comparable values for their respective sample means, large differences occur as soon as results are transferred to larger companies. In particular, the estimations of Kaserman and Mayo (1991) and Kwoka (2002) for "large" utilities (beyond an output of 15 million MWh) seem way too high as a measure for the expected costs of unbundling. It should further be noted that all studies have in common that they cannot (and do not aim to) take account of the adjustment processes taking place after vertical separation. Although Meyer (2010) indicates the existence of such a *specialisation effects*, a precise measurement of long-run effects is beyond the scope of a static cost function estimation. Furthermore, the efficiency gains resulting from *increased competition*, which in fact are a major argument for vertical unbundling, are not measured in these studies. Accordingly, the "net costs" of unbundling can be expected to be generally overestimated, while the net effect might be positive but probably small (see Brunekreeft, 2008b).

However, these restrictions do by no means weaken the important insights the empirical studies provide into the cost structure of electricity supply and its vertical relations. A major conclusion it that both *coordination economies* and *market risk economies* are important and should be considered in case of vertical restructuring. In particular, the market risk effect by splitting generation and retail appears to have a significant influence. Evidence from New Zealand, where a strong re-integration between these stages took place after distribution unbundling, confirms the importance of the risk hedging effect: by 2000, only one independent retailer remained in the market (see Bertram, 2006).[22] An important conclusion of these results seems to be that the introduction of retail competition, in the sense of granting open access to the distribution networks, is important to avoid an increase in market risks when vertical unbundling of the distribution stage from the generation level is applied. Pure network unbundling options, like transmission and distribution unbundling that still allow for an integration of the competitive supply stages, show a significantly lower loss of scope economies between 2 and 5 percent. Nevertheless, these values are still high! For the purpose of comparison: Newbery and Pollitt (1997) estimate an efficiency increase of 5 percent for the *whole* liberalisation and restructuring process in Great Britain.

[22] For the same risk arguments, Trevino (2009) sees vertical integration, in terms of self-generation, as a business model for energy intensive consumers.

It should be kept in mind, however, that the scenarios analysed are polar cases, and market structures observed in practice tend to lie in between. Comparing the GU and DRU scenario in figure 3 indicates, for instance, that the transmission stage makes an important difference. In the GU scenario, transmission is *fully separated* from generation. Accordingly, coordination losses between generation and transmission lead to higher efficiency losses compared to the DRU scenario, where these stages remain *fully integrated*. The ISO solution – that is quite common in the U.S. and is one of the European options of the third legislative package as well – represents an intermediate case, where neither full integration nor full separation is given. By outsourcing operational (and to some degree investment) decisions, much of the coordination economies may be preserved, and one might end up with significantly lower costs of unbundling compared to a strict ownership separation.

5 Conclusions

This paper reviews theoretical and empirical literature on sources and magnitudes of vertical synergies in the electricity sector as an indicator for the costs of unbundling.

Economic theory predicts two main sources of synergies, namely *coordination economies* and *market risk economies*. Furthermore, empirical evidence suggests that an opposite effects in terms of a *specialisation advantage* may occur, reducing the expected costs of unbundling at least in the long run.

Empirical results are presented for four different unbundling options. *Generation unbundling (GU)* refers to a separation of the generation stage from the two network stages (transmission and distribution) and the retail function. This turns out to be the most costly unbundling option, since it increases both coordination costs and market risks. Synergy losses can be expected to make up 17 percent of total costs for the average company. *Distribution and retail unbundling (DRU)* involves lower coordination losses, since generation and transmission remain vertically integrated. Accordingly, only distribution and retails are separated from the combined generation and transmission stage. This scenario leads to synergy losses below 5 percent. Similar results apply to pure network unbundling options. Both *transmission unbundling (TU)* and *distribution unbundling (DU)* only separate the respective network part from all other supply stages, resulting in synergy losses between 2 and 5 percent.

What conclusions can be drawn for the unbundling discussion in general and the development within the European Union in particular?

First, t*ransmission unbundling* does not come without a cost as it results in coordination losses between generation and transmission. Both theoretical and empirical literature indicates that network externalities may hinder efficient investment coordination unless a market mechanism – like a form of local network pricing – is established that internalises these external effects. Great Britain and Norway are examples for European countries that have gained experience with locational network charges, and the discussion has already started to extend to other European countries as well.

Second, although there is no direct empirical assessment of the *ISO* option, this may turn out to be the "golden mean". Coordination losses are most probably lower compared to ownership unbundling, given that optimisation takes place from a more integrated perspective. A critical issue is that of investment incentives, in particular the necessary split between decision-maker and risk-bearer, as required for a deep-ISO. This analysis, however, is beyond the scope of this survey (see Balmert and Brunekreeft, 2009).

Third, although the European debate focuses on transmission unbundling at the moment, *distribution unbundling* may become an issue in the near future. Given the current developments towards *smart grids*, the question whether distribution unbundling favours or hinders innovations on the distribution level has moved into the focus of discussion. New Zealand and the Netherlands provide examples for distribution unbundling.

Fourth, the analysis shows that market risk effects play an important role in vertical relations of the electric industry, in particular between the generation and retail stage. Both scenarios *generation unbundling* and *distribution and retail unbundling* correspond to electricity markets that did not establish retail competition. In other words, distributors still serve protected franchise areas as it was the case prior to liberalisation. In such an environment, the separation of generation from distribution, as analysed in both scenarios, results in a higher market risk, since distributors have to purchase electricity for their retail supply on the wholesale markets, and are subject to price volatility and face the risk of opportunistic behaviour of other players that may be able to exhaust market power.

Fifth, concluding on these market risk argument, a lesson for Europe is that – given retail competition in Europe is established – vertical integration between generation and retail may increase if distribution unbundling should be implemented in future. The re-integration between these stages that was observed both in the UK and New Zealand after distribution unbundling confirms the importance of the risk hedging effect of integration. However, as the ex-ante cost benefit studies of distribution unbundling in the Netherlands indicate, synergy losses may still be significant even if the risk effect is avoided.

Since most studies are based the U.S. electricity industry, one should consider the structural differences between the U.S. and Europe when interpreting the empirical results. In particular, it should be noted that in Europe a *legal unbundling* restriction has already been established. This requires a functional and management separation of network and competitive businesses. Accordingly, the additional step towards ownership separation is a smaller one, compared to fully integrated systems.

Finally, it should be noted that a measurement of scope economies only covers the negative aspects of vertical separation, while it does not take into account the positive aspects in terms of increased competition, which is the other side of the coin.

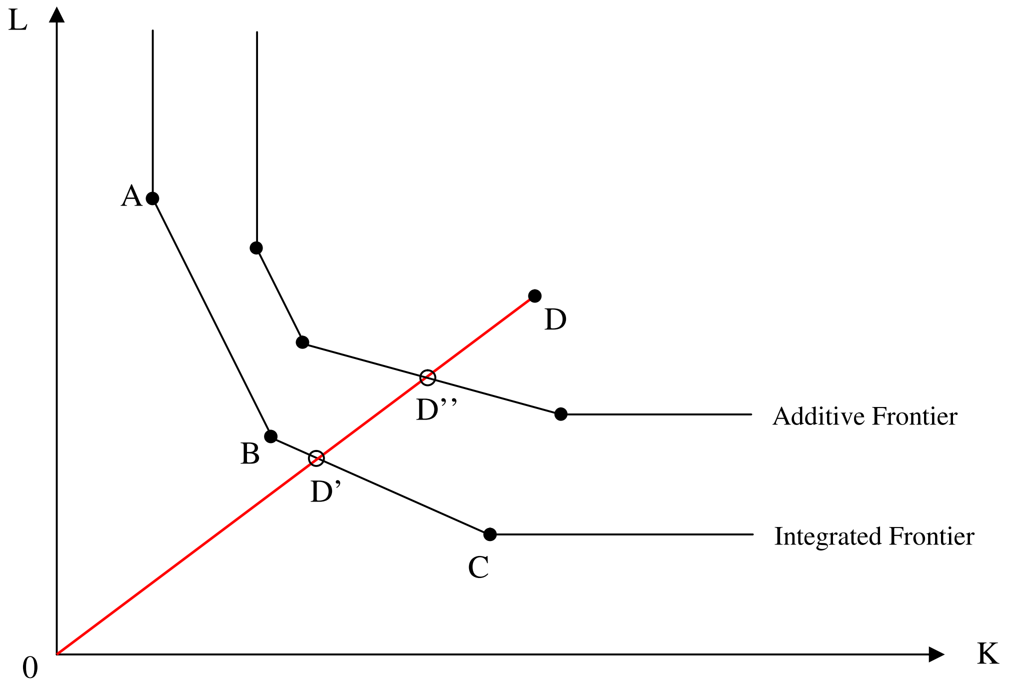
Annex

Arocena (2008) uses the non-parametric DEA approach to calculate vertical economies of scope for the Spanish ESI.[23] Based on a method introduced by Färe (1986), Arocena (2008) calculates different frontiers for integrated and separate, as figure 1 illustrates.

In a first step, Arocena (2008) calculates the 'integrated' frontier comparing integrated firms to their own best practice firms. In figure A1, the efficiency score of firm D is the ratio 0D'/0D. In a second step, "hypothetically integrated" firms are constructed by pairwise combining specialised generation and distribution companies, i.e. adding up costs and outputs. Comparing firm D with best practice firms under separate production ('additive' frontier), results in an efficiency score of 0D''/0D according to figure A1. Firm D turns out to be more efficient with regard to the additive than its own frontier, implying the existence of economies of vertical integration. The fact that the additive frontier lies above the integrated one indicates that even the most efficient firms perform weaker if they are vertically separated. This implies the existence of vertical economies of scope. The degree of synergies is then given by the ratio (0D'/0D) / (0D''/0D) = 0D'/0D'', where values smaller than unity imply advantages of joint production.

[23] There is a broad literature on parametric and non-parametric frontier approaches. See for instance Coelli et al. (2005). A comprehensive analysis of the DEA method is given by Cooper et al. (2007).

Figure A1: Data envelopment analysis with different frontiers (based on Arocena, 2008)



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