Institute of Economic Studies, University of Iceland

Institute of Economic Studies
Odda v/Sturlugötu
Tel: 525-4500/525-4553
Fax: 525-4096
Webpage: www.ioes.hi.is
E-mail: ioes@hag.hi.is

Skýrsla nr. R03:03

Economic Performance of the North Atlantic Fisheries

Final report

Desember 2003

Economic Performance of the North Atlantic Fisheries

Final report

Sveinn Agnarsson

Institute of Economic Studies

University of Iceland

Aragata 14, 101 Reykjavik

Email: sveinnag@hi.is

May 2003

Table of contents

1. Introduction

The project Economic Performance of the North Atlantic Fisheries was initiated in 1997 with the primary aim to advance knowledge in the area of productivity measurements in industries heavily dependent on natural resource use, such as fisheries, and to stimulate debate on the productivity and efficiency of the North Atlantic fisheries in a comparative perspective. The project organisers hailed from four North Atlantic regions, where fishing plays a major economic role; the Faroe Islands, Iceland, Newfoundland and Northern-Norway. To set the stage, a symposium was held in Reykjavik, Iceland, in September of 1997, where researchers from all over the world presented either theoretical papers on various issues related to fisheries, or descriptive studies of the regions involved.

The project was divided into three phases. In the first stage the harvesting and fish processing sectors in the four regions were analysed, while in the second phase detailed micro-level data was to be gathered on the fishing industries in these countries. During the third and final part of the project, the data gathered was to be used for thorough analysis and comparisons. The different parts of the project are discussed below, and the main findings of each paper briefly presented.

2. Theoretical papers

A number of theoretical papers were either presented at the symposium in Reykjavik or written later. The papers are outlined below, first the more general papers and then those papers dealing with natural resources and fisheries in particular.

2.1 General papers

The Malmquist productivity index, TFP and scale

Productivity is a key concept of production theory. There is a general consensus that productivity measures how productive inputs are in a transformation of inputs into outputs. The most common and natural measure of productivity is therefore outputs relative to inputs. In a situation with multiple inputs (and single or multiple outputs) total factor productivity (TFP) is used when the impact of all factors are measured simultaneously. The consensus view on the definition of TFP seems quite clear from the literature: “A change in total factor productivity is usually interpreted as: (i) the rate of change of and index of outputs divided by an index of inputs (Jorgenson and Griliches [1967, p. 253] or (ii) a rate of shift in a production function (Tinbergen 1i42] or Solow [1957, p. 312].” (Diewert (1981), p.17). These definitions are so well known among economists that Griliches states: “Whether they measured it [technical change, or change in total productivity, or efficiency] as a shifter of the production function … or as an output-over-input index …, they did not claim any particular originality for it. They were making illuminating calculations for a concept that was obviously already there.” (Griliches (1996), p. 1326). As to the index definition, Griliches states: “The first mention of what might be called an output-over-input index that I can find appears in Copeland (1938)” Griliches (1996), p. 1324).

The measurement of TFP has been an important and active issue in the economic literature on the aggregate residual (Griliches, 1994), at least since the seminal contribution by Solow (1957). The basic approach is to base the theoretical productivity measure on explicitly formulated production functions defined on continuous time, associating productivity improvement, measured as the change in output not accounted for by changes in inputs, with a shift in the production function. An important assumption is that there is no inefficiency. This approach based on production relations can therefore be called the technology approach.

However, it is very difficult, if not impossible, to follow up these theretical measured in practical applications. First of all, real world observations are always discrete. Secondly, establishing explicit production relations for discrete time observations is itself a formidable task. Various forms of approximations have therefore been used when calculating such productivity measures in practice.

A way of avoiding the problem of approximation is to base the productivity measure on a pure index approach, as represented by the most popular Törnqvist index, i.e. calculation total productivity change for discrete time observations as an output index divided by an input index, without using any knowledge of production technology. Prices must then be available, and cost shares and/or revenue shares are used as weights. The pure index approach can be linked to the technology approach based on production relations in the case of some special functional forms of the later, and assuming optimising behaviour (i.e. revenue maximisation, and/or cost minimisation).

The exact correspondence between the general translog production relation and the Törnqvist index was shown by Diewert (1976).

Parallel to access to better data and a need for a more micro-oriented approach, a more profound link between theoretically attractive productivity concepts and the nature of available data was clearly wanted. A stated purpose of Caves et *al.*. (1982) CCD), introducing the Malmquist productivity index, was just to introduce index number measures of productivity without having to approximate productivity concepts based defined with respect to continuous time. However, this index is explicitly based on production relations, expressed by distance functions (Shephard, 1970) for, which parameters have t be known. Thus, the index approach comprises two strands, the pure and the technology based.

As to the empirical potential of their approach, it is interesting to note that CCD themselves stated, with reference t the need for knowledge of the parameters of the distance functions in order to compute the indices: “Thus, the empirical usefulness of the Malmquist index is limited” (p. 1394). However, the reason for the growing popularity of the Malmquist index in recent years is that Färe et *al*.. (1994b), originally distributed in 1989 as a working paper, demonstrated that the values of distance functions for piecewise linear technology sets could easily be computed applying linear programming techniques as in the increasingly popular DEA-type Charnes et *al*.. (1978) analysis: In the 1994 bibliography of Seiford (1994) there is over 400 published applications of DEA.

In his paper on the Malmquist index, TFP and scale, Førsund (1997) notes that there seems to be a lack of effort in the literature relating the Malmquist index to the basic definition of TFP as outputs relative to inputs. Further, Førsund points out that there is some confusion as to how to interpret the Malmquist index in the case of non-constant returns to scale. In his paper, Førsund attempts to fill the former gap and show how the latter problem can be resolved. Since the questions at hand are of general nature piecewise linear models will not be used explicitly, but the author hopes the results can easily be adapted to that case.

A question not addressed adequately in the literature is how the Malmquist index relates to the concept of TFP. Reasonable definitions of TFP in the case of multiple outputs and multiple inputs are forming an output index over an input index using linear weighting, or using vector norms as averaging devices. The TFP-interpretation of the Malmquist index depends crucially on whether the observations are efficient or not. In the former case, as assumed by CCD, the Malmquist index measures the frontier shift at one of the observations, and there are no limitations as to the nature of the returns to scale.

However, when inefficient observations are introduced, as was the main contribution in Färe et *al.*. (1994b), TFP encompasses both catching up with the frontier and a frontier shift. But then the question of scale properties is decisive for the interpretation of the Malmquist index. The main result is that the index can only be related to the "natural" definitionof TFP if the technology is both constant returns to scale (CRS) and simultaneous or inverse homothetic. It is only under these conditions that the multiplicative decomposition into catching-up and frontier shift introduced in Färe et *al.*. (1994b) makes sense, and a percentage point when calculating catching-up can be combined with a percentage point when calculating shift.

But it is both of theoretical and empirical interest to be able to deal with variables returns to scale (VRS). In the latter case, the productivity change at optimal scale can be decomposed multiplicatively into a term measured by the Malmquist productivity index, and a term expressing the effects of variations in scale properties for the relevant reference points on the production frontier. Note that the Malmquist index itself has no obvious economic interpretation. The key variables involved in these terms are Farrell gross- and pure scale efficiency measures. These measures are rather awkwardly treated in the literature, making use of both CRS and VRS technology at the same time. The definitions adapted here should straighten up this confusing practice.

Both the productivity change at optimal scale and the scale effects can be calculated by means of computing directly without computing the Malmquist productivity index. When CRS the scale effects reduces to 1, and also assuming inverse homotheticity the productivity change at optimal scale reduces to the basic TFP measure.

An alternative to the Malmquist productivity index is to use a Malmquist output quantity index over a Malmquist input quantity index, as originally suggested by Moorsteen (1961) and studied in Bjurek (1996). This MTFP index does not correspond exactly to a basic TFP measure. Again, the productivity change at optimal scale substitute for the TFP measure when operating with a VRS technology, and a scale term can also be identified. But in contrast to the Malmquist productivity index, the MTFP index is constructed as an output index over an input index, so the number calculated is also a legitimate TFP measure incorporating the scale nature of the production technology. Assuming CRS the scale terms reduce to 1, and also assuming inverse homotheticity reduced the productivity change at optimal scale to the basic TFP measure. In fact, in this case all the Malmquist indices become equal, and equal to a basic TFP measure.

It should be noted that the so-called separability test of an TFP index, suggested by Førsund, is satisfied by a homothetic function, so it is to be expected that homotheticity plays a central role in relating the Malmquist indices to TFP. But the nature of the technology is an empirical fact, and non-homotheticity may be the normal case. This means that the Malmquist indices cannot be interpreted unambiguously in terms of basic TFP.

Empirical applications have usually been based on piecewise linear technology. It should be fairly straightforward to apply the results here to that special case. In Bjurek et *al.*. (1996) numerical exercises are performed to see the empirical importance of the differences between some of the Malmquist indices for this case. The empirical studies assuming CRS have not also assumed homotheticity. In view of the importance of homotheticity, the author recommends that possibilities for specifying this property should be developed, and differences between the specifications studies.

Externalitities, property rights and profitability

In their paper "Externalities, property rights and profitability, Rolf Färe, Shawna Grosskopf and Wen-Fu Lee introduce Data Envelopment Analysis (DEA) models that can be used to compute the way firms' profitability changes when the assignment of property rights changes.

Externalities in production are frequently observed. Generally, such externalities result in market failure, i.e., even a perfectly competitive market does not necessarily lead to a Pareto efficient outcome. To correct such failures, one remedy is the creation and enforcement of property rights, often referred to as a Coase (1960) solution. Although such a solution should be efficient, it will affect the profitability of the agents involved, which will depend on which party receives the property right. In this paper the authors investigate the relationship between property rights and profitability using DEA and the network theory of production. Although externalities may be positive (economies) or negative (diseconomies), the paper is confined to the latter case. Here, an upstream agent produces good and bad outputs, and the bad outputs adversely affect the downstream agent's production opportunity.

The problem addressed in this paper can easily be solved using DEA, if the relevant data is available. Despite their simplicity, the models explicitly take into account key aspects involved in production externalities: First, the joint production of good and bad outputs. Second, the role of bads as an "intermediate" input which adversely affects production of other firms. Third, the potential lack of free disposability of bads. Formulation of these problems in a profit maximising framework allows the authors to simulate the redistribution of "income" which would result from a change in ownership of property rights as well as allowing for a solution for the efficient outcome under merger or internalisation of the externality.

The authors note further that the network output vector in the model is not necessarily greater than the sum of the two independent technologies' output vectors, but the network profits are at least equal to the sum of the two independent technologies' profits. The potential profit gain from internalisation of the externality can then be measured, which in turn could be used a compensation benchmark for the agents involved when considering merging or buying out. Alternatively, this could be used to derive optimal quantity constraints for the effluents, or to verify whether existing restrictions are "optimal".

Profit efficiency

In a related paper, Rolf Färe and Shawna Grosskopf (1997) show how a modified definition of profit efficiency proposed by Nerlove (1967) can be used to derive both input and output based decompositions of Farrell (1957) efficiency, as special cases along with the associated Mahler inequalities. This paper thus generalises the results obtained in Färe and Grosskopf (1995) where it was shown how Farrell efficiency measured could be derived from a Mahler inequality, which related the cost function to the input distance function. The paper also takes up where Färe, Grosskopf and Roos (1996) left off with profit efficiency.

Outliers

"Efficiency analysis in uncertain operating environments: The problem with outliers" is the topic of the paper by Kevin J. Fox. The author notes that firms may be unfairly labelled as inefficient, using standard efficiency analysis techniques, due to random occurrences beyond their control. The fishing industry is in particular subject to random events, which may make the performance of fishers appear poor. Sources of uncertainty include catch variability and weather conditions. These are conditions, which are difficult to incorporate into standard efficiency analysis methods. It is then particularly important in such a context to identify possible outliers and the nature of these outliers. For example, are they outliers because of the scale they are operating at, or because of their mix of input utilisation and output performance? It is the outliers of the "mix" kind which one would expect to find where firms face uncertain environments – firms with the same technology and level of inputs may have quite different output levels due to random occurrences. In practice, firms typically use different technologies and input mixes, which make outlier detection considerably more difficult than just identifying firms with above and below average output performance.

The method of outlier detection employed is that introduced by Fox and Hill (1996) and allows for the possibility of both multiple inputs and multiple outputs. While the method is applicable to the general problem of outlier detection, the application of the method is particularly attractive in the context of efficiency analysis. Nonparametric methods based on constructing a best-practice frontier using linear programming techniques, such as DEA (Farrell 1957, Charnes, Cooper and Rhodes, 1978), do not yield the OLS residuals nor parameters, which are typically used by outlier diagnostics. Moreover, the detection of outliers can be complicated by the existence of multiple outputs. The stochastic frontier approach to efficiency analysis (Aigner,

Lovell and Schmidt, 1977) does allow for some stochastic variation n estimating the frontier, but requires the specification of particular distributions for stochastic deviations from the frontier, and the fit can similarly be affected by outliers. The only substantial difference in this case is that the efficient frontier can be affected by outliers that are well inside the frontier.
The results generated by frontier based efficiency models are particularly sensitive to outliers, since frequently it is the outliers that define the frontier. Hence it is perhaps surprising that the detection of outliers has not received more attention in the efficiency measurement literature. One notable exception is Wilson (1993), which generalises the outlier measure proposed by Andrews and Pregibon (1978) to the case of multiple outputs.

The method proposed here does not draw a distinction between observations on the best-practice frontier and inside the frontier, allowing the effects of uncertainly, measurement and other errors in all observations to become apparent. This is not possible if a sensitivity analysis approach to outliers detection is taken, e.g. if observations are deleted and the effect of their absence on average efficiency scores is used as a criterion.

The application of the model to Icelandic fishery data demonstrated the role that uncertainty and measurement errors can play in a ship being identified as either efficient or very inefficient. Using this method, ships which are different in some important aspect can be singled out for further investigation before drawing conclusions about efficiency.

2.2 Natural resources and economic growth

Despite extensive research, the empirical growth literature has only identified a couple of robust determinants of the rate of growth of per capita gross domestic production (GDP) across countries; initial GDP and ratio of investment to GDP. A few more variables have been suggested by some writers, such as foreign trade, school enrolment, inflations, political instability, corruption, inequality and the preponderance of the primary sector in the economy. In their paper, Gylfason et *al.* (1997) focus on the link between the primary sector and growth.

Dutch disease

The authors contend that the division of GDP between primary and secondary production affects economic growth in the long run. The statistically negative correlation between the share of the primary sector in the labour force and the ratio of investment to GDP across countries suggests that excessive primary production may inhibit growth by reducing investment in physical capital. The main hypothesis put forward in the paper is that an abundance of natural resources and a corresponding preponderance of primary production tend to inhibit economic growth by discouraging investment in human capital.

The paper is intended to shed further light on the contribution of human capital to economic growth by pointing out the possible role of sectoral differences in human-capital creation in explaining cross-country differences in growth. In particular, the authors claim that the primary sector, which includes agriculture, fishing, forestry, and mining, may need – and also generate- less human capital than services and manufacturing. It is for this reason that countries with a comparative advantage in the production or primary output may consequently experience less economic growth. The dominant primary sector causes the currency to appreciate in real terms, thereby reducing the profitability of other exports. Other exports therefore decline, while consumers gain as the price of tradable consumption goods fall. The term Dutch disease was coined to describe this phenomena following the discovery of natural gas in the Netherlands in the 1960s. The appreciation of the British Pound following Britain's offshore oil discoveries in the late 1970s is another classic example. In this paper the Dutch disease argument is extended by describing how a floating exchange rate regime can provide (social) insurance for the dominating primary export industry at the cost of increased exchange rate uncertainty for all other industries. These problems magnify the "distortions" in the inter-sectoral allocation of resources, so that economic growth is further reduced.

To tackle these issues, the authors lay out a simple stochastic endogenous growth model with a tradable and non-tradable sector, where the former has access to two different kinds of production technology, which are referred to as the primary sector and the secondary sector. It is assumed that learning-by-doing and knowledge spillovers only occur in the secondary sector. The conditions necessary for the

emergence of a secondary sector, which escapes diminishing returns and generates growth, are describes in the presence of a dominant primary sector. These conditions involve a “growth threshold”, in the following sense: The real exchange rate must be low enough for investment (in human capital) to take place in the secondary sector and thus for the economy to grow. When, on the other hand, the real exchange rate appreciates beyond a certain level, there is no such investment and no growth.
Because of the human capital generation and knowledge spillovers in the secondary sector – externalities – it would be socially optimal for investment in the secondary sector to start before the growth threshold is reached. Further, an increase in primary sector productivity causes the currency to appreciate in real terms, thereby moving the real exchange rate away form the growth threshold. This is the Dutch disease.

The model implies that the rate of growth of output varies inversely with productivity in the primary sector, because a larger primary sector causes a real appreciation of the currency and thus reduces the profitability of investment in the secondary sector. Similarly, growth is directly related to foreign indebtedness in the model, because the increase in the non-interest external surplus required to service increased foreign debt depreciates the currency in real terms and stimulates growth.

These and other related hypotheses are tested using cross-section and panel data constructed from the Penn World Tables and the World Data Bank. The data span the years 1960-1992. The main conclusion is that the statistically significant inverse relationship found between the size of the primary sector and the average rate of growth f output across countries appear to dominate the positive relationship observed between education – i.e., school enrolment – variables and growth: The effects of schooling generally drop in size and significance when primary employment or primary exports are added to the regressions. This lead the authors to conjecture that the size of the primary sector may give a better picture of the level and changes in human capital across countries than school enrolment rates, which measure output by input.

Three symptoms

In a related study Herbertsson et *al.* (1999) examine some of the forms that the Dutch disease can take through both product- and labour markets. These involve an effect of primary-sector output – through real-wages and the level and volatility of real-exchange rates – on secondary-sector employment output and investment. In this article the authors therefore building on the study by Gylfason et *al.* and show how the Dutch disease can be manifested in a genuine market failure that consists of a breakdown of insurance markets. Thus the effect of the natural-resource windfall sometimes appear through pure relative price effects but, importantly, will sometimes involve a genuine failure of markets to achieve a socially efficient outcome. These include labour-market externalities in addition to the failure of private insurance markets.

Three symptoms of the Dutch disease are suggested: First, the higher is the primary sector output, the more appreciated is the real exchange rate. In the short run this leads to lower secondary-sector employment and output. This is the conventional form of the Dutch disease. In the medium run, investment in capital is also affected since the real exchange rate is now further away from the investment threshold. This threshold is defined as the real-exchange rate threshold at which it is optimal to invest in a marginal unit of capital. Second, the more volatile is the primary sector, the more volatile is real exchange rate and the higher is the investment threshold. Thus a given level of the real exchange rate is less likely to give a positive level of investment the more volatile is the primary sector. Third, the higher are primary-sector wages, the higher is the level of secondary-sector wages. This has an immediate impact and medium-term impact. In the short run, employment falls in the secondary-sector and hence also output. But in the medium- to long term investment is also affected since the real exchange rate has to appreciate further in order to induce firms to invest.

These symptoms can be summarised as follows: The discovery of an abundant but volatile natural resource, such as fish stocks, leads to lower employment and output of secondary-sector tradable goods in the short run – following an appreciation of the real exchange rate and a rise in real wages. In the medium to long run, this effect is amplified when investment is deterred for the same reason. The volatility of the real exchange rate contributes further to this negative effect on investment.

The second and the third symptoms of the Dutch disease outlined above reflect some form of market failure. The impact of the volatility of real exchange rates on investment is due to the absence of the relevant insurance markets. The increase in secondary-sector wages induced by wage hikes in the primary sector is similarly due to problems of imperfect information and moral hazards in the labour market.

The three symptoms are tested by looking at Icelandic data and some evidence found for the third symptom but not for the first two. The labour market appears to play a key role. When real wages in the primary sector go up following an increase in profitability, wages in the secondary market follow suite. Higher wages in that sector then reduce employment, output and investment. The key role played by the labour market comes as a surprise since the classic example of the discoveries of oil in Britain and natural gas in the Netherlands involved only movements of the real exchange rate. The nature of the link between wages in different sectors is though unclear. This could be due to efficiency wages, as in the model used in this study, or union behaviour. Icelandic unions encompass workers in different industries and it may for that reason be impossible for relative wages across industries to change. If this is so, the best way to deal with the adverse effects on the secondary sector may be through labour-market reform instead of the often-proposed primary-sector stabilisation funds.

2.3 Natural resources and policy

A fundamental problem for an economy based on a common property resource is that competitive private users fail to take into account the cost that their use may impose on other users. Without organised management of the resource, this implied that firms have no costs in harvesting besides payment to capital and labour. Hence, there are divergencies between the private costs of the firm and social costs and rent dissipation is the result. This is referred to as a problem of the commons. Furthermore, production externalities in harvest activities can be present. The idea is that a small resource stock lowers productivity because the effort required to harvest a given output increases. This introduces a negative relationship between the size of production factors in harvesting and resource stock. Thus, if one firm harvests an extra unit of the resource and decreases the stock, it increases the marginal cost of harvesting to other firms, an effect the firm itself does not take into account. Consequently there is a tendency in such an economy to allocate too much physical capital to harvesting, which leads to rent dissipation and over-exploitation of the resource stock.

Two of the project papers discuss this problem. Sørensen and Herbertsson (1998) consider the policy rules for exploitation of renewable resources in a macroeconomic perspective, while Grafton et *al.* (1997) describe the effects privatisation of the British Columbia halibut on technical, allocative, scale and economic efficiency.

Policy rules

In the face of market failures government actions may be called for in order to achieve an equilibrium closer to the efficient outcome. The most direct instruments available are implementation of property rights or Pigouvian tax schemes. By using one of the instruments, the first best solution can be obtained. One the other hand, it seems plausible that the management of such policies will require a high information level and therefore be costly. Hence, it is relevant to ask if a simple tax schedule requiring a lower level of information could be preferable for the economy in terms of increased welfare. Sørensen and Herbertsson (1998) investigate the complexity and sustainability of a Pigouvian tax applied to the economy by simulating the outcome chosen by a social planner who maximises the utility of his representative household. This tax schedule is referred to as the optimal policy. Furthermore, as an experiment, a constant quantity tax is implemented in order to evaluate the share of the maximum welfare increase that could be internalised by such a simple policy. This policy is referred to as the rule-of-thumb policy.

The applied framework is a growth model which is used to investigate the relationship between different government policies and welfare. The model is, *inter alia*, based on an ecology sector that describes the development of a renewable resource stock. Furthermore, there are two sectors on the production side of the economy: an industrial sector and a harvesting sector. Harvest of the resource involves no cost other than payment to capital. Furthermore, the single harvesting firm ignores the effects its decision may have on productivity and thus on production costs of other firms. The growth potential of the resource stock is limited: although the growing environment of the resource stock can be improved to some extent, thereby improving its natural growth rate in the ecosystem, the renewable resource stock has an upper limit. On the other hand, if the growth rate of industrial output is positive, in the long run the quantitative importance of the harvesting sector the economy will eventually decline. Hence, a neoclassical model is the relevant framework if the harvesting sector contributes a significant share of gross national product (GNP).

The analysis is relevant, since the determinants for optimal harvest levels are not immediately clear. Where resource management is practiced it is generally based on the concept of maximum sustainable yield (MSY), which itself is based on models of biological growth (Clark 1990). This is not necessarily the best management method, because the long-run consumption profile does not coincide with that of utility maximisation. For example, the optimal harvest level can be below the MSY if households have high rates of time preferences. This is because high consumption today is preferred at the expense of low future levels. In addition, the resource stock under the MSY is not necessarily optimal with respect to production due to the positive relationship between productivity in harvesting activities and the resource stock size.

Two conclusions are drawn on the basis of the model results. On the one hand, it is possible to implement the command optimum by introducing Pigouvian taxation. The dynamic equivalent variation related to this intervention is considerable. In the baseline situation, the representative household's wealth in the laissez-faire case would have to more than double in order to make it indifferent to the two scenarios. A sensitivity analysis reveals that the change in wealth is relatively sensitive to changes in parameter values. On the other hand, it is shown that the optimal policy rule is highly complex. The quantity tax is a function of the state variables – physical capital and the resource stock – and the control variables – consumption and the share of physical capital devoted to harvesting. It seems plausible that such a policy would be costly in reality, since the information level required to carry out the policy is high. Therefore, a constant quantity tax – rule-of-thumb policy – requiring less information is introduced into an initial situation without government intervention, in order to evaluate the share of the maximum welfare increase that can be internalised. This is a hypothetical experiment, since the agents in the model are assumed to have perfect foresight, but is performed anyway to obtain some idea of the potential of a rule-of-thumb policy. The numerical analysis demonstrates that the share of the equivalent variation that the rule-of-thumb policy internalises under the optimal policy is almost 90% and is relatively insensitive to changes in parameter values. Hence, the potential of the rule-of-thumb policy is considered high.

Case study: The BC halibut fishery

The "privatising" of the British Columbia halibut fishery is a natural experiment of the effects of changes in property rights. The introduction of private harvesting rights in 1991 led to an important transformation in the industry and in how fishers behave. In particular, the creation of an exclusive harvesting right allowed for an increase in the fishing season from just six days in 1990 to over six months in 1991. A longer fishing season, in turn, allowed fishers to harvest their catches over a greater period of time, to increase the quality of the landed product, to receive a higher price for their fish, and may have increased revenues by as much as C$23 million over the period 1991 to 1994. Surveys of fishers indicate that private harvesting rights made fishing safer, reduced losses of fishing gear, and decreased wastage of fish. Further, a shift in the property-right regime led to greater cooperation or co-management between the fishers and the regulator.

An analysis of changes in the fishery from 1988 to 1994 shows that all short-run efficiency measures, with the exception of fuel technical efficiency, were less in 1991 than in 1988. Between 1991 and 1994, all short-run efficiency measures for both vessel sizes, with the exception of fuel technical efficiency, improved. Over the 1991-1994 period, small vessels significantly improved their short-run economic efficiency, fuel allocative efficiency and scale efficiency, while large vessels realised significant efficiency gains in short-run technical, economic, and fuel allocative efficiency.

The study has implications beyond showing the potential benefits of private harvesting rights for common-pool resources. Most importantly, the results suggest the importance of ensuring the desirable characteristics of property rights. For example, an initial two years limit on the duration and limits on the divisibility and transferability of the harvesting rights attenuated the property rights and may explain the lack of efficiency gains in the first two years of the program. Attenuation of the property rights suggest that the initial distribution plays an important role in setting the path for future changes in the industry. Regulators of common-pool resources should also consider the impact of pre-existing regulations and institutional structures (for example, rate of return regulations for coal-fired electric utilities) when devising changes in property rights (such as the introduction of tradable discharge sulfur dioxide permits). These considerations are especially important in industries, such as fisheries, where firms produce a range of outputs each of which is separately regulated. Finally, even accounting for deficiencies in the property right, changes in short-run efficiency may not be instantaneous and may involve a period of adjustment and learning by firms. Only by paying careful attention to the characteristics of the property right and their interactions, the pre-existing regulations, and the constraints faced by firms will regulators achieve the potential benefits of "privatising the commons".

2.4 Resource utilisation and green accounting

The Icelandic economy is to a large extent based on fisheries. According to the national accounts (National Economic Institute,1995), the direct contribution of the fishing industry to the net national product (NNP)has been 15 and 17% in recent years. Including multiplier effects the total contribution of the fishing industry to the NNP may be as high as 35-40% (Arnason, 1994).

At any point of time, the net output of the fishing industry is bounded by the availability of fish. Generally, the larger the fish stocks the less alternative inputs are needed to produce a given volume of output. It follows that the fish stocks have an economic value. This value is determined by the marginal contribution of the fish stocks to the net output value of fishing industry. Thus, fish stocks play very much the same role in fisheries as capital in traditional production theory. First, they are stock variables that restrict the volume of output obtainable from a given level of inputs. Second, they have an economic value determined by their marginal contribution to net output. Third, by the appropriate adjustment of catch levels, it is possible to invest or disinvest in fish stocks.

In spite of this and the importance of the fish stocks for the national economy, changes in the value of the fish stocks have so far not been included in estimates of the Icelandic NNP. Since both the size of the fish stocks and Iceland's access to them has changed dramatically over the past few decades, this omission may have significantly distorted the informational content of official economic growth rates. It may similarly have distorted a range of economy-wide measures of performance related to the NNP such as aggregate productivity.

This paper represents a first step toward including fish stocks in the Icelandic national accounts. Consequently, it seems appropriate to devote the first section of the paper to outlining an economic methodology for this purpose. This methodology, often referred to as green accounting, stems from the work of Weitzman (1976) and has been further developed by a number of authors including Kemp and Long (1982) Aronsson and Lövgren (1993 and 1995) and Aronsson (1996).

While the basic theory of green accounting is fairly straight-forward, it's practical application is almost never easy and usually quite complicated. In the case of fish stocks it is unusually problematic for two reasons: First, the fundamental common property aspects of most ocean fisheries gives rise to pervasive stock externalities that in the absence of an appropriate fisheries management system, result in seriously inefficient utilization of the fish stocks and, consequently, sub-optimal economic output. The standard green accounting methodology for assessing the NNP, on the other hand presumes that the economy follows the optimal path. If this is not the case, the standard theory is not strictly applicable. The second difficulty, related to the first, is that under most fisheries management regimes there are no market prices for fish stocks. Hence these data are not available to the green accountant who has no option but to attempt to infer the appropriate prices from other data

The main conclusions of the paper are that if the traditional GNP and NNP statistics are to measure consumption possibilities they must include fish stocks in very much the same way as physical capital. However, the valuation of fish stocks for the purpose of proper national accounting is difficult for the following reasons. First, biomass levels are difficult to estimate accurately. Second, there is a widespread lack of well-defined property rights in fish stocks. As a result market prices for fish stocks are generally not available. Third, due to the common property externality, ocean fisheries are generally not operated efficiently. This distorts whatever market prices there may be available and greatly complicates the appropriate expressions for the shadow value of fish stocks. Rough estimates of the cod stock corrected GNP for Iceland suggests that the traditional method of calculating net economic output often produce significantly biased estimates of the true GNP as well as economic growth rates. Therefore, provided reasonably accurate estimates of society's ability to consume in the long term are regarded as useful, it is of considerable importance to incorporate fish stock corrections in the national output statistics.

2.5 Fishing effort

The economic approach to fishing effort is the topic of Wil Smit 's (1997) paper. The author argues that while several criteria can be used to measure productivity, this case study gives special attention to the (seemingly technical) productivity ratio between fleet operations, fish stocks and landings. Assessing the relationships within this triangle may therefore explain the link between fisheries management systems based on output and input. The results may be a useful tool for the determination of an effective and efficient management system.

3. Descriptive papers

The North Atlantic is rich in fishery resources. Most of the countries of the North Atlantic derive much of their economic livelihood from the cold waters of the North Atlantic Ocean. The North Atlantic region covers a wide area, from Canada in the west to Norway in the east, and from the British Isles in the south to the Spitzbergen in the north. Despite their differences in geographical size, population, and the extent of their reliance upon the sea, each society has been and continues to be deeply influenced by the opportunities and challenges of its surrounding oceans.

The importance of the fisheries for the countries of the North Atlantic is illustrated by the fact that, in most of them, 10 per cent or more of the labour force is directly employed in the fishing industry, i.e. harvesting and processing fish. In addition to the labour it employs directly, the fishing industry generates a good deal of employment in associated industries and services through backward and forward linkages. Other measures of the economic importance of the fisheries, such as the share in commodity exports and GDP, tell a similar story. On these measures most of the North Atlantic nations are heavily dependent on their fishing industries. The degree of dependence varies considerably, however. The Faroe Islands and Greenland are probably the most dependent, with Iceland and Newfoundland close behind, and Norway the least (although the northern regions of Norway depend much on fisheries) . In all cases, a substantial reduction in the sustainable economic yield from the fisheries, due to either stock or market collapse, would require a radical economic restructuring that would inevitably entail painful social adjustments.

At the Reykjavik symposium in the autumn of 1997, four papers were presented that describe the fishing sectors in the Faroe Islands, Iceland, Newfoundland and Northern Norway.[1] The reports describe the background of the industries in each country, the role of the industries in the economy, particularly the importance of the fisheries for specific regions, and each country as a whole. The organisation of the industries is described, the number, type and size (capacity) of plants and vessels and the ownership structure. The most pertinent government policies regarding the fishing industry are discussed, including restrictions on entry and exit, ownership, size, gear and days at sea, currently and in a historical perspective. The main resource stocks are described, their historical development, current size, and outlook.

4. Data collection

One of the main aims of the project was to obtain micro-level data from the fishing sectors in the four regions – the Faroe Islands, Iceland, Newfoundland and Northern Norway – and use the data to conduct in depth analysis of the fisheries and fish processing industries in these countries. This part of the project was only partly achieved. Thus, such detailed data was not available in Newfoundland, and the Faroese data also proved to be incomplete. However, good quality data exist in both Iceland and Norway, but access to the databanks is restricted. The data collecting is briefly presented below.

4.1 Faroe Islands

The Faroese data was gathered from the records of Statistics Faroe Islands in 1999. Although the intention was to obtain data on both fishing sections, data for the fishing industry proved inadequate for the purposes of the project. The harvesting data was of better quality, but key variables were also missing.

.

Information on sales and landings could be obtained, observations were missing on inter-industry selling and buying of raw material, as well as imports of fish. Data on

[1] Hoydal (1997), Roy (1997), Runólfsson (1997) and Vassdal and Bárðarson (1997).

capital and labour was also lacking. Historically there has been a strong vertical integration between industry and fishing vessels, and many firms do not keep separate records for costs and revenues of each operation.

4.2 Iceland

In 1996, the Institute of Economic Studies approached a number of Icelandic harvesting and fish processing companies, including most of the larger ones, and asked their permission to access some of the data on these firms held by the National Economic Institute (NEI). In all, 51 firms gave their approval and consequently data for the 11 years period 1985-1995 was assembled from NEI records. Most of the firms included in the sample operated fishing vessels and fish processing facilities, but a few firms specialised in either activity. Thus, a total of 39 firms were both engaged in fishing and harvesting, eight specialised in harvesting and four in processing.

The NEI data is taken from the tax records of firms and includes a detailed breakdown of costs of revenue of each firm, measured in Icelandic krona. Additional information on vessels characteristics and catches were obtained from the Fisheries Association of Iceland (FAI) and Directorate of Fisheries (DF). The latter also provided us with information on crew size and the number of days the vessels spent at sea each year. Finally, data on the insurance value of the vessels each year was obtained from a special committee charged with keeping track of changes in the value of each ship in the fishing fleet. Detailed description of the data used is provided in Agnarsson (2002a).

4.3 Norway

In Norway, data spanning the years 1985-96 was collected for the trawler fleet from the Directorate of Fisheries. This institution collects data from a representative sample of vessels operated throughout the year. Detailed reports from vessels larger than 13 metres are published annually, but more detailed cost and catch statistics were constructed for the project. A detailed study of all Norwegian fishing vessels above 28 metres can be found in Vassdal et *al.* (1997).

Data for the land-based fish processing industries was obtained from Fiskeriforskning and from the SEBRA-database of the Norges Bank. A good account of the data is found in Ólafsson (2001).

5. Empirical studies

Most of the empirical research undertaken was based on the Icelandic data, but a couple of papers analysed the Norwegian fishing sectors. In addition, attempts were made to utilise the Faroese fisheries data, but the results were unconvincing. In what follows I fist discuss a comparative study that used more aggregated data, and then the Icelandic and Norwegian papers.

5.1 Labour productivity in the fish processing industries

In his article on labour productivity, Daníelsson (1997) claims that in the public debate in Iceland several statements about the fish processing industries in Iceland, Norway and Denmark are common. Firstly, it is claimed that the hourly wages in Norway and Denmark are much higher than those in Iceland. Secondly, it is claimed that the working hours are more than 25% longer in Iceland than they are in the other two countries (around 50 hours a week in Iceland, but less than 40 hours in Norway and Denmark). Thirdly, it is claimed that the working tempo is not less hectic in Icelandic fish-processing factories it is in the factories in Norway and Denmark. Fourthly, it is claimed that on the whole there is no less mechanisation in Icelandic fish-processing factories than there is in the Norwegian and the Danish ones. To a trained economist it seems obvious not all of these statements can be true.

The first two claims can easily be confirmed by public data. The total hourly labour cost in fish processing is estimated to have been 655 Icelandic kronor in Iceland in 1992, 1109 in Norway and 1089 in Denmark. The average weekly working hours in Iceland were 49.9, as compared to 38.8 hours in Denmark. These numbers show the number of hours paid by the employer while the number of hours that the employee is actually working is somewhat less. In Iceland 15.4% of paid working hours are negotiated breaks. A similar figure for Denmark is 9.4%. Poor organisation flow of products within the factories and lack of raw material do also cause breaks, but it is very difficult to estimate the average duration and frequency of these breaks. A recent report indicates that stoppages of this kind are significant in the fish-processing industries is all the three countries.

It is not possible to substantiate claim 3 and 4. Subjective estimates of the work tempo can be very misleading. It is quite possible that Icelandic workers which start working in Denmark or Norway getting better paid and work for fewer hours do feel the work tempo is slower tan it is. Reliable data on the mechanisation of the factories are not available, nor are there reliable data on the utilisation of the available machinery. In Iceland, at least, it is common to hear claims about the low degree of utilisation of machinery in Icelandic fish-processing factories.

The fact that Norwegian and Danish fish processors pay higher hourly wages than their Icelandic counterparts can be explained by subsidies, lower interest rates and lower profitability, lower landing prices or by higher labour productivity. There are some differences in subsidies, interest rates and profitability, but not enough to explain more than a fraction of the observed differences in wages.

It is easy to get data on the landing prices, but data on the quality of the fish is largely lacking. There are big differences in the landing prices according to size and quality. Large fish, a day old, is sold for a prices which is more than double the price of small fish which was caught five days ago. There are some differences in the same species in different ocean areas which can possibly affect the prices of the products and, as a consequence, the landing price. There are also reason to believe that the landing prices are not higher in Iceland than in Norway and Denmark. This leaves us in the situation that the observed differences in labour cost must be explained for most part by greater productivity in the fish-processing industries in Norway and Denmark.

Daníelsson (1997) shows that value added per paid hours was much lower in the fish processing in Iceland than it was in Norway and Denmark in 1992. The choice of the year 1992 is though somewhat unfortunate and the estimates are not very accurate. The differences in the productivity were much smaller between Icelandic and Norwegian fish processing in 1994, but the estimated difference was greater than what can be explained by inaccurate estimates.

Productivity in the fish processing in Northern Norway was considerably less than the productivity in Norway at large, but still considerably greater than the productivity in fish processing in Iceland. It is tempting to conclude from this that some part of the differences in productivity can be explained by factors which Iceland and Northern

Norway have in common, like long distances from the markets, sparsely populated areas and the structure of the production, more groundfish and less herring, capelin and mackerel, more fillets and less whole fish.

When it comes to explaining the differences in productivity there are a lot of suggestions but few reliable conclusions. It seems reasonable to expect that the explanation consists of a number of factors: different structure and composition of the production, differently efficient use of paid working hours, possibly related to the long working hours in Iceland, different “closeness” to the markets and ability to exploit these markets etc.

It should be noted that there are certain conditions in Iceland and Northern Norway that would lead us to expect that the productivity in fish processing would be higher in Iceland than in Northern Norway. The groundfish fishing in Northern Norway is heavily dependent on small boats, which causes very great variations in the landings, especially during the winter months, causing disruptions in the production and variations in the landing prices. The sale of fish in Northern Norway is restricted to certain regions and there are no fish markets like those, which have allowed Icelandic fish processing firms in recent years to specialise to larger extend than used to be possible.

There are some indications that Danish fish processing uses more capital-intensive methods of production than the Icelandic fish processing. The comparison is though quite difficult as the Icelandic sample excludes many of the big fish processing firms, which are also engaged in fishing and the Danish sample includes caning and smoking which are not included in the Icelandic sample.

Figures from the asset accounts indicate that the capital-labour ratio is similar in fish processing in Northern Norway and Iceland. Different accounting methods might indicate that this means that the true capital-labour ratio is higher in the Norwegian fish processing industry. Conclusive statements about the capital-labour ratios in the fish processing industries in the three countries do though seem to require further analysis.

5.2 Efficency in the Icelandic and Norwegian saltfish production

Despite the fact that both Iceland and Norway – especially the northernmost regions – are very dependent on the fisheries, relatively few studies have compared performance in these two sectors. In his candidate thesis, Ólafsson, attempts to partially plug that gap by analysing efficiency in Icelandic and Norwegian saltfish production. Both these countries are among the world leaders in the production of salted fish products and have been competing against one another for a century in the lucrative south European markets. The emphasis here is though not on sales and marketing, but rather on the production process itself.

Ólafsson used DEA to estimate technical efficiency in the saltfish production in the two countries, and decomposes the efficiency into scale effects and pure technical efficiency. He utilises the Icelandic data set described in Agnarsson (2002b), which covers the period 1985-1995, and Norwegian data for the period 1984-1997. The Norwegian data really consists of two different data sets, spanning the years 1984-1992 and 1992-1997 respectively. There are four inputs, raw material (fish), wages, capital costs, and other costs, and one output, salted fish products.

Rather than analyse the Icelandic and Norwegian data separately, Ólafsson chose to lump all the data together and then apply DEA to the pooled dataset. This approach enables Ólafsson to compare the performance of Icelandic firms directly with their Norwegian counterparts.

On average, the total efficiency of the Norwegian firms is greater than of the Icelandic firms. Indeed, average efficiency is lower among Icelandic firms in each and every year. In 1995, for instance, the average total efficiency of Icelandic firms was 0.51, while the average efficiency of Norwegian firms was 0.70. That same year, six firms are identified on the efficiency frontier, all Norwegian, but the efficiency score of the most efficient Icelandic firm was 0.81.

Closer analysis reveals that there is little difference between the levels of pure technical efficiency between firms in the two countries. The average score for all firms, both Icelandic and Norwegian, is 0.83, which is the same score as for Icelandic firms, with Norwegian firms attaining on average a score of 0.84.

The main difference in efficiency between the countries lies in the utilisation of scale opportunities. Here, the Icelandic firms lag far behind the Norwegian firms in all the years except 1993, when their scale efficiency is slightly higher. In 1995, the overall scale efficiency measured 0.77, but the scale efficiency of Icelandic firms was on average only 0.61 while it was 0.88 for Norwegian firms. Ólafsson shows that on average 87% of the Icelandic firms were enjoying economies of scale throughout the observation period, while the corresponding figure for Norwegian companies was 63%. This indicates that most of the scale efficiency differences arise from the fact that the Icelandic firms were not operating at optimal scale, but rather well below that mark. Consequently, increased production would have closed the efficiency gap between these two different groups of firms.

Ólfafsson points out that Icelandic processing firms are more often integrated with harvesting, and that it is quite common to find the same firm operating both boats and processing facilities. This is very different from the practice in Northern Norway. Thus, Icelandic firms may be more capital intensive than their Norwegian counterparts. During the periods 1985-1995, cod catches fell considerably in Iceland while they increased in Norway. In 1987, Icelandic boats harvested more then 400 thousand tons of cod, but the catch in 1994 was only just over half that amount. By contrast, Norwegian cod catches went up from 150 thousand tons in 1995 to just over 500 thousand tons in 1995. The poor scale efficiency of the Icelandic firms could possibly be explained by the fact that although these firms are more capital intensive, the raw material available was decreasing during the period under study. Thus, these firms have been raw material constrained, and these constraints have forced the firms to operate their saltfish production below optimal scale.

5.3 Efficiency in Norwegian trawl fisheries

Traditionally in Norwegian fisheries there has been a clear distribution of work between fishing and processing. Fishing vessels have delivered fish as raw materials to processing plants which have processed and sold the products. Lately there has been a tendency to bring some or all part of the production process onboard the vessels. Part of this tendency is simply a consequence of fishing farther away from the coast. The fish have to be conserved in some way, partly by salting the fish in semi processed form at sea, and partly by installing freezing machinery on the larger vessels. Other ship owners have install processing equipment for purely financial reasons. For the Norwegian cod trawler fleet this development has lead to the development of two groups of vessels; the onboard producing vessels (factory trawlers) and the fresh fish vessels (fresh fish trawlers). The fresh fish vessels may have freezing equipment installed but only for freezing whole fish, not filleted or otherwise processed fish.

The downward vertical integration of the production process, being the natural consequence of taking the production activities onboard, has lead to great conflicts in the Norwegian fishing sector. The trawlers with installed processing are therefore strongly regulated and consist only of 22 vessels. The dominant political view is clearly that such vessels shall be restricted in numbers, and also, all though this is more disputed, that the same group of vessels should have a more restricted access to the fish resources than proportional to their catching capacity.

One argument in favour of factory trawlers is that the factory trawlers claim to be more efficient and competitive than the combined operation of fresh fish trawlers and processing (usually pricing frozen fillets) in shore based factories. A few studies indicate that so is the case, especially in periods with generally small quotas in the cod fishing sector. Another argument is that production on board is part of an international trend. As most of the products from this sector is sold internationally to industrialised countries, Norwegian producers have to follow the cost structure of our competitors to be globally competitive. Internationally, in white fish production, the combination of catching at sea - processing on shore, have not been able to compete with modern sea going factory trawlers.

However, the lack of coherent financial and cost studies of on-board production vs land production necessitates more in dept studies of the productivity and efficiency of the two methods of organising the production process. The fishing sector is so heavily regulated in Norway, as in many other countries, that the observed differences seen from reading financial report, may as well be a result of different market structure or regulation schemes, more that efficiency. Some even claim that the alleged better profitability for factory trawlers is a result of open (but mostly hidden) subsidies, and this constitutes a part of modern self-fulfilling mythology (Hansen 1997).

This is the background of the study by Bárðarson and Vassdal (1997), in which they compare productivity between factory trawlers and fresh fish trawlers using the non-parametric DEA method.

Although the best approach to measure technical improvement over time, would be to use the Malmquist approach. However, due to data limitations that was not possible. Instead the authors employed DEA and sequentially expanded the reference technology.

One special characteristic of fisheries is the dependence of the resources. Both availability of the fish in form of catch rate per time unit, as well as total quotas allotted to the individual fishing vessels, influence the profitability of the vessels, and according to our results, the technical efficiency of the operations. There is a clear relationship between the total catches, largely set by the current regulation regime, and short-run efficiency.

There is also a positive relationship between catch value and efficiency for both vessel groups. This is not obvious as the emphasis here is on short run production frontiers and the issue of capacity utilisation, does only to a small degree influence the results. However, the quantity of catches does only explain from about 30 % (fresh fish trawlers) to 40 % (factory trawlers) of the total inefficiency. The sum of other factors, including random factors, is dominant and remains to be explained.

The issue of diseconomies of scale is not a large factor for fresh fish trawlers, but is somewhat more important for factory trawlers. This result may be due to the strict regulation of the vessels we have been studying. Fresh fish trawlers are regulated on size as well as catch quotas. Factory trawlers are subject to a more lenient regulation of size, but are similarly regulated regarding the commercially most important fish species.

When sequentially expanding the available technology, we have found a difference between the two vessel groups. The frontiers for factory trawlers are regularly dominated by last year observations. Since there have been very few new vessels entering the fleet after 1979, this is interpreted to mean either that the group are utilising the available resources better or that there is an genuine technical improvement going on. Fresh fish trawlers do not display the same pattern. Given the resources, they do not seem to produce more output per average unit of inputs now than ten years ago.

5.4 Icelandic studies

Most of the applied work of this project has been done on Icelandic data. This can partly be explained by the fact that there were more researchers engaged in the project in Iceland than in the other partner countries, but also by the fact that it appears the data, once it had been accumulated, was more accessible in Iceland. There were three papers written on the performance of the Icelandic fish processing industry and one on the harvesting sector.

The harvesting sector

Ever since the advent of duality in the 1970s, numerous applied studies have appeared in the literature that take advantage of the fact the multi-output production technologies can be described using either cost-minimisation or profit-maximisation. However, in some cases the behavioural assumptions underlying these models may be inappropriate, while in other the data necessary to apply the dual may be unavailable. In those instances, it may instead be feasible to take advantage of primal approaches, such as multi-output production functions or distance functions, to describe the technology of the production units at hand.

In his study, Agnarsson (2002c) applies three primal methods to estimate productivity in the Icelandic fisheries 1987-95: a single-output and multi-output production functions, and an output distance function. The latter two models are especially suited for an economic activity like fisheries, where by-catch is unavoidable although a certain fish species is targeted.

The data consists of four balanced panels. The first includes data on nine motorboats during the period 1987-89, and the second on seven motorboats during the years 1990-1994. The third data set includes observations on eight purse seiners in 1991-

1995, and the final data set is a balanced panel of 21 trawlers in 1990-1995.

The results indicate that motorboats and trawlers probably experienced some productivity gains in 1990-95, while it appears productivity of purse seiners declined during this period, most likely due to falling capelin catches in 1994 and 1995.

Fish processing

The Icelandic economy is heavily dependent upon fishing and fish production. In the years 1995-1997 fish products amounted to half of all exported goods and services and the fisheries direct contribution to GDP was 14-15%. Just over 10% of the workforce employed in the fishing sectors, with the fish processing industries employing slightly more people than fishing.

Yet, despite the paramount importance of fishing, relatively few studies have investigated productivity growth in the fish processing sectors in any detail. A notable exception is Gunnarsson (1990) who estimated multi-factor productivity (MFP) growth in Iceland during 1945-80 using aggregate data for fishing and fish processing, as well as other sectors of the economy. The analysis was based on two inputs, capital and labour and a value-added measure of output. A composite measure of the fish stocks was also included in the study. Gunnarsson compared estimates obtained from a translog cost function with traditional Divisia index measures. Average MFP growth in the former case was 0.53% for the fishing sector and 2.73% for the fish processing industries, while the corresponding index measures were 0.81% and 2.72% respectively.

Other studies have generally either estimated the productivity growth of certain inputs, such as capital and labour, and/or estimated MFP growth by indices such as the Divisia index.[2] These studies have all been based on aggregate data.

The three papers written by Agnarsson (1998, 1999, 2002b) were intended to fill that gap. The three papers utilised different methods – production function, cost function, DEA – to estimate productivity and although the results were a little different they all

[2] See Institute of Economic Studies (1997, 1999), Danielsson (1997) and Valsson and Klemensson

implied that productivity had been growing during the period 1985-1995.

In the first paper (Agnarsson 1998) primal techniques are used to estimate total factor productivity (TFP) : standard time trend (STT) models and models incorporating the Baltagi-Griffin (BGT) general index of time. Both fixed and random effect models were utilised and Hausman tests employed to decide which error structure to assume.

Figure 1.
Estimated TFP growth in the Icelandic fish processing industry 1986-95.
Comparison of the two STT models, NON-H and CRTS, and the BGT model.
Weighed percentage changes between years.

Measured TFP is positive in both STT models, but negative in the BGT model. It should be noted that estimated productivity will, of course, equal technical change in the constant returns to scale, as no scale effects are allowed in that specification. The scale economies in both the non-homoethetic models have a positive, but small, effect on TFP, boosting productivity growth on average by 0.001 and 0.008% in the STT and BGT models respectively.

The behaviour of TFP over time mimmicks that of technical change, with productivity growth increasing in both non-homothetic models, but falling during the last year of our period. The beginning of our sample period corresponds roughly to the time when the system of individual transferable quota (ITQ) was introduced in the Icelandic fisheries, but further research is necessary before any judgement can be passed on the effects of the ITQ arrangements on productivity.

(1998)

Estimated TFP growth is close to those obtained by the National Economic Institute (NEI) for the same period. Using a Cobb-Douglas function with two inputs, capital and labour, and constant returns to scale imposed, NEI estimates that TFP has on average grown by 2.0% in the Icelandic fish processing industry 1986-95. NEI uses aggregated data, which includes all production processes, not just salting and freezing as is done here. By comparison, we find in the STT CRTS case that TFP has on average grown by 1.9%. However, when the assumption of constant returns is relaxed, average TFP growth fall to 0.5% and is negative (-0.1%) in the BGT model. In a previous study by the Institute of Economic Studies (IoES), TFP in the fish-processing sector was found to have declined on average by -0.4% in the period 1981-87, but increased on average by 4.2% in the years 1988-94. The study by the IoES is also based on a CRTS Cobb-Douglas function with only capital and labour inputs. Finally, Kim and Björndal (1990) estimated TFP growth in Norwegian fish processing plants for the years 1985-87. The plants are divided into two groups, conventional plants where salting and fresh usage dominate, and freezing plants, where the emphasises is on frozen products. TFP growth in the former was on average -5.8% while it was 3.2% in the latter.

The advance of duality theory in the 1970s opened up a whole range of possibilities for microeconomics. Whereas previously production functions had been the workhorse of the applied economists, his arsenal now also consisted of cost, profit and revenue functions. In addition, the introduction of new and more flexible functional forms made it possible to test various restrictions that other, more stringent forms had placed on the production function. In another paper, Agnarsson (1999) analyses productivity growth in the Icelandic fish processing industries using one of these innovations, namely a translog cost function, and compare the results to those obtained using a more traditional techniques, e.g. a Divisia index.

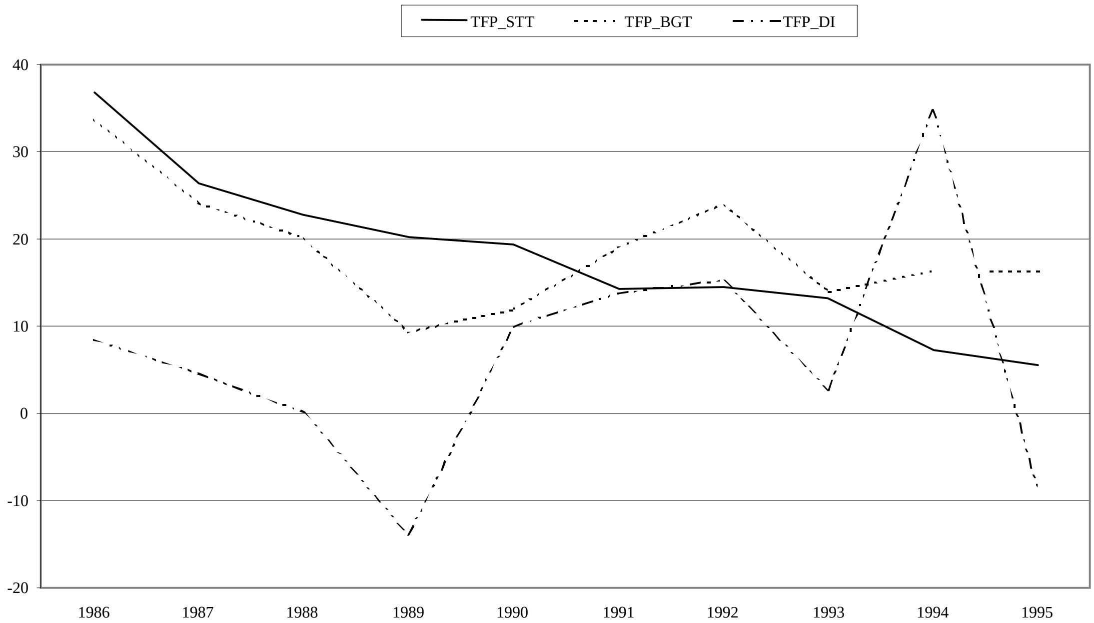
As in the previous article, technical change is modelled in two different ways: as the standard stimple time trend and as the Baltagi- Griffin general index of time. Both models point to the existence of significant returns to scale in the Icelandic fish processing industry. The estimated mean returns amount to 1.62 in the STT-model and 2.92 in the BGT-model. However, the development of the estimated scale elasticity differs between models; returns have been rising in the STT-model but falling in the BGT-model.

These high estimated returns could stem from the fact that most of the firms included in our sample operate more than one type of fish processing plants, allowing them to spread overhead costs and make more efficient use of manpower and capital.

Technical change has been labour and material using but capital saving. Average technical change was 8.11 % in the BGT-model, but 11.13 % in the STT-model. Estimated technical change was in both models dominated by the pure technical change component, with both the non-neutral and scale augmenting components almost insignificant in both the STT- and BGT-models. Technical change has always been progressive in the STT-model, but was regressive in one year, 1989, in the BGT-model.

Both regression models yield much higher estimates of TFP-growth than were obtained using the Törnqvist approximation of the Divisia index. Thus, TFP grew on average by 17.15 and 18.75 % in the STT- and BGT-models respectively, but only by 6.69 % when productivity is calculated using the non-parametric method. The main reason for these different estimates, lies in the fact that the Divisia method assumes the existence of constant returns to scale. This assumptions is, as we have seen, not likely to hold in our case. Indeed, the positive scale effects of increasing returns account for one third of total TFP growth in the STT-model and over half in the BGT-model.

Figure 2.
Total factor productivity in the Icelandic fish processing industry 1986-95. Comparison of the standard time trend (TFP_STT) and Baltagi-Griffin time trend (TFP_BGT), and the Törnqvist approximation of the Divisia index (TFP_DI).



Estimated technical change and productivity is also much higher than found in a previous study based on the same database, but a slightly different sample.[3] There, average annual technical change and productivity growth during the period 1986-1995 ranged between 0.5 and 1.9%, depending on the production function chosen. However, one specification yielded estimates of negative technical change and productivity growth.

In the third study (Agnarsson 2002b), DEA is employed to explore the development of productivity in the fish processing industry during the period 1985-1995. This method allows productivity changes to be composed into changes in technology and changes in technical efficiency, and thus adds a new dimension, that of efficiency to the picture. DEA is especially well suited to the data at hand, as it does neither require information on prices nor assume any behavioural objective, such as cost minimisation or profit maximisation. Furthermore, it requires no specific functional form of the function to be estimated.

DEA does however also have its shortcomings. In particular, the method does not

[3] See Agnarsson (1998)

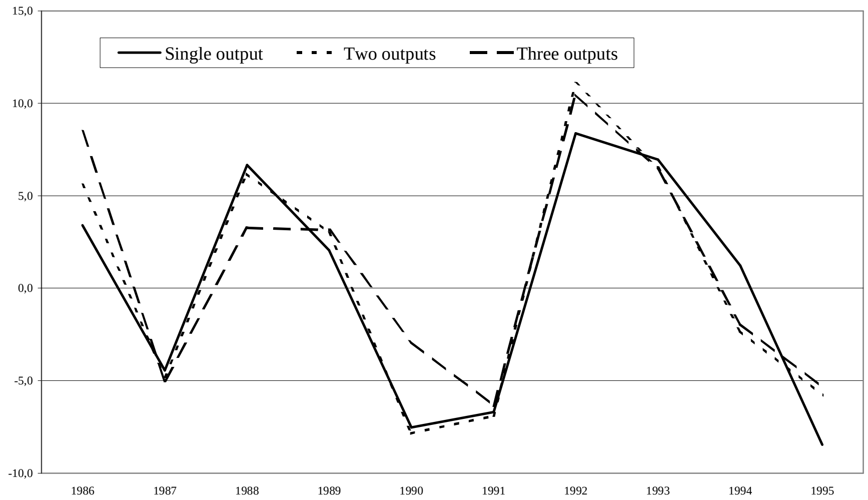
account for measurement errors or other noise upon the frontier. Instead, it is assumed that all deviations from the frontier are caused by technical inefficiency. The lack of statistical basis also means that it is not possible to carry out traditional hypothesis testing when DEA is used.

In the data at hand, distinction is made between the following output categories; frozen demersal products, salted demersal products, frozen shrimp, frozen scallop, salted herring, fish-meal and oil and dried demersal products. In this study, three output definitions are used. In the first case all output is aggregated into one good. In the second case, distinction is made between good products; fish-meal and oil on the one hand, and all other products on the other. In the third case, three output groups are defined, i.e. fish-meal and oil, frozen products (demersal, shrip and scallop), and salted and dried products (salted and dried fish and salted herring). All outputs are measured in fixed (1990) prices and deflated using the price indices for each product category that NEI compiles.

During the period 1986-1995, productivity grew on average by 0,15-1,02% each year, depending on the model chosen. Estimated productivity is lowest in the single-output case, but highest when the model with three outputs is employed. Productivity growth fluctuates a good deal in all models. It is negative in four years, 1987, 1990, 1991 and 1995, and positive in the other six years. Productivity increased the most between 1991 and 1992, or by between 8,4 and 11,1%, but the models yield slightly different results on the largest decrease. According to the single-output model, the largest drops occurred in 1995, -8,5%, but according to model to two-output model the most severe fall occurred in 1990, -7,9%, and in 1991 in the three-output model, or –6,4%. All models though agree that 1991 was a bad year for productivity growth.

Although the magnitudes may differ, all three models yield a similar story, as shown in Figure 3, and are always in step.

Figure 3. Productivity growth in the Icelandic fish processing industry 1986-95. Annual changes from the previous year.



As already mentioned, the Malmquist index allows total factor productivity to be decomposed into changes in technical efficiency and technical changes. Suppose a progressive technical change occurs and the frontier shifts up and to the right. Suppose further, that the proportional change in the technical efficiency of a certain firm exactly equals the proportional technical change in the production process of the same firm. The firm in question will then be located in precisely the same spot relative to the frontier, as in the previous period. Other scenarios are also possible. The firm could also move closer to the frontier, in which case changes in efficiency would outstrip changes in technology, or fall further below the frontier, in which case technical change would be greater than changes in technical efficiency.

During the period in question, technical efficiency declined on average by 0,7-1,4% each year. The decline is greatest in the single-output case, but smallest when the two-output model is used. Positive changes are only observed in four years, 1986-87, 1990 and 1992, with the improvements in the last two years quite pronounced.

By contrast, average technical change was progressive and boosted productivity by between 1,2 and 2,2 % each year. Changes in technology were though not always positive, and the year 1990 stands out in this respect. According to both the single-output and two-output model, regressive technical change amounted to 17,2 and 16,4%, depending on the model chosen, but in the three-output case, technical change was –4,8 that same year.

The productivity growth observed during the period 1986-1995 is therefore mostly due to progressive technical change, while changes in technical efficiency have generally hampered productivity growth. Firms have therefore, on average, been moving further away from the production possibility frontier, which has itself been shifting up.

6. Conclusions

The main purpose of the project Economic Performance of the North Atlantic Fisheries was to advance knowledge in the area of productivity measurement, and to stimulate debate on the productivity and efficiency of the North Atlantic fisheries in a comparative perspective. Considerable time and effort was also spent on putting together suitable databases for empirical research.

The project yielded a number of very interesting and novel theoretical papers on productivity measurements and related issues, some of which have since been published in academic journals. This aspect of the project must therefore be regarded as a resounding success.

The project also managed to bring together professionals – mostly economists – from a wide range of countries, not only from Northern Europe but also from the southern hemisphere. The bonds established there have been – and will be in the future – of considerable value and will doubtlessly lead to further cooperation in the years to come. Indeed, it can be said that the project lead to the creation of a network in applied micro and resource economics.

However, the applied part of the project met with considerable difficulties. The relevant data proved unavailable in Newfoundland, and the Faroese data was very incomplete. Data gathered in Iceland was used for a number of empirical papers, and the Norwegian data was also used for applied work. Attempts were also made to utilise the Faroese days, but the results were not encouraging.

On the whole, it is our view that the project Economic Performance of the North Atlantic Fisheries was quite successfull and proved a valuable vechicle to further research in the North Altantic region.

References

Agnarsson, S. (1998): Technical change and total factor productivity in the Icelandic fish processing industry1986-95. Economic Performance of the North Atlantic Fisheries, M-1/1998.

Agnarsson, S. (1999): *Productivity in the Icelandic fish processing industry: A dual approach*. Economic Performance of the North Atlantic Fisheries, M-2/1999.

Agnarsson, S. (2002a): Description of the Icelandic data used in the project Economic Performance of the North Atlantic Fisheries. Economic Performance of the North Atlantic Fisheries, M-1/2002.

Agnarsson, S. (2002b): *A Non-Parametric Study of the Performance of the Icelandic Fish Processing Industry*. Economic Performance of the North Atlantic Fisheries, M-2/2002.

Agnarsson, S. (2002c): *Productivity of the Icelandic Fishing Fleet*. Economic Performance of the North Atlantic Fisheries, M-3/2002.

Aigner, D.J., C.A.K. Lovell and P. Schmidt (1977): "Formulation and estimation of stochastic frontier production function models." *Journal of Econometrics* **6**, pp. 21-37.

Andrews, D.F. and D. Pregibon (1978): "Finding the outliers that matter." Journal of the *Royal Statistical Society, Series B* **40**, pp. 85-93.

Arnason, R. (1994): The Icelandic fisheries: Evolution and management of a fishing industry. Fishing News Books.

Arnason, R. (1997): *Fish stocks corrected national accounts for Iceland*. Mimeo, presented at the Symposium on the Efficiency of North Atlantic Fisheries in Reykjavik, Iceland, September 12-13, 1997.

Aronsson, T. 1996. *Welfare measurements, green accounting and distortionary Taxes*, Umeå Economic Studies No. 426, Umeå University.

Aronsson, T. and K.-G. Lövgren. 1993. Welfare consequences of technological and environmental externalities in the Ramsey growth model. *Natural Resource Modelling* **7**, pp. 1-14.

Aronsson, T. and K.-G. Lövgren. 1995. National product related welfare measurements in the presence of technological change, externalities and uncertainty. *Environmental and Resource Economics* **5**, pp. 321-332.

Bárðarson, H. and T. Vassdal (1998): Efficieny in Norwegian trawl fisheries; A nonparametric frontier production analysis. In A. Eide and T. Vassdal (eds.): Proceedings from the ninth biennial conference of the International Institute of Fisheries Economics and Trade, The Norwegian College of Fishery Science, University of Tromsø.

Bjurek, H. (1996): The Malmquist total factor productivity index." *Scandinavian Journal of Economics* **98(2)**, pp. 303-313.

Bjurke, H., F. R. Førsund and L. Hjalmarsson (1996): Malmquist productivity indexes: An empirical comparison. In Färe, R., S. Grosskopf and R. R. Russell (eds): *Essays in the Honor of Sten Malmquist*. Kluwer Academic Publishers, pp. 217-240.

Caves, D.W., L.R. Christensen and W.E. Diewert (1982): "The economic theory of index numbers and the measurement of input, output, and productivity." *Econometrica* **50**, pp. 1393-1414.

Charnes, A., W. W. Cooper ad E. Rhodes (1978): Measuring the efficiency of decision-making units." *European Journal of Operational Research* **2**, pp. 429-444.

Clark, C.W (1990): *Mathematical bioeconomics*. John Wiley and sons.

Charnes, A., W.W. Cooper and E. Rhodes (1978): "Measuring the efficiency of decision making units." *European Journal of Operations Research* **2**, pp. 668-697.

Coase, R.W. (1960): "The problem of social cost." *Journal of Law and Economics* 3, pp. 31-44.

Copeland, M.A. (1937): "Concepts of national income." *Studies in Income and Wealth.* NBER.

Daníelsson, Á. (1997): *Labour productivity in the fish processing industries in Iceland, Norway and Denmark.* Mimeo, presented at the Symposium on the Efficiency of North Atlantic Fisheries in Reykjavik, Iceland, September 12-13, 1997.

Diewert, W. E. (1976): "Exact and superlative index numbers." *Journal of Econometrics* **4**, pp. 115-145.

Diewert, W. E. (1981): "The theory of total factor productivity measurement in regulated industries." In Cowing, T. and R. Stephenson (eds.): *Productivity measurement in regulated industries*. Academic Press, pp. 17-44.

Diewert, W. E. (1992): "The measurement of productivity." *Bulletin of Economic*

Research **44:3**, pp. 163-198.

Fair, R. C. and J. B. Taylor 1983): “Solution and maximum likelihood estimation of dynamic nonlinear rational expectations models.” *Econometrica* **51**, pp. 1169-1185.

Farrell, M.J. (1957): “The measurement of productive efficiency.” *Journal of the Royal Statistical Society, Series A,* **CCX, Part *3***, pp. 253-290.

Fox, K.J. and R.J. Hill (1996): *Identifying outlier firms in multiple output – multiple input efficiency models*. School of Economics Discussion Paper 96/27, Univeristy of New South Wales.

Färe, R.,S. Grosskopf, B. Lindgren and P. Roos (1994): “Productivity developments in Swedish hospitals: A Malmquist output index approach.” In Charnes, A. , W. W. Cooper, A. Y. Lwein and L. M. Seiford (eds.): *Data Envelopment Analysis: Theory, Methodology and Applications*. Kluwer Academic Publishers, pp. 253-272.

Färe, R. and S. Grosskopf (1995): “Nonparametric tests of regularity, Farrell efficiency and goodness-of-fit.” *Journal of Econometrics* **69**, 415-425.

Färe, R. and S. Grosskopf (1996): “Malmquist productivity indexes: A survey of theory and practice.” In Färe, R., S. Grosskopf and R. R. Russell (eds): *Essays in the Honor of Sten Malmquist*. Kluwer Academic Publishers, pp. 127-190.

Färe, R., S. Grosskopf and P. Roos (1996): *Profitability, productivity and quality: A directional distance function approach*. Paper presented at the SCB conference in Stockholm, September 1996.

Färe, R. and S. Grosskopf (1997): *Profit efficiency, Farrell decompositions and the Mahler inequality*. Mimeo, Department of Economics, Southern Illinois University.

Färe, R., S. Grosskopf and W-F. Lee (1997): *Externalities, property rights and profitability. A data envelopment analysis investigation*. Mimeo, Department of Economics, Southern Illinois University.

Førsund, F. (1997): *The Malmquist index, TFP and scale*. Memorandum nr. 233, Department of Economics, Göteborg Univeristy.

Griliches, Z. (1994): “Productivity, R&D, and the data constraint.” *American Economic Review* **84(1)**, pp. 1-23.

Griliches, Z. (1996): The discovery of the residual: A historical note.” *Journal of Economic Literature* **XXXIV**, pp. 1324-1330.

Gylfason, Þ. T. Þ. Herbertsson and G. Zoega (1999): "A mixed blessing: Natural resources and economic growth." *Macroeconomic Dynamics* **3**, pp. 204-25.

Herbertsson, T.Þ. and A. Sørensen (1998): "Policy rules for exploitation of renewable resources: A macroeconomic perspective." *Environmental and Resource Economics* **12**, pp. 53-76.

Herbertsson, T. Þ., M. Skúladóttir and G. Zoega (1999): *Three symptoms and a cure: A contribution to the economics of the Dutch disease*. Discussion Papers in Economics 23/99, Department of Economics, Birkbeck College. Currently under review for publication in Journal of Development Economics.

Hoydal, K. (1997): *A Description of the fishing industry of the Faroe Islands.* Mimeo, presented at the Symposium on the Efficiency of North Atlantic Fisheries in Reykjavik, Iceland, September 12-13, 1997.

Institute of Economic studies (1997): *Framleiðni innan atvinnugreina á Íslandi, samanburður við Danmörku og Bandaríkin* (Productivity in Iceland, a comparison with Denmark and the US): Skýrsla unnin fyrir Verzlunarmannafélag Reykjavíkur. Research Report C97:09.

Institute of Economic Studies (1999): *Framleiðni íslenskra atvinnuvega* (Productivity in Iceland): Contractual Reserach Report C99:10.

Jorgenson, D. W. and Z. Griliches (1967): "The explanation of productivity change." *Review of Economic Studies* **34**, pp. 249-292.

Kemp, M.C. and N.V. Long (1982): "On the evaluation of social income in a dynamic economy." In G.R. Feiwel (ed.) *Samuelson and Neoclassical Economics*. Kluwer.

Moorsten, R. H. (1961): "On measuring productive potential and relative efficiency." *Quarterly Journal of Economics* **75(3)**, pp. 451-467.

National Economic Institute (1995): *Economic statistics: A historical account* (in Icelandic): National Economic Institute.

Nerlove, M. (1965): Estimation of identification of Cobb-Douglas production functions. Rand McNally Company.

Ólafsson, K. (2001): Efficiency and Productivity in the Production of Dry and Salted Fish in Norway and Iceland: A Comparative Study. BA thesis, Norwegian College of Fishery Science, University of Tromso.

Roy, N. (1997): *A description of the fishing industry of Newfoundland*. Mimeo, presented at the Symposium on the Efficiency of North Atlantic Fisheries in

Reykjavik, Iceland, September 12-13, 1997.

Runólfsson, B. Þ. (1997): *A description of the fishing industry of Iceland.* Mimeo, presented at the Symposium on the Efficiency of North Atlantic Fisheries in Reykjavik, Iceland, September 12-13, 1997.

Seiford, L. M. (1994): "A DEA bibliography (1978-1992):" Chapter 22 in Charnes, A., W. W. Cooper, A. Y. Lwein and L. M. Seiford (eds.): *Data Envelopment Analysis: Theory, Methodology and Applications*. Kluwer Academic Publishers, pp. 437-469.

Shephard, R.W. (1970): *Theory of cost and production functions*. Princeton University Press.

Smit, W. (1997): *An economic approach to fishing effort* Mimeo, presented at the Symposium on the Efficiency of North Atlantic Fisheries in Reykjavik, Iceland, September 12-13, 1997.

Solow, R. A. (1957): "Technical change and the aggregate production function." *Review of Economics and Statistics* **39**, pp. 313-320.

Tinbergen, J. (1942): "Zur Theorie der Langfristigen Wirtschaftsentwicklung." *Weltwirtschaftliges Archiv* **55**, pp. 511-549.

Valsson, Benedikt and Olafur Klemensson (1998*): Productivity and Profitability of the Icelandic Fisheries*. Paper presented at the X EAFE Conference, Den Haag 1.-4. April.

Vassdal, T. and H. Bárðarson (1997): *A description of the fishing industry of Norway.* Mimeo, presented at the Symposium on the Efficiency of North Atlantic Fisheries in Reykjavik, Iceland, September 12-13, 1997.

Vassdal, T., K. Kleven and L. Konradsdottir (1997): Den norske havfiskflåten. Konkurransesituasjonen og rolle I det maritime miljø. (The Norwegian sea-going fishing fleet. It's competitive situation and it's impact on the maritime sector.) FAFO report nr. 215, Oslo.

Weitzman, M.L. (1976): On the welfare significance of national product in a dynamic economy. *Quarterly Journal of Economics* **19**, pp.156-62

Wilson, P.W. (1993): "Detecting outliers in deterministic nonparametric frontier models with multiple outputs." *Journal of Business and Economic Studies* **11(3)**, pp. 319-323.