Total cost efficiency analysis for regulatory purposes: statement of the problem and two European case studies

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Abstract

This paper describes the issue economic regulators face when assessing the relative performance of network utilities by means of economic benchmarking. Using examples from two European regulatory agencies, we discuss how total expenditure (totex) benchmarking can achieve more consistent outcomes than building-blocks benchmarking, while generating a new set of practical issues which will make this regulatory tool feasible only under a specific set of (mainly country-specific) circumstances.

Keywords: total cost efficiency analysis, benchmarking, regulation, electricity networks, Data Envelopment Analysis.

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1 Statement of the Problem

Price-Cap Regulation

Regulatory authorities dealing with utility sectors are faced with the issue of regulating price and quality levels for natural monopolies. Not all of the production subsets that are typical of a utility sector are naturally monopolistic. Indeed, technology and demand conditions have made large chunks of the utility realm relatively competitive today, although different conditions exist in traditional industries such as electricity, gas, and water as opposed to – say – telecoms and media.

Regulating electricity and water networks, for instance, still requires a high measure of regulatory judgement as to which techniques and methods one should use to make up for the substantial lack of direct technical efficiency and cost comparability between decision units. As a result of the existence of natural monopolies in the fields of transmission and distribution of electricity and gas, regulators have resorted to various forms of either partial or total relative efficiency analysis - and even to pure yardstick competition in some cases. We will refer to this practice by the usual – albeit not entirely correct – name of "economic benchmarking".

Totex Benchmarking

Economic benchmarking can be either carried out by looking at technical variables only (for instance, the length of distribution networks, the number of serviced connections, and so on) or by examining different cost levels. Cost-based benchmarking is more popular with economic regulators because it better fits the regulatory concepts of "efficient allowed costs" and "regulatory revenue allowances" that are typical of incentive-based regulation as applied in a number or European, Asian, and South American countries.

Cost-based benchmarking can take place on the basis of either partial or total cost. Under the total cost or 'totex' approach, the regulator does not differentiate between opex and capex but sets the X-factor on the basis on the sum of these, i.e. on the basis of total cost (totex). In practical terms, this means that the regulator does not need to consider investment projections by the firm but instead it has to perform a benchmarking analysis of actually incurred levels of totex. The resulting efficiency scores, then, form the basis for setting future allowed totex levels.

The efficiency incentives of the totex approach stem from the fact that each regulatory period, the X-factor is set on the basis of performance achieved in previous years. If the firm manages to increase productivity, its efficiency score will be higher in future periods and consequently its X-factor will be lower. This is an important difference as opposed to the building blocks approach, whereby assessment problems for capex projections hinder the correct determination of efficient levels of capex.

The ideal solution for regulators is to avoid any trade-offs between separate components of cost i.e. opex and capex, and to analyse relative efficiency levels of network-based utilities by just looking at total cost levels, after allowing for regional differences and other identifiable peculiarities.

However, in the real world only a handful of regulators did manage to perform total expenditure (totex) benchmarking as opposed to other partial forms of this exercise. Notoriously, the British energy regulator Ofgem has traditionally preferred the so-called 'building-blocks'[1] approach whereby cost levels are analysed separately according to their nature of either capital (capex) or operating (opex) expenditure. Other regulators, however, have taken a different view. Having

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[1] Under the building blocks model, the present value of the capital costs at any point in time is just equal to the level of the regulatory asset base at that time. As a result, the power of the incentives for cost reducing effort on capital expenditure depends on the responsiveness of the regulatory asset base to the capital expenditure out-turn of the regulated firm. If the regulatory asset base is adjusted ex post by an amount equal to the actual capital costs incurred by the regulated firm, the regulated firm will have little incentives to economise on capital expenditure.

recognised the ‘double jeopardy’ problem stemming from building-blocks benchmarking – which results from the allocative and accounting trade-off between capex and opex – such regulators have moved towards the use of totex benchmarking for the sake of setting revenue requirements, with a view – at least in one case – to applying straight yardstick competition to network operators. Finally, the application of totex-based benchmarking may be preferred for practicability reasons where a large number of network service providers (for instance in Norway, Austria and Germany) exists, and the regulator is not in the position to check the investment plans of the companies ex ante.

Paper Outline

What follows is an overview of two totex benchmarking approaches that try and overcome the natural cost misallocation and allocative inefficiency bias implied by ‘waterproof’ opex and capex benchmarking, and the problems entailed by the subsequent construction of an infeasible total cost frontier obtained as the sum of the best feasible post-benchmarking opex and the best feasible post-benchmarking capex (‘double jeopardy’).

The first approach, adopted in Norway by the Norwegian Water and Energy Directorate (NVE), starts from conventional cost analysis to develop a total cost benchmarking framework with control factors that arrives at the determination of efficiency and revenue requirements for electricity distribution utilities. The second approach, developed in the Netherlands by the Dutch energy regulator DTe, is even more ambitious in that it turns total cost benchmarking into an almost completely mechanistic transposition tool to arrive at a semi-automatic yardstick competition regime. Both approaches were originally intended for electricity distribution utilities, and use Data Envelopment Analysis (DEA) (see reference 5 and 6 description) as the main benchmarking technique.

The two totex benchmarking approaches are described in turn and an evaluation of the totex approach is performed. A final conclusions section draws up a few considerations for future research.

2 The Norwegian Totex Benchmarking Strategy

Institutional Background

The Norwegian Water Resources and Energy Directorate (NVE) is the power industry regulator in Norway. The NVE is a directorate under the Ministry of Petroleum and Energy, with responsibility for managing the country's water and non-fossil energy resources. NVE's mandate is to ensure integrated and environmentally friendly management of the country's watercourses, to promote efficient energy markets and cost-effective energy systems, and to work to achieve a more efficient use of energy. NVE is also responsible for reducing damage caused by floods and erosion along rivers and streams.

Network regulation in Norway was based on rate-of-return regulation during the starting years 1992-1996. However, the deficiencies resulting from this approach were soon recognised. The main issues were the inefficiency caused by guaranteed cost recovery and the weak incentives for productivity improvements. This became the major reason that led to the replacement of the existing price control framework by a new incentive-based scheme in 1997. The current Norwegian regulatory system is an ex ante regulation method based on incentive regulation with the help of revenue caps. Through efficiency incentives, NVE strives to encourage network owners to reduce costs and improve their efficiency. Under the new system, network owners are no longer guaranteed full cost recovery. By establishing a system where each network owner is allowed to receive pre-determined maximal revenue, the profit will in principle be the difference between allowed revenue and actual costs. Allowed revenue requirements should cover the networks' total costs: operation and maintenance, capital costs in the form of depreciation and return on capital invested, network losses and profit taxes.

The new regulatory model is based on revenue cap regulation, supplemented by benchmarking and profit sharing mechanisms. Initial revenue caps were determined on the basis of the distribution firms' accounts from 1994 and 1995. In 2002, NVE reset the price control for the networks keeping the general logic of the revenue-cap from the first regulatory period (1997–2001) untouched, however adjusting some of the components and pursuing the improvement of the regulatory cap's properties.

Price Regulation

Norwegian revenue cap regulation in electricity transmission and distribution contains elements of different regulatory mechanisms. It consists of cost-plus regulation with a time lag, and benchmarking plays a crucial role in determining efficiency requirements. The revenue cap is determined by:

- The revenue cap from the preceding year, or primarily the cost in the first year of the regulation period, plus a standard return on capital for the same year;
- An expected efficiency improvement parameter, benchmarking-based; and
- An annual correction factor intended to provide an additional revenue as a function of pre-specified cost drivers.

The fact that the revenue cap is affected by these factors makes it possible for the grid owner to influence its return, not only by decreasing costs but also by operating and maintaining the grid in such a way to ease the revenue cap.

The initial revenue values consist of the average operating and maintenance costs, depreciation, return[2] on invested capital (book value + 1% to allow for working capital), and average grid losses. The market price for power is used to assess the value of grid losses.

In the first revenue cap period (1997-2001), the initial revenue caps were determined on the basis of the grid companies' accounts from 1994 and 1995, according to the following formula:

$$IT_e = DV + AVS + AVK + NT\ ,$$

where IT_e is the initial revenue cap determined by operating and maintenance costs (DV), depreciation (AVS), return on invested capital (AVK) and costs associated with energy losses (NT). $NT = NT_{MWh} \cdot$ P, where $\mathrm{NT}_{\mathrm{MWh}}$ denotes losses in MWh, and P is the average system price of energy during the whole year as gleaned from the NordPool spot market.

The dynamic time adjustment of the allowed revenue for the grids was based on the following formula:

$$IT_{e,n} = ((IT_{e,n-1} - NT_{n-1}) \cdot \left(\frac{KPI_n}{KPI_{n-1}} \right) + NT_{MWh} \cdot P_n) \cdot (1 - EFK) \cdot \left(1 + \frac{\Delta LE_{a,n}}{2} \right)\ ,$$

where:

IT is the starting revenue or cost;

KPI is the consumer price index;

EFK is the efficiency requirement calculated at the beginning of the regulatory period by means of Data Envelopment Analysis (DEA);

ΔLE is the percentage increase in transported energy on a year-on-year basis; and

[2] NVE annually sets a reference interest rate based on the long-term risk-free interest rate plus a risk premium. The reference interest rate, r_n, is the basis for the return. The basis for the risk free interest rate is the ST4X index from the Oslo Stock Exchange. The risk premium is valued at 2%.

n is the index for the year.

The initial revenue is annually adjusted for inflation, required efficiency increase and by the term ($1+1/2.\Delta\ LE_{a,n}$). The latter is designed to provide an additional revenue to the regulated grid companies that would contribute to the additional OPEX and CAPEX incurred by the companies because of the increasing volume of transported energy. The anticipated efficiency improvement includes:

- An individual efficiency increase component – measured via DEA on inter-company comparisons; and
- A general efficiency increase component – imposed exogenously by NVE and reflecting the general technological improvement in the industry.

The current revenue cap scheme (2002-2006), with initial cost values taken from 1996-1999, is slightly different from the above description. Amongst other things, the last term in the formula was removed and replaced by a new term (*Just*) that adjusts for new investment whereas the increase in transported energy was supplemented by a second driver, namely the relative increase in the number of buildings in each distribution area:

$$IT_{e,n} = ((DV + AVS + AVK \cdot r_n) \cdot \left(\frac{KPI_n}{KPI_{2000}}\right) + NT_{MWh} \cdot P_n) \cdot (1 - EFK) \cdot + \mathrm{Just}_n^i .$$

The Norwegian approach relies on the typical incentives to raise efficiency in the regulatory period while keeping the interim efficiency gains. The regulatory revenue reset is based on actual cost including checks for deviations between the prescribed revenue path and the actual companies' performance. In addition, the regulated grid providers are exposed to a repeated benchmarking that is aimed to eliminate inefficiencies. In the current regulation period (ending

2006), the grid owner cannot influence the revenue cap directly. The revenue path is decoupled by the actual cost via the application of the regulatory formula.[3]

If we assumed that last year's cost level is the only basis for determining the revenue cap in the current period, we would impose no cost-reducing incentives on the regulatees. What NVE does instead is to benchmark the opening level of costs via DEA, and to impose an efficient totex level objective upon all regulated companies throughout the duration of the regulatory period.

The Efficiency Requirement

The efficiency requirement contained in the formula (the *EFK* term*)* is based on a DEA comparison of all distribution companies (there are more than 150 in Norway, albeit now decreasing). As regards asset values, both book asset values and replacement asset values are considered as part of the total cost DEA runs, which are then computed twice. Companies are given the 'benefit of the doubt' in that the most favourable DEA scores are used for their revenue requirement calculations after comparing the efficiency score series from the two DEA runs. The relationship between the efficiency requirement and the efficiency measurements based on DEA is mediated in such a way that the individual requirement will never exceed 3% annually for any distribution company reporting a DEA cost efficiency score of 70% or lower ('efficiency flooring'). Formally, the efficiency requirement target *EFK* is given by the formula:

$$EFK_D = 1 - (1 - (1 - KE) \cdot 0.3824)^{1/4},$$

where *KE* is the totex efficiency level for any given company calculated by DEA, which is (generously) floored at 0.70 for all distribution companies with a reported raw DEA cost efficiency score of less than 70%. For a grid owner with regulatory cost efficiency in the floored 70-100% interval then, the formula will mean that 38.24% of the individual inefficiency in the

[3] Differently from the UK, the revenue formula does not use any building blocks and does not include any ex-ante expenditure projections.

distribution grid must be recovered over the regulatory time span of 4 years. Any residual inefficiency will be carried forward to the following regulatory period.

Dealing with New Investment

There is an adjustment term in the revenue cap formula that exceeds the compensation implicit in the incentive to 'beat' the regulatory benchmarking-based cost target. On the assumption that new investment may be caused by an objective need resulting from changes of certain cost drivers as well as being driven by safety and system security reasons, the investment revenue adjustment element in the revenue cap formula is intended to give the companies suitable compensation for expansion investments in the grid. However, it is important that the adjustment term does not favour unnecessary and/or gold-plated new investment. In other words, the adjustment term should not incentivise the companies to influence their own revenues through uneconomic actions.

New investments involve capital costs such as depreciation and return on invested capital. The majority of such costs is already taken into account by updating the cost base for the revenue cap periodically. Cost recovery is, however, delayed in time because the updates do not occur continuously. This entails that the net present value of the implied revenues is lower than what would be necessary to cover new capital cost incurred today. The purpose of the investment adjustment term in the revenue cap is to provide continuity in terms of investment recovery. In addition, new investments may have an impact on operation and maintenance costs, grid losses, and undelivered energy. Such (arguably positive) changes will not result in changed revenue caps for the firm until the next regulatory review, and must therefore be assessed when determining the level of the ongoing adjustment term. The share of capital costs associated with a new investment that the adjustment term is supposed to cover depends on:

- The real timing of investments in relation to the four-year update timetable for totex;

- The life time of the investments;
- Future inflation;
- Future efficiency requirements; and
- The return on capital (discount factor) for the grid owners.

NVE has calculated that between 64.8% and 94.5% of capital costs are already covered through the four-year totex revenue cap. The adjustment term shall therefore compensate for between 5.5% (100% minus 94.5%) and 35.2% (100% minus 64.8%) of the capital costs associated with the new investments.

3 The Dutch Yardstick Competition Experiment

Institutional Background

Before liberalisation, electricity tariffs in the Netherlands were set by a system that closely resembled cost-plus. Under this system, tariffs were primarily based on observed costs, plus a reasonable rate of return. Although much less legalistic and explicit than in the US, the generally observed weaknesses of the traditional rate-of-return regulatory approach also applied to the Netherlands. The 1998 Electricity Act introduced a completely new approach towards price regulation. Currently, tariffs for distribution network use are regulated on the basis of a price-cap system. Tariff levels are annually adjusted by CPI – X, in which CPI is the consumer price index and the so-called X factor is the regulator's estimate of future efficiency improvements.

For the first regulatory period, from 2001 to 2003, regulator DTe's price capping scheme can be characterised as an ex ante-*cum*-benchmarking approach. Tariffs are set beforehand for a number of years on the basis of regulatory judgments about future productivity improvements as disclosed through benchmarking. For both electricity and gas network monopolies, price-cap systems have been used as a basis for setting tariffs. The strategy for setting the X factors was to drive firms towards similar efficiency levels. This was done to create a level playing field, so that yardstick competition could be introduced in the second regulation period lasting from 2004 to 2007 (DTe 2002).

Price Regulation

In the second incentive-based regulatory period (2004-2006), DTe decided to move towards fully-fledged yardstick regulation of price and quality. However, the application of yardstick competition by DTe is different from the classic textbook approach (Shleifer, 1985). According to Shleifer's original proposal, price is set on the basis of average (*n-1*) costs. In the Dutch case, prices are simply *adjusted* by an X-factor reflecting the *change* in the total factor productivity of frontier-behaving firms. Thus, the yardstick formula is one whereby prices are based on relative changes in productivity rather than on absolute costs.

For each firm, an annual allowed revenue is determined. Based on this, tariffs are set such that the allowed revenue equals the sum of revenues generated by these tariffs and the actual volumes back in 2000. These volumes, y_{2000}, act as so-called "norm volumes". The calculation is made in the tariff basket where, for each year, prices are set such that a company *i* is allowed to earn the following revenue:

$$AR_t = \sum p_{j,t} \cdot y_{2000,j,t} \cdot$$

AR stands for Allowed Revenue and results from the yardstick scheme; p_j stands for the j^{th} tariff/price component. This formula is the starting point for setting annual tariffs.

AR comes from an opening total cost benchmarking and is set on the basis of the yardstick scheme, following the general CPI-X formula:

$$AR_t = (1 - X)^t AR_{2003},$$

where *t* runs through the regulatory years 2004-2006.

The Efficiency Requirement

So far, the system can be described as a common tariff basket system. The main issue that sets this system apart from others is the way in which the X (efficiency requirement) factor is set. This is done according to the following formula:

$$(1 - X_i)^3 = \theta_i \cdot (1 - g)^3 .$$

Here, θ_i is the efficiency score for each particular company. This efficiency score is based on the 2000 totex Data Envelopment Analysis study (the latest one available in the Netherlands), putting together capital and operating costs, and is adjusted for possible efficiency improvements made in the 2000-2003 period.

The factor g is the "frontier shift", measured on the basis of the change in total factor productivity for frontier companies (those with an initial or corrected efficiency score of θ=100%).

Note that the X factor is firm-specific, but the g one is the same for all companies. Thus, each company has its own X factor, which consists of two separate components:

- A general target (g), which is the same for all companies and is based on the change in total factor productivity throughout 2004-2006; and
- An individual target (θ_i) which is set individually by company, and aims at removing initial efficiency differences across companies.

The general idea of the Dutch yardstick system is that prices are adjusted on the basis of realised changes in general productivity (i.e. the frontier shift). This is done by measuring the change in the frontier (as reflected in factor g). Factor g is determined only by those companies that are 100% efficient on a total (not just operating) cost basis, i.e. those that either initially have a total cost DEA score of 100% or otherwise have caught up to the frontier in the meantime.

The reason for splitting the X factor into two components is to recognise the fact that those companies that are initially inefficient should not be included in the calculation of the frontier shift. Thus, companies that have less than 100% efficiency will be given two targets, namely (1) catching up to the frontier; and (2) shifting with the frontier.

After the second regulatory period, the value of θ will be set to one by default. Therefore, DTe will assume that all companies are equally efficient (level playing field) and that no further adjustment is needed to the yardstick scheme. At that stage, the X factor will be set on the basis of g only.

Yardstick-based Benchmarking

The value of θ_i is known, and directly follows, from the 2000 totex DEA study bundling opex and capex efficiency analysis together. The value of g is not known at the start of the period, but can only be measured once the productivity improvements have been achieved ex post. Therefore, DTe will have to forecast g at the start of the regulatory period. At the end of the period, DTe will measure the "true" g and will correct for any differences – including interest – in the subsequent regulatory period[4].

On top of the above formulas, a CPI adjustment is applied (CPI-X). Note that, for the purpose of measuring productivity changes and making any appropriate ex post corrections, costs need to be deflated to a common base year.

It is worth noting that, at the start of the third regulatory period, DTe will not yet have full information about costs in the last year of the second period. Therefore, the comparison between the forecast and the actual improvements will exclude this last year. That is, g will be based on changes measured in the period 2003–2005.

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[4] DTe's forecast for g during the first regulatory period was 1.5% *per annum*.

The factor g is derived from the relative change in the productivity of frontier companies. Here, productivity means TFP, i.e. it is defined in terms of an index number consisting of a ratio of weighted outputs to weighted inputs.

As regards inputs, DTe uses the following cost items:

- Operating cost (opex);
- Standardised depreciation (d); and
- Return on standardised book values (WACC times the Regulatory Asset Value or RAV).

Inputs are weighted equally, i.e. the single input in the comparative efficiency exercise is simply given by:

Totex = Opex + d + [WACC x RAV].

As an output, DTe uses a so-called "proxy" output which is defined as the weighted sum of sold quantities (measured by the number of customers, kWh, kW, etc.) for all customer classes.

The weighting is made on the basis of predefined factors which are set by DTe. The weighting factors correspond to an average tariff basket for the industry.

In the totex efficiency analysis, a company becomes efficient if its costs per proxy output in 2002 are less than or equal to the projected/target efficient level (which is the efficient, or frontier, cost level obtained under totex DEA). The general view of the regulator is that a company will be labelled a 'frontier' company if it managed to achieve the efficiency improvement required by its DEA score in 2000 by the end of the regulatory period. Any super-efficiency achievements will be pocketed, in the form of unregulated extra profits, by the over-achievers.

Once a company reaches the frontier, it will be considered fully efficient in the future 'by default'. That is, all firms with a DEA score of 100% in the 2000 benchmark by definition will stay on the frontier – irrespective of their performance afterwards. This is a courageous, albeit potentially faulty, policy assumption which might turn out to be wrong *ex post* because of efficiency leapfrogging.

4 Evaluation

Under the totex approach, the problem of investment assessment may be effectively bypassed. Furthermore, as the totex approach does not distinguish between opex and capex, the firm (as well as society) may also achieve efficiency gains by trading-off between labour and capital inputs. Under the totex approach, the regulator does not need to develop a view as to whether a given investment proposal should be allowed or not. Rather, the regulator will consider the actual total cost (including investments) incurred by the firm and set the X factor based on the analysis of such costs.

Capex Measurement

Differently from opex, the measurement of capex is more problematic. Investments are typically undertaken at different time intervals and tend to considerably vary in size. Investment lumpiness might be characterised by substantial fluctuations in the cash spending from year to year, which could lead to misleading results in the benchmarking analysis. Averaging capex spending for a number of years can partially smooth out the numbers but not completely account for differences, in particular when companies might turn out to be at different points in their investment cycles.

The superior alternative is to represent capex as an estimate of annual capital consumption. Under this framework, a stream of annual investment figures is converted into a stock of assets (on which a return is paid) and a stream of annual depreciation figures. In this case, annual capital consumption is measured as the sum of the capital cost components: return on assets and depreciation. This method replicates the classical regulatory accounting scheme used to establish the allowed revenue for the companies.

Long-Term Nature of Investments

There is an important problem to be considered under the totex approach. This is related to the long-term nature of investments. Capex (depreciation and return)[5] is spread over a number of years and therefore, ideally, the benchmarking analysis would need to consider a long enough period of time rather than taking only a snapshot of costs during a single year.

As the example from the below Table shows, the costs in a given year can be strongly influenced by the timing of investments. In this simple example, firms A1 and B1 both invest an amount of 400. In the long run, these firms will face the same level of depreciation costs. However, the firms differ in their timing of the investments. Firm A1 invests primarily in the last year while for firm B1, most investments are conducted in the first year. As can be observed, the effect of this is that firm B1 has high depreciation costs in the early years and relatively low depreciation costs in the later years.[6] If the benchmarking analysis considered only a single year, say the second year, firm A1 would turn out to be very efficient as it would have much lower costs (50) as compared with firm B1 (88). The reverse would apply if the benchmarking analysis were conducted later in time, e.g. in the last year.

This example demonstrates the importance of considering multiple years in a totex benchmarking analysis. Multi-year analysis, however, would make the benchmarking analysis more data demanding and therefore less practical. Consideration should also be given to the fact that the analysis may be hampered because of differences in cost measurement resulting from different accounting conventions in the treatment of capital costs. Consider the above example once more. Firms A1 and A2 (or B1 and B2) both have the same investment pattern, but use different depreciation periods. Because of this, their depreciation costs measured in the same year tends to

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[6] For simplicity purposes, only depreciation costs are compared. Similar effects would, however, apply to returns too.

be different. Firm A1, which uses a depreciation period of four years, has lower costs in the earlier years than firm A2 – the latter using a shorter period of two years. Conversely, in the later years, firm A1 still incurs depreciation costs while firm A2 would have already depreciated all assets.

Although the examples provided here are simplified, they illustrate the basic problem of how ignoring the long-term nature of investments can distort the benchmarking results. Even though in the long run firms will have invested at similar levels, their costs would still fluctuate from year to year, reflecting differences in investment timing and accounting policies. Including multiple years in the analysis could solve this issue, but it would also make the analysis more data demanding. This is particularly true if the firms considered in the analysis have been using different accounting conventions throughout. Performing a backwards calculation of book and depreciation values could eliminate monetary effects resulting from such differences. However, there may be a problem in obtaining such historical data, in particular given the relative long lifetimes of assets in the electricity distribution business.[7]

Table 1. Simplified example of the impact of different depreciation policies and investment timing. All firms invest the same amount over a period of three years and use straight-line depreciation, but differ in the timing of these investments and the depreciation period. Although in the long run depreciation costs are the same, annual depreciation varies considerably.

[7] In the Netherlands for example, lack of suitable data made any accurate correction of capital costs difficult. This was an important factor in leading the regulated firms to reject the benchmarking analysis conducted by the Dutch regulator (Ajodhia et al., 2003).

Firm A1 (depreciates in 4 years)						
		Depreciation (mln. EUR) for investments in year:			Depreciation Costs (mln. EUR)
Year	Investment (mln. EUR)	1	2	3	
1	100	25			25
2	100	25	25		50
3	200	25	25	50	100
4		25	25	50	100
5			25	50	75
6				50	50
Total	**400**	**100**	**100**	**200**	**400**

Firm B1 (depreciates in 4 years)					
		Depreciation (mln. EUR) for investments in year:			Depreciation Costs (mln. EUR)
Year	Investment (mln. EUR)	1	2	3	
1	300	75			75
2	50	75	13		88
3	50	75	13	13	100
4		75	13	13	100
5			13	13	25
6				13	13
Total	**400**	**300**	**50**	**50**	**400**

Firm A2 (depreciates in 2 years)					
		Depreciation (mln. EUR) for investments in year:			Depreciation Costs (mln. EUR)
Year	Investment (mln. EUR)	1	2	3	
1	100	50			50
2	100	50	50		100
3	200		50	100	150
4				100	100
5					-
6					-
Total	**400**	**100**	**100**	**200**	**400**

Firm B2 (depreciates in 2 years)					
		Depreciation (mln. EUR) for investments in year:			Depreciation Costs (mln. EUR)
Year	Investment (mln. EUR)	1	2	3	
1	300	150			150
2	50	150	25		175
3	50		25	25	50
4				25	25
5					-
6					-
Total	**400**	**300**	**50**	**50**	**400**

Controllability

Whatever is directly under managerial control in the short run is deemed as controllable. Controllable costs include for example the costs of maintenance, personnel, office rents, transportation, etc. In the long run, ideally, investments are also controllable as the firm is free to determine its investment policy and the proper mix between capex and opex. This is, in particular, important for the application of the totex approach whereby controllability is extended to the capital cost components.

Moreover, as explained earlier in this paper, benchmarking analysis is usually backward-looking and therefore it implies (when applied to totex) controllability over investments undertaken in the past. However not every investment and, correspondingly, annual capital measurement (return and depreciation) is in reality truly controllable. There may be some cost items that cannot be considered as being within the company's scope of control both in the short *and* long run. Therefore, these non-controllable costs should not be included in the benchmarking analysis but instead, they should be passed through. While the differences in the companies' operational environment and the corresponding objective cost differences can be reasonably considered in the model specification via additional output variables, there are still two additional factors that should be accounted for: externally imposed requirements and historically inherited constraints.

Typical non-controllable cost items stemming from externally imposed requirements are:

- force-majeure related costs;
- state security-related costs;
- environmental compliance costs;
- legislation and regulation compliance costs; and
- costs stemming from other externally-imposed requirements (e.g. rents and leases, rights of way etc.).

All these costs may be relevant for the provision of the regulated network service but should be excluded from benchmarking.

The second more difficult factor deals with the question of whether and to what extent the costs incurred in the past could be considered controllable today – due to the reason that decisions made in the past by a different management team cannot always be reversed by the company's current management team. This argument is even stronger if equity control has changed in the past and the company's shareholders today are different from the past. Finally, based on currently available knowledge, it may be difficult to distinguish clearly whether past decisions were correct or not as such decisions only reflected the knowledge, information and technologies available at that time.

To account for such historical per-conditions, the regulator may decide to exclude the assets acquired before a certain threshold date (e.g., to only consider the assets acquired in the last 20 years or so). While this approach appears reasonable and practicable, it may raise questions as to whether the choice of the appropriate backward-looking window period is fair to all of the benchmarked companies. For example, companies that had relatively young networks at the start of the window period and consequently spent less in the following years will appear to be more efficient than the companies that inherited older networks before the threshold date and therefore had to spend more afterwards.

5 Concluding remarks

Regulation of networks based on total cost benchmarking, as opposed to building-blocks and separate cost assessments, carries an obvious theoretical advantage in terms of creating a level playing field and ensuring that efficiency frontiers are set by regulators on a fair and achievable basis (hence avoiding the 'double jeopardy' problem). Furthermore, under the totex approach, the problem of investment appraisal as encountered under the more traditional building blocks approach is of less regulatory concern.

However, the application of regulatory analysis based on total cost benchmarking should be accompanied by a number of considerations to ensure that the analysis is practically feasible, as well as theoretically advantageous.

The totex approach may provide a stable and attractive long-run equilibrium, but may require some additional considerations, in particular for non-repetitive or unique investments. The regulator will usually use information on past observed capex cost out-turns in setting the capex forecast for similar projects in future periods. The extent to which past capex cost out-turns provide useful information in setting future capex forecasts obviously depends on how much the capex projects undertaken in the past are similar to those proposed for undertaking in the future. In the case of capex projects which are repeated regularly (either because the asset involved has a short life or because the firm has a number of very similar assets which must be replaced on an on-going and rotating basis), past cost out-turns may be a very good signal of the likely future cost out-turn.

In contrast, in the case of capex projects which are repeated very infrequently or not at all, the past cost out-turn(s) provide little information about the cost of capex projects in the future. A typical case of infrequently repeated projects are those reflecting the investments cycles stemming from the history of past network developments. Under such circumstances, some (not necessarily all) companies may face a 'cliff-edge' investment problem due to a number of ageing assets reaching the end of their useful life more or less simultaneously.

The regulator can undertake the following measures to mitigate this problem:

- measure capex via the annual 'capital consumption', defined by the depreciation and return on capital (or as an annuity) in order to smooth out the time profile of the capital consumption itself;
- average out the annual capital consumption over a number of years;
- group the benchmarked companies in sub-samples with a similar asset age structure;
- apply a capital cost standardisation approach if there are differences in depreciation policies.

This implies that the regulator will need historic information for investments undertaken in the past. The non-controllable cost items stemming from externally imposed requirements will need to be removed from the totex cost volume used in the benchmarking exercise. Regulators can decide to limit the backward-looking period to account for constrained controllability resulting from historical pre-conditions. This limitation, however, can induce disputes as to whether the threshold date allows for the fair and equal treatment of all the benchmarked companies.

Finally, quality regulation must be set up to counteract possible quality degradation incentives in response to the totex (or even yardstick) scheme. The interfaces of total benchmarking results with the revenue requirement schemes, and the general logic of the price control should be kept. This has been recognised by both the Dutch and Norwegian regulators. In these two countries, quality incentive schemes based on optimal quality incentives have now been put in place.

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