Productivity Development in Icelandic, Norwegian, and Swedish Fisheries

Håkan Eggert, Ragnar Tveteras

Productivity Development in Icelandic, Norwegian, and Swedish Fisheries

Journal:	*Applied Economics*
Manuscript ID:	APE-2010-0198.R1
Journal Selection:	Applied Economics
Date Submitted by the Author:	08-Mar-2011
Complete List of Authors:	Eggert, Håkan; University of Gothenburg, Economics Tveteras, Ragnar; University of Stavanger, Business School
JEL Code:	D24 - Production|Capital and Total Factor Productivity|Capacity < D2 - Production and Organizations < D - Microeconomics, O47 - Measurement of Economic Growth|Aggregate Productivity < O4 - Economic Growth and Aggregate Productivity < O - Economic Development, Technological Change, and Growth, Q22 - Fishery < Q2 - Renewable Resources and Conservation|Environmental Management < Q - Agricultural and Natural Resource Economics
Keywords:	convergence, fisheries, growth accounting, natural resources, total factor productivity

Acknowledgement Thanks to Bengt Sjöstrand, Institute of Marine Research, Sweden, for help with stocks and landings. Advice on Icelandic data from Sveinn Agnarsson, University of Iceland, is gratefully acknowledged. Financial support from The Nordic Working Group on Fishery Research, The Adlerbert Research Foundation, and support from Sida to the Environmental Economics Unit at University of Gothenburg is acknowledged.

Productivity Development in Icelandic, Norwegian, and Swedish Fisheries

Abstract

This paper analyzes the total factor productivity (TFP) performance of fisheries in Iceland, Norway, and Sweden during the period 1973-2003. We measure TFP growth using real gross value added as output and capital input, labour input and a stock input index based on the major fish stocks. In developed neighbouring countries, we expect rapid diffusion of fishing technology innovations contributing to productivity convergence. In addition, innovations in the public regulation and the industrial organization may also have influenced productivity growth during the period. We find that Iceland has had the highest annual TFP growth. Accounting for stock changes it amounts to 3 percent, while the corresponding figures for Sweden and Norway are 2.8 and 0.8 percent, respectively. Despite best-practice fishing technologies being widely available, we find no evidence of productivity convergence among the three countries.

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

JEL codes: D24, O47, Q22.

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. 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. Measuring productivity of nations' fisheries is basically similar to the approach for any other industry. The use of capital, labor, and intermediate inputs, how it is organized, and how technological innovations are adopted, all in relation to output, determine the development. However, fisheries provide an additional feature. Fish stocks are important for capture fisheries[1] and excluding those would lead to biased estimates (Squires, 1992).

Squires (1992) developed a method to estimate total factor productivity (TFP) where stock changes are included, which Jin et al. (2002) used in a long-term study of the New England ground fish fishery employing vessel specific data finding an annual TFP growth of 4.4%. Arnason (2003) combined national account data with

[1] Capture fisheries in this article refer to commercial catching of fish living and growing in in the sea without any control of the growth stages of the species (in aquaculture all stages are controlled but in between cases exist, but are not relevant for our study).

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 (2007a) 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.

This study is to our knowledge the first to explore potential differences in the productivity development of fisheries in several countries. An additional objective is to assess the general economic issue of convergence or divergence (Bernard and Jones, 1996b), i.e. whether differences in fisheries productivity between countries tend to diminish or increase over time. The effects of stock input and of the quality of landed fish on productivity are analyzed. We use a national account data approach like Arnason (2003) measuring output as real gross value added combined with the methodology developed by Squires (1992) and Hannesson (2007a). We find positive average annual productivity growth in all countries in the interval 0.8-3.0%. Iceland had the highest productivity growth while Norway experienced the lowest growth. We explicitly test for productivity convergence among the three countries over time, which is rejected for all reasonable levels of significance.

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.

In 2003, fisheries directly contributed 7% of the total Icelandic GDP. However, if we consider the multiplier effects on the service and manufacturing sectors it contributes a larger share directly and indirectly. The corresponding figures for Norway and Sweden were 0.7% and 0.04%, respectively (FAO, 2009). In some regions in Norway, with a total population similar to Iceland's, 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.

Some of the research on convergence across countries has focused on labor productivity (Bernard and Jones, 1996a). In the Nordic countries' fisheries sectors there are differences in labor productivity, 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.[2] Icelandic fishers' productivity is significantly above the national overall average in most years. Norwegian and Swedish fisheries, on the other hand, are substantially below the average values in their respective economies.

Productivity Growth Measurement Methodology

[2] 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 starting point for measuring technical change and productivity changes is the seminal contribution by Solow (1957) where labour 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) $$Y_t = f(K_t, L_t, E_t, M_t, t),$$

where Y is physical output quantity, $f()$ is the production function, K is capital input quantity, L is labour 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. The standard approach is to assume that the technology has constant returns to scale, which implies that input elasticities sum to unity (i.e. the production function is homogeneous of degree one in inputs), and 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 (Bernard and Jones, 1996a).[3] Total factor productivity growth can, under the assumption of competitive markets, be represented as

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

[3] More general functional forms like the translog or a CES production function would call for more details in the data.To study productivity differences using the CES production function requires that the elasticity of substitution between factors can vary across countries and perhaps even over time and using the translog would ask for a test whether coefficients on labor and capital are equal across countries (Bernard and Jones, 1996a). The same applies for a Harrod neutral instead of a Hicks neutral productivity measure and due to data limitations we use the outlined standard approach (for an extensive discussion, see also Hulten, 2000). An area for future research could be to explore non-neutral technical change, which often has been documented in production frontier studies (e.g. Battese and Broca, 1997).

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 labour, respectively.

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 (2007a) developed this approach further inter alia to 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) $$Y_{it} = F(K_{it}, L_{it}, t) S_{it}^{\alpha_i},$$

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

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

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

where s_i is the revenue share of species i, and c_K and c_L are cost shares of capital and labor, respectively.

Intermediate inputs like fuel, services, and materials represent an additional measurement issue as it is difficult to get such data. Arnason (2003) suggests measuring output change as change in gross value added, meaning that intermediate inputs are netted out from output, and are excluded among inputs.[4] Then, a value added-based Tornqvist measure of productivity growth can be expressed as

(8)

$$\frac{d\ln VTFP}{dt} = \ln VA_t - \ln VA_{t-1} - 0.5\sum\left(c_{Kt} + c_{K,t-1}\right)\left(\ln K_t - \ln K_{t-1}\right) - 0.5\left(c_{Lt} + c_{L,t-1}\right)\left(\ln L_t - \ln L_{t-1}\right) - \sum_i 0.5\alpha_i\left(s_{it} + s_{i,t-1}\right)\left(\ln S_{it} - \ln S_{i,t-1}\right).$$

The total factor productivity level of the fishing fleet in country *c* can be assumed to evolve over time according to (Bernard and Jones, 1996):

(9) $$\ln VTFP_{c,t} = \gamma_c + \lambda \ln VT\hat{F}P_{c,t-1} + \ln VTFP_{c,t-1} + \varepsilon_{c,t},$$

where γ_c is the asymptotic rate of growth of country *c*, λ is the catch-up speed parameter, and $\varepsilon_{c,t}$ is a country-specific stochastic productivity shock. The catch-up variable $\ln VT\hat{F}P_{c,t}$ is the log of the productivity ratio between country *c* and country 1 in time period *t*, the most productive country (in our case Iceland), i.e. $VT\hat{F}P_{c,t} = VTFP_{1,t} / VTFP_{c,t}$.

In this formulation productivity gaps between countries are a function of the lagged productivity gap. We then obtain the following equation for the time path of the TFP ratio:

(10) $$\ln VT\hat{F}P_{c,t} = \left(\gamma_1 - \gamma_c\right) + \left(1-\lambda\right)\ln VT\hat{F}P_{c,t-1} + \hat{\varepsilon}_{c,t}.$$

[4] Both the Tornqvist based TFP and the gross value added approach entail potential biases if intermediate inputs are not constant in share of inputs and outputs. Given our crude measures of labor and capital, which do not adjust for any change in intermediate input use, we prefer the gross value approach as it adjusts for changing intermediate input share of the output value.

where $\ln VT\hat{F}P_{c,t} = \ln VTFP_{1,t} - \ln VTFP_{c,t}$. Our test of productivity convergence will be based on this equation. A value $\lambda > 0$ provide an impetus for catch-up in the sense that productivity differentials between the two countries increase the growth rate of the country with lower productivity. But only if $\lambda > 0$ and $\gamma_c = \gamma_1$, i.e. the asymptotic TFP growth rates are the same, will countries converge (Bernard and Durlauf, 1995). The null hypothesis is H_0: $\lambda = 0$ and $\gamma_c \neq \gamma_1$. In other words, we test the null hypothesis of no convergence, which is defined to mean that the deviation in productivity from the productivity leader is a nonstationary process with nonzero drift.

Data issues

The data required according to equation (8) to undertake a TFP analysis is gross value added, labour 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 this study we deflate nominal value added in domestic currency units with the domestic consumer price index. We avoid using the procedure of first using the exchange rate or purchasing power parity index in each year to convert into a common currency of a numeraire country, and then deflate using a price index of the numeraire country. The reason is that there have been exchange rate regimes in these three countries that probably have created substantial exchange rate distortions during the data period. This choice is also motivated by studies that find ample empirical evidence that exchange rates do not vary in a way that reflect differences in price levels across countries (Rogoff, 1996; Pardey, Roseboom and Craig, 1992).

Labour 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 measure of capital input as gross registered tons (GRT) of the total fleet. We assume that the renewal of the fleet followed similar patterns in the three countries and since new technologies are generally available on the international market this approach should not affect the comparisons between countries. Both labor and capital are measured as stocks and ideally we would have figures on intensity use for those over the years in the three countries, but such figures are not available. Hence, our use of stocks as measures of flows implicitly assume that intensity use of both capital and labor have been constant in each country over the years.

Finally, we use fish stock data reported by the ICES working groups and compiled in collaboration with a former ICES fisheries biologist. Stock assessment is not an exact science and errors may lead to bias in productivity estimates. Another concern is that figures from ICES working groups often rely to some extent or even completely on commercial catches (Beare et al, 2005), which also may lead to bias. Still, ICES working groups represent state of the art and are to our knowledge the only provider of systematic stock assessment of all important species over a long time period. 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.

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, which represent two groups of fish demersal and pelagic species that differ in terms of the "stock effect". Bottom feeding, i.e. demersal species are often assumed to have a maximum stock effect implying uniform distribution and catches proportionate to stock size, following 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. Despite its importance there are few empirical studies of the stock effect, but existing ones indicate a significant stock effect for demersal species like cod, haddock and saithe (Hannesson, 1983; Hannesson, 2007b; Sandberg, 2006) while the stock effect for herring is very weak (Bjørndal, 1987; Sandberg, 2006). 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 (2007a).

Empirical results

In this section we analyze the development of output, inputs, prices, TFP growth, and ultimately whether there has been convergence in productivity when comparing our three Nordic countries. Figure 2 reports the value of landings during 1973-2003 in a common currency, Norwegian kroner. Each country's landed value is deflated by national consumer price indices, which provide us with time series on the relation between inputs and outputs for each country. We 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.

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 early 1970s, 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.

The explanation behind the increase in the average unit price cannot only be explained by changes in species composition. Table 1 presents the development of the cod real price index during the period; showing that Iceland's real price development was better than Norway's and similar to Sweden's. When examining 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.

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 more 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 Table 1, where we see a reduction in Swedish fishers from 1973 to 2003 by almost 70%.[5] Similarly, there was

[5] During the 1990s, Swedish fishermen had income substantially lower than unskilled labor in the manufacturing sector (Stigberg, 1997; Eggert and Ulmestrand, 1999), while Icelandic fishermen were highly paid (Danielsson, 1997). Norwegian fishermen on average had wages at pair with wages in other sectors (Hannesson, 2007a), but wages vary substantially between groups of fishermen. Hannesson (1985) found that small scale fishermen in the North and the West of Norway earned substantially lower wages than those in large scale trawl and purse seine fisheries.

more than a 50% reduction in Norway, while the number of Icelandic fishers actually increased by 7%.

In Table 1 we report the development of GRT for each country's fishing fleet. Iceland increased its fleet size by 60%, while Sweden had a small increase of 20% and Norway experienced a fleet reduction of 20%. As noted earlier, GRT is not an ideal measure of physical capital. Hannesson (2007a) used real capital investment figures from Statistics Norway and found an increase in capital for Norway of about 20% for the period 1973-2003, 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.

Next, we introduce fish stock input into the productivity analysis. The development in the fish stock index from 1973 is shown in table 1. For all three countries we see that the trend growth for the fish stock index is negative. 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%. If we separate between demersal and pelagic stocks, we find that demersal stocks have been slightly reduced in all countries. Pelagic stocks are a bit larger in Iceland and Sweden, but smaller in Norway

Figure 4 shows labor productivity measured by real landed value added per fisher in the three countries in NOK. 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 attract labor to 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.

We now turn to the measurement of total factor productivity growth. Table 2 shows TFP growth rates and their components for the period 1974-2003. Overall, average TFP growth for the entire time period is found to be positive for all three countries. Iceland has the highest TFP growth with 3.0% annual average growth followed by Norway with 2.8% and then Sweden with 0.8%.[6]

In figure 5 we show the annual VTFP changes for the three countries. We note the high volatility with large swings from substantial negative to substantial positive productivity changes which is similar to what have been found in previous studies (Hannesson, 2007a; Jin et al., 2002; Squires, 1992). Figure 6 translates the annual VTFP growth rates into a cumulative index which is normalized by the average for the data period 1973-2003. This index should not be interpreted as the VTFP3 absolute level. Iceland started the period with a higher total factor productivity than Norway and Sweden, and the figure indicates that the two countries were not able to catch up with the productivity leader Iceland.

We test formally for convergence using the augmented Dickey-Fuller (ADF) test. Our test is based on the first-difference transformation of equation (10). Table 3 presents ADF test statistics of convergence between the productivity leader Iceland

[6] When we exclude fish stock input, annual total factor productivity growth rates are 1.6%, 0.9%, and 0.3% for Iceland, Norway, and Sweden, respectively. See Appendix B for more information on this.

and the two other countries. Overall, we do not find support for convergence. For both Norway and Sweden, the augmented Dickey-Fuller test statistic does not reject the null hypothesis of nonstationarity.

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 would likely contribute to convergence in productivity over time. Permanent differences in biophysical characteristics that determine the abundance and other characteristics of fish stocks could potentially limit the degree of convergence in case of a traditionally regulated open access fishery. In a rights-based fishery we would expect differences in biophysical characteristics to be reflected by the price development for the catch rights and per se not preventing convergence. Finally, various approaches in government regulations over time may prevent convergence in TFP. If we divide the period into two periods, splitting by the year 1990 when Iceland started its full scale ITQ regime and Norway had introduced several IVQ regulations, we find that Norway after 1990 had the highest productivity growth, closely followed by Iceland while Sweden had a more modest productivity growth. However, given the previously noted high volatility between years, figures for a shorter time period are more uncertain that those based on the whole period.

Concluding Remarks

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. (2002). We calculated TFP growth based on output measured by value added, labor and capital use, and with fish stock input included. Including fish stocks, we found average annual total factor productivity growth rates of 3.0, 0.8, and 2.8% for Iceland, Norway, and Sweden, respectively. Several recent studies also indicate that there is scope for further productivity increases in these countries (Nøstbakken, 2006; Eggert and Tveterås, 2007; Asche et al, 2009).

During the initial years of our study Iceland had a substantially higher level of productivity in terms of value added per worker adjusting for capital input. We found that the null hypothesis of no convergence against the productivity leader Iceland was supported for both Sweden and Norway. During the thirty year period 1973-2003, Iceland went from an open-access to a completely implemented ITQ fishery, while Sweden relied on a traditional regulated open-access management (Homans and Wilen, 1997).[7] Norwegian fisheries management has gradually developed towards more rights-based fishing approaches, but the extent of individual quotas is less than in Iceland and the transferability is more restricted as well. If management regimes influence productivity growth we would expect highest growth in Iceland and lowest in Sweden, which is supported by our results for the period 1990-2003. If we look at the period after 1990 when the ITQ system really came into effect in Iceland growth slowed down in Iceland. Arnason et al (2004) studied cod fisheries efficiency in Denmark, Norway and Iceland focusing on harvest rates and

[7] Sweden introduced ITQs for its pelagic fleet in 2009.

biomass levels. They did not find differential effects of the different management systems in the three countries up to year 2000 and hypothesized that the impact of the ITQ system was yet to emerge. We also found an Icelandic fish stock decline from 1973 to 2003. If there are forces at work to increase stock levels in Iceland, they are certainly slow and have met substantial institutional obstacles so far.

References

Acemoglu, D. and Zilibotti, F. 2001. Productivity Differences. *Quarterly Journal of Economics* 116(2): 563-606.

Arnason, R. 2003. On Productivity and Productivity Growth in the Icelandic Fisheries. In Gudmundsson and Valtysson Eds. *Competitiveness within the Global Fisheries*. Proceedings of a conference held in Akureyri, Iceland, April 6-7, 2000. University of Akureyri.

Arnason, R., L.K. Sandal, S.I. Steinshamn, and N. Vestergaard. 2004. Optimal Feedback Controls: Comparative evaluation of the cod fisherik es in Denmark, Iceland, and Norway. *Amer. J. Agr. Econ*. 86(2): 531–542.

Battese, G.E. and S.S. Brocca. 1997. Functional forms of stochastic frontier production functions and model for technical inefficiency effects: a comparative study for wheat farmers in Pakistan. *Journal of Productivity Analysis* 8: 395–414.

Beare, D.J., C.L. Needle, F. Burns and D. G. Reid. 2005. Using survey data independently from commercial data in stock assessment an example using haddock in ICES Division Via. ICES *Journal of Marine Science* 62: 996-1005.

Bernard, A.B., and C.I. Jones. 1996a. Comparing Apples to Oranges: Productivity Convergence and Measurement Across Industries and Countries. *American Economic Review* 86: 1216-1238.

Bernard, A.B., and C.I. Jones. 1996b. Productivity Across Industries and Countries: Time Series Theory and Evidence. *The Review of Economics and Statistics* 78: 135-146.

Bernard, A.B., and S.N. Durlauf. 1995. Convergence in International Output. *Journal of Applied Econometrics* 10: 97-108.

Bjørndal, T. 1987. Production Economics and Optimal Stock Size in a North Atlantic Fishery. *Scandinavian Journal of Economics* 89: 145-164.

Danielsson, A. 1997. Fisheries management in Iceland. *Ocean and Coastal Management* 35(2-3): 121-135.

Dupont, D.P., K.J. Fox, D.V. Gordon, and R.Q. Grafton 2005. Profit and price effects of multi-species individual transferable quotas. *Journal of Agricultural Economics* 56(1): 31-57.

Eggert, H. and M. Ulmestrand. 1999. A Bioeconomic Analysis of the Swedish Fishery for Norway lobster (Nephrops norvegicus). *Marine Resource Economics* 14:225-244

Eggert, H. and R. Tveterås. 2007. Potential Rent and Overcapacity in the Swedish Baltic Sea Trawl Fishery. *ICES Journal of Marine Science* 64(3): 439-445

FAO. 2009. Fishery and Aquaculture Country Profiles. http://www.fao.org/fishery/en

Fox, K.J., R.Q. Grafton, J. Kirkley, and D. Squires 2003. Property rights in a fishery: regulatory change and firm performance. *Journal of Environmental Economics and Management* 46:156-177.

Hannesson, R. 1983. The Bioeconomic Production Function in Fisheries: A Theoretical and Empirical Analysis. *Canadian Journal of Fisheries and Aquatic Sciences,* 40(7): 968-982.

Hannesson, R. 1985. Inefficiency Through Government Regulations: The Case of Norway's Fishery Policy. *Marine Resource Economics* 2(2): 115-141.

Hannesson, R. 2007a. Growth Accounting in a Fishery. *Journal of Environmental Economics and Management*, 53(3): 364-76.

Hannesson, R. 2007b. A Note on the Stock Effect. *Marine Resource Economics* 22(1): 69-75.

Homans, F. R., and J. E. Wilen. 1997. A Model of Regulated Open Access Resource Use. *Journal of Environmental Economics and Management* 32, 1-21.

Homans, F. R., and J. E. Wilen. 2005. Markets and rent dissipation in regulated open access fisheries. *Journal of Environmental Economics and Management* 49(2): 381-404.

Hulten, C.R. 2000. Total Factor Productivity: a short biography. *NBER Working paper* 7471.

Jin, D., E. Thunberg, H. Kite-Powell and K. Blake 2002. Total Factor Productivity Change in the New England Groundfish Fishery 1964-1993. *Journal of Environmental Economics and Management* 44: 540-556.

Jorgenson, D., F.M. Gollop, and B.M. Fraumeni, Productivity and U.S. Economic Growth, Harvard University Press, Cambridge, 1987.

Mundlak. Y. 2005. Economic Growth: Lessons from Two Centuries of American Agriculture. Journal of Economic Literature 43: 989-1024.

Nøstbakken, L. 2006. Cost structure and capacity in the Norwegian pelagic fisheries. *Applied Economics* 38(16): 1877 — 1887.

Pardey, P.G., Roseboom, J. and Craig, B.J. (1992). A yardstick for international comparisons: An application to national agricultural research expenditures. *Economic Development and Cultural Change*, 40(2), 333-349.

Rogoff, K. (1996). The purchasing power parity puzzle. Journal of Economic Literature, 34(2), 647-668.

Sandberg, P. 2006. Variable Unit costs in Output-Regulated Fisheries. *Applied Economics* 38: 1007-18.

Schaefer, M. B. (1957) 'Some considerations of population dynamics and economics in realtion to the management of marine fish' *Journal of the fisheries Research board of Canada* 14: 669-81.

Smith, V.K. and J.V. Krutilla. 1982. Toward Reformulating the Role of Natural Resources in Econmic Models. In V.K. Smith and J.V. Krutilla, eds., *Exporations Natural Resource Economics*. Baltimore: Johns Hopkins University Press.

Solow, R.A. 1957. Technical Change and the Aggregate Production Funtion. *Review of Economics and Statistics* 39(3): 312-320.

Squires, D. 1992. Productivity measurement in common property resource industries: an application to the Pacific coast trawl fishery. *Rand Journal of Economics* 23:221-236.

Stigberg, D. 1997. Swedish Fisheries – efficiency, subsidies, and control (in Swedish) in L. Hultkrantz (ed.). Fishy Fishing: Decision-Making and Economic Performance in Swedish Fishery Policy (Fisk och Fusk in Swedish). Stockholm: Ministry of Finance.

UNDP. 2007. http://hdr.undp.org/hdr2006/statistics/

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 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 exchange rate that is the appropriate one 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, but only matter for 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.

Appendix B. TFP Growth excluding fish input

For reference we also present value added based TFP growth devoid of fish stock input, i.e. with the last term in equation (7) omitted. When we exclude fish stock input, average annual total factor productivity growth rates are 1.6%, 0.9%, and 0.3% for Iceland, Norway, and Sweden, respectively. Including fish stocks, we found earlier average annual total factor productivity growth rates of 3.0, 0.8, and 2.8% for Iceland, Norway, and Sweden, respectively.

Table B.1. 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
Value added	0.0222	-0.0112	-0.0234
VTFP ex. fish stock	0.0160	0.0092	0.0025

Table 2 presents ADF test statistics of convergence between the productivity leader Iceland and the two other countries for TFP growth excluding fish stock input. Overall, we do not find support for convergence, as the ADF test statistic for both Norway and Sweden does not reject the null hypothesis of nonstationarity.

Table B.2. Augmented Dickey-Fuller tests of convergence - Iceland vs Norway and Sweden

	Constant	Coeff. of $\ln \hat{TFP}_{c,t-1}$	DF test-stat	p-value**
Norway	0.279	-0.275	-2.185	0.212
Sweden	0.151	-0.122	-1.306	0.627

*Augmented Dickey-Fuller statistics lag length chosen by the BIC criterion. ** MacKinnon approximate p-value for the DF test statistic.

Table 1. Time Series of Miscellaneous Variables

Year	Real Price Index Cod[a]			Number of Fishers			Total Fleet size (GRT)			Fish Stock Input Index		
	Ice	Nor	Swe	Ice	Nor	Swe	Ice	Nor	Swe	Ice	Nor	Swe
1973	67.6	100.1	68.1	4772	37537	6503	92483	353911	47874	100.0	100.0	100.0
1974	69.3	131.0	84.5	5055	36406	6493	97778	359152	45539	93.4	75.3	121.3
1975	65.5	108.1	70.3	5139	35261	6319	98979	367533	46598	95.7	70.6	109.2
1976	76.9	121.8	65.1	5257	33264	5846	97063	367448	40204	83.9	69.9	98.9
1977	79.4	88.1	67.2	5319	32589	5961	102698	377812	40524	99.1	82.6	105.1
1978	79.8	83.5	89.6	5336	33599	5778	101962	396812	40843	104.3	68.0	105.1
1979	81.7	88.0	79.9	5823	33955	5541	102885	377947	44077	132.7	59.0	108.5
1980	73.3	93.0	71.9	5946	34798	5409	104419	362403	45173	136.1	55.3	108.9
1981	70.6	91.0	67.7	6037	35311	5224	106218	342784	46064	102.3	59.5	105.7
1982	72.4	79.0	77.7	6143	35311	5039	112036	341435	46245	70.7	70.6	112.7
1983	74.3	75.6	90.2	6207	28046	4856	112880	330100	46426	62.4	77.5	119.4
1984	78.1	76.1	86.1	6363	29632	4675	112885	333777	46607	71.0	65.8	129.7
1985	79.8	85.2	90.4	6641	29559	4304	111540	330329	46787	76.9	43.8	119.3
1986	86.7	98.2	113.9	6921	29981	4323	112892	331901	49908	84.7	31.8	91.9
1987	91.9	110.4	117.5	6545	29915	4152	120007	329454	50165	77.2	26.8	85.8
1988	88.3	93.3	105.3	7006	29350	3987	126244	325530	52337	76.1	36.1	76.2
1989	90.5	89.5	97.2	6929	28655	3828	124915	304245	54731	76.7	36.3	70.5
1990	111.2	114.5	122.7	7502	27518	3463	124419	301176	56153	77.5	43.4	67.0
1991	122.6	120.8	112.2	7480	26966	3528	123292	293424	56746	62.9	55.7	51.4
1992	115.2	102.3	115.0	7010	26752	3390	122164	285547	57399	64.6	58.5	39.3
1993	104.8	84.2	99.7	7550	25396	3260	122254	291928	55127	58.1	48.0	43.1
1994	109.2	86.2	86.3	6400	22920	3140	123985	286902	53056	63.7	44.3	49.9
1995	109.2	86.6	85.5	7000	23653	2999	120193	283328	56228	65.6	43.0	53.7
1996	106.8	78.2	76.8	7100	23397	2930	122003	293506	54686	70.2	49.5	53.6
1997	110.3	77.4	97.6	6300	22916	2841	119454	310139	54072	70.8	52.4	53.9
1998	129.3	111.1	134.6	6200	21298	2765	121557	323817	53691	59.1	45.1	41.1
1999	144.2	134.4	144.1	7200	24274	2629	119679	315424	53944	59.5	36.5	40.5
2000	144.7	134.5	144.4	6100	20094	2562	118353	304074	55097	54.6	33.7	41.0
2001	157.2	135.7	155.0	6000	18954	2576	123103	312111	52567	52.3	37.5	42.8
2002	160.7	121.1	153.3	5300	18648	2227	112828	307933	51325	61.8	41.5	41.1
2003	148.4	101.2	130.1	5300	17259	2066	147555	286390	50708	62.8	41.5	42.3

[a]Calculated around its average for the period 1973-2003.

Table 2. Average Annual TFP Growth Rates (in %) and 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
Value added	0.0222	-0.0112	-0.0234
VTFP	0.0300	0.0084	0.0282
$VTFP_{1973-1990}$	0.0340	-0.0045	0.0438
$VTFP_{post\ 1990}$	0.0247	0.0253	0.0077

Table 3. Augmented Dickey-Fuller tests of convergence - Iceland vs Norway and Sweden

	Constant	Coeff. of $\ln VT\hat{F}P_{c,t-1}$	DF test-stat	p-value**
Norway	0.330	-0.247	-2.186	0.211
Sweden	0.271	-0.263	-2.163	0.220

*Augmented Dickey-Fuller statistics lag length chosen by the BIC criterion. ** MacKinnon approximate p-value for the DF test statistic.

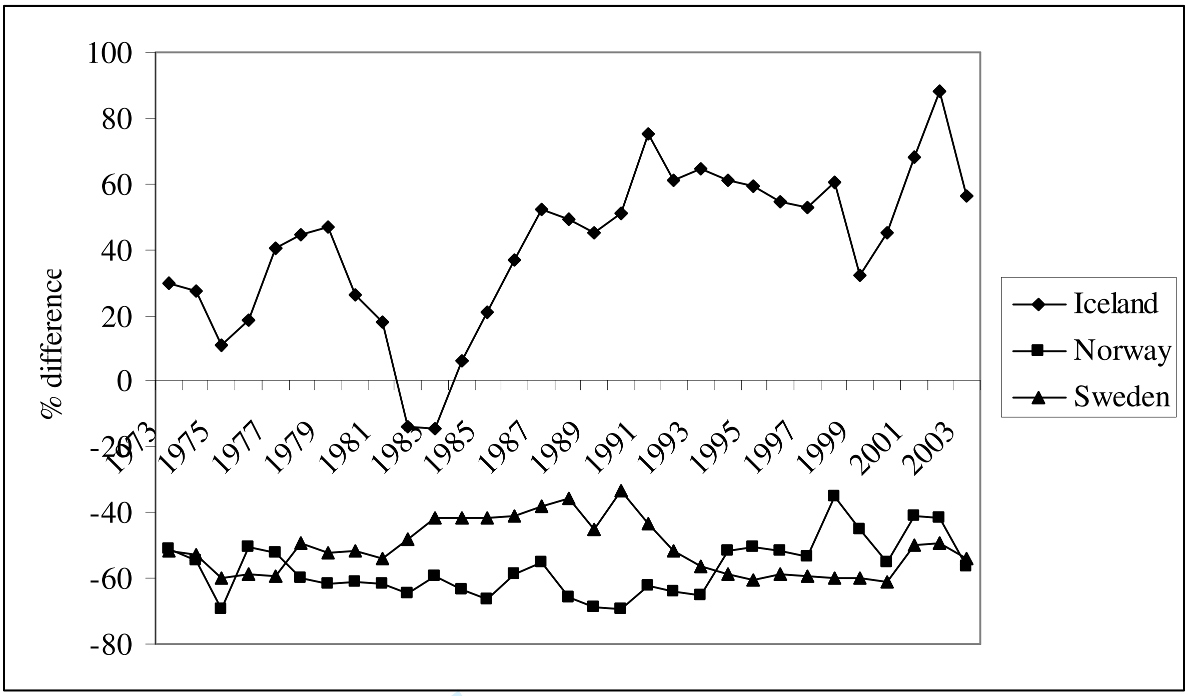

Figure 1. Percentage Difference in Average Value Added per Worker between Fisheries and the Total Economy (*Sources: Statistics Iceland, Statistics Norway and Statistics Sweden).*

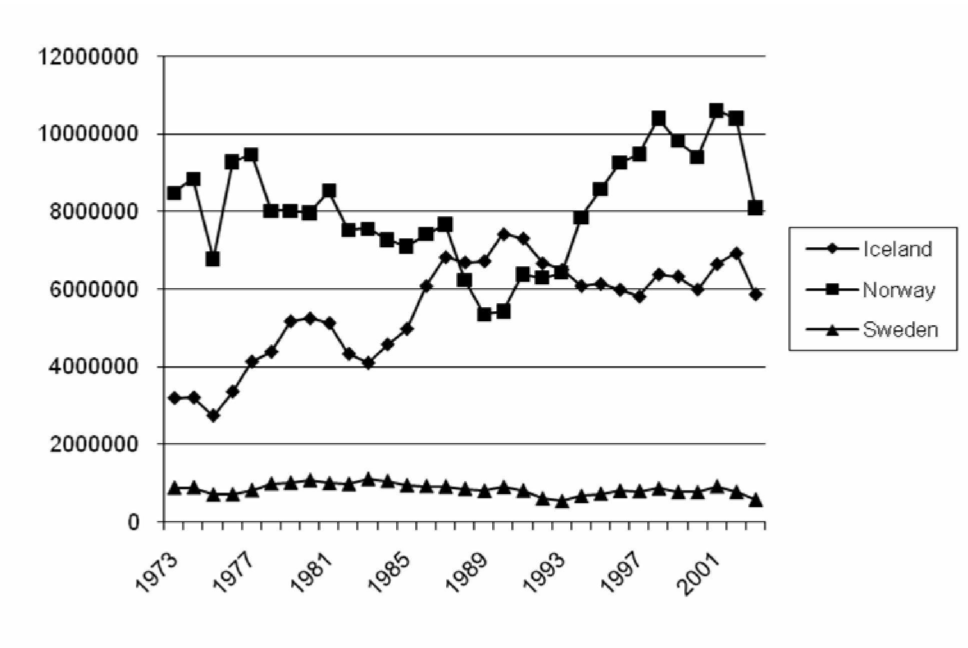

Figure 2. Value of Fish Landings in Iceland, Norway, and Sweden, 1960-2003 (Deflated by National CPI and Converted at 2003 Exchange Rates, i.e., NOK 1 = SEK 1.14 = ISK 9.23).

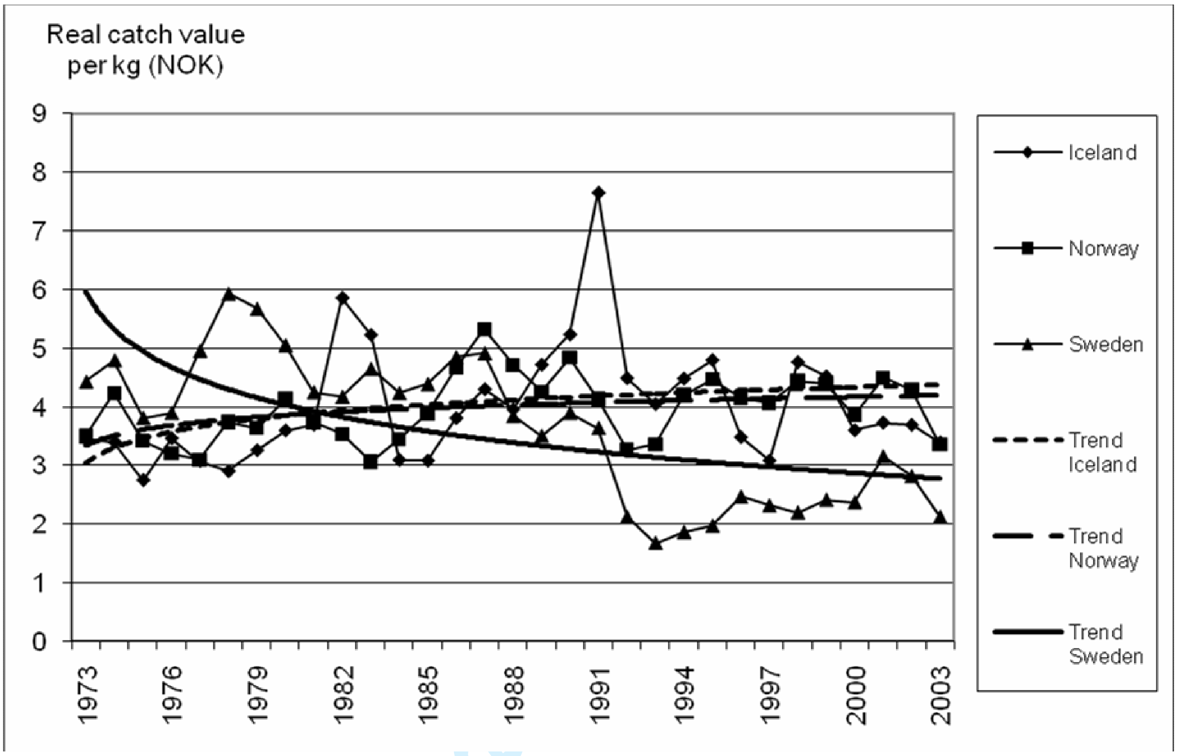

Figure 3. Real Average Unit Catch Value per Kg with Logarithmic Trend, in NOK

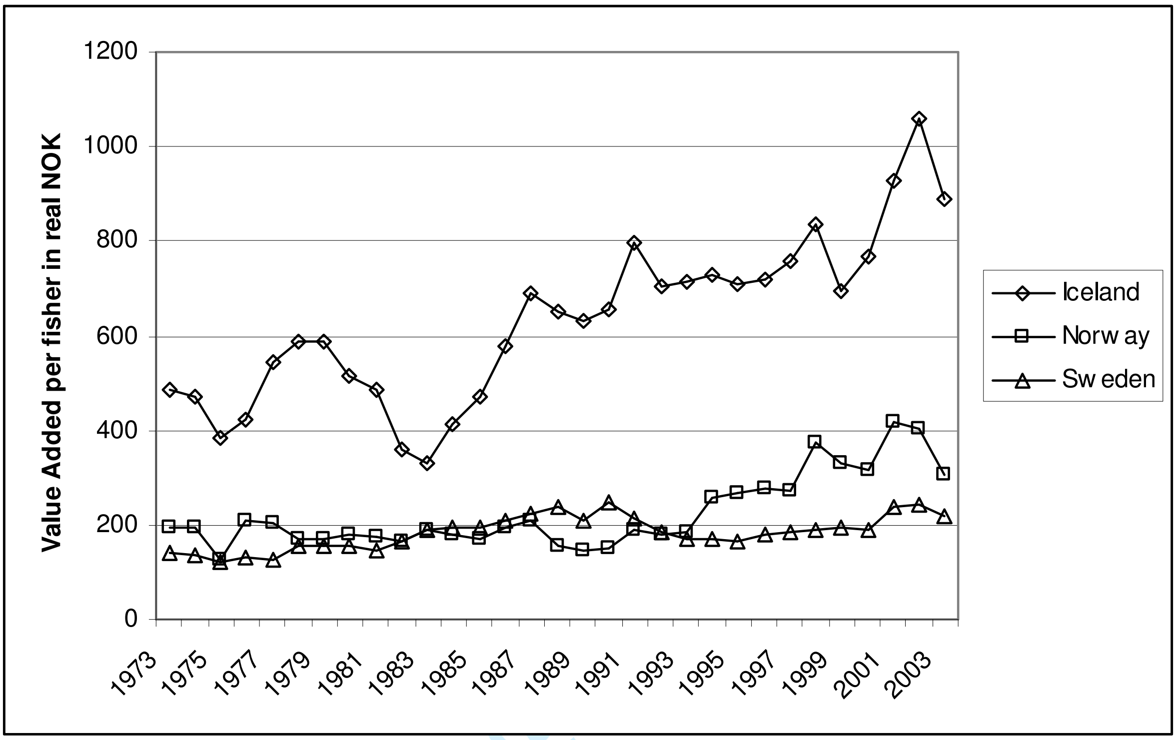

Figure 4. Labor Productivity Measured by Real Value Added per Fisher 1973-2003, in 1000 NOK (2003=100).

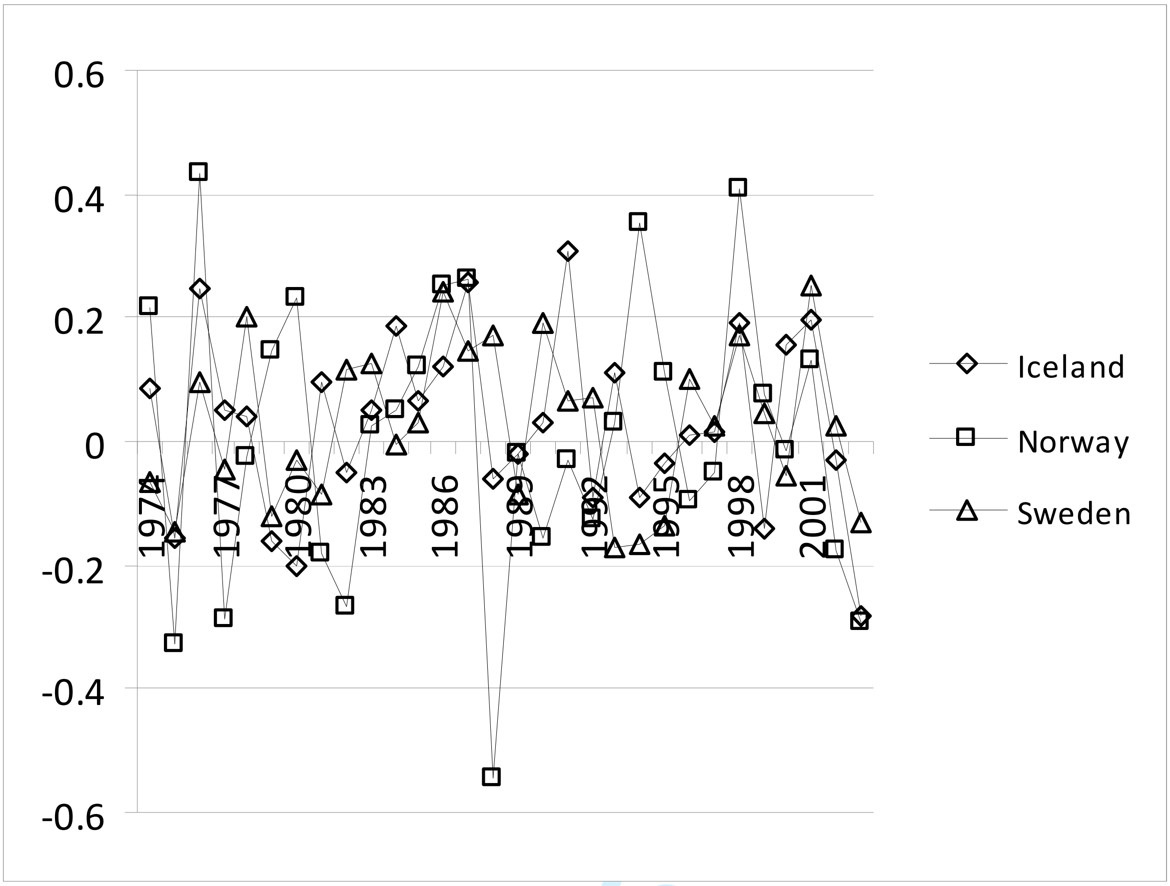

Figure 5. Annual Productivity Growth Rate Measured by VTFP in Iceland, Norway, and Sweden 1974-2003

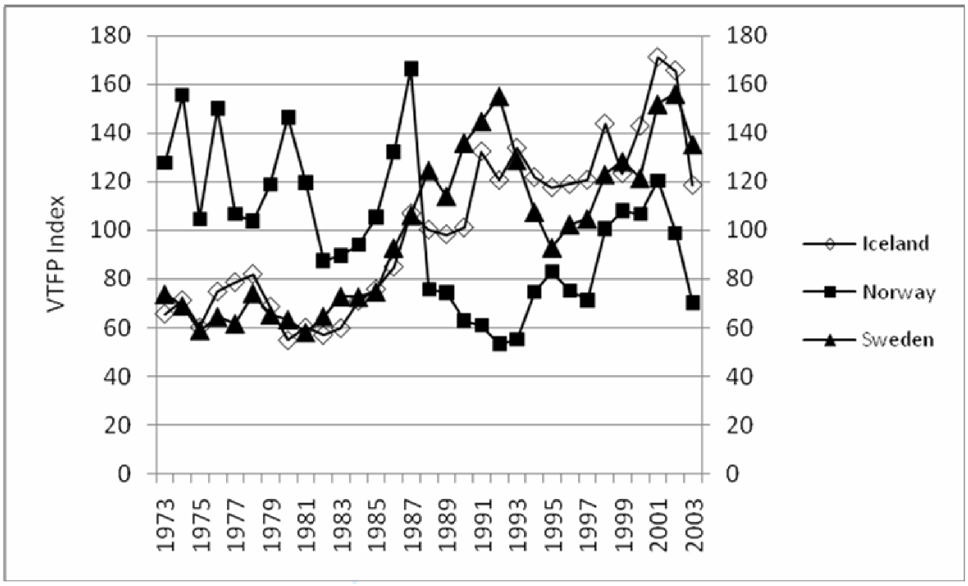

Figure 6. Cumulative VTFP Index in Iceland, Norway, and Sweden 1973-2003