Productivity growth in Norwegian ferry links 1988-1996, and implications for regulation[1]

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Introduction

Ferry links play a vital role in the national road network of Norway. Fare revenues do not cover operating costs, so the ferry operators receive a total subsidy of approximately 600 MNOK per year. This amount has been constant throughout the nineties. Up to 1990 costs were reimbursed at the end of the year. From 1990 on, the subsidy is contracted on in advance.

In this paper we study how the productivity of the ferry links has developed from 1988 to 1996. According to Førsund (1993) productivity in the ferry industry declined in the eighties. Has it improved since then? Has the effect of the fixed subsidy reform in 1990 petered out from 1993 to 1996? If so, what more can we do to improve efficiency, and what is the potential for improvement?

Given the high degree of control which the National Road Authority exerts over the stock of ferries, fares and investment policy, it is by no means obvious that the productivity development that we find can be ascribed to the ferry operators' own decisions and acts. We try to discuss the causes of the observed development and give advice on regulatory reforms based on our findings.

The nature of the production process of ferry transport services

A ferry company produces ferry transport services. It operates one or more ferry links. A ferry link can be seen as a production unit of the ferry company. Its productivity is its ability to transform inputs to products (ferry transport services).

But what is ferry transport services? From a technical point of view, the number of crossings per time unit and the capacity provided per crossing may be measures of how much is produced of ferry transport services. The productivity of the link is then its ability to perform crossings with a given stock of ferries, labour and energy use.

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[1] The study reported in this paper was commissioned by Rederienes Landsforbund, the association of Norwegian short sea shipowners. The study was reported in Norwegian in Minken et al (2000). There, we expressed our feeling that the data on passenger volumes in 1996 in the official ferry statistics were wrong. Consequently, our conclusions had to be phrased cautiously. For the present paper, the wrong data have been corrected. The main conclusions remain the same, but some finer points of interpretation have had to be changed.

But at a closer look, it is not this activity level in itself that is important. The activity must be suitable, which means that it is carried out at the times of day when travellers need it, and with a quality that suits them. How many that will actually want to use the ferry link is usually a good measure of how suitable its activity is. From this point of view, the number of passenger and car trips may be a better measure of ferry services than the number of crossings. The productivity of a ferry link will then be its ability to carry out passenger and car trips with a given stock of ferries, labour and energy use.

In short, we regard the production of ferry transport services as a two-stage production process. In the first, inputs like labour, capital and energy is used to produce a ferry transport supply, consisting of the offered frequency and capacity on crossings of given length. In the second, this ferry transport supply is used to perform ferry transport services. The two stages are of course performed simultaneously, but can be held apart conceptually.

The length of the crossings and the number of calls per round trip are important properties of the production process. Productivity analysis should not abstract from these site specific properties which might influence costs in important ways. In simple ferry links (shuttle services), these properties are given by the location of the two sites to be connected. But in some more complex cases, there might be a choice of where to call and the routes to service.

Even if demand is to some extent responsive to the price and quality of the service, potential demand and its composition (between passengers and cars, peak and off-peak, seasons etc.) will largely depend on the location of the link.

Since the length of the crossings, the number of calls, the potential demand and its composition are all site specific characteristics which could only be influenced to a limited degree, the ability to tailor inputs to the specific conditions of each ferry link is vital to the productive efficiency of the ferry sector.

Several important quality aspects of the service production deserve to be mentioned. Travel time and frequency are of course among them, as are opening hours. Also, queue lengths at the ferry quay might exceed the capacity of the ferry, resulting in waiting times of more than one headway for some of the cars. This excess waiting time is a recurrent problem in the peak season in many Norwegian ferry links. Finally, comfort and safety are relevant quality aspects, especially for some of the more windy and rough crossings.

The present study

A former study of the productivity of the Norwegian ferry industry was reported in Førsund (1993) and Førsund and Hernæs (1995). In that study, the focus was on efficiency in the operation of single ferries and companies rather than ferry links. This line of attack abstracts from the particular circumstances in which the ferries are operated, and thus they will probably produce results that are unrealistic with respect to the potential for improvement. Using data from the late eighties, a potential of input reductions of 25-30% for the industry as a whole was reported in these studies. Furthermore, they are only concerned with the first of our two stages of production of transport services. The production of the transport services and quality aspects like the frequency of the service are ignored.

The present study aims to take account of both stages of the production of ferry transport services. We are able to compare the results from the models of each stage with results from a model comprising both stages. The key characteristics of the particular sites of the ferry links are included in the model formulation. We thereby try to capture in an indirect way the quality aspects of frequency and speed, while data was missing or too unreliable to include excess waiting time, comfort and safety. Opening hours were also omitted. The focus is on the productivity growth in the industry as a whole. In the interpretation of the results, we try to identify the effects of the fixed subsidy reform of 1990.

Our study covers the period from 1988 to 1996. Efficiency in the four years 1988, 1989, 1993 and 1996 has been studied. The units studied are ferry links in the national road system, not single ferries. The following questions are treated at the industry level:

1. Has cost efficiency in the production of the ferry transport *supply* improved in this period? What has been the role of the fixed contract reform in this?
2. Has efficiency improved in the use of a certain ferry transport supply to produce ferry transport *services* (actual passenger kilometres and car kilometres)? What has been the role of the fixed contract reform in this?
3. Has *cost efficiency* in the production of ferry transport services improved in the period? What has been the role of the fixed contract reform in this?
4. How could the regulation of the national roads ferry industry be improved, based on what we find in this study?

Method

Efficiency measures and DEA

In the multi-product and multi-input case, productivity is measurable as some index of the outputs divided by some index of the inputs. If all inputs and outputs are market goods, a natural measure of productivity would be sales divided by costs, that is, using the market prices to form the indices. However, there are cases where prices do not exist or do not reflect the value we attach to the products. In other cases, we are interested in the purely technical transformation of inputs to outputs and would like to define the productivity of this transformation without making use of prices. The method we will apply – Data Envelopment Analysis or DEA – will make productivity well defined and measurable even in these cases.

Regardless of the competence and effort of the crews and the ferry company, there are upper limits to the production of ferry services with a given amount of inputs. This upper limit is a *norm* for what is achievable. When such a norm is established, we can speak of the efficiency of the ferry link. Efficiency is productivity as measured relative to a norm. A ferry link that achieves the productivity of the norm is called efficient. It is natural to seek a measure of efficiency between 0 and 1, where 1 is efficient production, 0 is the state where nothing useful comes out of the production process, and a number between 0 and 1 characterises the degree of inefficiency.

The norm could be derived from theory or practice. If we have data for a large set of ferry links, we might assume that the level of achievement that has proved to be attainable for the best of them should also be attainable for the others. It defines a practical norm for all of them. Furthermore, we assume that any linear combination of ferry links achieving the norm is also attainable, and that unnecessary inputs and outputs could be disposed of freely. These assumptions make the norm a continuous surface in the input-output space. Such a norm is often called a best-practice production frontier. Figure 1 shows the best-practice production frontier in the case of one input and one output, and will be used to illustrate the efficiency measures that we apply.

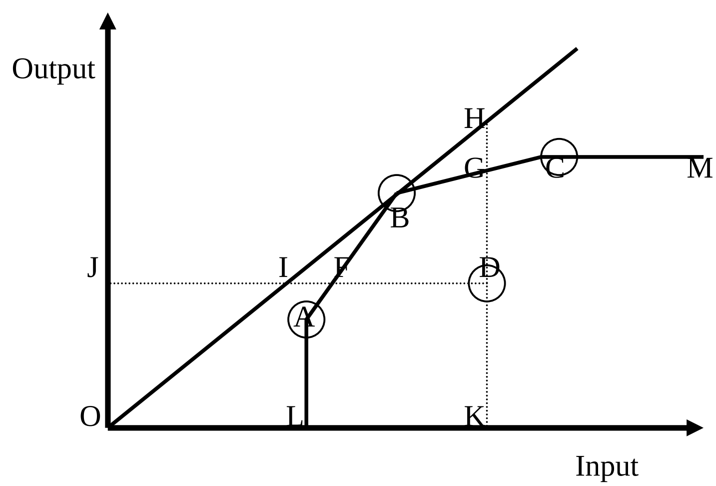

Figure 1 One input and one output. Constant returns to scale and variable returns to scale best-practice production frontiers.

In figure 1, the four circles mark our empirical data for four different units, A, B, C and D, assumed to produce under the same conditions. Assuming the technology is constant returns to scale, the productivity measure of point B is output divided by input, or the *slope* of the ray from the origin through the point B. Obviously, the rays from the origin through the other points have smaller slopes, so the achievement of point B constitutes the norm for all of them – point B is efficient. By the definition of constant returns to scale, any point on the ray from the origin through B is achievable. No point above that ray is proved to be achievable by the data we have, so this ray is the best-practice production frontier.

Consider the inefficient point D. One natural ways of measuring its efficiency is to take the ratio of the line segments DK and HK, that is DK/HK. This is measuring efficiency in the output-maximising direction. If D improved along this direction, it would ultimately get an efficiency score of HK/HK = 1. Another, equally natural efficiency measure would be in the input-minimising direction, that is IJ/DJ. The logic of the situation determines which of these two measures is the right one in each case. The efficiency of the other points A and C can be measured in the same way.

Now consider the case of variable returns to scale. The points A, B and C are proved to be achievable by our data, and by our assumptions any points on the line segments AB, BC, LA and CM are also achievable. No point to the north and west of this surface has been proved by the empirical data to be achievable. So {LA, AB, BC, CM} is the best-practice production frontier. The efficiency scores for A, B and C would be 1, while point D gets a score of DK/GK in the output-maximising and FJ/DJ in the input-minimising direction. Note that except for B, these scores are higher than in the case of constant returns to scale.

These efficiency measures can be extended to the case of many inputs and outputs. Provided that we reduce all inputs in the same proportion when going in the input-minimising direction, and increase all outputs in the same proportion when going in the output-maximising direction, the scores will be equally well defined in this case (Førsund and Hjalmarsson 1979). However, when all possibilities of reducing inputs or increasing outputs in an equiproportional way are exhausted, it might still be possible to reduce some inputs and increase some outputs. Such possibilities are called slacks, and they might be present both for "efficient" and inefficient units. Obviously, an "efficient" unit with slacks is not efficient in the precise economic sense, so the set of efficient units is a subset of the units on the frontier (units with an efficiency score of 1).

DEA is a family of linear programming problems that finds the units that belong to the best-practice frontier and turns out efficiency scores, slacks etc. for all units in an empirical sample of units producing the same outputs with the same inputs. Assumptions about the technology (constant, variable or non-increasing returns to scale) and the direction of improvement will have to be made. DEA was introduced by Charnes, Cooper and Rhodes (1978) and is now a large field of research and applications. To get a feeling of what a DEA data programme does, we can go back to our initial definition of productivity as an index of outputs divided by an index of inputs. Suppose we allow each unit the right to choose for themselves the weights to use in the two indices, and that they choose the weights that give them the highest efficiency score, subject to the condition that if these weights are applied by the other units in the sample, no-one gets a score of more than 1. This is the optimisation problem that DEA solves for each of the units. It means that instead of using fixed prices, each unit is allowed to put a high value on output that it is good at producing, and a low value on inputs which it uses a lot of. If some other unit or combination of units performs better even with these weights, there is a fairly strong case for deeming our unit inefficient.

Malmquist indices

To study productivity growth over time, we use Malmquist indices calculated from the efficiency measures for the single years. Such indices are defined somewhat differently by different authors, but basically they turn out the efficiency score of a unit in a certain year relative to the best-practice frontier of another (base) year, and divide it by the efficiency score that the same unit obtained in the base year (or any previous year, provided the base year frontier is used as the norm). A Malmquist index above 1 means productivity growth and under 1 means productivity decline. The Malmquist index may be decomposed in one factor showing how the current frontier has changed from the base year frontier, and another factor showing if the unit is getting closer to the current frontier or not. The first factor is called "technical change" and the second is called "catching up".

Industry performance

In the present study, the issue at stake is the performance of the ferry industry as a whole. Has it improved or deteriorated after the introduction of fixed subsidies in 1990? However, when location makes a difference to the production possibilities, or when the output is site specific, the concept of an industry is problematic. Any weighting of the individual performance indicators to form an aggregate industry performance indicator implies a value judgement. Will the industry performance indicator give preference to the development of the high-volume, low subsidy links or the low-volume, high subsidy links?

In Norwegian DEA studies, the performance of the average unit (using the average amount of each input to produce average amounts of outputs) has often been used as an indicator of the performance of the whole industry. However, if the possibilities for improvement vary with the particular conditions of each unit, the average unit could not represent anything but itself, so this is not a good idea here.

In this study, our industry performance indicator for one of our models has been the weighted average of the individual Malmquist indices, using fare revenue on the links as weights. This measure gives preference to the high-volume, low subsidy links. To see if the development has been much different for the low-volume links, the results have been compared with the results using link costs as weights. In the other two models reported here, the individual values are weighted by costs.

Data and models

The National Road Administration keeps a database of information about the ferry links. It also receives accounts and financial information from the ferry companies and produces accounting statistics (not public).

In total, there were 113 ferry links on national roads in 1996, and 32 more on county and municipal roads. Since the pattern of sailings on the complex links were often subject to seasonal and time-of-day variations that were difficult to establish, it was decided to include only simple shuttle links. For our purpose, it was important that the links were unaltered in the period 1988-96 and had a full set of fairly reliable data. This left us with 43 links. Most of them used only one ferry. On an annual basis, the number of ferries in each link in 1996 varied from 0,75 (seasonal service only) to 2,5 with an average of 1,2. The 43 links turn out to be representative for the industry as a whole in important respects. They are listed in Minken et al (2000).

Except for 1996, it was not possible to get reliable accounting data at the link level. Even if we would have liked to use labour, capital, energy and other cost as inputs, we had to settle for total annual link costs as the only input. Capital costs were a part of this. However, capital costs could not be taken from the accounts or any other part of the database. This is because the accounts only contained actual loan repayment and interest paid. We used available information on the building cost of some of the ferries and estimated a function for the building cost of all types and sizes. From information about the types and sizes of the ferries in each link and the part of the year they were applied, we computed annual capital costs for each link as the annuity of an infinite chain of investments in the same types of ferries. This was done for each year, as there were considerable changes in the allocation of ferries to links at the time, as well as a fairly rapid rate of renewal and scrapping.

The following variables were used in one or more of our DEA models:

I1 Annual operating cost of the ferry link, including capital cost

P3 Annual number of ferry round trips

P4 Length of a round trip in the ferry link

P5 Mean capacity per round trip, measured in private car equivalents (PCE)

P6 Average capacity-kilometres (PCE-km) per round trip

S1 Annual number of PCE transported

S2 Annual number of passengers transported

S3 Mean trip length for transported PCE's

S4 Annual transport work in PCE-km

S5 Annual transport work in passenger-kilometres

For our simple shuttle links, S4 = S1*S3 and S5 = S2*S3. Also, P4 = 2*S3 and P6 = P4*P5.

Three DEA models were set up. The first studies cost efficiency in the production of three outputs: crossings, capacity per crossing and the length of the crossings. The reason why we do not multiply these three products to get the annual number of capacity kilometres of the link, is that it makes a difference to costs and to travellers how the capacity kilometres are composed of these three factors. Average frequency is captured in the number of crossings, average ferry size is captured in the capacity per crossing, and even the effect of speed on capital and operating costs is implicitly contained in the relationship between input and outputs. For the links with no turn-around time and only one ferry, speed as a quality to travellers will also be reflected in the number of crossings.

The second model studies how the ferry transport supply defined by the three products of the first model is used to produce trips for passengers and cars. More precisely, we use two inputs, the number of crossings and the number of capacity kilometres per crossing, to produce passenger kilometres and PCE-kilometres (PCE = private car equivalents). The third model studies cost efficiency in the production of ferry services, as defined by the three products passenger trips, PCE-trips and ferry trip length.

The three DEA models are tailored to provide the answers to the three first questions above. As it turns out, we also use information at a more aggregate level to provide clues to the answers. Two important quality aspects - the frequency at low traffic periods and the number of cars left behind in peak traffic conditions - could not be included in the models for lack of reliable data. Thus we cannot be entirely sure that productivity growth in the second model is not achieved at the expense of these quality aspects.

The three models are summarised in table 1.

Table 1. *The three models*

Model	Inputs	Output	Returns to scale	Direction
Supply model	I1	P3, P4, P5	Variable	Input-min
Service model	P3, P6	S4, S5	Variable	Output-max
Cost efficient service model	I1	S1, S2, S3	Variable	Input-min

The length of the crossing, or ferry trip length, is obviously not an output that could be controlled by decision-makers. However, these outputs are only used in models with input-minimisation, where the levels of all outputs are kept constant.

Version 1.0 of the OnFront™ programme, supplied by Economic Measurement and Quality i Lund AB, was used. This programme did not allow us to use the chained Malmquist indices of Førsund (1993) that we would have preferred, but we could compute them from the model output ourselves. Also, it would have been nice to have a Malmquist index based on variable returns to scale. In this study, all Malmquist indices are based on constant returns to scale, and the two last columns of table 2 are only relevant for the single year efficiency analyses.

Results, discussion and conclusions

DEA and Malmquist analysis cannot tell us the causes of the observed development. Therefore they must be combined with other information. Often, this means to perform regression analyses on the efficiency scores. But when we want to find the effect of an event that affected all the units (the fixed subsidy reform), this will not do. Tables 2 and 3 shows some aggregate statistics that can be derived from our data, and which will be utilised in the interpretation of the results. The data pertain to a slightly wider set of 51 ferry links, including the 43 simple links and 8 more complicated links.

Table 2. *Number of ferries employed, capacity of fleet, average ferry size and capital costs in 51 ferry links. Development from 1988-1996.*

	1988	1989	1993	1996	Growth in per cent
Number of ferries employed in whole years	61,7	58,9	59,0	60,6	-1,2
Capacity of the employed fleet in PCE	2859,0	2803,0	3621,5	3909,3	36,7
Mean ferry capacity in PCE	46,3	47,6	61,4	64,5	39,3
Capital costs	149,6	145,9	200,7	219,4	46,7

Table 3. *Supply, demand, mean trip length and capacity utilisation rate in 51 ferry links. Development from 1988-1996.*

	PBEkm supplied (P3*P6) (1000 km)	PBE transported (S1) (1000 units)	Distance per trip (S3) (km)	Capacity utilisation rate (per cent)
1988	4557	181,4	7,33	29,2
1989	4810	185,5	7,32	28,2
1993	5149	191,7	7,34	27,3
1996	5641	221,0	7,37	28,9

From table 2 it is seen that the number of ferries employed was reduced slightly ahead of the fixed subsidy reform and kept at that level since. The striking feature is however the growth in the ferry size in the nineties and the even stronger growth in capital costs. New and more expensive ferry types were introduced. The high capital cost of these types might however be offset by lower operating costs. Table 3 shows how this development combined with the slow growth of demand during the economic downturn of the early nineties to produce falling capacity utilisation rates. However, from 1993 to 1996, demand picked up again and reversed this trend.

From the data of our 43 simple links, we can find that the number of round trips showed zero growth from 1988 to 1993 and a moderate total growth of 0,6% from 1993 to 1996. Thus near-zero growth in frequency and strong growth in the capacity provided and the capital employed characterises the period. (Comparing the mean ferry size from table 2 with the capacity-kilometres provided according to table 3, it seems the number of sailings have gone *down*. This impression might however be wrong if the new large ferries were available for shorter periods than we have assumed, or if the ferry companies' reports to the ferry database were inaccurate).

We now turn to the results of the Malmquist analyses. With respect to productivity growth, the results of the supply model are summarised in table 4, and the corresponding results for the service model and the cost efficient service model are shown in table 5 and 6, respectively.

Table 4. *Industry productivity growth in the supply model and its decomposition into technological change and catching up.*

Period	Malmquist index (productivity)	Technological change	Catching up
88-89	1,01	0,96	1,05
89-93	1,00	0,89	1,12
93-96	0,98	1,09	0,89
88-96	0,99	0,94	1,05

Table 5*.* *Industry productivity growth in the service model and its decomposition into technological change and catching up.*

Period	Malmquist index (productivity)	Technological change	Catching up
88-89	0,98	1,00	0,99
89-93	1,02	1,04	0,98
93-96	1,15	1,15	1,00
88-96	1,10	1,13	0,98

Table 6. *Industry productivity growth in the cost efficient service model and its decomposition into technological change and catching up.*

Period	Malmquist index (productivity)	Technological change	Catching up
88-89	0,98	1,07	0,92
89-93	0,96	0,81	1,19
93-96	1,03	1,15	0,89
88-96	0,97	0,98	0,98

In all three tables, the columns "Technological change" and "Catching up" should be interpreted cautiously, as the efficient units under constant returns to scale in any one year are very few in number. The overall impression is a slight decrease in cost efficiency, both with respect to the production of the supply and the production of the actual transport services. However, the utilisation of the supply to produce actual transport services has improved strongly, especially since 1993.

This apparent paradox can be partly explained by the weights that are used to form the industry Malmquist indices. In the case of table 4 and 6, link costs are used, whereas ticket revenue is used in table 5. If link cost weights were used in table 5, productivity growth in the first part of the period, 1988-1993, would have been 3% less, and the growth over the whole period would have been 1,07 instead of 1,10. Thus the low-subsidy (high volume) links where better able to adapt their supply of frequency and capacity to changing conditions (fixed subsidy contracts and slow growth of demand) in the short run.

For the last period, 93-96, all parts of the industry could benefit strongly from the new upsurge in demand (the Malmquist index in table 5 would have been 1,15 for that period even if we used costs as weights). The reason seems to be that frequency was kept fairly constant, so the capacity of larger ferries introduced in the early nineties were better utilised. Even so, the cost of producing frequency and capacity kept rising (table 4).

It is not clear who is responsible for the near-constant frequency throughout the period. It might initially be a reaction on the part of the companies to the fixed subsidy contracts. It would also be a natural response to the increase in ferry sizes. The increase in ferry sizes was brought about by the renewal program and the building of bridges. Under the current regulatory regime, a reallocation of ferries across the industry takes place in such cases, resulting in larger ferries in a lot of links and the scrapping of small and old ferries. Even if the individual companies is responsible for buying ferries and contracting on new ones, it is the National Road Authority who controls the whole process and must be responsible for the average ferry size at the industry level. The local companies will be eager to get more modern ships for their links and will probably expect to be reimbursed for the additional capital costs, but not for an increase in frequency.

Thus the fixed subsidy reform might have initiated a small drop in frequency as a cost-saving measure on behalf of the companies, while the subsequent near-constant frequency might be the result of government policy, both with respect to ferry renewal and the attitude taken in the negotiations about the fixed subsidy contracts.

In the light of the high capital costs of the new ferry types, one would have expected a larger drop in cost efficiency than is seen in table 4. We therefore think that the table is evidence that the companies did reduce their costs in other ways, but at a slower rate in the last part of the period, 93-96. This tendency might be attributed to the fixed subsidy reform, although this is uncertain.

Table 6 indicates that the need for subsidies in the industry as a whole may not have been reduced.

The high productivity growth in the service model might have taken place at the expense of unmeasured quality aspects like excess waiting times and the frequency in low-demand periods. Ideally, one would have needed a round of interviews to make sure that this did not happen.

To sum up, the answers to the questions asked in the study are:

1. There has been zero growth in productivity with regard to cost efficient production of the ferry transport *supply*. The fixed contract reform has probably contributed to not making it negative, but this effect has diminished after a few years.
2. There has been productivity growth with respect to the efficient use of the ferry transport supply to produce ferry transport *services*. This is probably mostly due to the heavy traffic links. The fixed contract reform may have contributed to the observed development either by inducing the operators to adjust their schedules to achieve higher capacity utilisation, or by inducing government to be more restrictive with frequency increases. The details of supply in high and low demand periods have not been studied, which makes it difficult to say if the observed productivity growth is accompanied by unwanted quality reductions.
3. There may have been a productivity decline in the cost efficient production of ferry transport services. The need for subsidies for the industry as a whole may not have been reduced.

The potential for improvement

Table 7. *Industry efficiency assuming variable returns to scale.*

	1988	1989	1993	1996
Supply model	0,83	0,82	0,79	0,83
Service model	0,82	0,82	0,81	0,79
Cost efficient service model	0,82	0,82	0,83	0,81

The numbers in table 7 are produced by running the three DEA models with variable returns to scale for each of the four years. Industry efficiency is calculated as a weighted mean of the efficiency scores for the individual units, using link costs as weights in the supply model and the cost efficient service model and ticket revenue as weights in the service model. These weights are the same that were used to compute the industry Malmquist indices above.

By and large, one could not expect it to be possible to remove inefficiencies due to scale, since the scale of the operation of each ferry link is pretty much given by demand conditions and other uncontrollable conditions like the length of the crossing. This is why variable returns to scale have been assumed when it comes to assessing the potential for improvement. The overall impression given by table 7 is that a potential of 20% exists. However, since a given ferry fleet will have to be allocated to the links, some of this potential can only be realised slowly as the fleet adapts to the particular conditions of the links in operation. In the short term, any improvement in size in individual links would mean a worsening for other links. It would probably not be realistic to assume a potential of more than 15% in the short to middle term – and even in the longer term if the number of links keeps declining due to new bridges. Also, the composition of the total fleet is at present not under the control of the companies.

The scale properties of the models have been studied more closely. In the supply model, most units produce under increasing returns to scale, while 7 are scale efficient and 11 experience decreasing returns to scale (1996 figures). Assuming variable returns to scale, 10 units are efficient, compared to only four if constant returns to scale is assumed.

In the service model, however, 13 units are scale efficient and the rest are experiencing increasing returns to scale. The four units with the highest volumes of PCE-kilometres, together with two medium-sized units, are efficient under constant returns to scale. This confirms that size makes it easier to adapt supply to demand. There are 11 efficient units under variable returns to scale.

Finally, in the cost efficient service model, the five largest links as measured by costs are experiencing decreasing returns to scale, two medium sized links are scale efficient, and the rest experience increasing returns to scale. Assuming variable returns to scale, the five largest by cost are efficient (along with five others). Obviously, from a cost efficiency point of view, it is possible to get too big, but at least it makes it easier to adapt supply to demand.

Implications for regulation of the industry

What are the implications of these results for the regulation of the industry?

At the moment, the use of auctions to allocate ferry links to operating firms is a hot issue. We do not intend to take it up here, but we may note that to the degree that auctions are seen as a way to circumvent the rather cumbersome system of ferry renewal and allocation in place now, there is the obvious alternative to change those rules. As a start, it must be recognised that the economic life of a ferry is 30 years ore more. This should be reflected in the depreciation rules.

Much longer periods of depreciation will give government and operators alike a better grasp on the real cost of capital. Secondly, the current very low maximum level of return on own capital should be abolished. It means that the operators are reluctant to invest their own capital in new ferries, and come to rely on a programme of state guaranteed loans for this purpose. This lifts the decisions to acquire new ferries to a level where it does not belong, as the huge growth in ferry sizes and close to zero growth in crossings show.

Government must of course set standards for ferries to ensure that they can be used in as many links as possible, here and abroad. This will give us a functioning second hand market for ferries, laying the foundation for increased competition in the long run. Government must also set quality standards. Beside this, decisions on ferry sizes, acquisitions etc. belong at the company level.

Government should retain control over maximum prices and subsidies. The subsidy mechanism can however not be based on a common formal norm, as our study shows that ferry links produce under widely varying conditions, and cannot be expected to all achieve the same unit costs. It is recommended to include a premium for frequency increases in the subsidy mechanism to get the operators to internalise the open and hidden waiting costs of travellers. As for prices, it is a good idea to allow peak load pricing in the form of summer prices or in other ways, to prevent the use of too much unutilised capacity during large periods of the year.

A freer allocation of ferries and correctly designed subsidy mechanisms and price regulations will open the way for realising a part of the potential for efficiency improvements that we have found. We leave it for the future to design these regulatory measures in detail.

We warn against the combined use of a ferry renewal programme that gives us larger and larger ferries and some form of common cost norm. This will either mean reduced frequencies or bring about increased subsidies over time.

The effect of the fixed contract reform might have diminished after a few years. The same tendency might as well show up in more sophisticated schemes to provide incentives to reduce costs. That is, it takes only a few years before any scheme that seems to give every incentive to the operator to reduce costs, transforms into a virtual cost plus contract. The reason is that the contract negotiations is a game that is repeated each year (Laffont and Tirole 1993). The solution is to offer longer term contracts that leaves as much as possible of the responsibility of cost overruns to the operator, and gives him a large part of any cost savings. To avoid the possibility that such contracts will be very costly to the government, they should either retain the present reports to the ferry database to learn as much as possible about costs and revenue of each link, or introduce auctions.

We think the model apparatus built up in this project to analyse the productivity growth in the ferry industry in the nineties might also be useful in the future. Among other things it could be used to assess the total subsidy requirement of the industry in a fairly objective way.

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