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The Role of the Fishing Industry in the Icelandic Economy. A Historical Examination.

Sveinn Agnarsson and Ragnar Arnason.[1]

Abstract

Expansion and development of the fisheries was the driving force behind Iceland's economic transformation during the 20th century. Yet, the overriding importance of this sector fails to show up in national accounts – such as contribution to GDP and employment statistics –because they do not take into consideration the various ways economic activity in the maritime sectors affects other branches of the economy. In addition, the national accounts do not fully reflect the significant part played by the fisheries as the county's largest currency earning industry. This ignorance of the true contribution of the fisheries can lead policy makers to underestimate the effects shocks to the fisheries will have on the economy. In this paper, econometric methods are employed to estimate the overall contribution of the fishing industry to Icelandic GDP during the period 1963-1996. Using data on GDP, marine production, capital and labour, it is shown that in the long-run a 1% change in the value of fishing industry production will lead to a 0.42% increase in GDP growth. This is considerably higher than the 11% the national accounts attribute to the fisheries.

JEL Classification: O13, Q20, Q22
Keywords: Fishing industry; gdp; economic growth, fisheries

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1. Introduction

Fisheries are generally regarded as Iceland's most important industry. Iceland's economic transformation during the 20th century is widely attributed to expansion in the fishing industry. (see e.g. Jonsson 1984, Nordal and Kristinsson 1987 and Arnason 1994 and references therein).

Somewhat curiously, these widely held beliefs are not based on any systematic measurements of the role of the fishing industry in the Icelandic economy. This is particularly intriguing when according to the available national statistics (Jónsson and Magnússon 1997), the fishing industry does not appear to occupy this domineering position in the Icelandic economy. Thus, in recent years, according to the national accounts, the fishing industry has only generated some 11% of the GDP and employs a considerably less fraction of the working population. In fact, since 1973, or as far as these particular GDP statistics reach, the contribution of fishing industry to GDP has never once exceeded 18%. Other industries such as manufacture, construction and commerce seem on this measure just as important, not to mention financial services and government services which, according to the national accounts, contribute substantially more to GDP than the fisheries. Looking further back in time, the available statistics reveal that for most of the 20th century, employment in the fishing industry was under 20% of the working population and its highest peak (around 1910) was only about 24%. It seems unlikely that the fishing industry's direct contribution to GDP ever exceeded this fraction by a substantial amount.

Thus, we are faced with an apparent paradox. On the one hand, there is this wide-spread, virtually uniform belief that the fishing industry was and is the backbone of the Icelandic economy and is responsible for Iceland's high rate of economic growth during the 20th century. On the other, we have the available economic statistics that, on the face of it, do not appear to support this claim.

In this paper we propose to attempt to throw some new light on this issue by employing econometric techniques to estimate the overall contribution of the fishing industry to the Icelandic GDP in the past. Not surprisingly, we are somewhat limited in this endeavour by the availability of historical data. Our shortest consistently measured time series, employment reaches back only to the year 1963. However, there is reason to believe that the structure of the economic growth relationships that may be discovered to apply since 1963 also applied in essence during the preceding period, perhaps as far back as the beginning of the 20th century. After all our econometric approach is designed to reveal fundamental production and macro-economic relationships that are generally thought to change quite slowly.

The paper is at least partly motivated by concerns about the impact global warming may have on fish stocks and fish availability in the Iceland-Greenland ecosystem and other sub-arctic areas in the North-Atlantic. Obviously, the more important the economic role of the fishing industries, the larger is the potential impact of global warming. Therefore, to judge this risk it is necessary to obtain numerical estimates of the macro-economic impact of a substantial change in fish availability in the economies in question.

This paper is broadly organized as follows: First we will briefly discuss one of the motivations for this study, the process of global warming and its possible impacts on Icelandic fisheries and those of Greenland. The following section, section 3, provides a historical background on the Icelandic economy and the role of the fishing industry therein. This is followed by the main section of the paper, the statistical estimation of quantitative impact of the fishing industry of the growth of the Icelandic GDP. More detailed statistical results are presented in the appendix. Finally, the main results of the paper are summarized and discussed in section 5.

2. Global warming and fisheries

Several large-scale meteorological models are currently predicting global temperatures in the future. These models are in broad agreement that there will be a general warming of the earth's atmosphere during the current century and beyond. However, the models differ significantly in their prediction of future temperature increases. Taking into account the confidence intervals presented by the model builders, the likely range of temperature increase is between 1.5 and 6°C by the year 2001 for the world as a whole.

The models generally predict that the temperature rises in the Arctic will substantially exceed the global rise. This applies especially in the high Arctic where the ice cover is expected to diminish substantially with the effect that the surface absorption of solar radiation will greatly increase. Further to the south, partly because of the effects of melting ice and possible changes in ocean currents, the situation is much less clear. In many of the sub-Arctic ocean areas, it may be the case that ocean temperature will rise little or not at all. The highest temperature rises are expected to occur in the Barents Sea, close to 6°C by 2100. In the Iceland - Greenland area, the predicted temperature increases by the end of this century are substantially less or only 2-3°C.

The impact of global warming on fish stocks and fisheries is hard to judge. There are several reasons for this: First, as discussed above, there is a great uncertainty regarding the extent and speed of global warming. Second, there is even more uncertainty regarding the warming in the North Atlantic. This holds not the least for those areas of the North Atlantic where most fishing currently takes place. These areas are often cold water- warm water frontiers where thermoclines are steep. Not surprisingly, it is precisely in these areas where global warming predictions are most uncertain. Third, fisheries depend very much on local conditions; up-welling, mixing of water masses, water salinity, currents, ice formation and melting and so on. Temperature is only one of the factors affecting fish stocks. On the other hand, changed temperature influences all these other hydrographical factors. What these effects will be, however, is very hard to predict. Fourth, it is clear that global warming will alter the configuration of ocean currents and, consequently, also the most favourable regions for fishing. This effect can be small or large. Some hydrological models suggest that global warming will have a major impact on the world's ocean current systems[2]. If that is the case, then there would be a corresponding major impact on fishing conditions in the North Atlantic. Fifth, any changes in habitat conditions due to global warming will alter the conditions for the various species in the marine ecosystem in different ways. This will give rise to an almost certainly very complicated and possibly drawn-out process of species adjustments and readjustments. The outcome of that process for individual species is very hard to predict. It may for instance easily be the case that species that experience favourable environmental changes are reduced in stock size due to less supply of prey that is unfavourably affected by the environmental change.

It follows from this that there is great uncertainty about the impact of global warming on the commercial fish stocks and fisheries in the North Atlantic. At our knowledge, there is simply not sufficient hydrographical, biological and ecosystem knowledge to translate predictions of global warming, uncertain as they are, into predictions for fish stocks and fisheries with a reasonable degree of confidence. What we can do, however, is to use our historical experience to speculate about possible changes in fish stock availability and then use econometric modelling to estimate the economic impact of the biological changes we find most likely.

On instance of an important stock of fish, which may be impacted by global warming, and for which we have an unusually complete set of historical information is cod in the Iceland-Greenland ecosystem. Extensive areas of the North Atlantic are currently marginally habitable for cod due to low temperatures. This holds in particular for the Greenland area and to a lesser extent for the northern part of the Barents Sea. A slight warming would make these areas habitable again with the consequent expansion in the range of cod of a very substantial magnitude. We know for instance, that during the warm period in the North Atlantic between 1930 and 1960, the geographically habitable range of cod in the Iceland-Greenland ecosystem expanded greatly. The Greenland based cod stock became very large, yielding annual catches similar those of the Icelandic cod stock for at least two decades (1950-1970). With the cooling trend in the late 1960s and continued fishing pressure, however, this cod stock was decimated yielding hardly any catches since the 1980s.

Thus, the historical experience suggest that some warming of ocean temperatures in the Greenland area will substantially improve the environmental conditions for cod and therefore, quite possibly, lead to a greatly increased size of the cod stock in the Iceland-Greenland ecosystem. Ocean warming may of course affect other species differently. However, due to the high commercial value of cod, this positive effect is probably going to dominate any negative effects on say shrimp and capelin in the region. With econometric estimates of the role of the fishing sector in the economies

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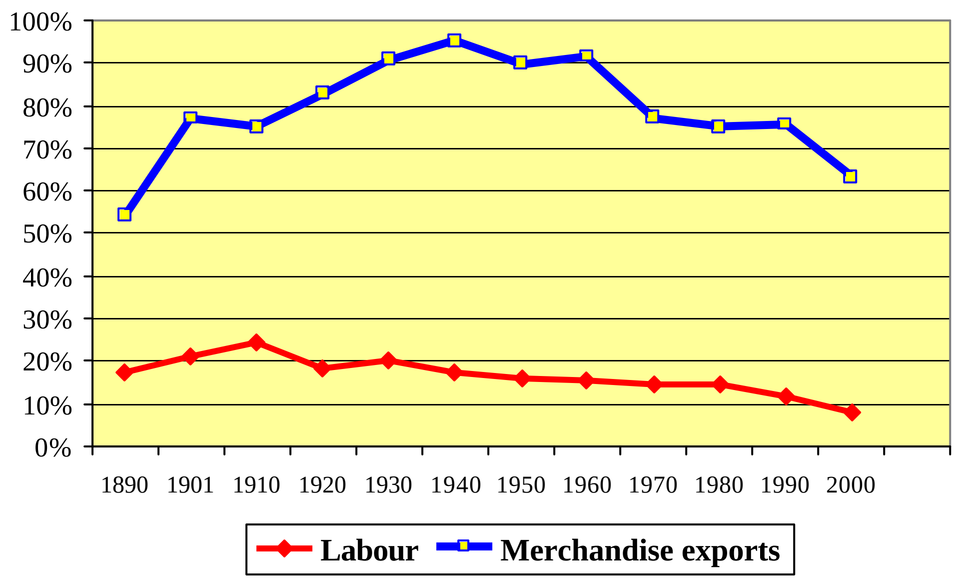
[2] Possibly weakening the Gulf-current substantially.

of Greenland and Iceland, we may be able to gauge the macro-economic impact of these changes when and if they occur.

3. Evolution of the Icelandic Economy: Historical Background

For centuries, pasture farming and fishing were Iceland's most important economic activities. By the end of the 19th century, fishing overtook farming in terms of economic importance. In 1910 almost 25% of the working population was engaged in fishing and fish processing generating almost 80% of the country's merchandise exports[3] (Figure 1). Although the fraction of labour working in the fishing industry declined from this high in the following decades, the importance of fish products in the exports actually increased to between 90-95% during the middle of the century. Since then, both the share of fish products in merchandise exports and the fraction of the total labour force engaged in fishing has declined significantly (Figure 1).

Figure 1
Fishing labour and fish exports (as a percentage of total labour and merchandise exports) (Source: Statistics Iceland 1997)

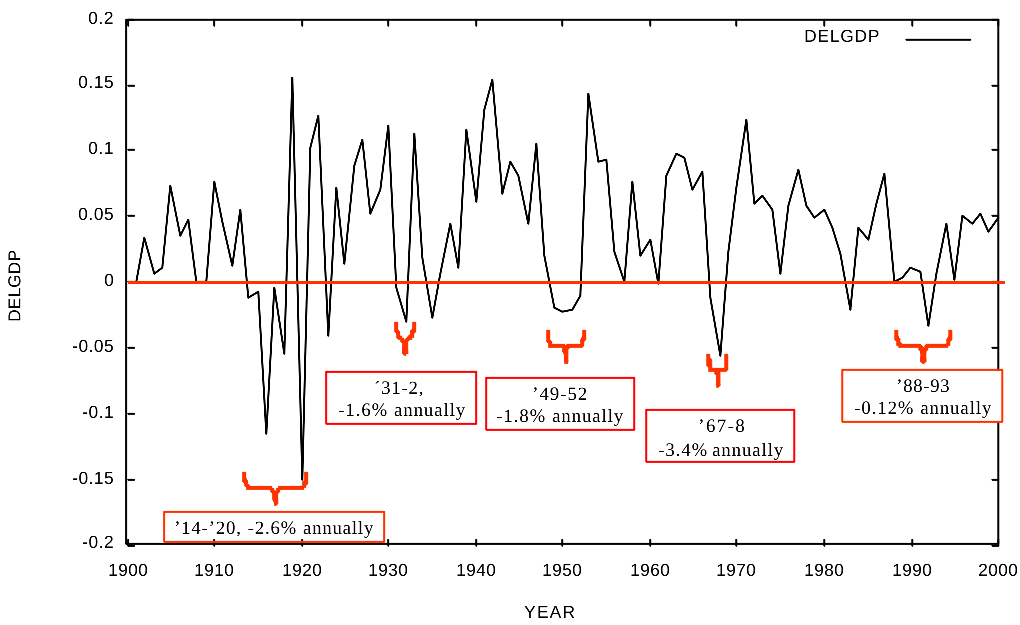


[3] Note that merchandise exports do not represent total export earnings. Total export earnings include the exports of services in addition to merchandise exports. Over time the share of services in total export has been increasing. Currently the export of services represents about 1/3 of total export earnings in Iceland.

During the 20th century, Icelandic gross domestic production (GDP) exhibited an average annual growth of about 4% per year. Extensive qualitative information (see e.g. Jonsson 1984, Nordal and Kristinsson 1987 and Arnason 1994 and references they quote) suggests that this economic growth was to a large degree generated by expansion in the fisheries and fish processing industries. Moreover, fluctuations in aggregate economic output were highly correlated with variations in the fishing industry. Good catches and high export prices incited economic growth, whereas poor catches and adverse foreign market conditions led to slowdowns and even depressions in the economy. All five major economic depressions experienced during the 20th century can be directly related to changes in the fortunes of the fishing sector, either wholly or partially.

The first of these major depressions covers the period of the First World War, which had catastrophic effects on Iceland as on so many other European countries. The first two war years were, however, favourable for the fishing sector, as increased demand pushed up foreign prices, but in 1916 the international trade structure broke down and Iceland had to accept harsh terms of trade with the Allies. In 1917, Iceland was forced to sell half of her trawler fleet to France. Demersal fish and herring catches were consequently seriously reduced in 1917 and 1918. The result was a sharp dip in the GDP and a generally depressed economy until 1920 (Figure 2).

Figure 2
GDP growth in Iceland 1901-2000: Major depressions



The effects of the “Great Depression” were first felt in Iceland in the autumn of 1930, and in the following two years GDP fell by 0.5% and 5% respectively as demand for maritime exports declined sharply. Following a brief recovery, the economy was hit again when the Spanish Civil War broke out in 1936 and closed Iceland's most important market for fish products. Despite these shocks, economic growth still averaged 3% in the 1930s, mostly because of strong rebound in the fisheries, especially the herring fisheries, in 1933 to 1939. From this it appears that it was primarily because of the strong performance of the fisheries in the 1930s that the "Great Depression" was less felt in Iceland than most other Western Countries.

The Second World War was a boom period for Iceland led by good catches and very favourable export prices. But in 1947 and subsequent years, herring catches fell considerably and real export prices subsided from the high wartime levels. The result was a prolonged economic contraction from 1949-52.

During the decade 1961-70, the economy exhibited a very respectable growth rate of 4.8% on average. This was to a large extent based on very good herring fisheries during most of the decade. When the herring stocks collapsed toward the end of the decade the result was a severe economic depression in 1968-69, when the GDP declined by 1.3% and 5.5% respectively. Unemployment reached over 2% - a great shock for an economy used to excess demand for labour since the 1930s - and many households moved abroad in search of jobs. Net emigration amounted to 0.6% of the total population in 1969, and 0.8% in 1970.

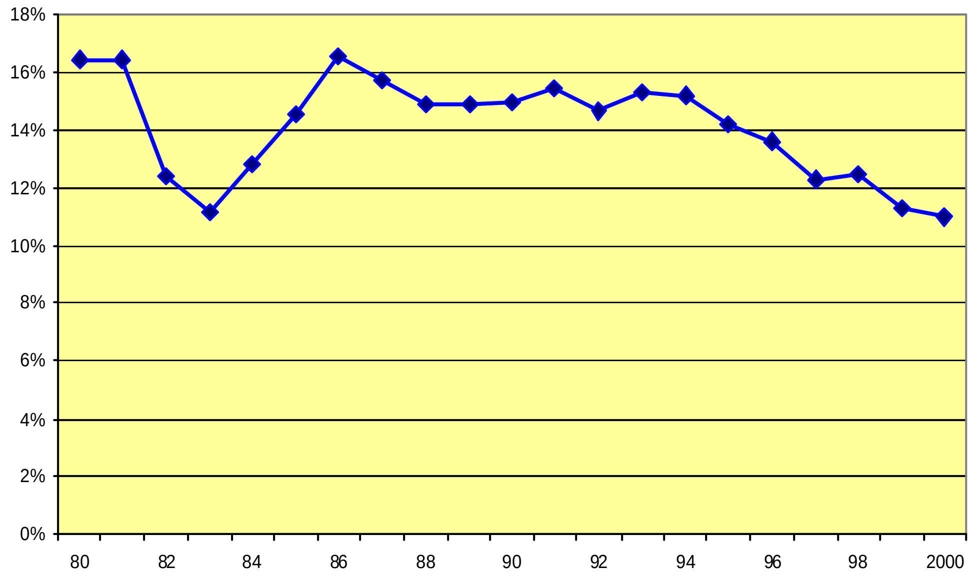
High economic growth rates resumed in 1971-80 averaging 6.4%. However, just as during the 1960s, this growth was to a significant extent based on over-exploitation of the most important fish stocks. Reduced fishing quotas and weak export prices reduced fishing profitability in the late 1980s. And, partly as a consequence of this, the Icelandic economy remained stagnant through the years 1988-1993, with an average annual decline in the GDP of 0.12%.

Since 1993, however, the Icelandic economy has registered steady and quite impressive annual growth rates. One reason for this is a recovery of some of the fish stocks. More importantly, however, are generally more favourable fish export prices and the impact of the individual transferable quota (ITQ) system. The ITQ system has enabled the fishing industry to increase and stabilize profits and much more easily adjust to changing quotas and fish availability.

Thus, looking at the 20th century as a whole, it appears that major fluctuations in the Icelandic economy may to a considerable extent be attributed to changes in the fortunes of the fishing industry both in terms of harvest quantity and output prices. This suggests that possible changes in fish stocks due to global warming may have similar macro-economic impact. This, however, would probably be something of an exaggeration. Most likely the macro-economic impact of any given change in fish availability will be smaller in the future than it has been in the past. First, the importance of the fishing industry for the Icelandic economy has declined substantially from its average during the 20^{th} Century. Second, the ITQ fisheries management system has probably made the fishing industry more capable of adapting effectively to changes in fish stocks than before. A word of caution, however, is in order. If the current depressed state of some of the most important fish stocks persists, adverse environmental changes may actually translate into larger biological shocks than those experienced in the past.

National accounts estimates of the contribution of fishing industry (fishing and fish processing) to the gross domestic product (GDP) are available since 1980. According to these figures, the direct contribution of the fishing industry to the GDP is currently (2000) just over 11%. In line with the trend in the fishing industry's labour and the export share, this represents a considerable decline compared to 1980 when the fishing industry contributed over 16% to the GPD (Figure 3). In fact, as suggested by Figures 1 and 3, the trend toward less economic dependence on fisheries has gained speed over time becoming particularly pronounced over the past 10-15 years. This declining trend in the relative importance of the fishing industry may be assumed to continue in the future.

Figure 3
Contribution of the fishing industry to the GDP (
(Source: National Economic Institute 1995, 2002).



In spite of the long-term decline in the macro-economic importance of the fishing industry, the Icelandic economy is still heavily dependent on fisheries. Thus, in the year 2000, the fishing industry accounted for some 8.2% of total labour, about 63% of merchandise exports and about 42% of total export earnings. In the same year the fishing industry contributed about 11% to the GDP.

4. Assessing the Economic Impact of the Fishing Industry: Statistical Estimation

We now turn our attention to the statistical estimation of the economic impact of a possible shift in the availability of fish to the fishing industries of the North Atlantic. The statistical estimation will be based on Icelandic data. However, due to the structural similarities of the economies in question, there are reasons to believe that the results for Iceland can be extrapolated to the economies of Greenland and possibly those of North Norway and Newfoundland as well.

General equilibrium considerations

It is important to realize that the national accounts statistics may well understate the real contribution of the fishing industry to the economies in question. There are two fundamental reasons for this. First there are a number of economic activities closely linked with the fishing industry but not part of it. These activities consist of the production of inputs to the fishing industry, the so-called backward linkages, and the various secondary uses of fish products, the so-called forward linkages (Arnason 1994). The backward linkages include activities such as ship building and maintenance, fishing gear production, the production of fishing industry equipment and machinery, the fish packaging industry, fisheries research, educations and so on. The forward linkages comprise the transport of fish products, the production of animal feed from fish products, the marketing of fish products, retailing of fish products, part of the restaurant industry and so on. According to Arnason 1994, these backward and forward linkages may easily add at least a quarter to the GDP contribution of the fishing industry.

The other reason why the national accounts may underestimate the true contribution of the fishing industry to the GDP is the role of the fishing industry as a disproportionately strong exchange earner. To the extent that the availability of foreign currency constrains economic output, the economic contribution of a disproportionately strong export earner may be greater than is apparent from the national accounts. While the size of this "multiplier effect" is not easy to measure, some studies suggest it may be of a significant magnitude (Arnason 1994). If that is true, the total contribution of the fishing industry to the GDP might easily be much higher than the above direct estimates suggest, in the sense that removal of the fishing industry would, ceteris paribus, lead to this reduction in the GDP.

It is equally important to realize that there are economic reasons why a change in the conditions of the fishing industry due e.g. to global warming, might have a lesser economic impact than suggested by the direct contribution of the fishing industry to GDP. This holds especially in the long run. Most economies exhibit certain resilience to exogenous shocks. This means that the initial impact of such shocks is at least partly counteracted by labour and capital moving to the economic activity made comparatively more productive by the shock. For instance, a negative shock in the fishing industry would be to a certain extent offset by labour and capital moving from the fishing industry to alternative industries and vice versa. As a result, the long-term impact of such a shock may be much less than the initial impact. The extent to which this type of substitution happens depends on the availability of alternative industries. However, with increased labour mobility, communication technology and human capital this type of flexibility is probably significantly greater than in the past.

Statistical estimation

The neoclassical theory of economic growth (see e.g. Solow 1970) suggests that economic output can be explained by the usage of capital and labour and the level of technology and, consequently, economic growth by the increase in these factors and technical progress. In the case of the Icelandic fishing industry, however, it appears that the output of the fisheries sector — to a large extent exogenous to the economic relationships of the neoclassical theory — needs to be added as an explanatory variable to this process.[6] Thus, it would seem reasonable to model changes in Icelandic GDP as the following growth function:

(1) $$\Delta y_t = a_0 + \sum_{i=0}^{m} b_i \Delta k_{t-i} + \sum_{i=0}^{m} d_i \Delta l_{t-i} + \sum_{i=0}^{m} g_i \Delta f_{t-i} + m_t$$

where Δy_t is the one-year percentage change in GDP, i.e. economic growth, Δk_t the one-year percentage change in capital, Δl_t the one year percentage change in labour and , Δf_t the one-year percentage change in fishing industry output The a_0 and the *ß*'s, *d*'s and *?*'s are parameters to estimated. As stated here, GDP is defined as a function of both current and lagged values of capital, labour and the fisheries, with the lag length set equal to *m* for all three explanatory variables. This is, however, only a general form of the equation, which will subsequently be simplified as suggested by the data by imposing linear constraints on the parameters. There is, for instance, no a priori reason to believe, that the lag length will be the same for all variables in the final reduced model.

To estimate an equation of type (1) we used official time series data on the four variables during 1963-1996 (Statistics Iceland, National Economic Institute). Summary statistics of the variables are presented in Table 1. GDP, the value of marine products and the capital stock are all measured in constant 1990 prices, while labour is measured in man-years.

Table 1. **Descriptive statistics. GDP, production of marine products and capital stock in fixed prices (1990 million kr.), labour in man-years. Period is 1963-1996.**

	Min.	Max.	Mean	Stdev
GDP	110,649	397,048	255,689	94,830
Marine products	18,783	80,494	52,070	18,909
Capital stock	363,759	1,249,159	830,958	289,610
Labour	67,315	131,836	103,638	19,965

Source: Statistics Iceland and National Economic Institute

The first step in our analysis consists, though, of determining the order of integration of the four variables used in our study. To this end, augmented Dickey-Fuller (ADF) tests were conducted using constants, lags and time trends as appropriate (see e.g. Davidson and MacKinnon 1993). The lag length used was determined on the basis of the Akaike information criteria. The results of this study are summarized in Table 2. As suggested in Table 2, all four variables (when tested with a time trend) seem to be integrated of order one — the null hypothesis of zero roots is not rejected for the levels and rejected for the differenced series.[4] We can thus safely proceed with the estimation of equation (1). *

Table 2. **Augented Dickey Fuller test for stationarity. Time period is 1963-1996**

	With constant		With constant and time trend	
	Value	Lags	Value	Lags
Levels:				
GDP	-1.477	0	-1.436	1
Marine production	-1.824	4	-1.636	4
Capital	-3.254 *	2	1.261	4
Labour	-1.477	1	-0.877	1
First differences:				
GDP	-4.193 **	0	-3.835 *	4
Marine production	-4.988 **	4	-6.552 **	4
Capital	-1.361	2	-3.806 *	0
Labour	-4.055 **	0	-4.179 *	3

* and ** denote 5 and 1% level of significance respectively.

4 See also Figures A1 and A2 in the Appendix.

Our next step is to investigate the direction of causality. Does fishing industry output cause GDP or, as is conceivable, does GDP cause fishing industrry output. This can be checked using the Granger causality or, rather, non-causality test (Granger 1969). According to the Granger approach X, (Granger) causes Y if past values of X contain information about Y, while X does not (Granger) cause Y if past values of X contain no information about Y.

Using a lag length of four, we therefore estimated the following two equations:

$$\Delta y_t = a + b_1\Delta y_{t-1} + b_2\Delta y_{t-2} + b_3\Delta y_{t-3} + b_4\Delta y_{t-4} + d_1\Delta f_{t-1} + d_2\Delta f_{t-2} + d_3\Delta f_{t-3} + d_4\Delta f_{t-4} + m_t,$$

$$\Delta f_t = a + b_1\Delta y_{t-1} + b_2\Delta y_{t-2} + b_3\Delta y_{t-3} + b_4\Delta y_{t-4} + d_1\Delta f_{t-1} + d_2\Delta f_{t-2} + d_3\Delta f_{t-3} + d_4\Delta f_{t-4} + m_t.$$

Wald tests were used to test the restrictions $d_1 = d_2 = d_3 = d_4 = 0$ in the first equation and $b_1 = b_2 = b_3 = b_4 = 0$ in the second equation. The former restrictions are rejected at the 5% level – the test statistic is 11.03 and the critical 5% value is 9.49 — suggesting we have to reject the hypothesis that marine production does not (Granger) cause GDP. The second restrictions are not rejected — the test statistic in that case is 3.26 while the critical level is 9.49 as before — suggesting that GDP does not (Granger) cause marine production. The Granger causality tests thus lend support to our belief that the short-run causality between GDP and the fisheries sectors only runs in one direction, from the latter to the former.

The third step in our estimation procedure was to use cointegration tests to check for the existence of a cointegration vectors. The results of these tests (reported in the Appendix) indicated the existence of one cointegration vector then may be may interpreted as a long run relationship between GDP capital , labour and marine production.

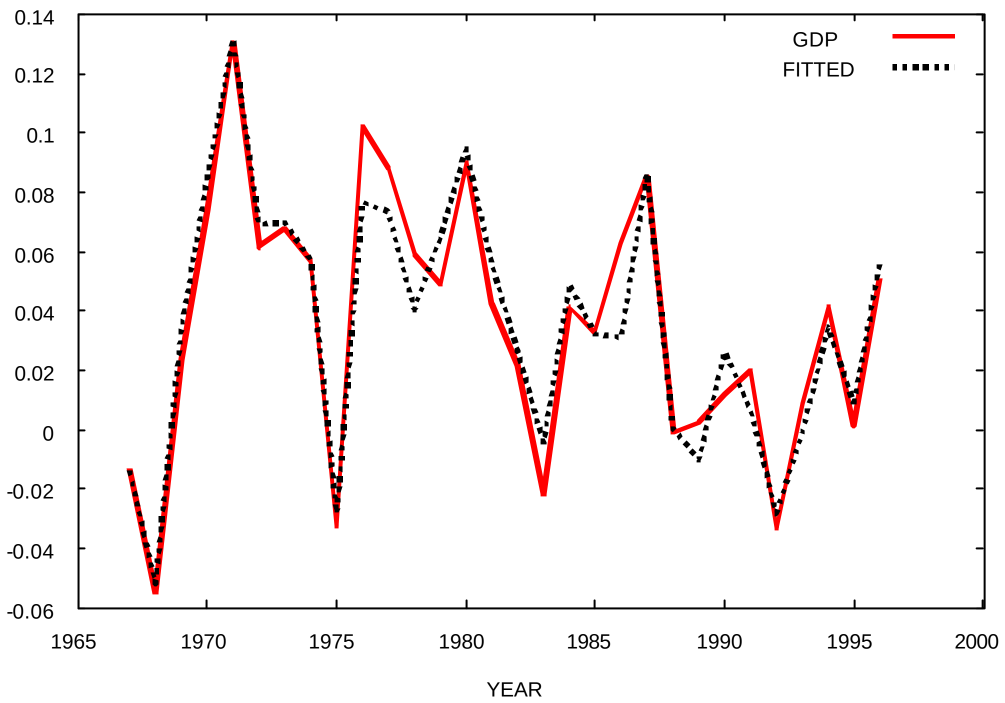
With these preliminaries out of the way we went to the estimation of equation (1). We first estimated equation (1) with three lags for each of the variables, *k*, *l* and *f*. The estimation procedure was OLS. The key results of this initial regression are presented in Table A1 in Appendix. Consequently, the model was simplified using Wald tests to reduce the number and form of the lags. The final estimated equation is presented in Table A2 in the Appendix. According to this equation, lagged labour terms should be excluded (a chi-square test of these restrictions yielded $\chi^2(3)$=2.52, far below the critical value of 7.82.[5] Zero restrictions on the lagged terms of the other explanatory variables were all rejected.

The final estimated equation thus explains percentage economic growth in Iceland in terms of a 3 year distributed lags of percentage changes in fishing

[5] A more through discussion is present in appendix.

industry output and capital, the percentage change in the current usage of labour and autonomous growth, a_0. This equation exhibits a good fit to the data (Figure 4)[6]. Moreover its statistical properties appear reasonable.[7]

Figure 4
GDP Growth in Iceland: Actual and fitted values



Estimates of the total impact of the three explanatory variables on GDP is provided in Table 3.

Table 3. **The estimated total impact of changes in fish production, capital and labour on GDP growth in Iceland.**

Explanatory Variable	Estimated total impact	Mean lag (years)
Fish exports, Δx	0.42	1.5
Capital, Δk	0.21	2.4
Labour, Δl	0.51	0

[6] The multiple correlation coefficient is $R^2 = 0.93$.
[7] See appendix.

According to the results presented in Table 3, a 1% change in the value of fishing industry production in Iceland will ultimately lead to a 0.42% increase in GDP.[8] The GDP impact emerges gradually over a period of 3 years with about half of the impact apparent 1.5 years after the initial increase in fish production. This suggests a long term value added multiplier in the fisheries (i.e. $\partial GDP/\partial f$, where f represents value added in fisheries) of approximately 3.[9]

Thus we are faced with widely different estimates of the contribution of the fishing industry to the Icelandic GDP. On the one hand, the national accounts estimate the direct contribution of the fishing industry to the GDP to be some 11%. Including immediate forward and backward linkages, this contribution could increase 14%. On the other hand, the overall "portmanteau" estimates comprising the macro-economic multiplier effects discussed above, indicate a total GDP impact of the fishing industry of some 40%. While we would certainly like to stress the statistical uncertainty of this last estimate, there are grounds to believe that it, being all-inclusive, may be most sound.

It is interesting to note that according to the estimates reported in Table 3, the returns to expanding capital and labour scale by the same proportion are only 0.72, considerably less than unity. Thus, the economy-wide returns to scale to these two basic factors of productions are substantially less than one. Adding fish production, however, the returns to scale exceed unity (1.14). Now, having accounted for the impact of capital and labour by separate explanatory terms in equation (1), fish production may be regarded as a the contribution of the third production factor, the fish stocks or, more generally, marine resources. When this contribution can be expanded at the same rate as capital and labour, the economy, according to our estimation results, enjoys (slightly) increasing returns to scale. When, on the other hand, the contribution from the marine resources are approaching an upper limit, as seems to be the case now, the growth potential of the significantly reduced.

5. Discussion

In this paper, econometric methods have been used to analyse the "true" contribution of the fisheries to the Icelandic economy. Using data on GDP, marine production, capital stock and labour for the period 1963-1996, it was found that a 1% increase in the value of production of the fishing industry will in the long-run increase GDP by 0.42%. The effects are spread out over a period of three years, with the impact multiplier amounting to 0.15%. These estimates imply that the national accounts may severely underestimate the economic importance of the fishing industry. According to official national accounts, the fishing and fish processing accounted directly for 10-15% of GDP during the last two decades of the 20th century.

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[8] The 95% confidence interval around this estimate is ±11.3%.

[9] To see this note that the elasticity of GDP w.r.t. marine exports is approximately equal to the elasticity of GDP w.r.t. value added in fisheries. Multiplying this elasticity with the ratio of GDP to value added in fisheries (approximately 7 during the data period) yields a multiplier of approximatley 3.

Our results indicate that taking direct as well as indirect effects into account, as in our estimated economic growth equation, the overall contribution of the fishing industry to the Icelandic GDP may well be double to triple that shown in the national accounts.

A misconception concerning the economic importance (in terns of GDP generation) of the various sectors may have seriously detrimental consequences. Global warming, pollution accidents, stock collapses, the erection of tariff barriers and so on may lead to substantial shocks to the fishing industry. If the macro-economic role of the fishing industry is underestimated when shocks of this kind happen — and they will —, then it may well be that this underestimate will lead to the adoption of incorrect, probably inadequate, economic policy responses. Clearly, a more complete understanding of the true economic significance of the fisheries will help policy makers in anticipating the economic impacts of fisheries shocks and, thus, increase the chances that the appropriate economic policies be implemented.

As already mentioned in the introduction, we believe that these measurements of the economic importance of the fishing industry in Iceland are also indicative of the importance of the fishing industries in similar fish-based economies across the North Atlantic, Newfoundland, Greenland, Faroe Islands and Northern Norway. By this we mean that we would expect similar multipliers to apply. The actual overall contribution of the fisheries to the GNP in these countries would then depend on the size of the fishing industries (in terms of production or direct value-added) to the rest of the economy. We further expect that the methodological approach adopted in this paper can be employed to investigate the overall role of fisheries and, for that matter, other base-industries in other countries, provided of course the necessary data are available.

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Appendix

Figures

Figure A1. **Percentage changes from the previous year in GDP and marine production 1964-1996.**

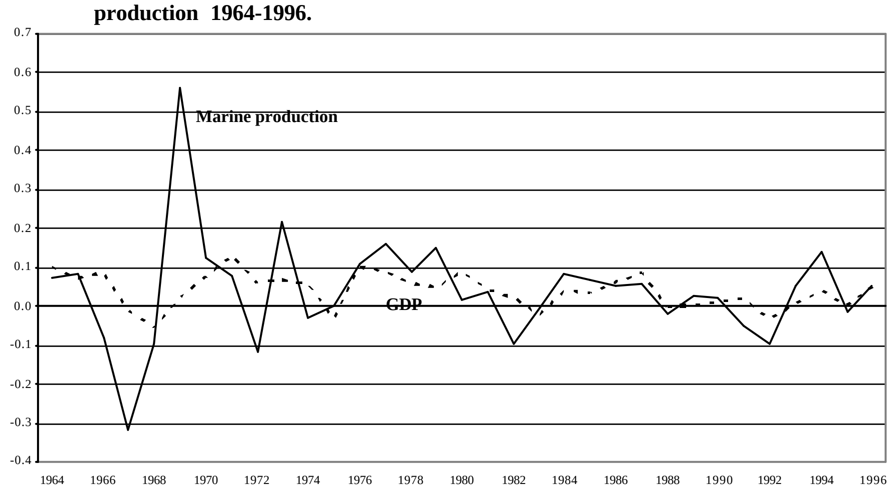
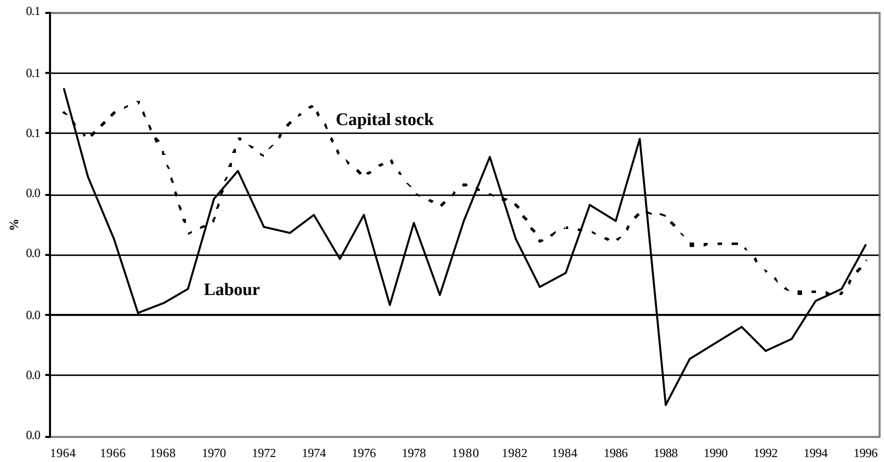


Figure A2. Percenatage changes from previous year in capital stock and labour 1964-1996.



Statistical estimation

1. Unrestriced equation

The following summarizes key results of the statistical estimation of equation (1)

Estimation equation: $\Delta y_t = a_0 + \sum_{i=0}^{m} b_i \Delta k_{t-i} + \sum_{i=0}^{m} d_i \Delta l_{t-i} + \sum_{i=0}^{m} g_i \Delta f_{t-i} + m_t$

$\Delta y_t = \ln(y_t - y_{t-1})$; y_t is GDP in year t

$\Delta k_t = \ln(k_t - k_{t-1})$; k_t is total capital value in year t

$\Delta l_t = \ln(l_t - l_{t-1})$; l_t is size of labour force in year *t*.

$\Delta y_t = \ln(f_t - f_{t-1})$; f_t is export value of fish products in year *t*

Table A1. **Results from estimating the unrestricted version of equation (1).**
Dependent Variable: ? y_t
Method: Ordinary least squares
Sample(adjusted): 1967 1996
Included observations: 30 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	7.76E-05	0.007638	0.010163	0.9920
? f_t	0.149799	0.025739	5.820017	0.0000
? f_{t-1}	0.074637	0.026278	2.840271	0.0113
? f_{t-2}	0.041256	0.026703	1.544995	0.1408
? f_{t-3}	0.151680	0.026264	5.775240	0.0000
? k_t	1.831387	0.419307	4.367652	0.0004
? k_{t-1}	-2.472921	0.462264	-5.349581	0.0001
? k_{t-3}	-0.011508	0.495866	-0.023209	0.9818
? k_{t-3}	1.012432	0.387961	2.609625	0.0183
? l_t	0.456281	0.169245	2.695977	0.0153
? l_{t-1}	-0.106904	0.169519	-0.630634	0.5367
? l_{t-2}	0.173497	0.169117	1.025901	0.3193
? l_{t-3}	-0.200670	0.165309	-1.213908	0.2414
R^2	0.935022			
Adjusted R^2	0.889155			
Standard error of regression	0.014608			
SSR	0.003628	Akaike info criterion		-5.315842
Log likelihood	92.73763	F-statistic		20.38547
Durbin-Watson stat	1.465114	Prob(F-statistic)		0.000000

Wald test on restrictions:

H_o: $d_1 = d_2 = d_3 = 0$:

Chi-square statistic 2.53, probability 0.47.

Critical value with three degrees of freedom: 7.82.

Conclusion: Can not reject H_o.

2. Restricted equation

Can therefore respecify the equation as: $\Delta y_t = a_0 + \sum_{i=0}^{m} b_i \Delta k_{t-i} + d_o \Delta l_t + \sum_{i=0}^{m} g_i \Delta f_{t-i} + m_t$

Table A2. **Results from estimating a restricted version of equation (1).**
Dependent Variable: ? y_t
Method: Ordinary least squares
Sample(adjusted): 1967 1996
Included observations: 30 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.001555	0.007391	0.210431	0.8355
? f_t	0.145578	0.024933	5.838731	0.0000
? f_{t-1}	0.078566	0.024908	3.154250	0.0050
? f_{t-2}	0.046191	0.025240	1.830027	0.0822
? f_{t-3}	0.154544	0.025567	6.044687	0.0000
? k_t	1.647083	0.377333	4.365064	0.0003
? k_{t-1}	-2.426934	0.447691	-5.421006	0.0000
? k_{t-3}	0.041973	0.476654	0.088058	0.9307
? k_{t-3}	0.949757	0.371001	2.559984	0.0187
? l_t	0.506716	0.160457	3.157960	0.0049

R-squared	0.925353		
Adjusted R-squared	0.891762		
Standard error of regression	0.014435	Jarque-Bera test for normality	4.74
Sum squared resid	0.004167	Akaike info criterion	-5.377129
Log likelihood	90.65693	F-statistic	27.54760
Durbin-Watson stat	1.817355	Prob(F-statistic)	0.000000

The following table summarizes key results of the statistical estimation of the reduced equation.

Table A3.**Key results of the reduced equation.**

Variable	Aggregate coefficients	t-statistic	Mean lag
Fish exports, Δx	0.42	7.4	1.5
Capital, Δk	0.21	1.2	2.4
Labour, Δl	0.51	3.2	0
Constant	0.002	0.2	

3. Cointegration analysis

As noted earlier, equation (1) describes short-run changes to GDP following changes in one or more of the explanatroy variables, k, l and f. It would however, be interesting to test if a long-run relationship between these four variables exists, and this can be achieved by applying cointegration tests. The most widely used of these is without doubt the Johansen procedure. For this purpose we apply the Johansen maximum likelihood procedure, which is based on vector autoregression (VAR) and consists – in our case – of subsequently testing for zero, one, two or three cointegrating relationships. We include an intercept in the cointegrating relationships, and estimate the system using one lag.

Table A4. **Cointegrtion results.**
Sample: 1963 1996
Included observations: 32
Test assumption: No deterministic trend in the data
Series: LGDP LMPROD LLAB LCAP
Lags interval: 1 to 1

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.614049	56.91431	53.12	60.16	None *
0.387375	26.44887	34.91	41.07	At most 1
0.196446	10.76879	19.96	24.60	At most 2
0.111138	3.770043	9.24	12.97	At most 3

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
L.R. test indicates 1 cointegrating equation(s) at 5% significance level

Unnormalized Cointegrating Coefficients:

LGDP	LMPROD	LLAB	LCAP	C
-7.645172	2.883164	2.645587	3.478367	18.69013
2.328855	0.913789	-1.816840	-2.264599	-8.483766
-3.044809	0.904436	-4.113634	5.196475	52.89815
-3.736890	0.464458	6.193273	0.752581	-33.61487

Normalized Cointegrating Coefficients: 1 Cointegrating Equation(s)

LGDP	LMPROD	LLAB	LCAP	C
1.000000	-0.377122	-0.346047	-0.454976	-2.444697
	(0.04072)	(0.13417)	(0.07534)	(1.15231)
Log likelihood	317.0633			

According to thses results, there exists one cointegration vector, which may be rewritten as:

$$y_t = 2.445 + 0.455k_t + 0.346l_t + 0.377 f_t + m_t .$$

This function is basically a long-run production function, and since all variable are in logs, it can be taken to show that the long-run output elasticity of the marine production equals 0.377. Thus, a one percentage point increase in the value of the marine sector will in the long-run lead to a 0.38 percentage point increase in GDP.