ISSN 1011-8888

INSTITUTE OF ECONOMIC STUDIES

WORKING PAPER SERIES

W04:07 Oktober 2004

On the Relationship between Greenland's Gross Domestic Product and her Fish Exports: Empirical Estimates

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0. Introduction

Global warming may among other things affect the size, location and distribution of fish stocks. Consequently it may also affect the gross domestic production (GDP) of countries that are engaged in fishing as an economic activity. In order to predict the possible magnitude of this effect it is obviously necessary to obtain estimates on the relationships involved. This paper constitutes an attempt to carry out this task for the case of Greenland. It is written as a part of an ongoing large scale research project — Arctic Climate Impact Assessment or, in short, ACIA — to gauge the potential impacts of global warming on Arctic economies

Greenland's economy is highly dependent on fisheries. In fact, apart from public services and financial transfers from Denmark, fisheries and fish exports are, by far, the greatest source of income in Greenland (Statistics Greenland 2002). Consequently, it may be assumed that variations in fish stock availability and hence fish production and export will have a significant impact on GDP in Greenland. In the following we will attempt to estimate this relationship. However, as will become clear below data limitations will severely constrict our ability to do this in a consistent manner. Hence, this study should be regarded as a preliminary effort at measuring this impact.

1. Theory

The theory of GDP generation has been extensively studied in economics under the heading of growth theory.[1] A key result of this theory is that aggregate production (or GDP) can be explained in terms of the application of capital, labour and technical knowledge. A more recent addition (Dasgupta and Heal 1979) is that these man made things can only generate output when they are combined . Formally, this may be written as the production function:

(1) $y = Y(k,l,t,x)$,

where y represents aggregate production GDP and k, l, t and x the use of capital, labour, technology and natural resources respectively. GDP growth is:

(2) $\dot{y} = Y_k \cdot \dot{k} + Y_l \cdot \dot{l} + Y_t \cdot \dot{t} + Y_x \cdot \dot{x}$,

where dotted variables represent first derivatives with respect to time and subscripted variables derivatives of the function Y with respect to the variables in question.

[1] Excellent introductory references to growth theory are Solow 1956 and Romer 1996.

So, according to this theory, GDP should depend on the use of capital, labour, technology and the use of natural resources and the growth of GDP on the growth in these variables. Moreover GDP and GDP growth should be increasing or at least nondecreasing in these variables. Otherwise few general restrictions on the function $Y(.,.,.,.)$are available. Therefore this function has to be determined for particular empirical cases on the basis of available data.

2. Data

For Greenland it turns out that only limited data on the relevant variables to explain GDP are available. Annual time series for GDP and fish exports, which can be taken as a proxy for natural resource use, since 1966 are available. On the other hand time series data on capital and labour usage are not readily obtainable. Therefore, theoretically appropriate estimates are not possible. However, if fish production, measured by fish exports, is the primary determinant of GDP in Greenland then the errors of ignoring capital and labour as independent explanatory variables may not be serious.

The time series for GDP and export of fish products in fixed value termsare listed in the appendix. These two variables in levels and logs are plotted against time in the Figures 1 and 2 below.

Figure 1
GDP and fish exports plotted aginst time
(Fixed prices 1990)

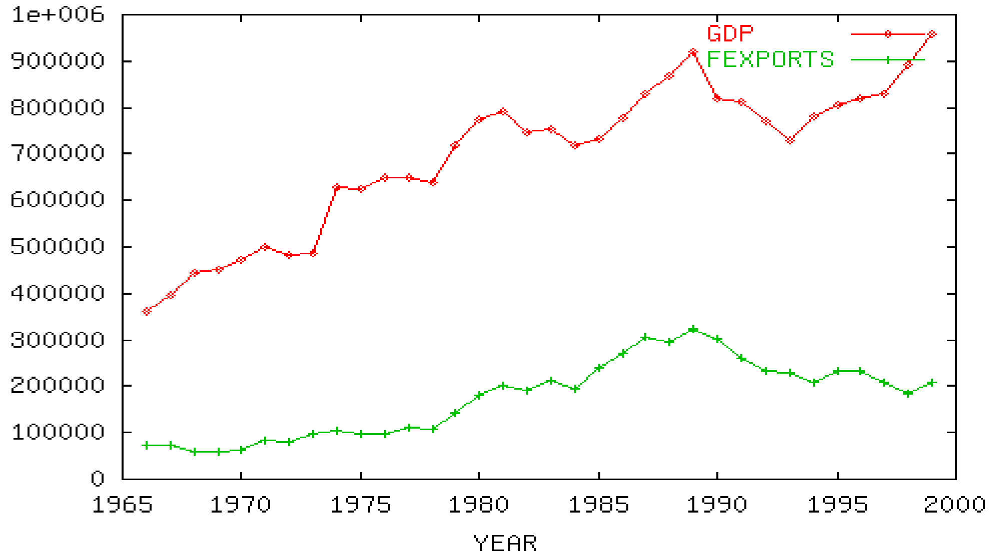
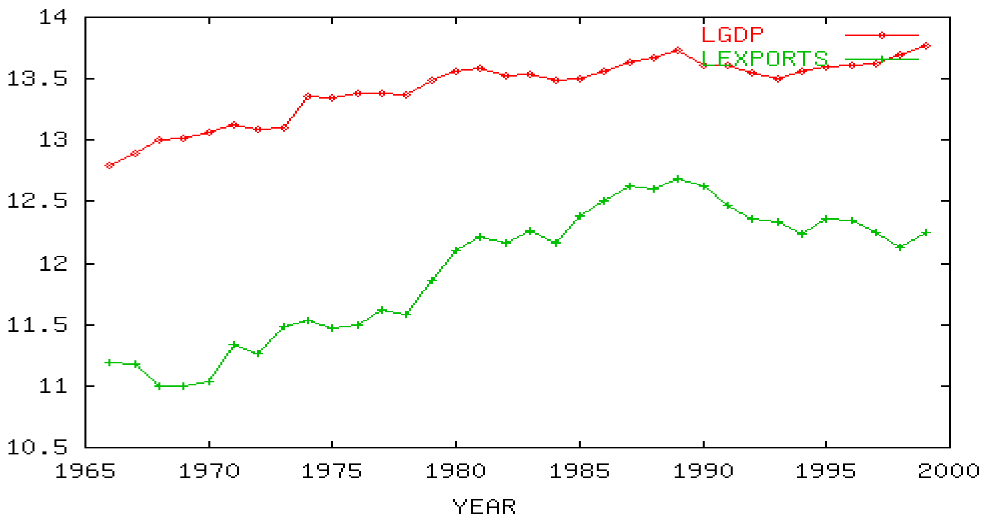
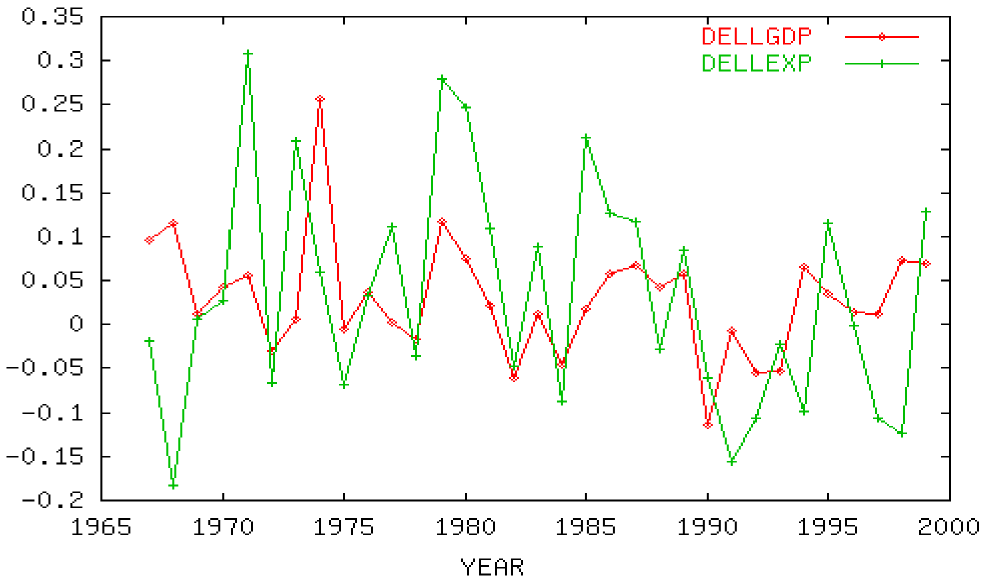


Figure 2
Logs og GDP and fish exports plotted aginst time
(Fixed prices 1990)



From Figures 1 and 2 it is apparent that there is a high degree of correlation between these two series. In fact, the simple correlation coefficient between them is 0.87. This obviously lends support to the possibility that fish exports dominate the generation of GDP in Greenland. Note, however, that as is so common with economic time series, both series exhibit a similar growing trend that may exaggerate the causal relation between the two. Therefore, in an attempt to eliminate this common trend first differences of the logs or in other words percentage changes of the two series are plotted in Figure 3.

Figure 3
The percentage changes in GDP and fish exports plotted against time



A visual inspection of Figure 3 suggests a marked positive relationship between the percentage changes in fish exports and percentage changes in GDP. Although the simple correlation between the two series is now much smaller than before or 0.3, peaks and troughs in the two series are quite coincidental. This again may be taken to indicate that data on capital and labour usage may not be crucial in correctly measuring the relationship between GDP and fish production.

3. Estimation

We now turn to the task of estimating a relationship between GDP and fish exports. For that purpose we should ideally estimate aggregate production functions of the form defined by (1) or (2) in the section 1 above. As discussed in the section on data above we have time series observations on GDP and fish exports. Moreover we can include time as a proxy for technical progress and an underlying exogenous GDP growth. However, as explained above, we do not have any data on capital and labour usage.

Due to the lack of data on capital and labour usage it is clear that we cannot estimate the theoretically correct aggregate production function. As a result it is unlikely that we can obtain statistically consistent estimates of the partial relationship between GDP and fish exports. However, depending on the importance of the fisheries in the Greenland economy, we may be able to get reasonable estimates, i.e. estimates that are not seriously biased.

Preliminary estimations suggest that the following basic functional form is adequate to represent the observed data:

$$y = a \cdot x^b \cdot e^{c \cdot t}$$

where *y* represents GDP and *x* the exports of fish products. *a*, *b* and *c* are coefficients to be determined by the data. The coefficient *b* encapsulates the partial relationship between fish exports and GDP. It represents the elasticity of GDP with respect to fish exports, i.e. the percentage change in GDP as fish exports are increased by one percent. This, of course is exactly the relationship we seek. The coefficient *c* represents the rate of technical change and exogenous economic growth.

The following three variants of this basic form were estimated:

(1) $$ln(y_t) = ln(a) + b \cdot ln(x_t) + c \cdot t,$$

where the *t*-subscripts refer to observations at that time.

(2) $$ln(y_t) = ln(a) + \sum_{i=0}^{3} b_i \cdot ln(x_{t-i}) + c \cdot t$$

(3) $$\Delta ln(y_t) = c + \sum_{i=0}^{3} b_i \cdot \Delta ln(x_{t-i}),$$

where the symbol Δ indicates first time differences. Thus e.g. $\Delta ln(y_t)$ is the percentage change in GDP from time *t*-1 to *t*. It is important to realize that equation (3) is merely equation (2) in differenced form.

These equations were estimated by OLS (ordinary least squares) employing the data discussed in section 2. The most pertinent results of the estimation are reported in Table 1.

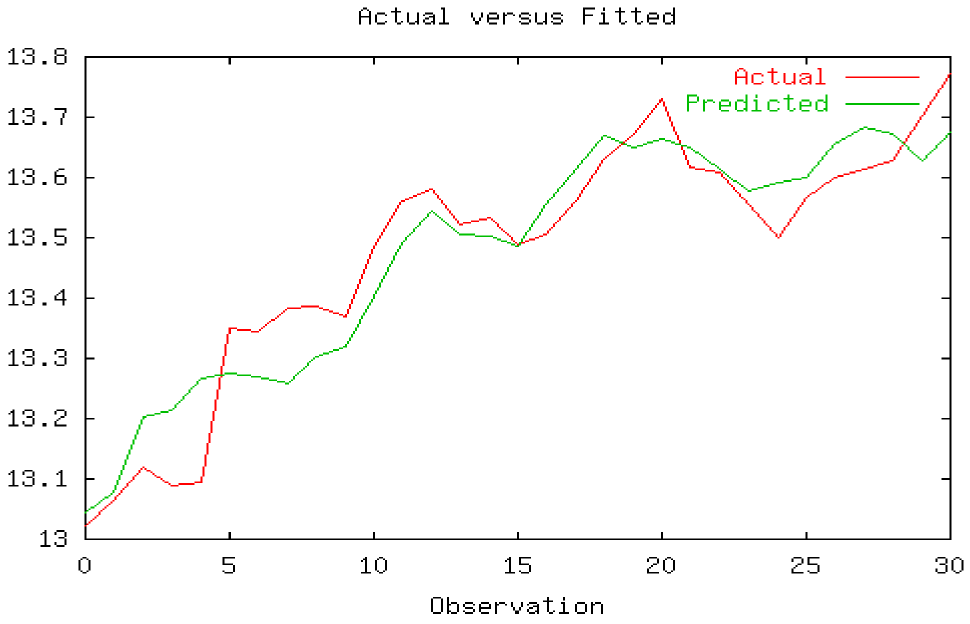
Table 1
Estimation results

Estimation method: OLS
Data period: 1966-1999
t-statistics in parenthesis

	Equations		
	(1)	(2)	(3)
Deg of freedom	31	25	25
ln(*a*)	-11.5 (-2.0)	-14.4 (-2.1)	-
b	0.26 (4.3)	-	-
$\sum_{i=0}^{3} b_i$	-	0.18 (2.9)	0.29 (1.7)
c	0.011 (3.4)	0.013 (3.4)	0.013 (1.0)
R^2	0.87	0.88	0.24
DW	0.49	0.82	2.0
Normality	Rejected	Rejected	Rejected

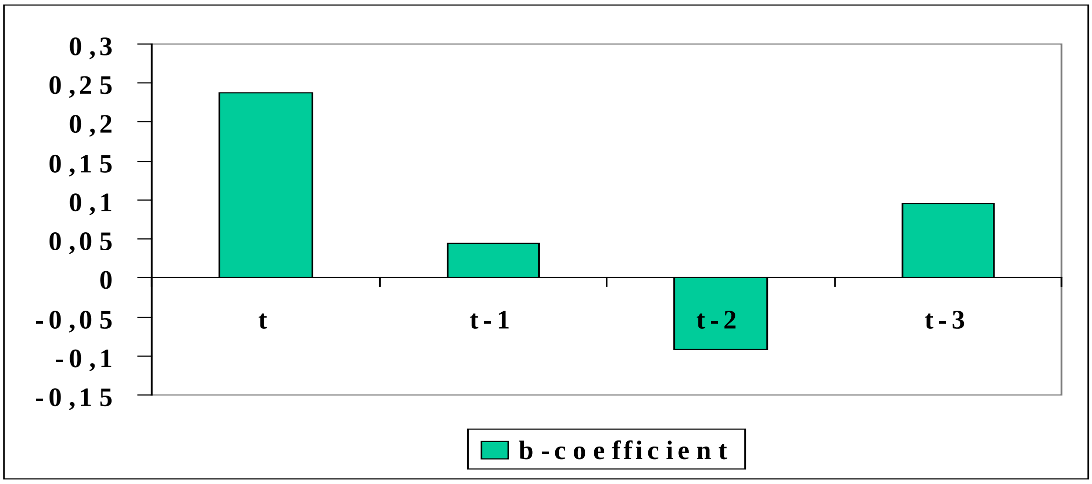
None of these regressions appears entirely satisfactory. All three show indications of non-normal residuals. Equations (1) and (2) also show strong signs of autocorrelated residuals. This may reflect the impact of misspecification. The absence of autocorrelation from equation (3) suggests that this equation is statistically more robust and hence preferable to the other two. Note that the reduced fit of equation (3) as measured by the R^2 is an artificial consequence of differencing. In an undifferenced form this equation has the same R^2 as equation (2). The fit of this latter equation to the observations is illustrated in Figure 4.

Figure 4
Fit of equation (2) to the data



The crucial parameter to be estimated, the elasticity of GDP with respect to changes in fish exports, i.e. the *b* in equation (1) and $\sum_{i=0}^{3} b_i$ in equations (2) and (3) is similar between the equations or 0.26, 0.18 and 0.29 in equations (1), (2) and (3), respectively. Note, however, that in the case of equations (2) and (3) this effect appears as a distributed lag function over time. In the case of equation (3) the mean the mean lag is 1.5 years, i.e. the average impact on GDP occurs half a year after the change in fish exports. A plot of the distributed lag structure is provided in Figure 5.

Figure 5
Distributed lag impact effect of fish exports on GDP



4. Conclusions

This study suggests the use of equation (3). This implies that GDP equation is

$$y_t = a \cdot \sum_{i=0}^{3} x_{t-i}^{b_i} \cdot e^{c \cdot t} \ .$$

The long run impact of a change in fish exports is $\sum_{i=0}^{3} b_i$ = 0.286. This means that if fish exports increase permanently by 1%, GDP would increase permanently by 0.286% due to that change.

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Appendix
Data

Year	GDP 1000 DKR	Fish exports 1000 DKR
	(Fixed prices 1990)	
1966	361000	72880
1967	397536	71534
1968	446078	59630
1969	451790	59966
1970	471525	61665
1971	498804	83834
1972	483814	78402
1973	486411	96619
1974	628512	102513
1975	625106	95737
1976	648777	98879
1977	650381	110616
1978	639893	106832
1979	719225	141228
1980	775089	180883
1981	791216	201969
1982	745111	192556
1983	754238	210438
1984	720409	193001
1985	732925	238607
1986	776340	270852
1987	830581	304320
1988	867001	295975
1989	919469	322001
1990	819780	302959
1991	813532	259393
1992	770530	233229
1993	730187	227985
1994	779634	206655
1995	807049	232083
1996	818540	231648
1997	829189	208201
1998	892852	184035
1999	957168	209403

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