FROM SECTOR SPECIFIC NITROGEN POLICIES TO A COMMON INDIVIDUAL TRANSFERABLE QUOTA SYSTEM - SECTOR AND MACROECONOMIC IMPLICATION

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Abstract (350 words)

In 2003, The Water Framework Directive (WFD) was implemented into legislation in all EU countries. The aim of the WFD is to achieve “good ecological status” for all water bodies by 2015 and no later than 2027. Measures differ among Member States (MS), but common to most MS are that individual sectors are governed by individual policies, not taking into accounts that the marginal abatement cost between producers in all sectors governed by these individual policies should in principle be equal to reach an economically optimal regulation practice. In this paper, we will analyze the policy targeting nitrogen leaching from agriculture and aquaculture and the overall as well as sector specific economic consequences of introducing an individual transferable nitrogen leaching quota system (ITQs) covering both sectors. The empirical analysis is carried out with Denmark as a case.

Simulating a common ITQ system, nitrogen leaching is reallocated from agriculture to aquaculture, which results in an increase in production of 55 percent in the aquaculture sector. The effect on the production in the agricultural sectors varies between -1.8 and -0.2 percent. The common quota price is calculated to €5.2 very close to the initial calculated shadow price in agriculture, reflecting that agricultures is the predominant polluter of nitrogen. At the macro level there are small positive effects on GDP and gross national expenditures (0.005 and 0.003 percent).

Current policy analysis suggests that Denmark still needs to reduce the total nitrogen leaching by 17.6 percent to reach the aim of the WFD. The above results suggests that a common quota system could be used as an instrument for the required future reduction in the Danish nitrogen leaching, since this reduction can be achieved with less welfare losses, due to the dynamic effects of reallocation of nitrogen between sectors.

Keywords : Applied General Equilibrium model (GE), WFD, Sector economic costs, Agriculture

JEL classification : C68, Q25, Q28, Q52.

1. Background and previous research

[Current policies internationally and in Denmark, can we argue that the paper if of interest to other countries?]

This paper seek to investigate to what extend a common quota system would yield benefit to the economy and specifically to what extend such a system could reduce cost associated with the future requirement for reduced nitrogen loss to meet the goals required by the WFD.

The paper proceeds with shadow price calculation in the next section, while section 3 describes the applied model and specifically the development needed to simulate a quota system. In section 4 we describe the scenarios applied while results from the simulations are covered in section 5. In section 6 we round of the paper with a discussion of our findings.

2. Shadow price calculation

2. The applied CGE model and added code for common quota trading

The applied model is based on the generic CGE model by Horridge (2003) a descendant of the original ORANI model of the Australian Economy by Dixon et.al. (1982). Orani-G is very detailed described in Horidge (2003) therefor we will limit the description of the core model to a summary including a details of the specific implementation for the Danish version. The specific Danish implementations covers details in regard to agriculture where we seek to include a range of agricultural products, specific treatment of inputs used to treat the land, and assumptions in regard to allocation of land among agricultural sectors.

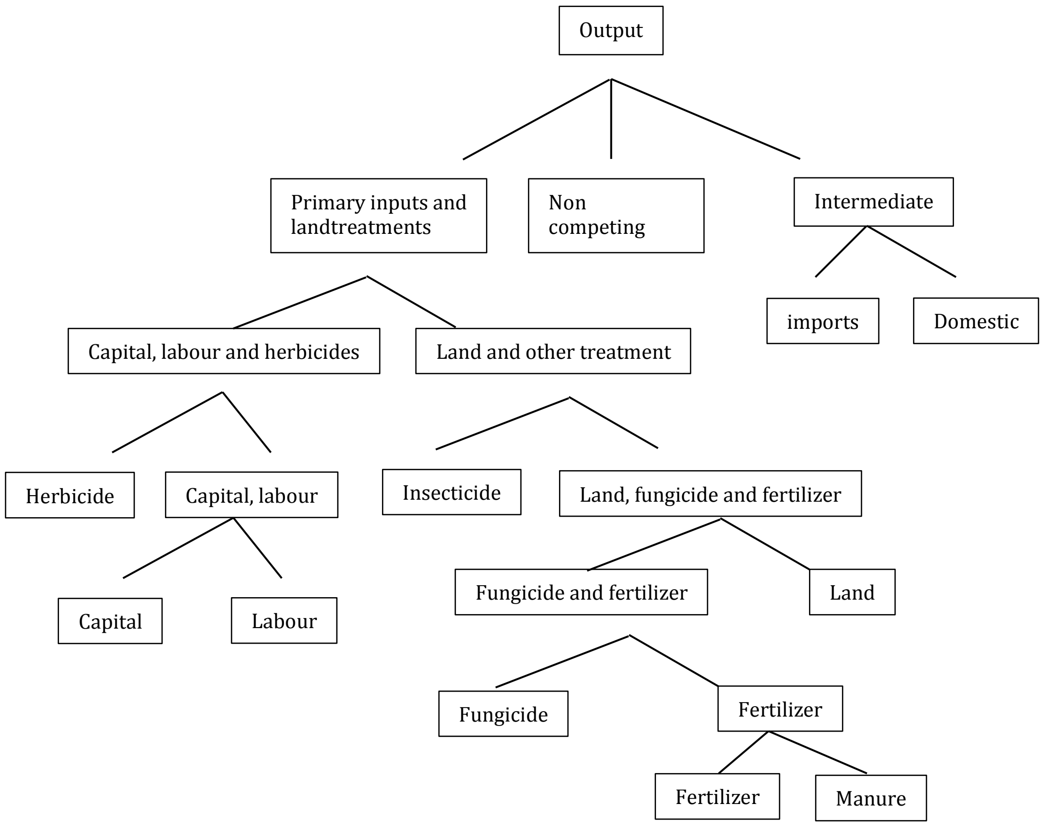
The model is, in principle, a complete model of the Danish economy and consists of five types of agents, namely: industries; capital creators; households; governments and foreigners. The current database of the model identifies 132 industries producing 136 commodities. For each industry there is an associated capital creator. The capital creators each produce units of capital that are specific to the associated industry. There is a single representative household and a single government sector. Finally, there are foreigners, whose behaviour is summarised by export demand functions for Danish products, and by supply functions for imports to Denmark.

The model determines supplies and demands of commodities through the optimising behaviour of agents in competitive markets. Optimising behaviour also determines industries’ demands for labour and capital. The assumption of competitive markets implies equality between the producer price and the marginal cost in each industry. Demand is assumed to equal supply in all commodity markets. The government intervenes in markets by imposing sales taxes on commodities. This places wedges between the prices paid by purchasers and prices received by the producers. The model recognises margin commodities (e.g. retail and wholesale trade) that are required for each market transaction. The costs of the margins are included in purchasers' prices.

The model recognises two broad categories of inputs: intermediate inputs and primary factors. Firms in each industry are assumed to choose the mix of inputs, which minimises the costs of production for their level of output. They are constrained in their choice of inputs by nested production technologies (see Figure 1).

For the land-using industries the model has a very detailed nesting structure. Apart from primary factors, the model specifies substitution possibilities for a range of environmental harmful input, highlighting the agricultural focus of the model. For non-land using industries substitution is allowed between capital and labour and aggregate intermediate inputs.

Figure 1. Nesting structure



The representative household buys bundles of goods to maximise a utility function subject to a household expenditure constraint. Bundles are combinations of imported and domestic goods.

Capital creators for each industry combine inputs to form units of capital. In choosing these inputs they minimise costs, subject to technologies similar to that used for current production; the only difference being that they do not use primary factors. The use of primary factors in capital creation is recognised through inputs of the construction commodity.

The government demands commodities. In the model, there are several ways of handling these demands, including: (i) endogenously, by a rule such as moving government expenditures with household consumption expenditure or with domestic absorption; (ii) endogenously, as an instrument which varies to accommodate an exogenously determined target such as a required level of government deficit; and (iii) exogenously. For this analysis we chose to fix government consumption exogenously.

Two categories of exports are defined: traditional, which are the main exported commodities; and non-traditional. Traditional export commodities face individual downward-sloping foreign demand curves. The commodity composition of aggregate non-traditional exports is treated as a Leontief aggregate. Total demand is related to the average price via a single downward-sloping foreign demand curve.

For all industries, the model includes the standard Armington specification for imported and domestically produced inputs. This assumes that users of a given commodity regard the domestic and the imported varieties of this commodity as imperfect substitutes. The Armington assumption is also used in input demands for industry investment and in household demands for consumption.

The model is closed with a long run focus. We assume that the capital stock in each industry will adjust to restore pre- simulation gross rates of return, defined as the investment prices index divided by an index of capital rental. In effect, the long run capital rental is determined by the investment price index. In the labour market we assume that aggregate employment remains unchanged in the long run, through adjustment in the wages. Investment is determined through fixed investment to capital ratios. Finally we assume an overall budget constraint through fixed balance of trade as a share of GDP, in effect determines real household consumption.

The flows database consists of an agricultural disaggregated input-output table (IO table) for the year 2008. In the official IO table from Statistic Denmark, agriculture is specified in one sector alone. For the purpose of simulation detailed agricultural specific policy analysis, the agricultural sector in the official IO table has been disaggregated into several sectors as well as on the input side the table describes the use of fertilizers, pesticides and land. The disaggregation is based on the detailed supply and use tables (SUT) for more than 2.300 commodities, using Statistic of Agricultural activities 2010, Statistics Denmark (2010), Account Statistics for Agriculture 2010, Statistics Denmark (2010) and Agricultural Statistic 2010, Statistics Denmark (2009). Using the agricultural statistics, input and output to/from the agricultural sector can be disaggregated into several sub-sectors. The disaggregated SUT then forms the basis for compiling the disaggregated IO table following the normal procedures used by Statistics Denmark. A detailed description of the disaggregation procedure can be found for an earlier year in Jacobsen (1998).

The model is a system of non-linear equations. It is solved using GEMPACK, a suite of programs for implementing and solving economic models. A linear, differential version of the model equation system is specified in syntax similar to ordinary algebra. GEMPACK then solves the system of non-linear equations as an Initial Value problem, using a standard method, such as Euler or midpoint. For details of the algorithms available in GEMPACK, see Harrison and Pearson (1996).

ADAPTATION OF THE MODEL FOR THE CURRENT ANALYSIS

It is necessary to expand the AAGE model, as it only covers the production of goods using inputs of goods and primary factors (capital, labor and land). The model is extended with

• Functions linking sectoral nitrogen loss as a function of the input that causes the loss

• Calculation of agriculture and aquaculture quota returns by the current regulation

• Possibility of implementing a common quota system where the model ensures that the shadow price of nitrogen loss is the same in agriculture and aquaculture

• Conversion of quota returns for the taxation of the input causing nitrogen loss. This ensures the correct behavior changes among producers

The relationship between the input causing nitrogen loss in agriculture and the actual loss can be written as

$$e_i^{agg} = a^{agg} * l_i^{agg} * n_i^{agg} \qquad (0.0)$$

Where e is the loss in kg. from the agricultural sector i. a is a coefficient describing the leaching per. applied amount of fertilizer while l is the area and n describes applied fertilizer per. ha. Total agricultural nitrogen losses can be calculated as

$$e^{agg} = \sum_i e_i^{agg} \qquad (0.0)$$

For aquaculture, the nitrogen loss is described by

$$e^{ak} = a^{ak} * f^{ak} \qquad (0.0)$$

Where f is the input of feed in kg. The total nitrogen loss is the sum of the loss in aquaculture and agriculture

$$e = e^{agg} + e^{ak} \qquad (0.0)$$

Technically implemented quotas on nitrogen losses by introducing a tax (tq) of the loss corresponding to the shadow prices of nitrogen loss in individual sectors. It is assumed here that the shadow price is the same for each agricultural sector. The total quota returns (rq) can thus be described by

$$rq^{ak} = tq^{ak} * e^{ak} \qquad (0.0)$$

$$rq_i^{agg} = tq^{agg} * e_i^{agg} \qquad (0.0)$$

Then, two equations are added which ensure that the model can be described with a quota system for agriculture and aquaculture respectively and partly by a common quota system covering both agriculture and aquaculture.

$$tq^{ak} = ftq^{ak} + ftqtot \tag{0.0}$$

$$tq^{agg} = ftq^{agg} + ftqtot \tag{0.0}$$

Since land (l), fertilizer (n) and feed (f) usage are already in the exsisting model we need to exogenize three of the new variable when 1.1-1.8 has been introduced. In describing the current structure of agriculture and aquaculture we exogenise the level of emissions (e^{agg} and e^{ak}) for agriculture and aquaculture as well as ftqtot, whereas the model calculates changes in shadow prices / taxes on nitrogen loss ftq^{agg} and ftq^{ak}, thus the tq variables will be determined by the ftq variables. In effect we have implemented two independent quota systems, one for agriculture and one for aquaculture.

Et fælles kvotesystem kan simuleres ved, at ændre på sammensætningen af hvilke variable der bestemmes i modellen. Hvis (e^{agg} og e^{ak}) ikke fastholdes, men i stedet bestemmes af modellen, er det nødvendigt at sætte to andre variable fast. Sættes nu ftq^{agg} og ftq^{ak} fast (bestemt uden for modellen) er det muligt at fjerne de 2 kvotesystemer ved, at ændre værdierne af skyggepriserne ftq^{agg} og ftq^{ak} til 0. Foretages nu den yderligere ændring, at det samlede kvælstoftab e fastholdes mens ftqtot bestemmes inden for modellen, vil modellen bestemme en fælles skyggepris for både landbrug og akvakultur genne (1.7) og (1.8).

A common quota system can be simulated by changing the composition of which variables are determined in the model. If we specify (e^{agg} and e^{ak}) as endogenous, it is necessary to exogenise two other variables. If instead we exogenise ftq^{agg} and ftq^{ak}, it is possible to remove the two individual quota systems by shocking the values of ftq^{agg} and ftq^{ak} to zero. Furthermore if we exogenise the total nitrogen loos (e) instead of ftqtot, the model determine a common shadow price for both agriculture and aquaculture through (1.7) and (1.8).

To ensure that changes in quotas and shadow prices affect producers' behavior, the quota return has to be integrated into the existing production structure. This is done by transforming the quota return to taxation of the inputs causes nitrogen loss (feed and fertilizer). The model's existing taxation of goods input is described as ad valorem tax rates, while the above is described as shadow prices / taxes per kg. lost nitrogen (unit taxes). To incorporate quota return into the existing tax structure the quota return are converted to ad valorem equivalent tax rates (ta) on input by calculating the total quota returns relative to the value of each input at basic prices (vi).

$$ta = rq / vi \tag{0.0}$$

The total tax rate t, on the input causing the losses, is now calculated as the sum of the existing tax rates tea and the recalculated ad valorem tax rate of nitrogen loss ta

$$t = te + ta \qquad (0.0)$$

A strengthening of the quota in e.g. aquaculture in (1.2) will now lead to an increase in the shadow price / tax per. kg. loss through (1.7) and thus an increase in the return of (1.5) resulting in an increase in the input price of feed through (1.9) and (1.10). This increase will ensure that the producer will change the input of feed such that, the now lower quota is met.

Inputdata

The model is calibrated initially with information about the current nitrogen loss and the current quota returns. Quota return is calculated based on the losses and current shadow prices per. kg nitrogen loss in agriculture and aquaculture respectively (section x.x). Shadow Prices and the differences in these are central to the results predicted by the model and thus govern the extent of the changes in agriculture and aquaculture productions.

For agriculture, it is assumed in an average N loss of 21.65 kg. per. ha. (KILDE) The loss is divided into agricultural sectors by the number of hectares and input of fertilizers and manure. For aquaculture the starting point in a total loss of 999 tonnes (KILDE) which is then broken down by the input of feed. Feed input mainly provided by other food manufacturing and fishing industry but also from the three slaughterhouse sectors cf. Table 1

Tabel 1. Nitrogen loss, tonnes N.

	Cereal	Oilseed	Seed for sowing	Potatoes	Sugar beet	Roughage	Horticulture	Aquaculture	Total
Cattle meat	0	0	0	0	0	0	0	8	8
Pig meat	0	0	0	0	0	0	0	52	52
Poultry meat	0	0	0	0	0	0	0	5	5
Fish industry	0	0	0	0	0	0	0	135	135
Other food manufac.	0	0	0	0	0	0	0	800	800
Chemical industry	10890	1427	1225	763	503	4253	593	0	19654
Manure	11160	1453	1258	772	514	4396	593	0	20146
Total	22050	2880	2484	1535	1017	8649	1186	1000	40800

The calculated quota returns for aquaculture is based on a shadow price of 10.6 € per. kg. lost N, while agricultural quota rent is based on a shadow price of 5.2 € per. kg. lost N. cf. (section X). With these shadow prices and information about nitrogen losses in Table 1, the total quota returns allocated to sectors and the input causing nitrogen loss in table X.

Table X Quota return, mill. €.

	Cereal	Oilseed	Seed for sowing	Potatoes	Sugar beet	Roughage	Horticulture	Aquaculture	Total
Cattle meat	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1
Pig meat	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,6
Poultry meat	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1
Fish industry	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4	1,4
Other food manufac.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	8,5	8,5
Chemical industry	56,9	7,5	6,4	4,0	2,6	22,2	3,5	0,0	103,1
Manure	58,3	7,6	6,6	4,0	2,7	23,0	2,7	0,0	105,0
Total	115,3	15,1	13,0	8,0	5,3	45,2	6,2	10,6	218,7

3. Formulation of scenarios

1. Replacement of the current regulation with a common quota system (ITQ)
2. ITQ combined with reduction of aggregate N loss (ITQ reduced quota)
3. Common N quota system with changed factor productivity in aquaculture (ITQ and productivity)
4. As 3 with reduction of N loss as in scenario 2 (ITQ reduced quota and productivity)

5. Current regulation with agricultural N loss reduction (Agg reduced)

Although new plant types with recycling effectively remove nitrogen from wastewater and thus allows for a higher feed quota and production for the same discharge, it has in practice been particularly difficult for interested manufacturers to obtain the permits required and feed quotas. With a common quota system for agriculture and aquaculture regulation beyond the quota system and control would be redundant. This means that it is likely that growth in aquaculture will consist of the newer types of systems (Model Type 3) as they have a higher efficiency. Based on Accounts Statistics for aquaculture is possible to calculate the relative difference in inputs of capital and labour between the most efficient plants and an average of the current structure of the aquaculture sector cf. Table x. Using depreciation as a proxy for capital input we first calculate input of wages and capital per kg. fish produced and then then relatives percentages changes. The model type 3 production system uses capital at a level 6.88 percent above the current average structure of the sector as a whole, whereas the labour input is much lower (37.7%). In the scenario we implement the common quota system and apply shock to capital and labour according to table X. The initial effect of the productivity shock would reduce unitcost by 2.8 percent (capital and labour share are 21.3 and 11.4 percent respectively).

Table x. Comparison between average of all types and most efficient, average 2009-12

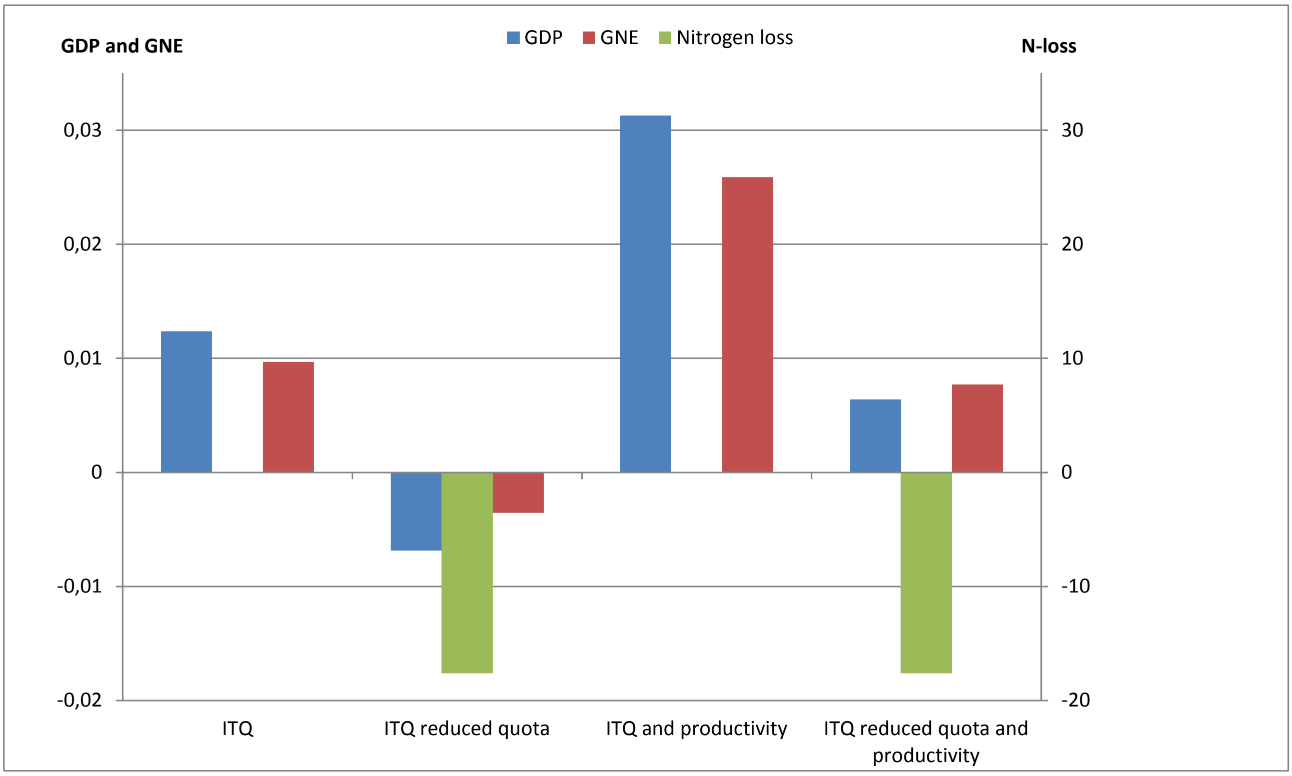
	Model type 3	Average of all types	Relative difference
Production, tonnes	6890	28834	
Depreciation, 1.000 DKK	9237	36168	
Wages, 1.000 DKK	12650	84989	
Depreciation per kg.	1,34	1,25	6,88
Wages, per kg	1,84	2,95	-37,71

Source; Accounts Statistics for aquaculture, Statistic Denmark

HVAD MED SHOCK TIL UDLEDNINGEN??????

4. Results

	ITQ		ITQ reduced quota		ITQ and productivity		ITQ reduced quota and productivity	
	Percent	Mill. €	Percent	Mill. €	Percent	Mill. €	Percent	Mill. €
Real GDP	0,012	32,35	-0,007	-17,91	0,031	81,80	0,006	16,71
Real import	0,067	42,35	-0,105	-66,03	0,138	86,78	-0,058	-36,49
Real export	0,054	52,70	-0,078	-75,93	0,113	109,87	-0,038	-37,30
Real GNE	0,010	21,98	-0,004	-8,03	0,026	58,74	0,008	17,51
Real private consumption	0,004	4,54	0,024	26,97	0,020	22,44	0,036	40,63
Real public consumption	0,000	0,00	0,000	0,00	0,000	0,00	0,000	0,00
Real investment	0,040	17,45	-0,080	-35,01	0,083	36,29	-0,053	-23,12
CPI	0,019		-0,051		0,034		-0,042	
Real wage	0,018		-0,079		0,031		-0,072	
wages	0,037		-0,129		0,066		-0,114	
Capital rent	0,002		-0,061		0,004		-0,067	
Land rent	-3,283		-32,387		-7,580		-35,818	
Export prices	0,001		-0,015		0,000		-0,017	



Sectoral effects

In table X the effect on production in each scenario is shown as an aggregation of the models 132 industries. Not surprisingly, the larger effects are seen for agriculture and aquaculture and forward linked industries in the food industry, highlighted in bold in the table below.

Table X, Production changes for aggregated sectors, pct.

	ITQ	ITQ reduced quota	ITQ and productivity	ITQ reduced quota and productivity	Agg reduced
Crop	**-0,462**	**-4,630**	**-0,992**	**-5,210**	**-4,753**
Livestock	**-0,137**	**-1,335**	**-0,300**	**-1,519**	**-1,375**
Extraction	*-0,066*	*0,171*	*-0,120*	*0,141*	*0,163*
Aquaculture	**88,268**	**-13,620**	**184,056**	**49,035**	**0,005**
Fishing	0,000	0,000	0,000	0,000	0,000
Food industry	**0,106**	**-0,824**	**0,216**	**-0,806**	**-0,820**
Fish Industry	**1,676**	**-0,252**	**3,114**	**1,039**	**0,051**
Beverage & Tobacco	*-0,027*	*0,082*	*-0,045*	*0,072*	*0,078*
Textile & Leather	*-0,045*	*0,179*	*-0,080*	*0,163*	*0,174*
Wood & Paper	*-0,025*	*0,117*	*-0,040*	*0,112*	*0,114*
Pharma & Plastic	*-0,021*	*0,333*	*-0,030*	*0,334*	*0,332*
Cement & Glass	*-0,021*	*0,109*	*-0,032*	*0,106*	*0,107*
Metal Product	*-0,041*	*0,172*	*-0,072*	*0,158*	*0,167*
Furniture	0,019	0,075	0,052	0,099	0,079
Utility	0,045	-0,028	0,102	0,008	-0,022
Construction	0,018	-0,031	0,044	-0,015	-0,028
Trade	*-0,009*	*0,086*	*-0,006*	*0,092*	*0,086*
Transport	*-0,013*	*0,087*	*-0,019*	*0,086*	*0,086*
Hotel & Rest	0,006	0,032	0,023	0,046	0,033
Business	-0,008	0,042	-0,006	0,045	0,042
Post & Communication	-0,008	0,063	-0,005	0,067	0,063
Finance & Insurance	-0,003	-0,086	0,005	-0,086	-0,087
Public service	0,001	0,005	0,003	0,006	0,005
Education	0,002	0,000	0,006	0,003	0,000
Healthcare	-0,001	0,010	0,000	0,011	0,010
Culture	0,003	0,020	0,012	0,027	0,021

Remark: Aggregated from 132 sectors

[Stigende løn og kapitalleje I ITQ og ITQ productivity som følge af effekt på arbejdsmarkedet]

For the rest of the sectors effect are predominantly a result of effect on unit cost through the labour and capital markets and as **well as effects on real household consumption, by the implicit financial policy implementes to fix the balance of trade, cf. Macroresults tabel.**

[Furnitures 72 til eksport men også 20 pct til invest og household]

[Construction følger Investment pattern]

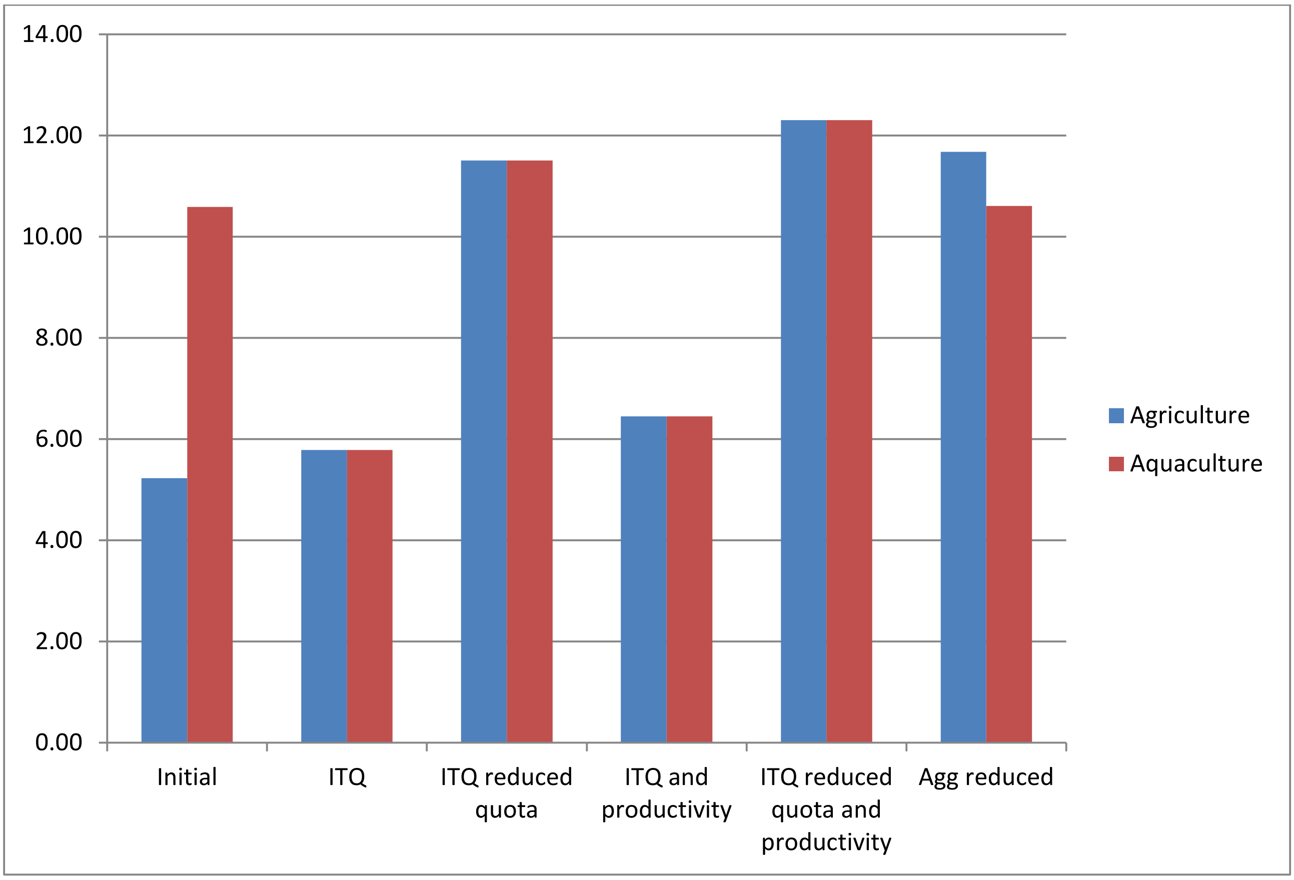
[Trade is an aggregation of wholesale (high shares in export and intermediat] and retail predominantly household consumption. Thus household contribute positively in all scenarios, while there is a negative contribution in ITQ og ITQ productivity from reduced demand from the export intensive industries]

[Aggregate Transport result is dominatred by the the very large Danish see transport sector]

[Post & communication supply the major part to intermediate and the result is dominated by the demand from export intensive industries]

[Healtcare, public service and education has large saleshares to the public consumption which is fixed in real terms thus we expected the smallest effects. Thouse we see is a result of input price changes but also a result of private consumption as house hold is the second largest demander of these services]

Fig X, Shadow price / quota return per kg. N lost, €



Forklaring på hvorfor det samfundsøkonomiske tab er større ved ITQ_red sammenlignet med Agg_red alene. Ved ITQ_red dominerer landbruget i prisfastsættelsen på kvoteafkastet som stiger til et niveau der er større en det initiale i akvakultur hvorfor denne sektor påvirkes i negativ retning større enhedsomkostninger produktionen i akvakultur falder med 13%

5. Discussion

We have ignored the regional aspect of