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# The Development of Productivity
# in the Norwegian Fisheries

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**Abstract**

The development of total factor productivity in the Norwegian fisheries 1961-2002 is estimated, using data on catches at constant fish prices, capital stock, labor input, and fish stocks. Data on fish stocks have been complied from reports by the International Council for the Exploration of the Sea and aggregated into a single stock index by using shares in catches at fixed prices as weights. Total factor productivity is shown to have increased rapidly in the mid-1960s, hardly having been surpassed ever since, while the development in total factor productivity has been uneven. The real capital stock was little higher at the beginning of this century than in the early 1960s, while labor input and fish stocks have declined. The increase in catches since the early 1960s is thus due to technological progress rather than an increase in inputs of any kind.

## INTRODUCTION

The fishery is one of the industries which depend critically on natural resources and not just the use of labor, capital and produced goods. Ultimately, the productivity of fisheries is limited by the regenerative capacity of the fish stocks available. Within those limits, fisheries must be able to provide fishermen and boatowners with incomes and return on invested capital comparable with other industries, if they are to remain competitive. In an economy with productivity growth in the market-oriented sectors, this can only happen if fishing technology continually improves and capital replaces labor, so that fewer and fewer people share the incomes essentially limited by nature while a competitive return on capital is maintained.

Given the critical dependence on nature, studies of productivity development in fisheries must take into account the role of fish stocks as determinants of productivity. Data on the abundance of fish stocks must be combined with data on the use of capital and labor, and perhaps intermediate goods, to estimate production functions or apply other methods. A considerable number of productivity studies using data at the firm level have been carried out. Typically these studies focus on comparison among firms or industry segments. Sometimes they involve comparisons over a few years, but they seldom if ever take a long time perspective.

For studies at the aggregate level and taking a long, historical perspective, data at the firm level are usually not available, and so one will have to do with aggregates. From national accounts, data may be available on investment in the fishing industry, the capital stock, the input of labor, and output both in physical and monetary units. Estimates may be available of the biomass of the most important fish stocks. Combining these is not unproblematic. Underneath the aggregates on capital stock and labor input there is a multitude of individual firms which exploit different fish stocks with different technologies. Nevertheless, combining aggregates of capital, labor and available fish stocks is unavoidable if one wants to obtain an overall picture for a long time period.

There appear to be few studies of productivity development in fisheries at the industrial level taking a long term perspective. One such is a study of the Icelandic fisheries by Arnason (2003). The present study is in a similar vein and looks at productivity development in the Norwegian fisheries since 1961. It relies on industry-wide data on use of labor, the capital stock, and the value of catches. Data on the abundance of the various fish stocks are combined into an aggregate index of resource stocks available to the industry. An Appendix further describes the data and how they have been used. As often is the case for long time series there are some gaps that need to be filled, changes in definitions that need to be dealt with, and some series go further back than others. The further one goes back in time the greater becomes the problem of getting continuous and reasonably comparable time series, but the early 1960s appear to be a reasonable compromise in this regard (see Appendix).

## THE DEVELOPMENT SINCE THE EARLY 1960S

The development of catches ($Y$),[1] capital stock ($K$), labor use ($L$), and resource stocks ($R$) since 1961 is shown in Figure 1. The figure tells an interesting story. Up to about 1970 there

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[1] I.e., catch value at constant fish prices.

was little change in the capital stock or the input of labor, and the resource stocks declined. Yet there was an enormous increase in the catch volume. Looking behind the aggregate catch, we find that the increase was due to two kinds of fish, herring and mackerel. This was made possible by technological leaps that occurred on two fronts. Fish finding equipment (the sonar) made it possible to find aggregations of fish underneath the sea surface, whereas previously these had to be spotted as ripples on the surface. The power block made it possible to haul nets mechanically instead of by hand and allowed the use of much larger and effective nets and boats than earlier. It was apparently possible to take advantage of this without any major investment in new boats.
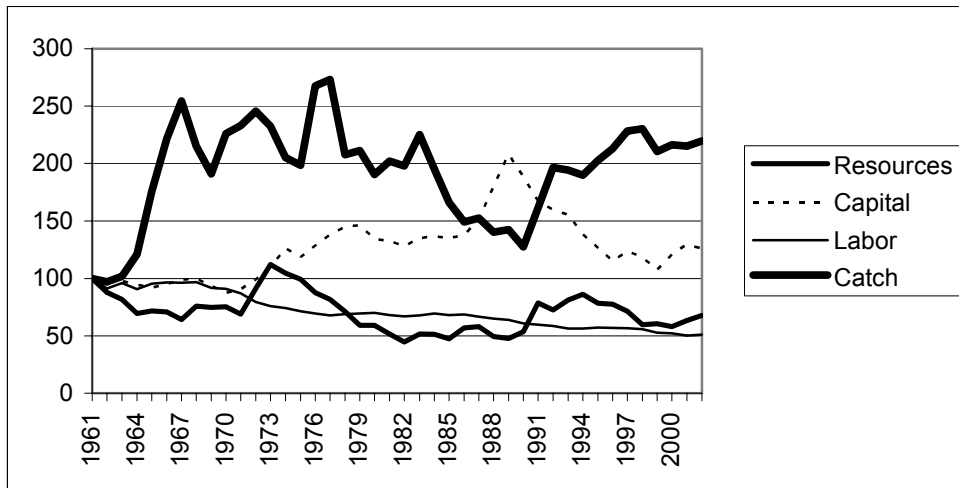


Figure 1: Indices of catches (value at constant prices of fish), capital stock, use of labor, and resource stocks.

After 1970 there was a major increase in the stock of real capital. Some, and possibly all of this was presumably due to the new technology; in order to take full advantage of the power block one needed larger seines, and in order to accommodate the greater catch volumes one needed larger boats. The investment boom was over by 1980, and after that the capital stock remained roughly constant, until the next investment boom 1987-89. Despite a greater capital stock, the catches fluctuated on a declining trend, and the peak of 1967 was only surpassed briefly in 1976-77. The latter peak was due to exceptionally large catches of capelin, but this fishery developed around 1970 and replaced the herring fishery, the herring stocks having been virtually wiped out through the confluence of the new fishing technology and the absence of any limits on fishing. After the investment boom of 1987-89 the capital stock reached an all time high. It declined sharply until the mid-1990s, but has remained relatively stable after that; since the late 1980s the capital stock in the fisheries has declined by almost a half.

Curiously, the investment boom of the late 1980s coincided with a sharp fall in catches, and the decline in the capital stock after 1990 coincided with a sharp rise in catches. Some, and perhaps all, of the investment boom 1987-89 was due to replacement of old and worn out trawlers fishing for cod. It has been alleged that the investors held inflated expectations of the prospects for the cod stock in the mid-1980s and hence went on an investment binge.

The increase in catches in the mid-1960s was accompanied by a decline in the resource stocks, especially of mackerel and herring, the fishing of which took a quantum leap at this time due to the sonar and the power block. The catches nevertheless remained high but fluctuating until the early 1980s. There was a sharp increase in the resource stocks in the early

1970s, due mainly to increased stock of capelin. To some extent this is due to the capelin stock being "discovered" at that time; prior to the collapse of the herring stocks around 1970 there was not much fishing of capelin; this fishery developed in response to the need to find alternative supplies for the fish meal industry. Even if estimates of the capelin stock are lacking for earlier years, it is generally believed that the collapse of the Norwegian spring spawning herring stock resulted in or was accompanied by an increase in the capelin stock.

From the early 1980s to 1990 the catch volume declined by almost a half. By that time the exclusive economic zones had been established in the Northeast Atlantic, and the fisheries were generally controlled by a total catch quota, often referred to as the total allowable catch. The decline in catches was mainly due to the decline in the total allowable catch for Northeast Arctic cod and Barents Sea capelin. In the late 1980s the cod stock had been pushed to an all time low and was perceived as possibly being in danger, and there was certainly no intention to repeat the debacle of the Northern cod of Newfoundland, which practically disappeared in the early 1990s. As to capelin, it was realized that this stock is an important food supply for the cod, and the total allowable catch of capelin was set lower than otherwise would have been the case, in order to secure enough feed for the cod. Catches recovered in the 1990s, and so did the resource stocks, even if they have not reached the previous peak of the early 1970s or the early 1960s.

Looking at the entire period since 1961, we see that the catches of fish have about doubled. Yet the stock of real capital in the industry is currently not much higher than in 1961. The stock of resources is considerably less than in 1961, but has recovered somewhat since the 1980s. The input of labor has declined by about one half, a trend that was temporarily halted in the late 1970s and early 1980s when generous subsidies were given to the fishing industry. The increase in catches is thus largely due to technological progress; one krone invested in a fishing boat today buys totally different equipment than one krone forty years ago, adjusted for the change in the value of money. This comes as no surprise to students of technological progress; a powerful strand of growth theory holds that the only sustainable source of GDP growth per capita is technological progress; further investment runs into diminishing returns and is, in the end, self-defeating, unless accompanied by technological progress. In our case, the increase in the catches of fish has been achieved despite little change in the stock of capital and a decline in the input of labor and the resource stock. We can, however, be sure that no technological progress would compensate for a decline in resource stocks beyond a certain point; while some decline in resource stocks below a natural equilibrium is a necessary prerequisite for generating the surplus growth that sustains fisheries, too small stocks would lead to diminishing surplus growth and ultimately a decline in fish catches. In this case it appears that the overall decline in resource stocks has not been sufficient to cause a long term decline in catches, but there are periods when declining catches have been accompanied by a decline in resource stocks; this was clearly the case in the 1980s, and the increase in catches in the 1990s was associated with an increase in resource stocks.

## TOTAL FACTOR PRODUCTIVITY

As a glance at Figure 1 would lead one to expect, estimation of a production function such as $Y = AK^{\alpha}L^{\beta}R^{\gamma}$ was unsuccessful, both on logarithmic form and on first differences; all coefficients are insignificant and sometimes of the wrong sign.

In the absence of a meaningful estimation of a production function, the development of productivity can be traced by calculating an index of total factor productivity (TFP). The definition of this index is (see, e.g., Coelli et al., 1998):

$$TFP = \frac{I_o}{I_K^\alpha I_L^\beta I_R^{1-\alpha-\beta}} \times 100$$

where $I_o$ is the index of output, and the indices in the denominator are indices of capital, labor, and resource stocks. The weights $\alpha$, $\beta$ and $1 - \alpha - \beta$ are normally taken from the cost shares of the factors in question. This is not possible in our case, because there is no monetary cost of utilizing fish stocks. Cost shares could provide some guidance for determining the weights $\alpha$ and $\beta$, but there are problems with this. In the Norwegian fisheries statistics the value added in the fisheries is split into labor and capital income, but there is a gap in this series from 1984 to 1990. The capital income is calculated as a return on invested capital whereas the rest is defined as labor income (Figure 2).[2] Given that the revenues in the fishery vary greatly over time, mainly because of variations in fish stocks and catch quotas but also because of price fluctuations, the labor income varies greatly while the capital income is relatively stable. Since the variation in fish prices has been eliminated from the catch series,[3] it is tempting to conclude that the labor income absorbs the income variability due to variability in resource stocks and, hence, the payment that would be due to the resource stock.
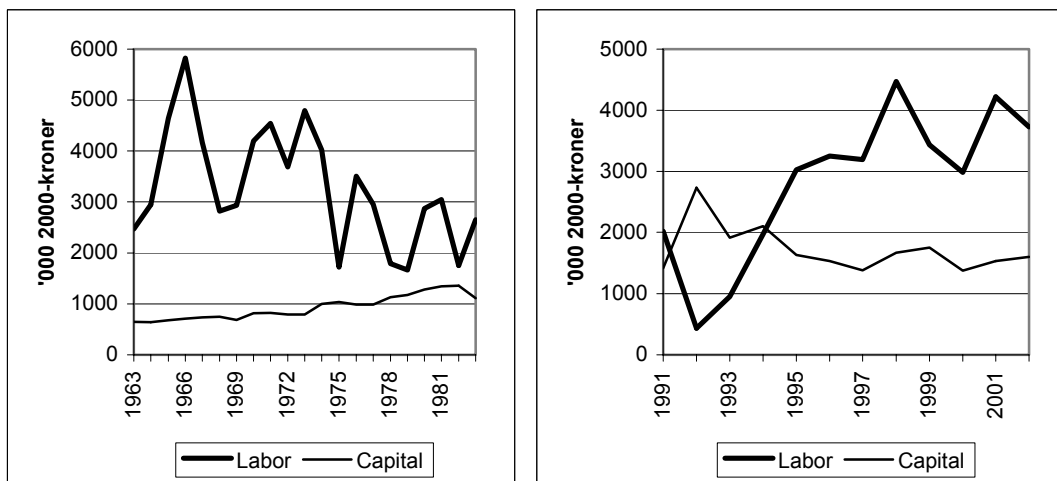


Figure 2: Remuneration of labor and capital.

Hence we proceed to calculate the TFP-index by using assumed and fixed weights in the composite input index. The high variability in the cost shares of labor and capital hardly reflects variations in the importance (output elasticity) of these factors of production. From Figure 3 we see that the share of capital in value added has increased over time from 20 percent or less to 30 percent or more. The value of $\alpha$ would thus appear to be about 0.2 - 0.3, while the remainder should be split between labor and resources, given that labor absorbs most of the variability of income due to variability of resources.

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[2] The unusually high remuneration of capital in the early 1990s is probably due to the high interest rates prevailing at that time.
[3] The catch value was adjusted to prices in 2000 by using the price index for the first hand sales of fish.
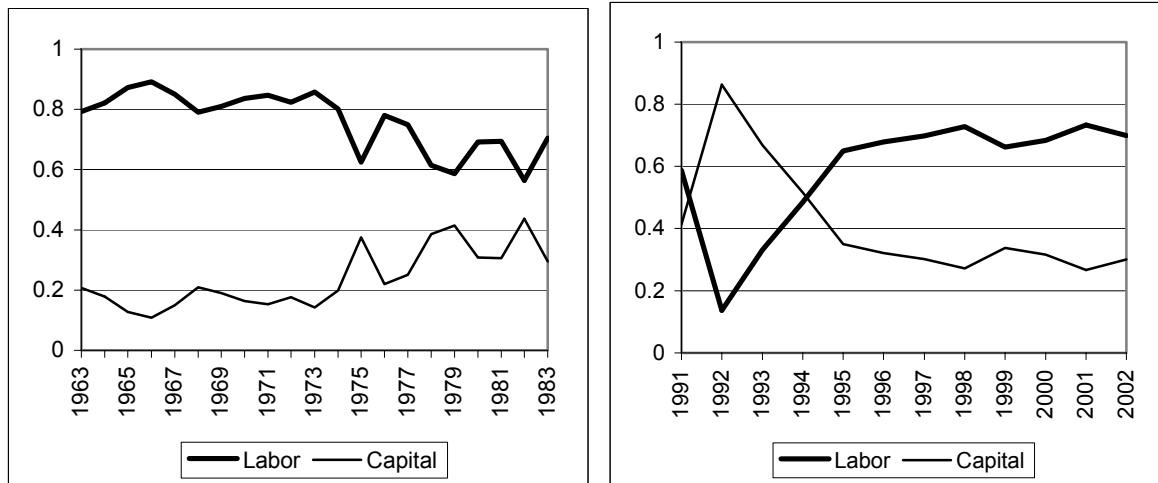
Figure 3: Shares of labor and capital in value added.

As to the weight to be given to the resource stock, one might look for guidance to empirical analyses of production or cost functions for individual fish stocks. If the stock is important for the productivity of the industry, the catch for any given application of labor and capital (catch per unit of effort) should be sensitive to the size of the resource stock. For some stocks this does not appear to be the case (Bjørndal, 1987). Results for other stocks indicate that the catch per unit of effort could be highly sensitive to the size of the stock (Hannesson, 1983). The difference between these results is probably due to different behavior of the stocks involved; some tend to be spread over a given area that does not change much while others contract to a smaller area as they are depleted. Arnason (2003) deals with this by constructing a stock index with different exponents on each stock, using low values for schooling stocks where the catch per unit of effort is likely not to be sensitive to the size of the stock, and high values for stocks where the catch per unit of effort can be expected to be near-proportional to the size of the stock.

The parameter value to be assigned to the stock may, however, reflect fish stock management rather than the production function. Since the exclusive economic zone was established in the late 1970s, the most important fish stocks exploited by Norwegian fishermen have become regulated by an upper limit on the total catch. This upper limit is set on the basis of estimates of the abundance of the fish stocks. While these estimates are imprecise and the limit on the total catch is not always determined as a fixed share of the estimated stock size, there is supposedly a relationship between the size of each stock and the permitted catch from the stock, such that a more plentiful stock would result in a larger permitted catch. Furthermore, it will normally be easier to catch fish from a plentiful stock than from a depleted one.

These musings do not leave us with anything more precise than saying that $\alpha$ and $\beta$ should sum to something less than one, assigning some role to the resource stock as a factor of production.[4] As it turns out, the results are not very sensitive to reasonable assumptions about $\alpha$ and $\beta$.

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[4] Taking the production function in the denominator of the TFP expression at face value, one might conclude that the exponent of the resource stock must be greater than the sum of the exponents on the capital stock ($K$) and the input of labor ($L$), as the opposite would imply that labor and man-made capital could replace the resource stock, so that we would be able to fish even from an empty ocean. Taking logarithms of the production function, we get $\ln Y = \ln A + \alpha \ln K + \beta \ln L + (1 - \alpha - \beta) \ln R$. As $R$ approaches zero, $\ln R$ approaches $-\infty$, but if $\alpha + \beta > 1 - \alpha - \beta$, it
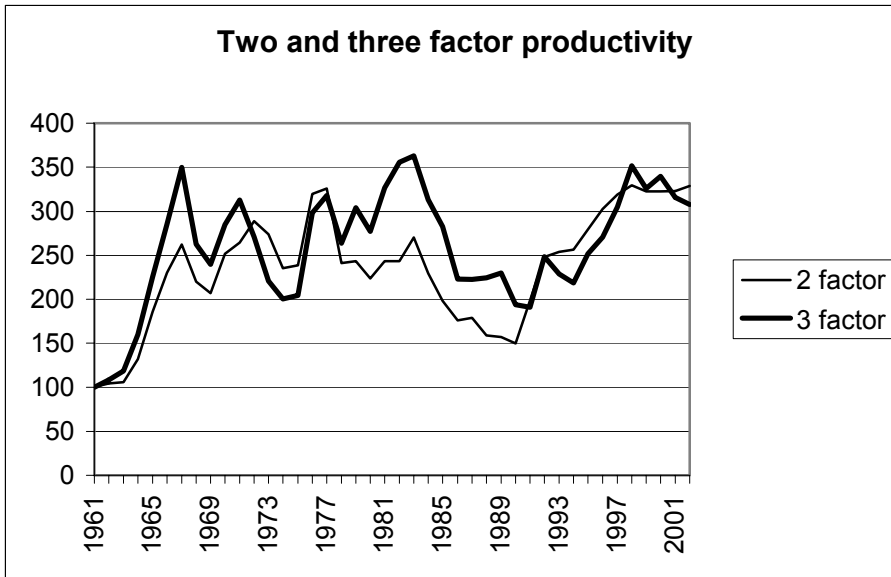
### Two and three factor productivity



Figure 4: Two and tree factor productivity.

Figure 4 shows the development in total factor productivity for alternative assumptions for the said parameters. In one of these $\alpha = 1/3$ and $\beta = 2/3$ and hence sum to one, so that no role is ascribed to the resource stock and we are in fact dealing with a "two factor productivity." In the other case, we have $\alpha = \beta = 0.15$ and so a quite important role is assigned to the resource stock. Yet the difference between the two- and three factor productivity cases is not very great. Both follow a broadly similar pattern, and both are about the same towards the end of the period under consideration. Both indicate a very substantial increase in total factor productivity in the mid-1960s, at the time the power block and the sonar were introduced. The three factor productivity shows a greater increase, as this technological development was accompanied by a decline in the resource stock. There was an upward trend in the three factor productivity 1978-83, but stagnation in the two factor productivity. The resource stock fell about one third over this period while catches, capital stock and labor input changed relatively little. Both productivity measures fell drastically 1984-1990. The two factor productivity fell 1987-89 while the three factor productivity stagnated; the stock of capital increased sharply in these years while the catch volume fell, which primarily affected the two factor productivity. After 1990 both productivities recovered equally drastically, but stagnated after1998.

Looking at the whole period, the two factor productivity is now somewhat greater than in the mid-1960s, while the three factor productivity is about the same as then. The big gains in productivity were apparently made over a relatively short period in the early 1960s. Since then productivity has had a rickety ride, but the gains achieved about 40 years ago have now been restored.

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would always be possible to find finite ln$K$ and ln$L$ such that $\alpha$ln$K + \beta$ln$L$ exceeds $- (1 - \alpha - \beta)$ln$R$. Since it is impossible to produce fish from a sea empty of fish, one would have to define the production function as zero for $R = 0$ for the case where $1 - \alpha - \beta < \alpha + \beta$. For an example involving non-renewable resources, see Dasgupta and Heal (1979), Chapter 7.

**CONCLUSION**

The productivity analysis above has highlighted several points, some of which are idiosyncratic for the fishing industry and some that are not. First, productivity can grow by leaps and bounds. It can change suddenly, because of the introduction of a new technology. This happened in an important segment of the Norwegian fisheries in the mid-1960s and has not since been repeated.

Second, it could be important to take into account the development of resource stocks. Three factor productivity shows small gains since the mid-1960s, two factor productivity some.

Third, new regulations have an impact on TFP. After the exclusive economic zones were introduced in the late 1970s, overall catch limitations were put in place. These appear to have reduced catch volumes more than corresponded to the decline in fish stocks over the same period. This shows up as a fall in TFP over the period 1983-1990, but some of that decline is due to an increase in the capital stock. This reduction in catches may well have been a sensible policy; at any rate resource stocks recovered in the 1990s, but catches rose even more, leading to an increase in TFP. That leads us to a fourth point, the substantial variations over time in TFP, due to variability of fish stocks, changes in regulations, and capital accumulation that turns out to have been unwarranted.

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**APPENDIX: SOURCES OF DATA**

*Index for catches*

Information on total catches of fish, in volume and value, is available from Fisheries Statistics, published by Statistics Norway and, before 1977, the Directorate of Fisheries. Adding tonnes of different kinds of fish is of doubtful validity. The value figures have been converted to value at constant fish prices by using the annual index for first hand prices of fish, also published in the Fisheries Statistics. The index changed base in the 1990s, but the series overlap for the years 1987 - 1990, and the two series have been chained by using the average of the indices in the overlapping period. The index began in 1963, but we have extended it back to 1961 by assuming the same index for 1961-62 as for 1963.

*Index for labor*

From Statistics Norway we have obtained a time series of the input of man-years in the fisheries from 1970. There also exists a time series of the number of fishermen, both full time and part time. These categories were redefined in 1980. The series for full time fishermen before 1981 follows a pattern similar for the number of man-years, especially for the years 1970-73, but with a tendency for a falling number of man-years per fisherman. We have extended the man-years series back to 1961 by using the number of full time fishermen, adjusting for the difference between the two series in 1970.

*Index for real capital*

A time series of real capital invested in capture fisheries was obtained from Statistics Norway. This series goes back to 1970 and looks a bit suspicious; it shows a negative value of machines and equipment for a few years in the early 1970s (the series is split up in one for vessels and one for machines and equipment; we have used the sum of the two).

There exists another series for real capital in the fisheries, published in the Fisheries Statistics, but unfortunately it covers only the period 1965 - 1987. The series match reasonably well for 1970-71 but start to deviate thereafter; for 1987 the latter shows a level of capital only about one-third of the series obtained from Statistics Norway. We have extended the series back to the 1960s by using the series published in Fisheries Statistics, which goes back to 1965. For the years 1961-64 we have calculated the real capital by subtracting the net investment each year, which was published in the Fisheries Statistics until 1987, from the real capital of the subsequent year.

*Income of labor and capital*

The Fisheries Statistics contains information on the remuneration of labor and capital. For the years 1963-1971 figures on this were published. For the years 1972-83 we have calculated these figures from national account figures published in the fishery statistics. For 1984-90 there were no figures published on interest on borrowed capital and hence impossible to calculate the remuneration of capital. From 1991 there are again figures on labor income and income of capital, both equity and borrowed capital.

### *Stock index*

Indices for fish stock abundance were calculated for 12 different stocks from stock estimates (for sources, see below). In 2004 these stocks accounted for about 85 percent of the catch value in Norway's fisheries. The resource stock index is a weighted sum of these indices, with the weights determined as the share of each stock in the value of landings from the 12 stocks each year, landings being evaluated at the average price of fish 1999 - 2003. The prices were not adjusted for inflation, which in any case was low in that period; the prices were, with some exceptions, higher in 2001 and 2002 than in 1999-2000 or 2003.

Various papers from the International Council for the Exploration of the Sea (ICES) provide the catches of individual nations from the various fish stocks and estimates of these stocks. We have used the 2004 reports of the appropriate working groups, as follows:

*Arctic Fisheries Working Group:*

Northeast Arctic cod, Table 3.3 (catches) and Table 3.27 (stock).
Northeast Arctic haddock, Table 4.3 (catches) and Table 4.18 (stock).
Northeast Arctic saithe, Table 5.1 (catches) and Table 5.11 (stock).
Redfish (sebastes mentella), Table 6.1 (catches) and Table D4 a and b (stock, index).
Redfish (sebastes marinus), Table 7.1 (catches) and Table D10 a and b (stock, index).
Greenland halibut, Table 8.1 (catches) and Table 8.15 (stock, index).
Northeast Arctic shrimp, Table 9.1, 2003-report (catches).

*Working Group for Northern Pelagics and Blue Whiting:*

Norwegian spring spawning herring, Table 3.2.1.2 (catch) and Table 3.6.3 (stock).
Barents Sea capelin, Table 4.2.1 (catch) and Table 4.3.2.2 (stock).
Blue whiting, Table 6.2.1 - 6.2.3 (catches) and Table 6.4.4.3.1 (stock).

*Herring Working Group:*

North Sea herring, Table 2.6.2.3 (stock only)

*Working Group on Mackerel, Sardines and Anchovy:*

Northeast Atlantic mackerel, Table 2.9.1.11 (stock only).

*Other sources and assumptions:*

*Barents Sea capelin*: the time series on stock abundance starts in 1973, but there are catches recorded from 1965 onwards. The stock 1965-72 was calculated by assuming that the catches had been the same proportion of the stock as in 1973.

*Northeast Arctic shrimp*: the time series on abundance was taken from the 2004 report on fish stocks issued by the Institute of Marine Research, Bergen (IMR, 2004). This series starts in 1982, but there are Norwegian catches recorded from 1970 onwards. The stock 1970-81 was calculated in the same way as for capelin.

*Northeast Atlantic mackerel*: the time series for the stock abundance goes back to 1972. Prior to that time there were substantial catches of mackerel, taken in the North Sea. Estimates of North Sea mackerel 1965 - 1971 were taken from Hamre (1980). For 1961-64 a stock of 3 million tonnes was assumed (the stock was 2.9 million tonnes in 1965 according to Hamre [1980]).

Catches of mackerel and North Sea herring were taken from Statistics Norway, Fisheries Statistics and IMR (2004).