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Productivity Development in Icelandic, Norwegian and Swedish Fisheries

by

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Several factors contribute to the productivity of nations' fisheries: The biophysical conditions that determine the abundance of fish stocks, government regulation of fisheries, and innovation and investments in new fishing technologies. Many governments have struggled with the challenging task of designing regulations for fisheries that increase economic welfare in the shorter while ensuring the sustainability of fish stocks in the longer run. This paper analyzes the long-run total factor productivity (TFP) performance of Iceland, Norway, and Sweden during the period 1973-2003. Several competing TFP measures are presented, where some of these account for stock changes and product quality differences between countries. The estimates show that both the absolute and relative productivity performance of the three countries is affected by the choice of TFP measure. Although best-practice fishing technologies are widely available on the international market, we do not find uniform evidence of productivity convergence among the three countries over time.

Keywords: fisheries, growth accounting, natural resources, total factor productivity.

JEL codes: D24, O47, Q22.

Keywords: Fisheries, Total Factor Productivity.

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1. Introduction

Measures of productivity and technical change give important information about the performance of an industry. In fisheries, where regulation often is of the open-access or regulated open-access type, technical change or productivity growth may have ambiguous effects like speeding up of the dissipation of resource rent and depletion of already overexploited stocks (Smith and Krutilla, 1982). Still, accurate indices of development in a fishery can assist fisheries managers and potentially also indicate the impact of regulatory measures in fisheries. Evaluation of changes in fisheries requires long time series since many important fish species are long lived and the stochastic element of changes in environmental conditions is substantial, which can have a significant effect on productivity performance in a short-term perspective.

In this paper, we measure the long-term productivity development for the fisheries in Iceland, Norway, and Sweden during the period 1973-2003. Several factors contribute to the productivity of nations' fisheries: (1) The biophysical conditions that determine the abundance of fish stocks, (2) government regulation of fisheries, and (3) innovation and adoption of (i.e. investments in) new fishing technologies. The three countries represent interesting cases for a comparative analysis due to the differences among them in terms of endowments from nature, their fisheries' relative importance for their national economies, and policy objectives and regulatory regimes for fisheries.

Governments in many industrialized countries have struggled with the challenging task of designing regulations for fisheries that increase economic welfare in the shorter run yet also ensure the sustainability of fish stocks in the longer run. In principle, industrialized countries should be well positioned to regulate their fisheries thanks to generally strong national legal institutions and potentially abundant resources available for monitoring of fish stocks and fishing activity. However, despite increasing knowledge on fish stock dynamics and the availability of many regulatory instruments in North America and Europe, a large number of fish stocks have approached unsustainable levels due to overfishing. In fact, the high fishing pressure has in the most extreme cases led to depletion of some fish stocks to levels that seem difficult to recover biologically from, since severe overfishing can lead to alternate stable states of ecosystems (Scheffer et al, 2001; Pauly et al., 2002). One example is the depletion of the Newfoundland cod stocks in the 1980s and 1990s. Recently, high fishing pressure has probably been the main cause of the dramatic decline in the Baltic Sea and North Sea cod stocks. Since the fish stock is a crucial input in fisheries, a severe decline will generally have a large negative effect on a fishery's productivity.

This paper is to our knowledge first to explore potential differences in the productivity development of fisheries in several countries. An additional objective is to assess whether the differences in management have had an impact on productivity development. The effects of stock input and of the quality of landed fish on productivity are analyzed. For this we need to use several competing total factor productivity measures. Further, we examine whether total factor productivity in the three countries has converged or diverged over the period.

2. Background

While the three studied countries do differ in several respects concerning their economies, they also hold a lot in common. For instance, UNDP's Human Development Index, which weighs GDP per capita together with aspects such as life expectancy, literacy, and educational level, ranks Norway, Iceland, and Sweden first, second, and fifth in the world, respectively (UNDP, 2007). The importance of the fisheries sector for GDP and employment differs widely among the three countries. Fisheries and fish processing directly contributed 8-14% of the total Icelandic GDP in the period 1973-2004. However, if we consider the multiplier effects on the service and manufacturing sectors, it really contributes a much larger share, directly and indirectly. In both Norway and Sweden, fisheries and processing represented less than two percent of GDP in 1973-2004. However, in some regions in Norway, the direct and indirect contributions of fisheries to GDP total well above 10%. In Iceland the performance of the fisheries sector is regarded as critical for the economy as a whole, while in Norway the sector's performance is seen as critical only for some regions. In terms of the Swedish economy it is hard to argue that the sector is of critical importance at either level, nationally or regionally.

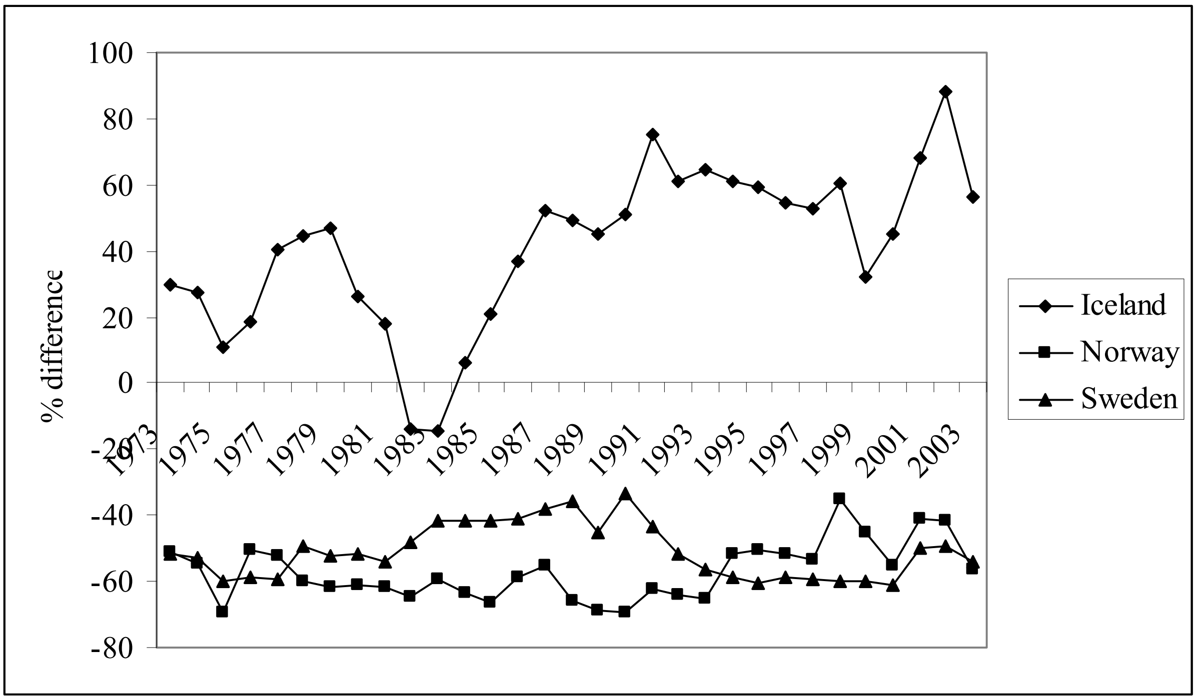

Figure 1. Percentage difference in average value added per worker between fisheries and the total economy (*Sources: Statistics Iceland, Statistics Norway and Statistics Sweden).*

One motivation behind this study is the observed differences in labor productivity among the Nordic countries' fisheries sectors. Labor productivity is here defined as value added per worker. Figure 1 shows the percentage difference in average value added per worker between fisheries and the total economy. It shows clearly that there is a dramatic gap in fisheries' relative labor productivity between Iceland on one hand, and Norway and Sweden on the other.[1] We see that Icelandic fishers have a productivity that is significantly above the national overall average in most years (the reference, or the total economy, includes fisheries, implying that the “true” gap is even wider for Iceland). Norwegian and Swedish fisheries, on the other hand, have much lower labor productivity than the average values in their respective economies.

Fisheries have a long tradition in all three countries, and several institutions have over time been established to secure the interests of stakeholders such as fishers, the processing industry, and local fishing communities. It can be argued in for example Norway that the fisheries sector is regarded as more critical for coastal regions and local communities than its share of value added suggests. The viability of many coastal communities is often strongly associated with the economic performance of local fishers and fish processors. There has been a strong tendency to try to preserve existing economic structures in the Norwegian fishing sector. For example, legislative measures have been undertaken to preserve the structure of the fishing fleet in terms of size distribution of vessels, spatial distribution, and ownership structure, often following pressure from stakeholders (typically small-scale fishers and their local communities). However, it can be argued that legislation in Norway has been more geared towards maintaining status quo than has been the case in Iceland, which has allowed for a greater firm consolidation of the fishing fleet (although there are limits on the catch rights that can be owned by individual firms). All three Nordic fisheries are industries that have been fairly heavily regulated through use of many regulatory measures that cannot be related to sustainability of fish stocks or the economic sustainability of the fishing sector as a whole, but rather to regulation of the distribution of income and ownership.

[1] These differences can only partly be explained by differences among the countries in terms of labor productivity in the general economy, where Norway has higher and Sweden lower labor productivity than Iceland. A higher capital-labor ratio in Iceland than in both Norway and Sweden can also explain the differences to some extent.

The post World War II period meant almost 30 years of economic growth in Western Europe accompanied by significant technological advances. In fisheries this meant that the technical capacity of fishing fleets eventually became high enough to deplete fish stocks to a level of collapse, which is what happened with some of the herring stocks in the North Sea, leading to complete moratoria for some stocks during several times in the 1970s. While the causes of resource depletion in fisheries are long established (Gordon, 1954), the means to address the problem of the lack of well defined property rights in fisheries in terms of regulatory approaches over the last 30 years have differed substantially among countries. Up until the 1970s, fisheries were of pure open-access nature, with 50% of the catches around Iceland landed by foreign vessels. Swedish fisheries had their most important fishing grounds outside Norway. By the late 1970s many coastal countries established exclusive economic zones 200 nautical miles outside their coast lines. This meant sovereignty for Iceland and reduced the number of co-sharing countries for Norway with respect to important stocks, while the only effect on Swedish fishers was a loss of previously international fishing grounds. The newly gained sovereignty also led to the introduction of total allowable catches (TACs), which countries (also for co-shared stocks) started to apply. Swedish fisheries management has ever since been built around TACs jointly agreed upon with neighboring countries with restrictions on gear, minimum landing size, and sometimes regulated season length; i.e., a traditional regulated open-access system (Homans and Wilen, 1997). Norway started the introduction of non-transferable individual vessel quotas (IVQs) in the 1980s. There were often quite limited options to sell and buy quotas, and several restrictions have been used to support peripheral areas. Iceland introduced individual transferable quotas (ITQs) in the herring fishery already in the 1970s, and since 1990 the whole fisheries management has been based on the concept of privately owned catch rights that can be bought and sold among fishing companies. The economics prediction is that a system that improves the poorly defined property rights in fisheries should promote productivity and make fisheries more profitable, while open-access fisheries will suffer from overcapacity and probably also from depleted fish stocks which we expect would lead to slower productivity growth.

Economists often promote the use of ITQs to reduce the property right problem in fisheries (Grafton et al., 1998). But what is the empirical experience in terms of productivity? Fox et al. (2003) and Dupont et al. (2005) evaluate the introduction of ITQs using data from before and after the introduction and do find substantial firm-level productivity improvements despite fairly short data periods of 5-6 years, although stock changes are not adjusted for.

Squires (1992) developed a method to estimate total factor productivity (TFP) where stock changes are included, which Jin et al. (2001) used in a long-term study of the New England ground fish fishery employing vessel specific data. Arnason (2003) combines national account data with fish stock measures in order to examine long-term productivity development in the Icelandic fisheries, estimating an annual TFP growth of 3.5% during 1974-1995. Recently, Hannesson (2007) used an industry-wide approach to study TFP development in Norway over a long period of time, accounting for fish stock inputs, and arrived at estimates of annual TFP growth of 1.7-4.3% during 1961-2004.

3. Productivity Growth Measurement Methodology

The starting point for measuring technical change and productivity changes is the seminal contribution by Solow (1957) where labor and capital were used in an aggregate production function to detect technical change over time. A general form of the production function for a sector which can be used as a basis for productivity analysis is (Jorgenson et al., 1987)

(1) $$Y_t = f\left(K_t, L_t, E_t, M_t, t\right),$$

where *Y* is physical output quantity, *f()* is the production function, *K* is capital input quantity, *L* is labor input quantity, *E* is energy input quantity, *M* is materials input quantity, and *t* represents the state of technology (time). This production function is often called a *KLEM* production function due to the four included inputs. If the technology has constant returns to scale then the input elasticities sum to unity; i.e., the production function is homogeneous of degree one in inputs.

Total factor productivity growth can, under the assumptions of constant returns to scale and competitive markets, be represented as

(2) $$d\ln A = d\ln Y - \alpha_K d\ln K - \alpha_L d\ln L - \alpha_E d\ln E - \alpha_M d\ln M \ ,$$

where the α‘s are the cost shares of inputs.

The production technology can also be represented in gross value added form as (Jorgenson et al., 1987, pp. 49-51):

(3) $$VA_t = g(K_t, L_t, t),$$

where *VA* is gross value added (i.e. gross output value minus the intermediate inputs energy and materials) and *g()* is the value added function. The existence of the value added aggregate requires that time and labor and capital inputs are separable from the intermediate inputs energy and materials.

Total factor productivity growth in terms of the value added function can be represented as

(4) $$d\ln A = d\ln VA - \alpha_K d\ln K - \alpha_L d\ln L \ ,$$

where α_K and α_L are the average value added shares of capital and labor, respectively.

3.1. Productivity growth measurement in a fishery

The output of a fishery also depends on the state of the fish stocks that are exploited. Fish stocks can be treated as inputs in the production process. Squires (1992) developed a procedure to account for changes in stocks when measuring multifactor productivity in fisheries. Hannesson (2007) developed this approach further to inter alia take into account that output elasticities with respect to demersal and pelagic stocks are different.

The relationship between fishing output and controlled and stock inputs can be specified as (Hannesson, 1983)

$$(5) \qquad Y_{it} = F(K_{it}, L_{it}, t) S_{it}^{\alpha_i} ,$$

where Y_{it} is output (harvest) of species i in period t, S_{it} is the stock of species i in period t, α_i is the elasticity of output with respect to stock input and assumed separability of stock and the other factors of production. Expression (5) implies that

$$(6) \qquad \frac{\partial Y_{it}}{\partial S_{it}} \frac{dS_{it}}{dt} = \alpha_i Y_{it} \frac{d \ln S_{it}}{dt} .$$

Using this expression, the Tornqvist approximation of total factor productivity change in discrete time is given by

$$(7) \qquad \begin{aligned} \frac{d \ln TFP3}{dt} &= \sum_i 0.5(s_{it} + s_{i,t-1})(\ln Y_{it} - \ln Y_{i,t-1}) - 0.5(c_{Kt} + c_{K,t-1})(\ln K_{it} - \ln K_{i,t-1}) \\ &\quad - 0.5(c_{Lt} + c_{L,t-1})(\ln L_{it} - \ln L_{i,t-1}) - \sum_i 0.5\alpha_i (s_{it} + s_{i,t-1})(\ln S_{it} - \ln S_{i,t-1}) \end{aligned} ,$$

where s_i is the revenue share of species i, and c_K and c_L are cost shares of capital and labor, respectively. Following Hannesson (2007) we use output elasticities α_i with respect to the pelagic species stock index equal to 0.1 and the corresponding measure for demersal species equal to 1. The total factor productivity change in discrete time, with only capital and labor as inputs, is given by

$$\begin{aligned}(8)\qquad \frac{d\ln TFP2}{dt} = &\sum_i 0.5\left(s_{it} + s_{i,t-1}\right)\left(\ln Y_{it} - \ln Y_{i,t-1}\right) - 0.5\left(c_{Kt} + c_{K,t-1}\right)\left(\ln K_{it} - \ln K_{i,t-1}\right) \\ &- 0.5\left(c_{Lt} + c_{L,t-1}\right)\left(\ln L_{it} - \ln L_{i,t-1}\right)\end{aligned}$$

The relationship between TFP growth measures (7) and (8) is

$$(9)\qquad \frac{d\ln TFP3}{dt} = \frac{d\ln TFP2}{dt} - \sum_i 0.5\alpha_i\left(s_{it} + s_{i,t-1}\right)\left(\ln S_{it} - \ln S_{i,t-1}\right).$$

In words, the difference between TFP3 and TFP2 is the sum of value-share weighted changes in fish stocks.

Intermediate inputs, such as fuel, services, and materials, represent an additional measurement issue. In the Tornqvist-based TFP calculation, these should ideally have been included as inputs along with labor and capital if present. However, as Hannesson (2007) points out, it is difficult to get data on intermediate input use. He therefore implicitly treats intermediate inputs as either a constant or a constant share of output value.

An alternative to measuring output change as the sum of value-share weighted output quantity changes would be to use change in gross value added, as suggested by Arnason (2003). When a value-added function is used as a basis for TFP calculation, intermediate inputs have already been netted out from output, and consequently do not need to be included among inputs. In either approach, we assume that technical change improves marginal productivity of all inputs equally, shifting the production function by the same proportion at all combinations of inputs; i.e., it is Hick's neutral (Squires, Reid, and Jeon, forthcoming). Then, a value added-based Tornqvist measure of productivity growth can be expressed as

$$(10)\quad \begin{aligned}\frac{d\ln VTFP3}{dt} &= \ln VA_t - \ln VA_{t-1} - 0.5\sum\left(c_{Kt} + c_{K,t-1}\right)\left(\ln K_{it} - \ln K_{i,t-1}\right) \\ &- 0.5\left(c_{Lt} + c_{L,t-1}\right)\left(\ln L_{it} - \ln L_{i,t-1}\right) - \sum_i 0.5\alpha_i\left(s_{it} + s_{i,t-1}\right)\left(\ln S_{it} - \ln S_{i,t-1}\right)\end{aligned}.$$

A value added-based Tornqvist measure of productivity growth that ignores stock inputs can be expressed as

$$(11)\quad \begin{aligned}\frac{d\ln VTFP2}{dt} &= \ln VA_t - \ln VA_{t-1} - 0.5\sum\left(c_{Kt} + c_{K,t-1}\right)\left(\ln K_{it} - \ln K_{i,t-1}\right) \\ &- 0.5\left(c_{Lt} + c_{L,t-1}\right)\left(\ln L_{it} - \ln L_{i,t-1}\right)\end{aligned}.$$

An additional motivation for using a value added-based TFP measure is quality changes that are reflected in the real prices of outputs. Real price changes are a source of divergence between calculated TFP growth rates based on equations (7)-(8) and (10)-(11). The average real value of a nation's catches can increase either because of an increase in the average real price of individual species or because there is a shift in the catch mix from more low-value to more high-value species. It can be argued that a real value-based measure of output from an economic welfare viewpoint can be the most appropriate to use, since it also accounts for producer activities that increase the quality and thus real value of output, and not only output quantity. In many fisheries in our three Nordic countries, several operational and investment activities have been geared towards increasing the quality of output during the data period. One problem with equations (7)-(8) is that, for example, if successful quality-increasing measures in fisheries were to lead to a general 10% increase in the real price for all species, the Tornqvist output aggregate would not be affected since all output value shares would remain constant. Yet, if the quality-increasing measure were to increase the value of only one species (output), then the value share and thus the weight of that species in the Tornqvist output aggregate would increase, while the value shares and thus the output aggregate of other species with constant quality would decline. There are, of course, problems with a value-based output measure since it may capture shifts in supply and demand in the market for a species rather than "true" productivity changes. Given the global decline in fish stocks and increases in the global seafood-eating population, it may on the other hand be argued that real price increases for some species are a result of increased scarcity. In order to get a more complete understanding of productivity growth, one should nevertheless try to account for output quality changes. Most species caught by the three countries are generally sold in a relatively integrated international market – primarily the European market which has become increasingly integrated over time. This is the case for species such as cod, haddock, saithe, shrimp, and herring. Different developments in the average price per kilo of a particular species among the countries should thus reflect different developments in the average quality of that product.

4. Data issues

The data required according to equations (7)-(8) and (10)-(11) to undertake a TFP analysis is gross value added, output quantities and prices, labor input and costs, capital input and costs, and fish stock quantities. Our aim to undertake a comparative analysis of the fisheries in the three countries poses additional challenges, as collected data for each country must be compatible with data for the other countries. In the Tornqvist approximations (7)-(8) we use catch quantities as output, and employ revenue shares in each country as weights. Labor input is approximated by the total number of active fishers in each country, where at least the initial years include a substantial minority of part-time fishers in Norway and Sweden. Concerning physical capital, particularly the Swedish data turned out to be problematic, which led to the use of total fleet capacity measured as gross registered tons (GRT). This measure is not ideal since we for our data period 1973-2003 would expect an average GRT in the 2003 fleet to be more effective in fishing than one in 1973. However, given that the renewal of the fleet followed similar patterns in the three countries since new technologies are generally available on the international market, this dilemma should not affect the comparisons among countries. Finally, we use fish stock data reported by the ICES working groups and compiled in collaboration with a former ICES fisheries biologist. We use data on six species for Sweden and ten species for Iceland and Norway, which in catch value correspond to roughly 80% of each country's total landed value (see also Appendix A). The aggregate stock indices were constructed by giving each stock a weight corresponding to its share of each country's landed value. For the TFP analysis we have data for the period 1973-2003 for the three countries. Data on some variables, such as output quantity, output value, and labor input, are also available from 1960, and we will use this in parts of the analysis.

The fisheries sectors in the three countries target similar species to a large extent, and in some cases partly the same stocks. Cod and herring are the two most important species, and also represent two important groups of fish: demersal and pelagic species. Bottom feeding, or demersal, species fit fairly well with the assumption of uniform distribution and catches proportionate to stock size, as predicted by the classical Schaefer production function (1957). Pelagic species like herring, mackerel, and capelin live higher up in the water column and have a different distribution pattern. Bjørndal (1988) refers to studies that indicate that catch per unit fishing effort is independent of stock size for herring. Hence, explicitly accounting for this implies that stock changes in pelagic species may have only a limited effect on productivity. This is the rationale for employing output elasticities with respect to the pelagic species stock index equal to 0.1 and the corresponding measure for demersal species equal to 1 in this paper and in Hannesson (2007).

5. Empirical results

In this section we examine the development of output, inputs, prices, and ultimately TFP growth in our three Nordic countries. Figure 2 reports the value of landings during 1960-2003 in 2003 prices. Each country's landed value is deflated by national consumer price indices and then converted to Norwegian kroner using the 2003 exchange rates. More than 60% of the total Swedish landed value came from pelagic species at the beginning of the studied period, while the corresponding figure was fully 40% at the end of the period. In the 1960s, pelagic catches were dominated by herring primarily sold for human consumption, while pelagic catches since the 1970s have been gradually more and more sold for reduction, implying a substantial drop in real price paid per kilogram. Norway had a fairly stable mix: almost 60% of the landed values came from demersal species both at the beginning and at the end of the period. This led to an increase in real landed value thanks to substantial increases in prices paid for demersal species like cod, haddock, saithe, redfish, and Greenland halibut.

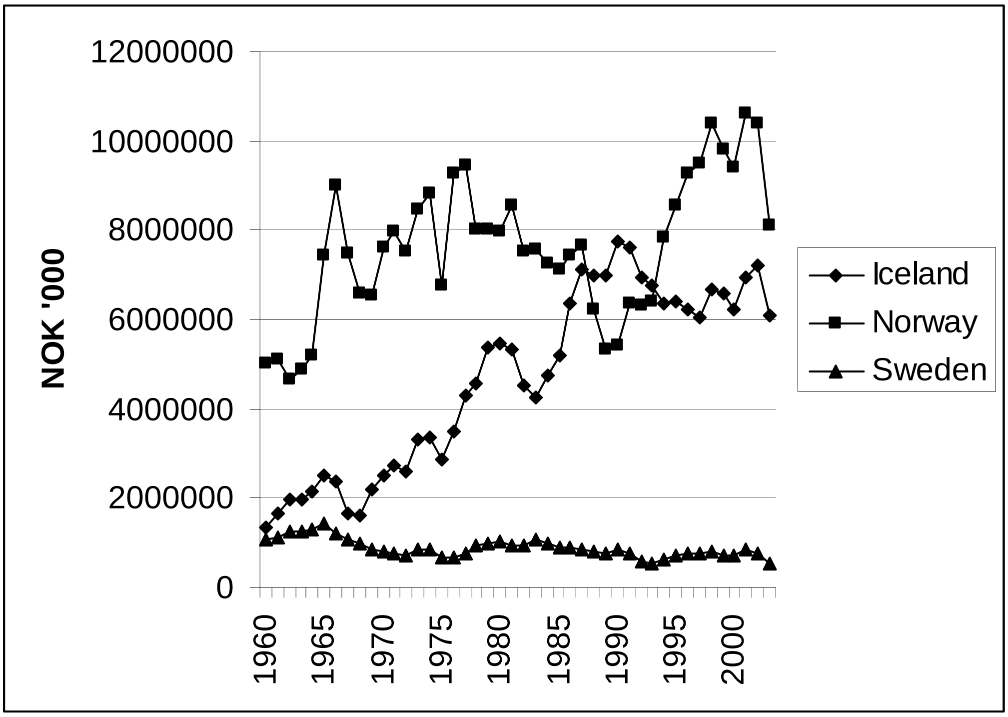

Fig 2. Value of fish landings in Iceland, Norway, and Sweden, 1960-2003 (deflated by national CPI and converted at 2003 exchange rates, i.e., NOK 1 = SEK 1.14 = ISK 9.23).

Figure 3 shows the development of the real catch value per kilo in NOK from 1973 to 2003, with the logarithmic trend for each country. Iceland and Norway experienced a roughly similar increase in average unit price according to the trend lines, while Sweden experienced a dramatic decline, with real unit prices in the later years that were roughly 50% of that in the early years. Iceland had a composition of 60% demersal species in the 1960s, while the value share from demersal species increased to about 70% at the end of the period. The increasing and dominating share of demersal species, which all increased substantially in real price, is a central explanation to the tremendous growth in real value of landings for Iceland during the period 1973-2003.

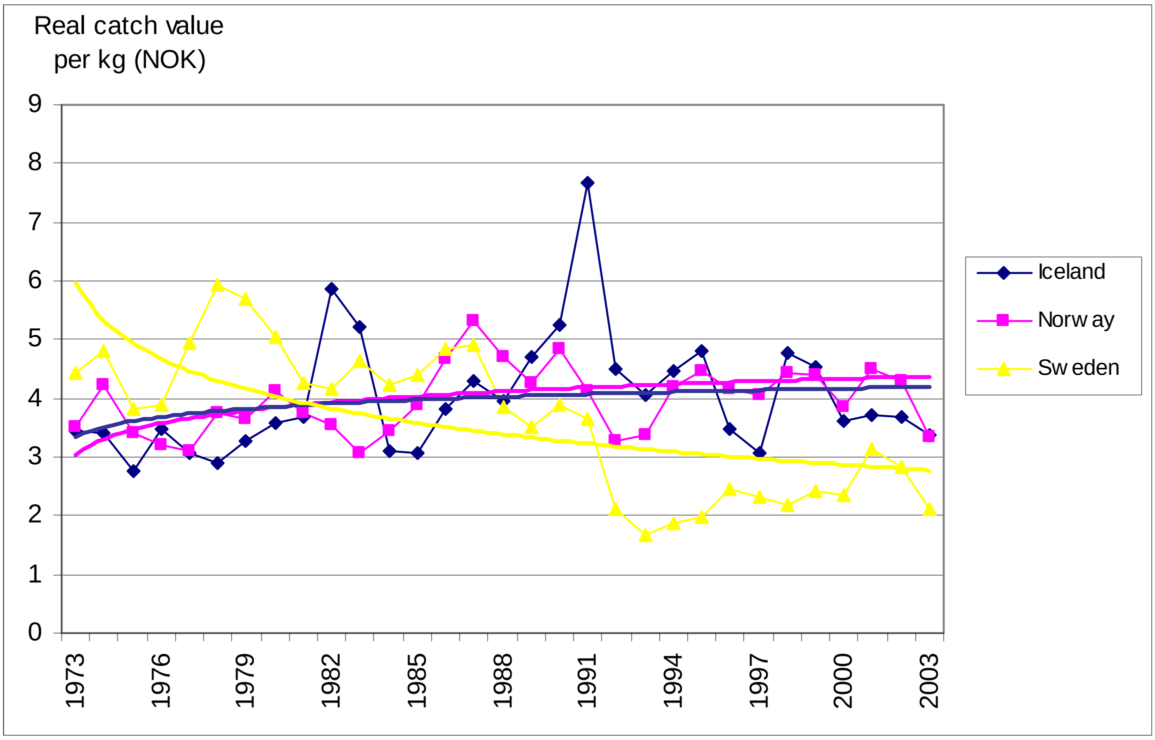

Figure 3. Real average unit catch value per kg with logarithmic trend, in NOK (2003=100).

The explanation behind the increase in the average unit price cannot only be explained by changes in species composition. Figure 4 shows the development of the cod real price index during the period; we see that Iceland's real price development was better than Norway's and similar to Sweden's. When we examined all relevant species we found that Iceland generally experienced a similar or better real price development than the two other countries over the period. Since the different species to a large extent are sold in integrated international markets (primarily the European market), this suggests that Iceland has been able to increase the quality of its product more than the other two countries.

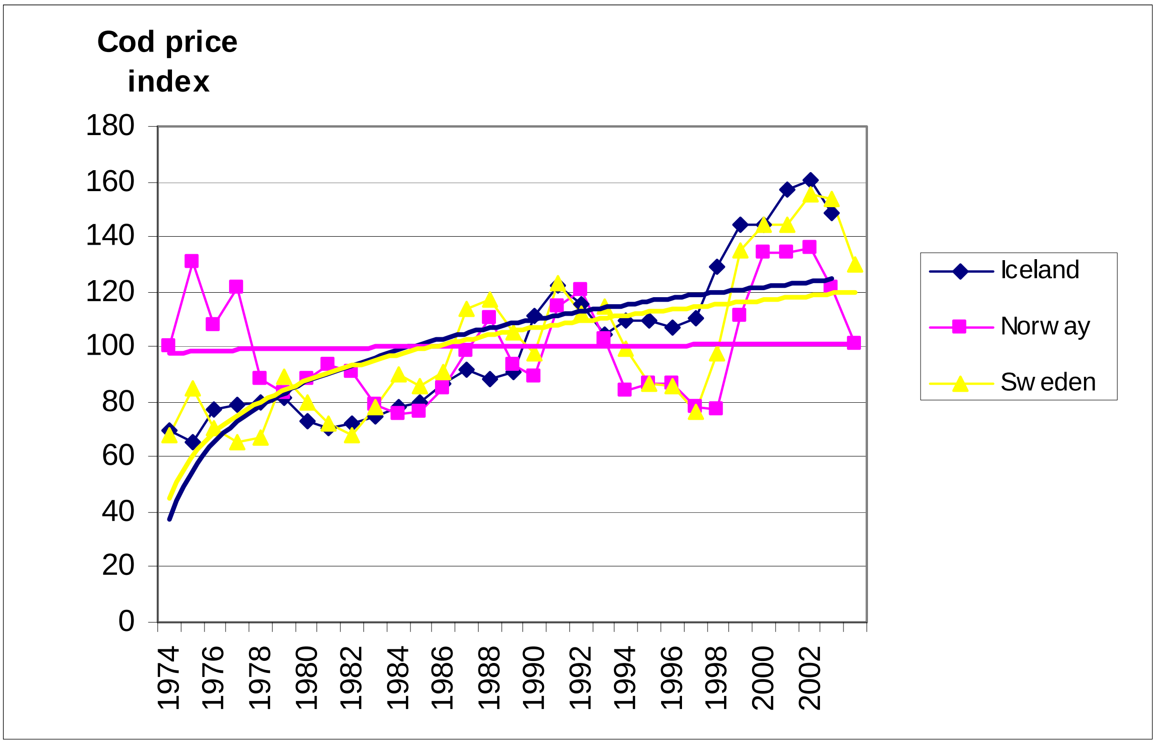

Figure 4. Development of the real price index for cod with logarithmic trend (average 1973-2003=100).

Recent studies report that an initial effect of the introduction of ITQs was increased revenues thanks to increased quality (Fox el al., 2003; Dupont et al., 2005; Homans and Wilen, 2005). This could gain some support from the Icelandic data. However, real prices of Icelandic landings started to increase already in the late 1960s, probably largely due to transportation technology innovations and reduced transportation costs, which resulted in better access to the large fish import markets in continental Europe and the UK and hence increased revenues from fish export. For example, transportation technology improvements have led to a shift from frozen cod to higher valued fresh cod in the UK market.

Mundlak (2005) analyzes long-run trends in the US agricultural sector and points out that occupational migration from one sector to another is driven by the gap in income between sectors. Given the increase in real wages in other sectors of the economy and the real landed value decline, we would expect a substantial reduction in the number of Swedish fishers. This is also confirmed by Figure 5, where we see a reduction in Swedish fishers from 1960 to 2003 by almost 90%. Similarly, there was a 70% reduction in Norway, while the number of Icelandic fishers actually increased by 2%.

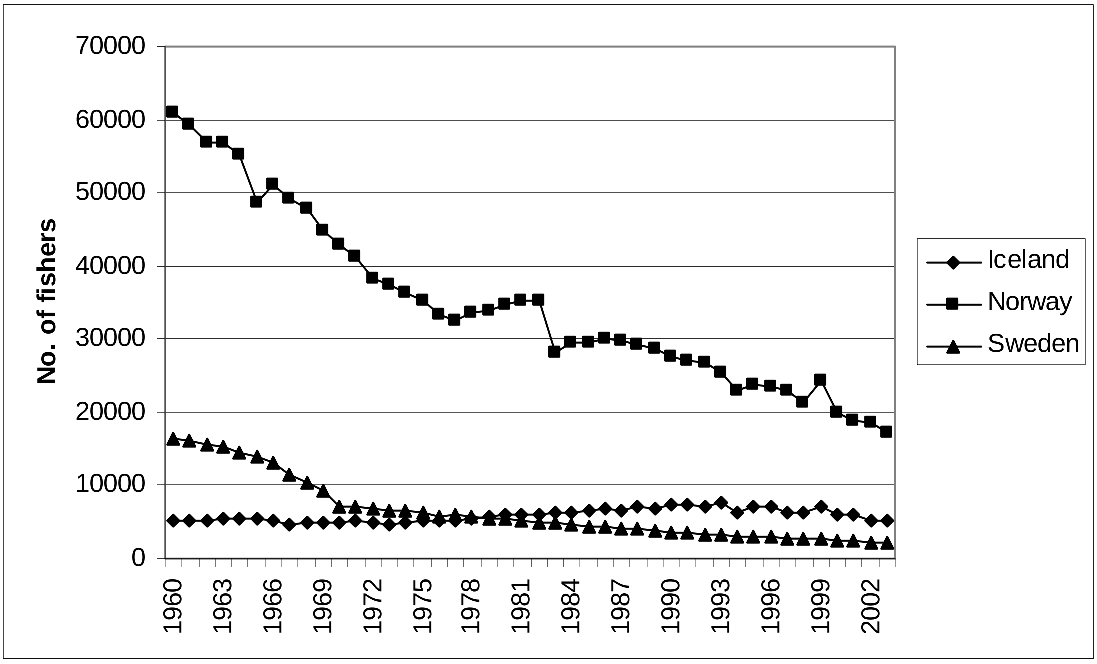

Figure 5. Number of fishers in Iceland, Norway, and Sweden, 1960-2003.

In Figure 6 we report the development of GRT for each country's fishing fleet. Iceland more than doubled its fleet size, while Sweden had a small increase of 20% and Norway experienced a fleet reduction of almost 30%. As noted earlier, GRT is not an ideal measure of physical capital. Hannesson (2007) used real capital investment figures from Statistics Norway and found an increase in capital for Norway of 30-40% for the period 1961-2003, while our GRT measure indicates a 20% reduction. Arnason (2003) used total real value of fleet and found an increase of Icelandic capital of about 70% from 1974 to 1995, while our GRT measure indicates a 23% increase over the same period. Hence, in comparison with the previous studies, we would expect a slight upward bias in productivity growth using GRT figures.

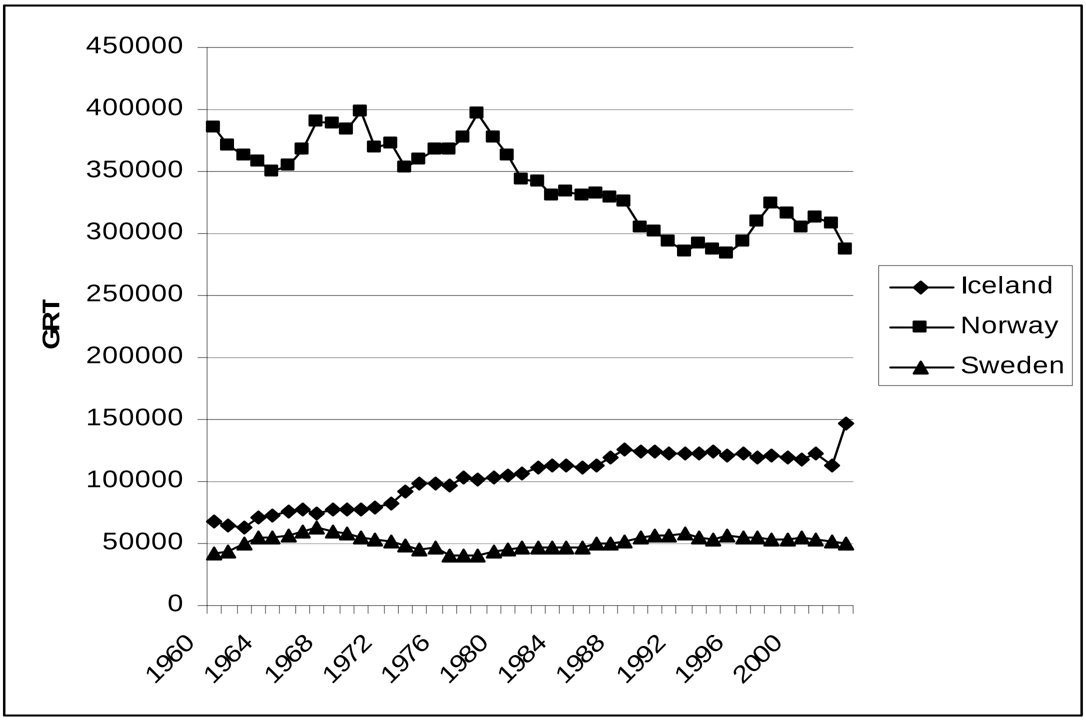

Figure 6. Total fleet size in gross registered tons (GRT) in Iceland, Norway, and Sweden, 1960-2003.

Next, we introduce fish stock input into the productivity analysis, which may to some extent explain the development in TFP2 from 1973. The development in the fish stock index from 1973, which is chosen as a starting point after an assessment of data quality, is shown in figure 7. One noteworthy feature of the fish stock index for all three countries is the substantial volatility over time, a volatility which is much higher than for the 'controllable' inputs labour and capital. For Iceland fish stock input declined by around 45% from 1973 to 2003, for Norway the decline was 25%, and for Sweden 60%. Later in this section we will see how the inclusion of stock input influences TFP estimates.

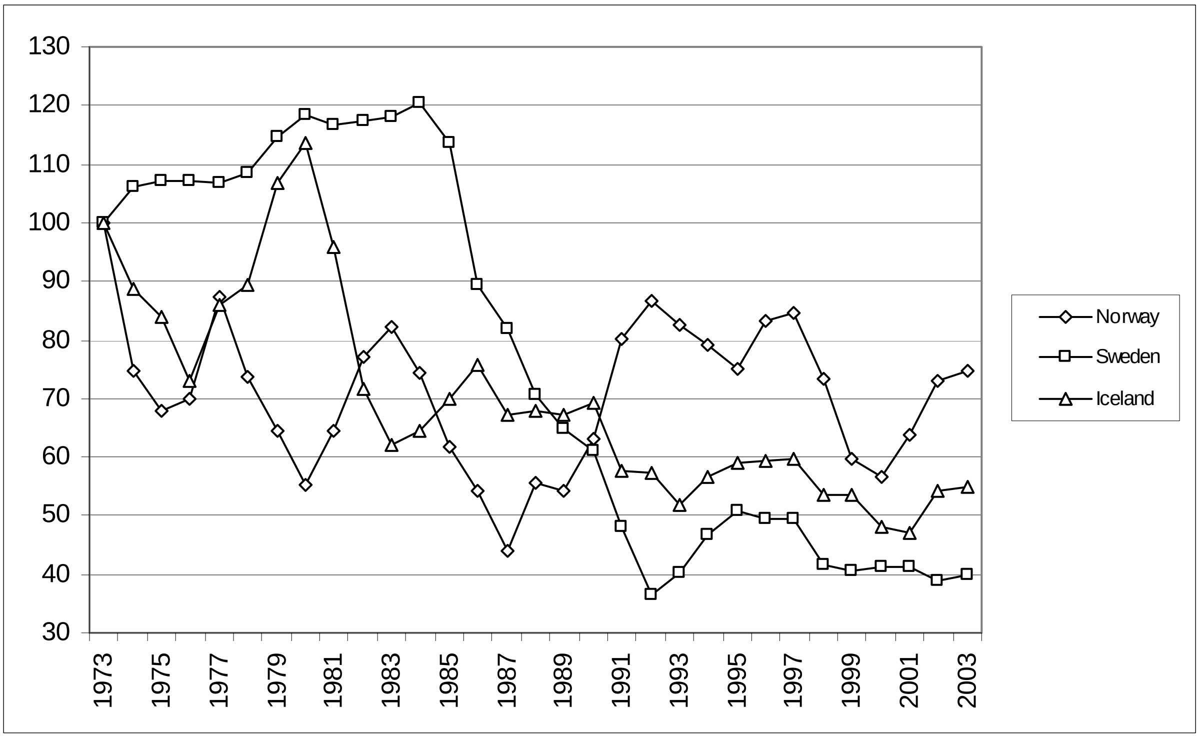

Figure 7. Fish stock input index (1973 = 100)

Figure 8 shows real landed value added (in 2003 NOK) per fisher in the three countries. Despite the fact that Norway and Sweden experienced a massive labor migration out of the fishing sector, there are still fishers in Sweden and most likely Norway who earn substantially less than the respective country average for unskilled labor. The development is different in Iceland. Due to increasing real revenues, the earnings of Icelandic fishers are high enough to keep labor in the industry. Similarly, capital is to a larger extent attracted to fisheries in Iceland than in Norway and Sweden. Only to some extent can the difference in value added be explained by a higher capital-labor ratio in Iceland than in the other two countries.

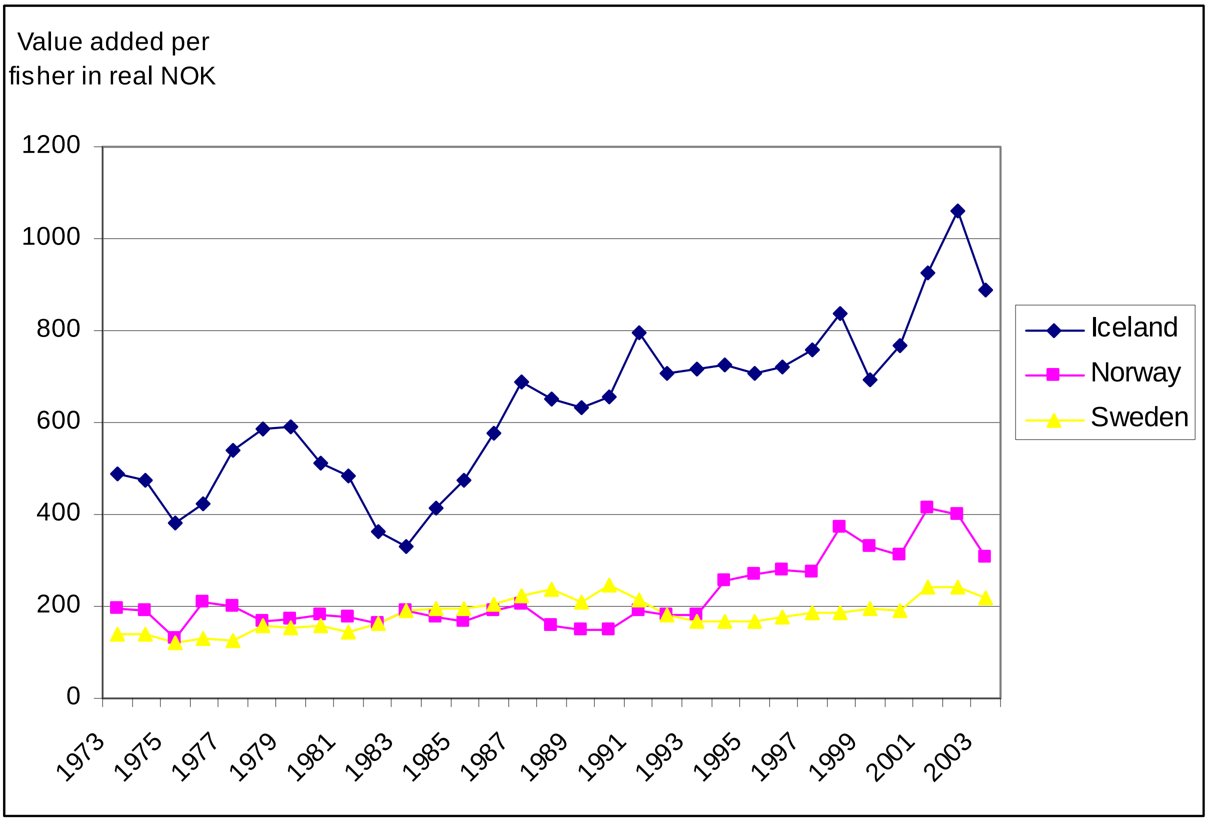

Figure 8. Labor productivity measured by real value added per fisher 1973-2003, in 1000 NOK (2003=100).

We now turn to the measurement of total factor productivity growth. Table 1 shows Tornqvist output value-weighted TFP growth rates (TFP2 and TFP3), value added-based TFP growth rates (VTFP2 and VTFP3), and their components for the period 1973-2003. Overall, TFP growth is on average found to be positive for all three countries during the period for all four measures, with the exception of the negative TFP2 for Iceland. The positive average TFP figures in Table 1 lie in the 0.8-4.3% range. For all countries we see that the average TFP growth is quite influenced by the inclusion or exclusion of stock input (TFP2 vs TFP3, and VTFP2 vs VTFP3) and the choice of output measure (value-weighted output aggregate- or value added-based). For Iceland and Sweden, TFP growth increases significantly when stock input is included, while for Norway it decreases slightly.

Table 1. Tornqvist output value-weighted and value added-based TFP growth rates (in %) and their components 1973-2003.*

	Iceland	Norway	Sweden
Fishers	0.0016	-0.0183	-0.0268
Capital	0.0047	-0.0021	0.0009
Demersal stock	-0.0147	0.0026	-0.0261
Pelagic stock	0.0077	-0.0175	0.0044
Tornqvist Output Aggregate	0.0019	0.0013	-0.0076
Value added	0.0222	-0.0112	-0.0234
TFP2	-0.0043	0.0217	0.0182
TFP3	0.0097	0.0209	0.0439
VTFP2	0.0160	0.0092	0.0025
VTFP3	0.0300	0.0084	0.0282

* Tornqvist-based TFP growth, TFP3, is defined by equation (7), TFP2 by equation (8). Value added-based TFP growth, VTFP3, is defined by equation (10), and VTFP2 by equation (11).

The four different TFP growth measures do not produce a consistent ranking of the three countries' productivity performances. We see that TFP2 ranks Norway first, followed by Sweden and then Iceland. When TFP3 is used, Sweden is ranked first, followed by Norway and then Iceland. The value added-based VTFP2 measure ranks Iceland first, followed by Norway and then Sweden. Finally, VTFP3 ranks Iceland first, followed by Sweden and then Norway. It is interesting to note that the two Tornqvist output value-weighted TFP measures (TFP2 and TFP3) rank Iceland last, while both TFP measures based on value added (VTFP2 and VTFP3) rank Iceland first. The source of this discrepancy is Iceland's ability to increase the average real unit value of its catch relative to its neighboring countries. Iceland increased its real average catch value both through a change in species mix and through an increase in the real prices of the most important species.

Best-practice fishing technologies are available on the international market. State-of-the-art fishing equipment has over time increasingly been manufactured and sold by companies to fishers in many countries. This should contribute to convergence in productivity over time. On the other hand, permanent differences in biophysical characteristics that determine the abundance and other characteristics of fish stocks will limit the degree of convergence. Finally, the development of government regulations over time may lead to convergence in TFP if regulatory regimes become more harmonized. According to our TFP estimates, there is no uniform evidence of productivity convergence among the three countries over time. While the Tornqvist output value-weighted TFP measures TFP2 and TFP3 imply convergence between the productivity leader Iceland and the productivity laggards Norway and Sweden, the value added-based measures VTFP2 and VTFP3 imply divergence.

6. Discussion and conclusions

This is as far as we know the first comparative study of total factor productivity development in fisheries involving several countries. We use comparable data for Iceland, Norway, and Sweden and analyze their 1973-2003 productivity development on an aggregate level. The accomplishment of making the data on the three countries compatible came at the expense of some loss in accuracy of measuring the inputs. We do not have information on capacity utilization and cannot adjust for this potential source of bias as in Jin et al. (2001). We calculated four competing measures of TFP growth: two used value-weighted output quantity and two used value added. TFP was also calculated with and without fish stock input. For Iceland and Sweden we found that inclusion of stock input in our TFP measures led to a significant increase in average TFP growth during the period. Assuming that including fish stocks gives more accurate results, we found total factor productivity growth rates in the interval 1.0-3.0%, 2.1-0.8%, 4.4-2.8% for Iceland, Norway, and Sweden, respectively.

The TFP3 measure based on value-weighted output ranks Iceland last among the three countries, while the TFP measure based on value added ranks Iceland first. This shows the effect of Iceland's ability to increase the average real unit value of its catch relative to its neighboring countries. Iceland has increased its real average catch value both through a change in species mix and through an increase in the real prices of the most important species. Hence, if we put more confidence in the results from the value-added TFP measure compared to the value-weighted output, they imply divergence in productivity growth.

During the thirty year period 1973-2003, Iceland went from an open-access to a completely implemented ITQ fishery, while Sweden basically still relies on a traditional regulated open-access management. Norwegian fisheries management has gradually developed in the direction of more rights-based fishing approaches, but the extent of individual quotas is less than in Iceland and the transferability is more restricted as well.

Mundlak (2005) emphasizes that growth is determined by the economic environment in a country. Iceland, Norway, and Sweden have had similar economic development and should be at a similar stage of technological development, since state-of-the art technology is transferred rapidly across countries. However, they differ in terms of incentives, constraints, and institutions when it comes to fisheries. Icelandic firms holding ITQs in 1999 enjoyed a total annual rental value of USD 450 million, which is roughly half of the landed value for that year (OECD, 2002). Such a development towards wealth creation is in principle absent in Swedish fisheries, and is at a substantially lower level in Norway. During the last 30 years, rapid changes have evolved in the fish market in Western Europe. Two characteristic features have been noticed: Demand for demersal species has increased faster than output, which has led to a substantial increase in real value prices of species like haddock and cod. In parallel, human consumption of pelagic species like capelin and herring has declined, and pelagic fisheries are currently dominated by species that are mainly sold for reduction purposes where demand has grown slower than output, resulting in lower real value prices for those species. Icelandic fisheries have enjoyed a greater level of market integration, with higher paying

European fish markets leading to more harmonized real value prices compared to Norwegian and Swedish fisheries. They have also managed to increase their share of demersal landings. Together, this has led to a substantial increase in real catch revenues. Norwegian real value output has experienced a more modest growth, and Swedish fisheries have suffered from a large dependence on an increasing share of pelagic species in landings, leading to a substantial real value drop in revenues. In order for citizens to keep up with the growing real income levels in Norway and Sweden, both countries have experienced a drastic labor migration out of the fisheries. Our data indicates that despite this reduction in the fisheries labor force, there are still Swedish and most likely Norwegians fishers who earn low incomes, while Icelandic fishers already in the 1960s were paid well on average. This has led to a situation in Iceland where other sectors are only modestly attractive to fishers.

According to economic theory, the technological advances in the 1960s combined with the open-access fisheries should lead to increased investment in fisheries capital and maybe increased employment, which in turn implies reduced fish stocks. Hence, we would expect that Icelandic fish stocks were below optimal levels in 1973 and that if the ITQ regime has been successful, stocks would have recovered to higher levels today. Icelandic demersal stocks, which are the most valuable, have been slightly reduced since 1973, while pelagic stocks are a bit larger. Sweden experienced a similar pattern, while Norwegian demersal and pelagic stocks were both larger in 2003 than in 1973.

Overall, our results indicate that the flourishing Icelandic fisheries have managed to attract both labor and capital by remuneration in level with or potentially even above the rest of the economy. This has been fueled by growth in real output value. In Sweden and Norway labor remuneration has not kept up with the rest of the economy, leading to dramatic labor force reductions. This trend has been reinforced by poor development of real value revenues, particularly in Sweden. An area for further research would be to study remuneration levels for labor and capital in order to analyze the driving forces of input changes in greater detail. Concerning the stock development, we note that despite the introduction of the exclusive economic zones in the late 1970s and the rights-based fisheries in Iceland, pelagic stocks have grown only slightly while demersal stocks have decreased somewhat. If there are forces at work to increase stock levels in Iceland, they are certainly slow and have met substantial institutional obstacles so far.

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Appendix A. Sources of data

Data for this study was collected from Statistics Norway and The Norwegian Directorate of Fisheries, Statistics Sweden and The Swedish Board of Fisheries, and from Statistics Iceland and the Icelandic Marine Institute. Below, we indicate some of the various issues arising for each group of variables when creating compatible data sets for the three countries.

The general approach for various types of prices and values has been to use the consumer price index or producer price index provided by each country's official statistics body for deflation into 2003 prices, and to convert Swedish kronor (SEK) and Icelandic kronor (ISL) into Norwegian kroner (NOK) using the 2003 exchange rates. It is not obvious which is the appropriate exchange rate to use. Some studies use purchasing power parity (PPP) based exchange rates, e.g. Acemoglu and Zilibotti (2001). It should be noted that the choice of exchange rate has no effect on the TFP estimates that we present here, only cross-country comparisons of monetary variables in levels, such as value added per fisher.

A.1. Catches

Data on total catches of fish, in volume and value, and prices of different types of fish were cross-checked and calibrated with data from Working Group Reports from the International Council for the Exploration of the Sea (ICES) with the assistance of a former ICES biologist (see also discussion under stocks). Swedish catches included the following species: shrimp, cod, Norway lobster, herring, and sprat. Norwegian catches included: Greenland halibut, shrimp, saithe, cod, redfish, haddock, capelin, mackerel, and herring. Icelandic catches included: Greenland halibut, shrimp, saithe, cod, redfish, haddock, Norway lobster, capelin, herring, and blue whiting.

A.2.Labor

Statistics Sweden and The Swedish Board of Fisheries provided annual numbers of professional fishers, except for some of the interior years of the period where interpolated means were used. Statistics Norway and Statistics Iceland provided full time series of annual numbers of fishers for each country.

A.3.Capital

Time series on gross registered tons were obtained from Statistics Sweden and The Swedish Board of Fisheries, The Norwegian Directorate of Fisheries and Statistics Norway, and by Statistics Iceland and the Icelandic Directorate of Fisheries.

A.4.Stocks and stock-specific catches

We used the 2005 reports of the following ICES working groups: For stocks exploited by Swedish fishers, Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak, Pandalus Assessment Working Group, Working Group on Nephrops Stocks, The Herring Assessment Working Group for the Area South of 62ºN, and the Baltic Fisheries Assessment Working Group. For Norwegian fisheries, Pandalus Assessment Working Group, Herring Assessment Working Group for the Area South of 62ºN, the Northern Pelagic Working Group, and the Arctic Fisheries Working Group. For the stocks exploited by Icelandic fishers, we used the report by the ICES North-Western Working Group.

Stock assessments for shrimp (Pandalus in IIIa and IVaE) started in 1984, and the previous years were assumed to equate an average of the first ten years, 1984-93. Similarly, an average of the first ten years of stock assessments for Norwegian shrimp (Pandalus in I and II) was used for 1973-1979. The same approach was also applied to the Norwegian North Atlantic blue whiting stock for the years 1973-80, and for Norwegian redfish during 1973-85.

For Icelandic stocks, an average of the first available ten years provided stock figures for Icelandic shrimp (Pandalus Va) 1973-1986, capelin 1973-78, Greenland halibut 1973-75, redfish 1973-84, and blue whiting 1973-80.