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SMAM - Salmon Market Analysis Modules

by

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Background of the project

The project group from University of Tromsø, International Research Institute of Stavanger/University of Stavanger and University of Life Sciences, international collaborators and the industrial partner CAPIA AS, applied the Research Council of Norway in 2007 about a KMB project called SMAM – Salmon Market Analysis Modules. The project group was for 2008 given an individual pre-project, financed by the Research Council of Norway (NFR) and the Fishery and Aquaculture Industry Research Fund (FHF). The project had three goals:

1. Provide better documentation the applied methodology in the main project
2. Document how this methodology is used by other commodities and industries, and show how this knowledge is going to be utilised in the main project.
3. Through a workshop or a similar venue, the findings of the pre project should be disseminated to relevant industry partners.

Brief Contents

Demand structure for salmon

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1. INTRODUCTION

Until the mid 1980s, the structure of the demand for seafood received little academic attention. During the last decades, there has been virtually an explosion in the number of studies of the demand structure for seafood markets. This is due to several factors including the expansion of the Exclusive Economic Zone to 200 miles and increased trade with seafood due to improved logistics and the expansion of aquaculture (Anderson, 2002; Asche, Bjørndal and Young, 2002). The most studied species is salmon, as the most successful aquaculture species together with shrimp. The most common approach is demand analysis, where demand equations are estimated either individually or in a system of demand equations. These studies of the demand structure focus on the price sensitivity of demand, on the degree of substitution between potentially competing products and on income/expenditure effects. However, as price information is often more available than quantity, there have been a number of market integration studies that primarily focus on the competition between different products.

The different studies are empirical and are of course in each case conducted on a specific data set. This gives, strictly speaking, information about the demand structure for some specific products or species in a specific market for the time period covered by the data set used. The purpose of this paper is to give a review of demand and market integration studies with respect to salmon, focusing on the method used the information that is obtained, and how this information varies with the approach used. That is, are there any patterns that become apparent when one looks at the results obtained in a number of demand studies of seafood markets? What can we say about the demand for fish in general or about the demand for specific groups of species or markets?

To present results from many different studies creates a number of problems that one should be aware of when comparing the results. In addition to the different markets and species studied, a number of different methods have also been used. Since the methods used affect the interpretation of the results, it is also important to be aware of the potential differences. Moreover, measuring data at different market levels e.g., import or retail has important implications for interpretation of the results.

The different methods used for data measurement at different market levels make the results incomparable in a strict sense. Nevertheless, some comparisons are possible. In particular, one might observe whether the price responsiveness for fish is in a specific range, or whether this varies systematically with species, markets or measurement level for the data.

Some implications of economic theory for the magnitudes of the elasticities are worthwhile to note immediately. A demand elasticity of –1 is a focal point. A good with constant budget share and no substitutes will have an elasticity of –1, so that a 1% increase in the price will lead to a 1% reduction in the quantity demanded and vice versa. In particular for aggregated goods, the budget shares are relatively constant with few substitutes. This indicates that one should expect many demand elasticities to be close to –1. It is also of interest to note that the value of a market is at its highest when the demand elasticity is –1. If the supplied quantity increases above the level that gives a demand elasticity of –1, the value of the market will fall. Finally, the more elastic the demand for the good, the greater substitution possibilities there will be and therefore the keener the competition.

We will of course be limited to the markets that have been studied. This might unfortunately leave some big holes. In particular, few studies have been carried out on the demand for fish in developing countries. Moreover, we cannot hope to cover the substantial number of reports and working papers on the demand for salmon. In section 2 we provide a brief description of the approaches used in estimation. In section 3 we discuss market integration studies and show to what extent demand analysis and market integration provides complementary information. In section 4, we will provide a review of a number of demand studies related to fish. The review will focus on own-price or demand elasticities. We will try to emphasise main trends, and not necessarily to discuss too many specific studies. While we do not give much attention to cross-price effects, these are also obviously important when considering demand structure, and the degree of competition will be commented on briefly. In section 5 we discuss the results form market integration studies before some concluding remarks are provided in section 6.

2. DEMAND ANALYSIS

In this section, the most common functional forms for demand system specification are presented and discussed. We start with single equation specifications, before we review the most common flexible functional forms; the Rotterdam system and the almost ideal demand system (AIDS).

The first empirical demand studies were mostly concerned with estimating elasticities and paid little attention to consumer theory (Deaton and Muellbauer, 1980b, p. 61). The researchers specified (mostly quantity dependent) single equation demand functions linear in the parameters, of which the double log was the most common specification. This specification is still common today. Letting q_{it} be the quantity consumed of good *i* at time *t*, p_{jt} the price of good *j* at time *t* and X_t the expenditure at time *t*, the equation to be estimated with this specification is

(1) $$\ln q_{it} = \alpha_i + \sum_j e_{ij} \ln p_{jt} + e_i \ln X_t$$

The advantage with this specification is that the estimated parameters can be interpreted as elasticities as $e_{ij} = \partial \ln q_{it} / \partial \ln p_{jt}$ (the own and cross price elasticities) and $e_i = \partial \ln q_{it} / \partial \ln X_t$ (the expenditure elasticity). The range of j varies, and typically includes commodities which are assumed to be closely associated with good i. The measure of expenditure X_t is typically a (often highly aggregated) measure of the consumer's income.

Economists had early discovered that dynamics might be important in consumer behaviour. The first explicit attempt to specify demand functions that distinguished between short- and long-run behaviour was, to the author's knowledge, Houthakker and Taylor's (1966) habit formation model. This model is based on the double log and may be written as

(2) $$\ln q_{it} = \alpha_i + c_i \ln q_{it-1} + \sum_j e_{ij} \ln p_{jt} + e_i \ln X_t .$$

The dynamics are introduced in the lagged consumption variable, q_{it-1}, which makes current consumption dependent on the previous period's consumption. The short-run elasticities are e_{ij} and e_i, and the long-run elasticities are found by setting $\ln q_i$ equal at all times, as implied by the notion of long-run equilibrium. The long run elasticities may then be computed from (2) as $\eta_{ij} = e_{ij}(1 - c_i)^{-1}$ and $\eta_i = e_i(1 - c_i)^{-1}$. To be consistent with utility maximisation, the parameter c_i must be between zero and one. This seems to hold in all empirical analyses.

During the 1970s, very dynamic models, mostly motivated by problems with persistent autocorrelation and bad forecasting abilities, appeared in the macro economic literature, particularly in connection with the consumption function. The work of Davidson *et al*. (1978) has left a major impact, not only on macroeconomic work, but on all empirical work in economics based on time series data, including demand analysis. The basic formulation is an autoregressive distributed lag model based on some functional form, usually a functional form linear in the logarithms of the variables. Based on a double log, this may be written as

$$(3) \qquad \ln q_{it} = \alpha_i + \sum_{k=1}^{r} c_{ik} \ln q_{it-k} + \sum_{j} \sum_{l=0}^{s} e_{ijl} \ln p_{jt-l} + \sum_{l=0}^{s} e_{il} \ln X_{t-l} \, .$$

The numbers of lags, *r* and *s*, is an empirical question. They are chosen large enough to account for all dynamics such that the resulting residual in the empirical specification is white noise.

There are both statistical and economic arguments for including lags in a model such as (3). The statistical arguments are founded on the observation that often in time series data there exists dependencies in the data over time. To capture these dependencies, dynamic specifications are necessary. Economic arguments focus on the lagged or dynamic adjustment to changes in economic variables. As instantaneous adjustment implies a static model, the arguments against instantaneous adjustment are also arguments against a static model. The hypothesis of habit formation discussed above is a dynamic model. However, other limitations on the adjustment process such as contractual obligations and imperfect information, which induce adjustment costs, can also invalidate the hypothesis of instantaneous adjustment. These restrictions require more general dynamic specifications than the habit formation model. To model demand when these features are present, a general dynamic model is necessary. The advantage with (3) is that all linear dynamic structures are included as special cases.

Note that the habit formation model in (2) is a special case of (3) with r=1 and s=0. Each parameter in (3) gives the elasticity of one variable at a particular lag with respect to current consumption. The long-run elasticities are found by summing over all the lags. Hence, the long-run elasticities from (3) are $\eta_{ij} = \sum_l e_{ijl} (1 - \sum_k c_{ik})^{-1}$ and $\eta_i = \sum_l e_{il} (1 - \sum_k c_{ik})^{-1}$. An inconvenience with this model is that the long-run elasticities that are of greatest interest must be computed after estimation. The model in (3) was therefore transformed into an Error Corection Model (ECM);

(4)
$$\begin{aligned}\Delta \ln q_{it} &= \alpha_i + \sum_{k=1}^{r-1} C_{ik} \Delta \ln q_{it-k} + \sum_j \sum_{l=0}^{s-1} E_{ijl} \ln p_{jt-l} + \sum_{l=0}^{s-1} E_{il} \ln X_{t-l} \\ &\quad - \omega(\ln q_{t-r} - \sum_j \eta_{ij} \ln p_{jt-s} - \eta_i \ln X_{t-s})\end{aligned}.$$

The advantage with this specification is that the long-run parameters (elasticities) are directly estimated. The parameter ω is also of interest as it may be interpreted as the adjustment speed towards equilibrium. An inconvenience with this specification is that it is nonlinear, requiring use of the more computationally difficult nonlinear estimation techniques.

Other single equation specifications similar to the double log but without or with only some logarithmic variables have also been used in the literature. These are, for instance, specifications where the data series are linear in their levels, see e.g. DeVoretz and Salvanes (1993). More recently, Box-Cox transformations have been estimated. The advantage with these models is that the functional form decides the right transformation of the variables, and includes the double log and the linear model as limit cases. An empirical example may be found in Bjørndal, Salvanes and Andreassen (1992).

Even if the major body of work on demand function estimation with single equation specifications has used quantity dependent models, there are examples where price is used as the dependent variable. This is especially true in studies of agricultural and fishery commodities (see e.g. Shonkwiler and Taylor, 1984). It must also be noted that the much studied problem of simultaneity in price and quantity has usually been formulated and studied with single equation demand (and supply) functions (Eales and Unnevehr, 1993). This problem has generally been ignored in demand system specifications, as demand has been assumed to be completely price or quantity dependent.

There exist two major problems with single equation models. In general, they are not theoretically consistent. The most common of these specifications, the double log is theoretically consistent only when demand is independent of expenditure, i.e., the consumer's preferences are homothetic (Deaton and Muellbauer, 1980b, p. 17-18). This also violates Engel's law, which claims that the propensity to consume a particular group of goods varies with total expenditure. It should be noted that it is sometimes argued that in the analysis of a single commodity, where the functional form of the other goods in the system remains unspecified, the double log specification may give a satisfactory local approximation, in particular if there is not too much variation in total expenditure. For specifications linear in the variables and using the Box-Cox transformation, it is not possible to be theoretically consistent, possibly with the exception of an approximation point. This might be seen by noting that the demand equation cannot be homogenous of degree zero when using these specifications.

The single equation models specify uncompensated demand equations. The prices of the goods omitted from the specification may then cause problems because any change in either of them causes changes in demand for the commodity in question through changes in expenditure. This problem may be reduced if one specifies a compensated demand function (Stone, 1954a). In empirical work this problem may not be too serious, as the effect is small if the particular good represents a small portion of the budget.

In order to estimate demand functions that are consistent with utility maximisation, the concept of weak separability is used to separate a group of goods from the rest of the consumer's bundle. The demand functions for the goods inside the group are then specified in a system of demand functions where the restrictions associated with consumer theory can be tested or imposed (i.e. adding up, homogeneity, symmetry). These conditions, together with the trivial assumptions of positive prices and consumption, ensure that the demand system is consistent with consumer theory.[1] Most, but not all systems are derived from an explicitly formulated utility, indirect utility or cost function. However, this is not a necessary condition for theoretical consistency. Also, only demand systems are used in empirical work as it is not possible to measure or compare utility. For a discussion of the connection between the functional forms of a utility, indirect utility or cost function and each of the demand systems where this can be explicitly formulated, see Pollak and Wales (1992). We will concentrate on demand systems in the following, where some of the most commonly used demand systems, the Rotterdam system and the almost ideal demand system, will be presented.

The Rotterdam System

In the Rotterdam system of Theil (1965) and Barten (1966; 1967; 1968), the demand equations are in budget share form and satisfy the adding up condition automatically. The symmetry and homogeneity restrictions implied by consumer theory may be expressed as linear functions of the estimated parameters. Consequently, one may either test if the data are in accordance with the consumer theory for this specification, or impose these restrictions on the estimated parameters to ensure theoretical consistency. Note that this, and most other empirical specifications, is an approximation to the underlying demand equations.[2] The results may in all specifications be dependent on the functional form. In particular, a rejection of the hypothesis of symmetry and homogeneity does not necessarily imply that the consumer theory is false. It might just as well be caused by model specification problems, of which choice of functional form is an important part.

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[1] It should be noted that positive consumption is not absolutely necessary, and in some studies using cross section data at a micro level, zero consumption is allowed, see e.g. Heien and Wessells (1988; 1990), Wellman (1992) and Salvanes and DeVoretz (1993).

[2] It is of course possible to postulate that the consumers' preferences actually correspond to the demand equations from a particular functional form.

Another improvement with the Rotterdam system compared to the linear expenditure system is that it allows for free estimation of price effects and this includes complements and inferior goods without losing theoretical consistency. Each equation in the Rotterdam system may be written as

(5) $$w_{it} d \ln q_{it} = b_i d \ln \bar{x}_t + \sum_j c_{ij} d \ln p_{jt},$$

where $w_{it} = \dfrac{p_{it} q_i}{x}$

$$d \ln \bar{x}_t = d \ln x_t - \sum_j w_{jt} d \ln p_{jt} = \sum_j w_{jt} d \ln q_{jt}$$

$$b_i = w_{it} e_i = p_{it} \frac{\partial q_{it}}{\partial x_t}$$

$$c_{ij} = w_{it} e_{ij}^* = \frac{p_{it} p_{jt} s_{ij}}{x_t}$$

Remember that e_i is the expenditure elasticity for good *i*. We also have that e_{ij}^* is the compensated cross-price elasticity, which is related to the uncompensated and expenditure elasticities by Slutsky's equation on elasticity form, $e_{ij} = e_{ij}^* - e_i w_j$. The continuous difference operators *d*, in applied work, are replaced by their discrete approximation Δ.

The adding up restrictions imply that

(6) $$\sum_i b_i = 1, \quad \sum_i c_{ij} = 0.$$

These restrictions are automatically satisfied when the budget shares in the data set add to unity. However this restriction makes the covariance matrix singular. One must therefore delete one equation from the demand system before estimation. With correct estimation technique and an $iid(0, I \otimes \Sigma)$ error term, the system is invariant to which equation is deleted (Barten, 1969), and the adding up restrictions from (6) are used to retrieve the parameters in the deleted equation. This is also a feature the Rotterdam system has in common with all the other systems of demand equations formulated in their budget share equations. The symmetry and homogeneity restrictions may be expressed as functions of the parameters in the Rotterdam system. They may be written as:

$$\text{Symmetry:} \quad c_{ij} = c_{ji}.$$
$$(7) \qquad \text{Homogeneity:} \quad \sum_j c_{ij} = 0.$$

As mentioned above, the restrictions may be used to test whether the data support a theoretically consistent specification of the Rotterdam system. They may also be imposed to ensure that the estimated system is theoretically consistent.

The Rotterdam system is common in the literature, and this work has been extended to an inverse demand approach (Barten and Bettendorf, 1989). The Rotterdam system differs from most other functional forms in that the underlying utility or cost functions have never been explicitly formulated, and that differential demand functions are used instead of functions formulated in the levels of the variables.

The Almost Ideal Demand System

The most common functional form in demand system specification since the early 1980s has been the almost ideal demand system (AIDS) of Deaton and Muellbauer (1980a). As with the Rotterdam and translog systems, the almost ideal demand system is formulated in terms of the budget shares, and each demand equation can be written as

(8) $$w_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i \ln\left(\frac{X_t}{P_t}\right),$$

where

$$\ln P_t = \alpha_0 + \sum_i \alpha_i \ln p_{it} + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_{it} \ln p_{jt} .$$

The almost ideal demand system is linear except for the translog price index $\ln P_t$. This problem has traditionally been circumvented in most applied work as suggested by Deaton and Muellbauer, by using a Stone price index, i.e., $\ln P_t^* = \sum_i w_{it} \ln p_{it}$, which makes the system linear. Recently the use of the Stone price index has been shown to be inappropriate as it causes the estimated parameters to be inconsistent (Pashardes, 1993; Buse, 1994; Moschini, 1995). Moschini attributes this problem to the fact that the Stone price index does not satisfy what Diewert calls the commensurability property, and suggests that the problem may be solved by using a price index that satisfies this property.[3] Moschini suggests several other price indices that satisfy this property and may be used to keep a linear specification of the almost ideal demand system. He also shows that these indices perform as well as the translog index in a Monte Carlo experiment.

The restrictions to ensure theoretical consistency for the almost ideal demand system are:

[3] The commensurability property means that a price index should be invariant to the unit of measurement for the prices.

Adding up: $\sum_i \alpha_i = 1, \quad \sum_i \gamma_{ij} = 0.$

(9) Symmetry: $\gamma_{ij} = \gamma_{ji}.$

Homogeneity: $\sum_j \gamma_{ij} = 0.$

The almost ideal demand system is parallel to the Rotterdam and translog systems in that the adding up restrictions are automatically imposed and one equation must be deleted before estimation to avoid a singular covariance matrix. The symmetry and homogeneity restrictions may be tested or imposed. There exist no clear criteria for choosing among the almost ideal demand system and the other two systems, and which functional form will perform best depends on the true structure in the underlying data. The almost ideal demand system has the advantage that it is linear and formulated in levels. It may accordingly be encountered as more intuitive and easier to use than the Rotterdam systems. In common with the Rotterdam system, the almost ideal demand system also has an inverse demand representation (Eales and Unnevehr, 1993).

3. MARKET INTEGRATION

While measuring the degree of substitution is the preferred way of determining to what extent commodities compete, the development or changes in prices overtime provides valuable information on the relationship among commodities. The importance of prices in defining markets was recognized early on by economists. In 1838 Cournot defined a market in the following way:

> *"It is evident that an article capable of transportation must flow from the market where its value is less to the market where its value is greater, until*

difference in value, from one market to the other, represents no more than the cost of transportation" (Cournot, 1971)

Similar definitions have been provided by a number of prominent economists like Marshall (1947), Cassell (1918) and Stigler (1969). Stigler maintains the spirit of Cournot in defining a market as "the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs". While Cournot and Stigler focus on geographical space the concept also applies to product space, where quality differences take the place of transportation costs (Stigler and Sherwin, 1985).

To motivate the Law of One Price (LOP) and price-founded definitions of a market, Figure 1 sketches the equilibrium for two markets. For expository purposes prices in both markets are initially normalized at P. Assume then that there is a supply shock in Market 1 that shifts the supply schedule to S1', giving p' and q1' as new price and quantity. This causes the price to decrease while the quantity increases. What happens in Market 2 depends on the degree of substitution between the two commodities.[4] If there is no substitution possibilities between the two markets/commodities there will be no change in price and quantity in Market 2. If the goods are perfect substitutes, the demand schedule in Market 2 is shifted down to D2' as consumers substitute commodity 1 for commodity 2, and the fall in price is just enough to equilibrate prices in both markets at $P^{'}$. (This is the Law of One Price.) If the goods are imperfect substitutes, the demand schedule in Market 2 is shifted down somewhat, say to D2'' but not enough to equate prices in the two markets.

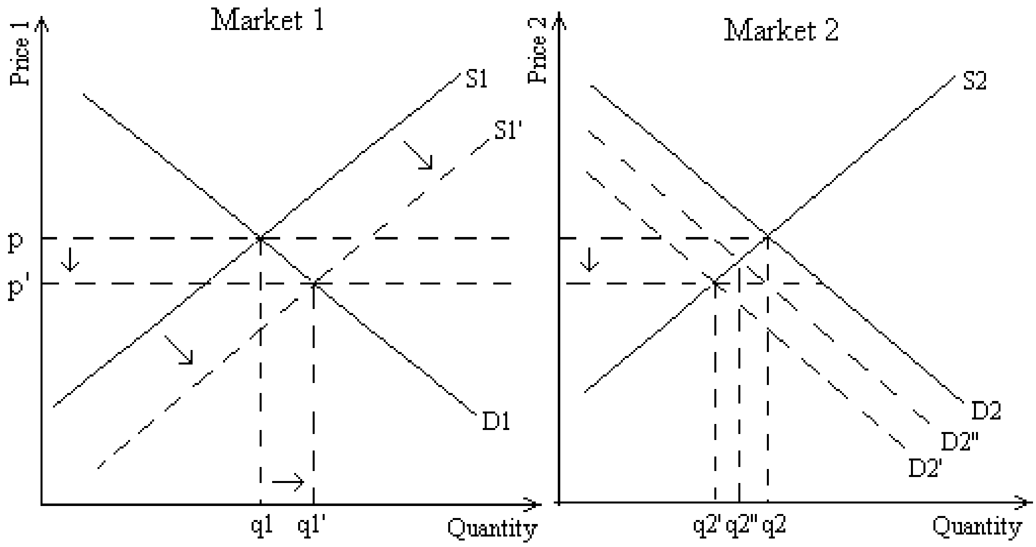

Figure 1. Potential Market Interaction Between Two Markets

As mentioned above, the strength of the influence of the shock in Market 1 on Market 2 is normally measured by the cross price elasticities which provide a measure of the shift in the demand schedule.[5] However, one can also look at the effect of the supply shock only from the price space. The price change in Market 1 can impact price in the other market in a number of ways. If there is no substitution effect, the demand schedule does not shift and there is no movement in price in Market 2. If there is a substitution effect the demand schedule in Market 2 shifts down, and the price in this market shifts in the same direction as the price in Market 1. At most the price in Market 2 can shift by the same percentage as the price in Market 1, (i.e., the Law of One Price holds) and relative prices are constant. Hence, with respect to structural

[4] For completeness one should also mention that if the demand schedule in Market 2 shifts upwards, the two goods are complements.
[5] The same story can be told based on a demand shock, but where it is the producers that potentially adjust their supply.

information about a market, analysis of relationships between prices can provide us with information of

1) whether the two markets (goods) do not compete,
2) whether they are imperfect substitutes,
3) whether they are perfect substitutes so that the relative price is constant.

This is then the basis for the hypotheses we want to test when investigating relationships between prices.[6]

Several studies have pointed out that the adjustment towards a new equilibrium can be delayed by adjustment costs (Ravallion, 1986; Slade, 1986; Goodwin, Grennes and Wohlgenant, 1990). This can be modelled when investigating relationships between prices by specifying a dynamic model. With a dynamic model one can also investigate whether the adjustment process is bi- or unidirectional. If causality goes only in one direction, this can be interpreted as price leadership for the price that does not adjust. This can be the case if there is one central market that affects the price in smaller regional markets.[7]

It is common in studies of market integration to perform the analysis on the logarithms of prices, and we will proceed using this transformation. Given time series on two prices, say, p_t^1 and p_t^2, the simplest specification to test for market integration is

(10) $$p_t^1 = a + bp_t^2 + e_t$$

[6] A negative relationship between the prices implies complements

[7] In product space, the quality of one commodity is the reference quality.

A null hypothesis that b = 0 is a test that no substitution possibilities exist. A null hypothesis that b=1 is a test for constant relative prices and the LOP.[8] The constant term a is the logarithm of a proportionality coefficient, and is zero if the prices are identical with exception of the arbitrary deviations caused by the error term. A nonzero constant term is in most cases interpreted as transportation costs or quality differences, which then are assumed to be constant.[9] Economic theory gives little guidance as to the choice of dependent variable, and the test is therefore often repeated by interchanging price variables in Equation (10).[10]

In the early 1980s, several authors argued that adjustment could be costly and therefore take time. To account for this, models were introduced with variable specifications that could distinguish between short- and long run effects. Slade (1986) used a simple model to account for dynamic adjustment to market integration.[11] This test is performed by first running the regression[12]

$$(11) \qquad p_t^1 = a + \sum_{j=1}^{m} b_j p_{t-j}^1 + \sum_{i=0}^{n} c_i p_{t-i}^2 + e_t$$

The lag structure on prices is chosen so that e_t is white noise. The data support a hypothesis that there is a relationship, or in statistical terms that p_t^2 causes p_t^1, if a

[8] See the analysis of Isard (1977) and Richardson (1978).
[9] Some authors argue that the assumption of constant transportation cost is to restrictive, and can at times cause tests to show less market integration then what there actually is. For instance, Goodwin, Grennes and Wohlgenant (1990) show closer market integration when transportation costs are explicitly modelled.
[10] This also gives rise to a simultaneity problem that often is acknowledged, but otherwise ignored. A good discussion can be found in Goodwin, Grennes and Wohlgenant (1990).
[11] Slade's (1986) analysis is an extension of Horowitz (1981), but Horowitz assumes more restrictive dynamics.

joint test that all c_i parameters are zero is rejected.[13] Interchanging price variables in Equation (11), allows a test of the null hypothesis that p_t^1 causes p_t^2. In this dynamic specification, test results based on different dependent variables have an economic interpretation. If one price causes the other while the opposite causality does not hold, this is evidence of price leadership. If causality is not observed in any of the equations, this is evidence that the goods are not in the same market. A test for a long run LOP relationship corresponds to a test that the restriction $\sum b_j + \sum c_i = 1$ holds.[14] What is more, if the restrictions $c_o = 1, \; c_i = 0$ and $b_j = 0, \; \forall ij > 0$ cannot be rejected, this is evidence that the LOP holds in a static sense, and hence Equation (11) nests Equation (10).

In the 1980s economists became increasingly aware that most economic time series are nonstationary. This means that normal statistical inference is not valid for linear regressions on nonstationary data and casts doubt on the reliability of early results obtained using the approach described above. In general, for nonstationary data there will be no linear long-run relationship. However, it the data series in question have common stochastic trends, the linear combination of two nonstationary data series can be stationary and the data series are said to be cointegrated (Engle and Granger, 1987).

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[12] In some cases, exogenous variables that represent common trends for the prices are also included.

[13] This is in econometric terms a test for Granger noncausality (Granger, 1969).

[14] Ravallion (1986) discusses in more detail the interpretation of different restrictions on the dynamic process.

There are two common approaches to testing for cointegration; the Engle and Granger (Engle and Granger, 1987) test and the Johansen test (Johansen, 1988; 1991). The Engle and Granger test for cointegration is a straightforward regression procedure. However, there are two problems with this test. First, it is subject to the same normalization problem in setting the dependent variable as with stationary data. Second, and more seriously, is that normal statistical inference and tests for the LOP are not valid, although cointegration tests for a (substitution) relationship between two commodities are possible. These problems are avoided when the Johansen approach is used.

3. DEMAND ELASTICITIES FOR SALMON

In this section we will review demand studies related to salmon published in international journals over the last decades. We will focus on classical demand studies in the sense that a demand schedule must be estimated. There are also a number of studies obtaining market information from surveys, which at times will also give elasticity estimates. However, this type of study is mostly concerned with marketing issues, valuation issues, or seafood safety issues etc., and not relevant when one is interested in price-quantity relationships. An excellent review of this literature through the early 1990s can be found in Wessells and Anderson (1992). Another strand of literature which might be of interest is studies where fish/salmon is one aggregated good in a more general demand system that includes other foods and at times also other goods. Unfortunately, the focus is often on aspects other than demand elasticities in this kind of study, and we will therefore not pay too much attention to them. However, we do include studies where the seafood demand or the relationship between seafood and other goods are an important part of the paper (e.g. Salvanes and DeVoretz (1997) or Johnson, Durham and Wessells, 1998).

We will report the results from the studies considered here in a table (Table 1) that reports the product studied, own-price elasticity (flexibility), the study, the type of data used, the region studied and whether a price dependent or quantity dependent model was used. These results will also be discussed and compared. The degree of substitution will receive less attention. However, one should be aware that in general, there are more substitutes for products with own-price elasticities of a higher magnitude.

When looking at the demand elasticities in Table 1 it is clear that there is substantial variation. However, two things become clear immediately. For most species, product groups and product forms, demand is elastic. In many cases the demand is also highly elastic. Demand for all categories are also found to be elastic in Guillotreau, Peredy and Bernard (1998); the study that uses the most aggregate data. However, the magnitudes also seem to vary systematically with model specification and measurement level for the data. This issue is addressed also by Schrank and Roy (1991).

There is a tendency that demand is less elastic the closer one comes to the consumer in that retail demand seems to be least elastic while ex. vessel demand seems to be most elastic. However, this picture might also have other causes in that price dependent model specifications are more common the further the data is removed from the retail level. Also, in most specifications using data at the retail level and quite a few at the trade level, system specifications are used. This is uncommon with ex. vessel data as single equation specifications seem to be preferred. There is also a tendency that demand becomes less elastic the more recent the study. This might be caused by a move down along the demand schedule, but again specification issues might be important factors. There is a tendency that more recent studies use quantity dependent specifications and demand systems. Both these factors seem to push in the direction of making demand less elastic.

If one looks at the studies where retail level data is used in ordinary demand systems (Wessells and Wilen, 1993; 1994; DeVoretz and Salvanes, 1997; Eales, Durham and Wessells, 1997; Johnson, Durham and Wessells, 1998), we see that the demand elasticities tend to vary around –1, with an average quite close to –1. There are certainly deviations from –1, and as expected, there is a tendency that more valuable fish have more elastic demand. However, it should also be noted that the aggregation level for the data used in these studies is relatively high, and therefore this would tend to make demand less elastic. This is because the substitution possibilities are likely to be larger between similar disaggregated products than more dissimilar highly aggregated products.

The first studies focusing on the demand for salmon were carried out in Canada and the US, with focus on wild Pacific salmon and the potential competition from salmon aquaculture (DeVoretz, 1982; Kabir and Ridler, 1984; Anderson and Wilen, 1986; Bird, 1986). With the exception of Bird (1986), all these studies indicate that the demand elasticity for salmon is highly elastic. However, it is worthwhile to note that DeVoretz found that the demand for canned salmon is substantially less elastic than the demand for fresh/frozen salmon.

Hermann and Lin (1988) estimate the demand for Norwegian farmed salmon, and with the exception of the studies that target the Japanese market, the demand for farmed salmon is the main focus of most of the studies from the 1990s. We will here not say anything about the results in Hermann, Mittelhammer and Lin (1992) and Asche (1997), as these two studies focus respectively on seasonality and dynamics. Given the large number of studies of different markets with different methods, it is as expected that the elasticity estimates differ substantially. However, Asche (1996) noted that a general trend seems to be that demand for salmon is getting less elastic. This is also as expected given that the total supply of salmon (both wild and farmed) has increased threefold from the early 1980s, and that this has led to shift down along the demand schedule. Bjørndal, Salvanes and Andreassen (1992) also indicate that generic marketing has led to an outward shift in demand. The reported elasticities are averages for data sets covering most of the 1980s and parts of the 1990s, and that total value of the salmon market has remained fairly constant over the last decade. It seems reasonable to assume that the demand elasticity for salmon is quite close to –1 at the present time. However, the elasticity does vary by product form and species, and demand for frozen Pacific salmon seems to be inelastic (Hermann, Mittelhammer and Lin, 1993; Asche, Bjørndal and Salvanes, 1998). Xie, Kinnucan and Myrland (2008) report price flexibilities for aggregate export demand from Chile, Norway, UK and other producers. Although the flexibilities differ, they are all inelastic, indicating elastic demand.

Catfish is the only other species where the aquaculture production has increased substantially over a period where the demand has been investigated to any extent. Since catfish was a low-value species to start with, its elasticity of demand was not too elastic. However, despite successful generic advertising, Kinnucan and Miao (1999) note that the elasticity has become less elastic with the increased supply, indicating a shift down along the demand schedule.

In several studies, different product forms are also studied. It seems hard to generalize the results, with the exception that demand for canned products are more inelastic than demand for other product forms. It also seems like the fresh product form tends be the most elastic. One would also expect that demand for frozen blocks was more inelastic than for frozen fillets, but this does not seem to be the case.

DeVoretz and Salvanes (1997) and Johnston, Durham and Wessells (1998) also address the issue of competition between meat products and seafood products. Estimating systems which contain both types of product is important if the two types of products are not separable for the consumers. While the results are somewhat mixed, one can conclude that the substitutability between seafood and meat products are rather limited.

So far we have focused only on own-price effects, as they are the main topic of this study. However, while own-price effects are of interest on their own, in most cases one also needs information about substitution effects. These are measured by cross-price elasticities or flexibilities, depending on whether an ordinary or an inverse demand specification is used. Although it is difficult to generalise, it is clear that most seafood products have substitutes. Moreover, as expected similar species and product forms tend to be the closest substitutes. For instance, different species and product forms of salmon tend to be closer substitutes than any given salmon category and other seafood species/products.

4. EMPIRICAL MARKET INTEGRATION STUDIES

In this section, we will give a brief review of market integration results. As there are a number of variations in what econometric approach is used, one can only sketch the results if one does not want to present each study in to large detail. The only common feature of all studies is that they test whether there is a statistically significant relationship between at least two different prices using an F-test for cointegration. In some studies there are no additional tests, while others test for the Law of One Price, leading prices, central markets, speed of adjustment etc.

Gordon, Salvanes and Atkins (1993) is the first in a string of studies that investigate the relationship between salmon and cod and other species, and are also the first to find that salmon is a separate market from other wild fish. Asche, Bjørndal and Young (2003), Asche, Gordon and Hannesson (2002; 2004), Jaffry and Hartman (2003) and Nielsen et al (2007) are other studies providing similar results.

As in demand studies, salmon is the most studied species. Asche and Sebulonsen (1998), Asche, Bremnes and Wessells (1999) and Asche (2001) provide evidence that there is a global market for salmon including farmed as well as wild salmon. Asche et al (2005) show that salmon trout also belong to this market. However, Gordon and Clay show that at in the US, the different regional markets are segmented. Asche, Guttormsen and Tveterås (2002) and Asche and Guttormsen (2001) looks further into the micro structure showing that although there are seasonal variation in the prices for different weight classes of salmon, their prices are also highly related. In total, these studies indicate that there is a highly integrated market for salmon both globally, and for different product forms, and as such all forms of salmon are competing in the same market. Each product form or species need not be directly substitutable with any other, but there are so many species and product forms that are substitutable, that there is a link in the price formation process.

5. CONCLUDING REMARKS

In this paper, we have provided a review of demand and market integration studies for salmon. Given that estimating demand elasticities and testing for market integration is an empirical exercise, it is clear that each study must focus on a specific market for a given period of time. This is a problem since, strictly speaking, it gives information only about a given market for a given time period, and there is no reason why for example that the demand for salted salmon in Japan should have any resemblance to the demand for fresh salmon the UK. Moreover, a number of different model specifications have been used, making it even harder to compare results.

Demand in most markets seems to be price elastic. This is good news for the salmon industry in general, if one still regards it as a growing industry, as it implies that the total revenues are likely to increase if production continues to increase. However, it must also be noted that demand is not elastic in all market segments. For instance, the reported elasticities indicate that the demand for canned salmon, and maybe also frozen salmon in aggregate most likely is inelastic. Also for other species and product forms one can find examples of market segments where demand seems to be inelastic.

There seems to be a tendency that demand gets less elastic the closer to the consumer the data are measured, with retail demand the least elastic. Economic theory gives no reason to expect retail demand to be more or less elastic than demand lower in the value chain. This relationship will depend on the production process of the intermediaries (Gardner, 1975). One might of course speculate whether competition is keener in intermediary markets, as the fish can be processed into several product forms. However, the model specifications used might also be at least part of the reason for this result.

For species with a rapidly increasing production, like new aquaculture species such as salmon and catfish, the demand gets less elastic with increases in supply. This is very much as expected, as one in this situation is likely to observe a movement down the demand schedule. Hence, even though there is substantial evidence of successful generic marketing campaigns, it seems like lower prices facilitated by productivity improvements are more important in increasing the quantity sold of these species.

Very little has been done on aggregate demand for species. As such, even though we know a bit about different markets, we know substantially less about the aggregate markets. This is a major shortcoming, since the salmon markets are becoming more and more globalised. Knowledge about the global market structure is then instrumental in understanding the price determination process. There are most likely two reasons why aggregate demand structures have received little attention. First, it is very difficult to obtain good data. Second, there are substantial methodological issues both with respect to aggregation and because the simultaneity problem cannot be assumed away.

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Table 1. Demand elasticities

Product	Own-Price Elasticity	Study	Type of Data	Region
Canned, all	-7.14	DeVoretz (1982)	Wholesale	Canada
Canned Sockeye	-5.00	DeVoretz (1982)	Wholesale	Canada
Canned Pink	-13.70	DeVoretz (1982)	Wholesale	Canada
Canned Chum	-1.28	DeVoretz (1982)	Wholesale	Canada
Canned Coho	-1.64	DeVoretz (1982)	Wholesale	Canada
Fresh/froz	-8.33	DeVoretz (1982)	Wholesale	Canada
Fresh/froz Pink	10.00	DeVoretz (1982)	Wholesale	Canada
Fresh/froz Chum	2.04	DeVoretz (1982)	Wholesale	Canada
Fresh/froz Coho	50.00	DeVoretz (1982)	Wholesale	Canada
Fresh salmon	-13.51	Kabir and Ridler (1984)	Apparent consumption	Canada
Fresh salmon	-10.75	Kabir and Ridler (1984)	Apparent consumption	Canada
Fresh salmon	-14.28	Kabir and Ridler (1984)	Apparent consumption	Canada
Fresh/froz. salmon	-10.00	Kabir and Ridler (1984)	Apparent consumption	Canada
Fresh/froz. salmon	-8.33	Kabir and Ridler (1984)	Apparent consumption	Canada
Fresh/froz. salmon	-10.75	Kabir and Ridler (1984)	Apparent consumption	Canada
Pacific salmon	-3.62	Anderson and Wilen (1986)	Ex. vessel	USA
Salmon	-0.88	Bird (1986)	Ex.vessel	World
Shellfish	-0.89	Cheng and Capps (1988)	Retail	USA
Finfish	-0.67	Cheng and Capps (1988)	Retail	USA
Norwegian Salmon	-1.83	Hermann and Lin (1988)	Trade	EU
Norwegian Salmon	-1.97	Hermann and Lin (1988)	Trade	USA

Fresh salmon	-1.30	Bjørndal, Salvanes and Andreassen (1992)	Wholesale	France
Atlantic salmon	-1.92	DeVoretz and Salvanes (1993)	Trade	EU
Atlantic salmon	-2.00	DeVoretz and Salvanes (1993)	Trade	USA
Atlantic salmon	-2.38	DeVoretz and Salvanes (1993)	Trade	World
Norwegian salmon	-1.94	Hermann, Mittelhammer and Lin (1993)	Trade	EU
Norwegian salmon	-1.35	Hermann, Mittelhammer and Lin (1993)	Trade	USA
Norwegian salmon	-2.28	Hermann, Mittelhammer and Lin (1993)	Trade	Japan
High-value salmon	-1.88	Hermann, Mittelhammer and Lin (1993)	Trade	EU
High-value salmon	-3.02	Hermann, Mittelhammer and Lin (1993)	Trade	Japan
Low-value salmon	-1.16	Hermann, Mittelhammer and Lin (1993)	Trade	EU
Low-value salmon	-1.92	Hermann, Mittelhammer and Lin (1993)	Trade	Japan
Fresh salmon	-1.28	Wessells and Wilen (1994)	Retail	Japan
Salted salmon	-1.00	Wessells and Wilen (1994)	Retail	Japan
Tuna	-0.93	Wessells and Wilen (1994)	Retail	Japan
Cuttlefish	-0.98	Wessells and Wilen (1994)	Retail	Japan
Cod roe	-0.98	Wessells and Wilen (1994)	Retail	Japan
Horse mackerel	-1.28	Wessells and Wilen (1994)	Retail	Japan
Flounder	-1.24	Wessells and Wilen (1994)	Retail	Japan
Yellowtail	-1.25	Wessells and Wilen (1994)	Retail	Japan
Sea bream	-0.49	Wessells and Wilen (1994)	Retail	Japan
Shrimp, lobster	-1.37	Wessells and Wilen (1994)	Retail	Japan
Shellfish	-0.55	Wessells and Wilen (1994)	Retail	Japan
Other	-0.83	Wessells and Wilen (1994)	Retail	Japan
Norwegian Salmon	-1.27	Bjørndal, Gordon and Salvanes (1994)	Trade	Italy

Norwegian Salmon	-1.78	Bjørndal, Gordon and Salvanes (1994)	Trade	Spain
Fresh salmon	-1.73	Asche (1996)	Trade	EU
Frozen salmon	-0.28	Asche (1996)	Trade	EU
Smoked salmon	-0.60	Asche (1996)	Trade	EU
Red meat	-0.69	Salvanes and DeVoretz (1997)	Retail	Canada
White meat	-0.93	Salvanes and DeVoretz (1997)	Retail	Canada
Processed meat	-0.86	Salvanes and DeVoretz (1997)	Retail	Canada
Fresh fish	-0.91	Salvanes and DeVoretz (1997)	Retail	Canada
Cured fish	-0.96	Salvanes and DeVoretz (1997)	Retail	Canada
Canned fish	-0.98	Salvanes and DeVoretz (1997)	Retail	Canada
Other fish	-0.94	Salvanes and DeVoretz (1997)	Retail	Canada
Residual food	-0.88	Salvanes and DeVoretz (1997)	Retail	Canada
Fresh Salmon	-3.73	Asche, Salvanes and Steen (1997)	Trade	EU
Frozen Salmon	-2.57	Asche, Salvanes and Steen (1997)	Trade	EU
Crustaceans	-1.56	Asche, Salvanes and Steen (1997)	Trade	EU
Salted salmon	-0.89	Johnson, Durham and Wessells (1998)	Retail	Japan
Salmon	-1.43	Johnson, Durham and Wessells (1998)	Retail	Japan
Tuna	-0.85	Johnson, Durham and Wessells (1998)	Retail	Japan
Flatfish	-0.54	Johnson, Durham and Wessells (1998)	Retail	Japan
Lobster/shrimp	-1.11	Johnson, Durham and Wessells (1998)	Retail	Japan
Shellfish	-0.59	Johnson, Durham and Wessells (1998)	Retail	Japan
Cuttlefish	-1.08	Johnson, Durham and Wessells (1998)	Retail	Japan
Other	-0.80	Johnson, Durham and Wessells (1998)	Retail	Japan
Fresh salmon	-1.33	Asche, Bjørndal and Salvanes (1998)	Trade	EU

Frozen Atl. Salmon	-1.86	Asche, Bjørndal and Salvanes (1998)	Trade	EU
Frozen Pac. salmon	-0.51	Asche, Bjørndal and Salvanes (1998)	Trade	EU
Seafood	-1.35	Guillotreau, Peridy and Bernard (1998)	Trade	EU
Fish	-1.05	Guillotreau, Peridy and Bernard (1998)	Trade	EU
Shellfish	-2.04	Guillotreau, Peridy and Bernard (1998)	Trade	EU
Norwegian peeled shrimp	-1.89	Myrland og Vassdal (1998)	Trade	UK
Icelandic peeled shrimp	-1.08	Myrland og Vassdal (1998)	Trade	UK
Danish shell-on shrimp	0.02	Myrland og Vassdal (1998)	Trade	UK
Danish peeled shrimp	-0.67	Myrland og Vassdal (1998)	Trade	UK
Thai peeled shrimp	-0.26	Myrland og Vassdal (1998)	Trade	UK
Frozen fillets of cod	-1.22	Myrland og Vassdal (1998)	Trade	UK
Frozen cod	-1.06	Myrland og Vassdal (1998)	Trade	UK
Fresh fillets of haddock	-0.89	Myrland og Vassdal (1998)	Trade	UK
Frozen fillets of Alaska pol.	-0.69	Myrland og Vassdal (1998)	Trade	UK
Frozen fillets of hake	-0.82	Myrland og Vassdal (1998)	Trade	UK
High Quality Fish	-0.82	Eales and Wessells (1999)	Retail	Japan
Medium Quality Fish	-0.75	Eales and Wessells (1999)	Retail	Japan
Low Quality Fish	-0.98	Eales and Wessells (1999)	Retail	Japan
Norwegian salmon	-0.60	Xie, Kinnucan and Myrland (2008)	Trade	
UK salmon	-0.28	Xie, Kinnucan and Myrland (2008)	Trade	
Chilean salmon	-0.19	Xie, Kinnucan and Myrland (2008)	Trade	
Other salmon	-0.43	Xie, Kinnucan and Myrland (2008)	Trade	

The Supply Module

by

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Introduction

While demand for seafood is extensively studied, studies of seafood supply have not caught the same interest among academics. There exist a series of paper with bioeconomic models presenting supply for fish from specific fisheries, but very few aggregate empirical supply models.

As an input to the equilibrium displacement model, estimates of supply is a core element and we have to acquire these parameter estimates from econometric models. The econometric models for supply will provide the EDM model with estimates of different elasticities, such as supply and input demand.

In this report the theory of supply will be outlined, theoretically as well as empirically. In addition the supply structure of salmon will be outlined, and the relatively few estimates of salmon supply will be presented.

Theoretical background

A common assumption maintained when modeling production is that firms seek to maximize profit:

$$\Pi = PQ - C^{*}\left(Q, w; k\right) - FC\left(k\right) \tag{1}$$

where Π is profit, P is output price, Q is output quantity, $C^{*}\left(Q, w; k\right)$ is variable cost, w is a vector of variable input prices, k is a vector of quantities of quasi-fixed factors, and FC(k) is fixed cost. This is a highly stylized model that has provided a very useful set of guidelines for modeling production operations. Firms are constrained by available technology. In the short-run technology is fixed, it cannot be altered. In the longer-run, however, technology can be altered though investment in new capital and/or new technology.

At any particular time, the available technology that constrains firms' profit maximization can be characterized by a cost function (dual form):

$$TC(Q,w,r;k) = C^*(Q,w;k) + FC(k) \quad (2)$$

where: TC(.) is total cost, C^*(.) is variable (or restricted) cost (*direct labor & materials*), FC(.) is fixed cost (*plant overhead, selling & distribution & administrative*), w is a vector of variable input prices associated with variable input quantities x, and k ={k_1, k_2}is a vector of quasi-fixed input quantities.

The variable or restricted cost function is based on the notion that, within a specified time period (short-run), not all inputs can be adjusted to minimize cost of producing an output, Q, with output price p. Restrictions may arise from numerous circumstances including: costs associated with making adjustments in the input used in the production process, biological restrictions, incomplete or costly information, and government regulations. Other short-run restrictions may include quantity of family labor used in production, production capital including use of specialized machinery or facilities, and leased space.

Variable cost is derived through cost minimization subject to a production technology (e.g. Varian(1992)). From a producer's point-of-view, the program that will minimize (variable) cost of producing a specific quantity of *Q* is:

$$C^*(Q,w;k_1,k_2) \equiv \min_x \{x'w : F(x,k_1,k_2) \geq Q\}, \quad (3)$$

where $F(x, k_1, k_2)$ is a production function that describes the maximum attainable output from a set of inputs. Put another way, the production function describes the technically efficient relationship between input (variable and fixed) use and production. The * superscript means that the cost function is for "fixed" levels of inputs k, i.e., factors k_1 and k_2 cannot be adjusted in the period of time under consideration. The restricted (or variable) cost function $C^*(Q, w; k_1, k_2)$ measures the short-run minimum variable cost of producing *Q* excluding the cost of quasi-fixed factor k_1 and k_2. Specifically, it measures the minimum cost associated with variable input use conditional on a specified output quantity and specific quantities of fixed inputs (k_1 and k_2).

So for example:

$$
\begin{aligned}
&\min_{x_1,x_2} w_1x_1 + w_2x_2 \\
&s.t.\ Q_0 = F\left(x_1,x_2,k\right) \\
&L = w_1x_1 + w_2x_2 + \lambda\Big(Q - F\left(x_1,x_2,k\right)\Big) \\
&FOC \\
&\frac{\partial L}{\partial x_1} = w_1 - \lambda\frac{\partial F\left(x_1,x_2,k\right)}{\partial x_1} = 0 \\
&\frac{\partial L}{\partial x_2} = w_2 - \lambda\frac{\partial F\left(x_1,x_2,k\right)}{\partial x_2} = 0 \\
&\frac{\partial L}{\partial \lambda} = Q_o - F\left(x_1,x_2,k\right) = 0
\end{aligned}
\tag{4}
$$

When the production function is known, in principle it is possible to solve for optimal x_1^* and x_2^* and substitute these solutions into the variable cost to obtain:

$$C^*\left(Q,w,r;k\right) = w_1x_1^*\left(Q,w_1,w_2;k\right) + w_2x_2^*\left(Q,w_1,w_2;k\right) \tag{5}$$

This function is often called a *conditional* or *restricted cost* function since it conditioned on a given level of quasi-fixed input k; most often some form of capital that is adjusted only slowly over time but remains fixed in the short-run. While other (most notably the profit function) approaches are useful for representing firms' technologies, the cost function approach will be used through the rest of this investigation. The reason is the cost function allows empirical modeling under a wide range of institutional settings including: imperfect competition in the output and possibly inputs markets, and under risk aversion.

Properties of the Restricted (or Variable) Cost Function

The variable (restricted) cost function has several important theoretical properties (e.g. Varian(1992)):

i. $C^*(.)$ is nonnegative for positive valued arguments *x, w*, and *k*.
ii. $C^*(.)$ is homogenous of degree 1 in all variable input prices, *w*.

iii. $C^*(.)$ is nondecreasing and concave in variable input prices, w so $\partial C^*(.)/\partial w_i > 0$ and $\partial^2 C^*(.)/\partial w_i^{\,2} < 0$.

iv. $C^*(.)$ is nonincreasing and convex in fixed input quantities, k (see Chambers, pp.102 & 109).

v. $C^*(.)$ is nondecreasing in output quantity, Q.

vi. $C^*(.)$ is twice differentiable with respect to all arguments.

Conditional (or Variable) Input Demand Functions

Shepard's Lemma establishes the relationship between variable cost and conditional (for a fixed level of output and fixed inputs) or variable input demands. In particular, if $C^*(Q, w; k_1, k_2)$ is differentiable with respect to all variable input prices at (Q, w, x) and if the firm is a "price taker" with respect to all variable inputs, then the firm's conditional (on output) input demand is:

$$\frac{\partial C^*\left(Q,w;k_1,k_2\right)}{\partial w_1} = v_i^*\left(Q,w,k\right), \text{ for all i.} \tag{6}$$

The * superscript means that the input demand function is expressed for optimal values of variable inputs x and "fixed" levels of output Q and quasi-fixed inputs k. Suppose w_i changes, in this case, neither output, Q, nor quasi-fixed inputs, k, are allowed to adjust in new profit maximizing levels. The conditional variable input demand functions have several important theoretical properties:

i. $v_{ij}^*\left(\equiv \partial v_i^*\left(Q,w,k\right)/\partial w_j\right) = v_{ji}^*$ for all i and j, $i \neq j$.

ii. $v_{ij}^* \leq 0.\,\mathrm{v_{ij}}^* \leq 0.$

iii. The determinants of the matrices of second derivatives of the restricted cost function with respect to variable input prices alternate in sign starting with negative.

iv. $|\{v_{ij}{}^*\}| = 0.$

Condition i) is a symmetry condition that results from Young's theorem. Condition ii) states that conditional input demands slope downward. Condition iii) is a restatement of concavity of the variable cost function in input prices. Condition iv) is a consequence of homogeneity in the cost function and means that if all variable input prices are increased proportionately, the real allocation of inputs would remain unchanged (i.e., the conditional variable input demands are homogenous of degree 0 in prices).

Conditional Output Supply Function

Under the assumption of "price taking" behavior in the output market, the derivative of the variable cost function with respect to output quantity y defines short-run marginal cost:

$$\partial C^{*}\left(Q, w, k_{1}, k_{2}\right) / \partial Q = m^{*}\left(Q, w, k\right) \tag{7}$$

The competitive firm's inverse short-run output supply is given by:

$$p = m^{*}\left(Q, w, k\right) \tag{8}$$

Total Costs

Total costs include both variable and fixed costs. Hence, total costs are given by:

$$C\left(Q, w, k_{1}, k_{2}, r_{1}, r_{2}\right) = C^{*}\left(Q, w, k_{1}, k_{2}\right) + r_{1}k_{1} + r_{2}k_{2}. \tag{9}$$

The last two terms constitute payments for factors that cannot be adjusted in the period under consideration, typically the short-run.

Variable costs $C^{*}(Q, w; k_{1}, k_{2})$ are minimized for any choice of *k*. If producers can adjust quasi-fixed inputs, long-run cost is obtained by selecting all inputs to minimize cost. Assuming price taking behavior in quasi-fixed factor markets, long-run cost, where all inputs are selected to minimize costs, is given by the solution to the program:

$$C\left(Q, w, r\right) = \min_{k_{1}k_{2}} C^{*}\left(Q, w, k_{1}, k_{2}\right) + r_{1}k_{1} + r_{2}k_{2}. \tag{10}$$

This optimization highlights that producers' long-run optimization can be decomposed into two components. First, minimize short-run variable costs. Second, if possible, select the optimal quantity of "fixed" factors. The long-run problem given by (10) further emphasizes:

$$C\left(Q, w, r\right) = C^{*}\left(Q, w, k_{1}^{0}\right); k_{2} \leq C^{*}\left(Q, w, k_{1}, k_{2}\right), \tag{11}$$

where the *o* superscript represents the optimal solution of the long-run minimization problem given by (10). Together, (10) and (11) imply that long-run cost is the lower envelope of short-run restricted costs. Further, it is easy to show:

$$C\left(Q,w,r\right)\leq C^{*}\left(Q,w,k_{1}^{0}\left(Q,w,r\right);k_{2}\right)\leq C^{*}\left(Q,w;k_{1},k_{2}\right), \tag{12}$$

that is, successive relaxation of input constraints results in increases in the lower envelope of restricted costs.

Relationships Between Restricted and Unrestricted Behavior

The first order conditions associated with (10) result in the "long-run" demand for (quasi-) fixed factors:

$$\partial C^{*}\left(Q,w;k_{1},k_{2}\right)/\,\partial k_{i}+r=0 \text{ for } i=1,2 \tag{13}$$

The first term in (13) is negative and represents variable cost savings associated with relaxing constrained input k_i. Often r_i is an unobserved shadow price. Convexity of $C^*(Q, w; k_1, k_2)$ in k_1 and k_2 implies the fixed factor shadow prices approach zero as the endowment of fixed factor rises.

Concavity of the production function, $F(x, k_1, k_2)$, in all inputs implies:

$$\partial m\left(Q,w,r\right)/\,\partial Q=\partial^{2}C\left(Q,w,r\right)/\,\partial Q^{2}\leq\partial C^{*2}\left(Q,w;k_{1},k_{2}\right)/\,\partial Q^{2}=\partial m^{*}\left(Q,w,z\right)/\,\partial Q. \tag{14}$$

Hence, short-run marginal cost is more steeply sloped than long-run marginal cost so that the observed short-run supply function with quasi-fixed restricted inputs is more steep than the unobserved (hypothetical) "long-run" supply where all inputs are variable.

Producer surplus, or quasi-rent, is the difference between revenues and avoidable costs, i.e. costs that would be avoided if the firm shuts down. Resultant quasi-fixed factor rents can be measured as producer surplus:

$$PS=pQ^{0}-\int_{0}^{Q^{S}}m^{*}\left(Q,w,k_{1}^{0},z_{2}^{0}\right)dQ=pQ^{0}-C^{*}\left(Q^{0},w,k_{1}^{0},k_{2}^{0}\right)=r_{1}k_{1}^{0}+r_{2}k_{2}^{0} \tag{15}$$

The middle term expresses producer surplus as profit. The last term expresses quasi-rent as payments to "avoidable" fixed factors.

Empirical Modeling of the Restricted (or Variable) Cost Function

Econometric estimation requires specific equations for firms' conditional cost functions. There are a number of possibilities, consider the Cobb-Douglas functional form as an example:

The 2-variable input constant-returns-to-scale Cobb-Douglas cost function is given by:

$$C^*(Q,w) = \varphi w_1^{\alpha} \cdot w_2^{1-\alpha} Q \tag{16}$$

In this case, variable cost can be separated into a unit cost $C^*(w) = \varphi\ w_1^{\alpha}\ \ w_2^{1-\alpha}$ and output Q. This is because the constant returns-to-scale is maintained. In addition, the cost is constrained to maintain homogeneity in prices (i.e. the powers on the input prices sum to one).

Application of Shepard's lemma results in the conditional factor demand equations:

$$x_j = \partial C^*(Q,w)/\partial w_j$$

so

$$x_1 = \partial C^*(Q,w)/\partial w_1 = \varphi \alpha w_1^{\alpha-1} w_2^{1-\alpha} Q$$

and (17)

$$x_2 = \partial C^*(Q,w)/\partial w_2 = \varphi(1-\alpha) w_1^{\alpha} w_2^{1-\alpha} Q$$

A competitive firm's supply function can also be easily found from a cost function formulation.

Profit is given by:

$$\pi = PQ - C(Q,w)$$

where P is output price. Maximum profit is given by:

$$\partial \pi / \partial Q = P - \partial C(Q,w)/\partial Q = 0$$

Which implies:

$$P - \partial C(Q,w)/\partial Q = \varphi w_1^{\alpha} w_2^{1-\alpha} \tag{18}$$

or price equals marginal cost under competitive conditions. Homogeneity of degree zero in prices can be maintained by dividing both sides of (18) by one of the input prices and simplifying.

This equation is called the inverse output supply function. It expresses output price (marginal cost) in terms input prices (and output quantity when constant returns-to-scale is not maintained).

Other Constant Returns to Scale Cost Functions

Constant Elasticity of Substitution (CES) Cost

$$TC = Q\left[\beta^{\sigma} w_1^{1-\sigma} + \left(1-\beta\right)^{\sigma} w_2^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{19}$$

Applying Shepard's lemma *($\partial TC/\partial w_i = x_i$)* results in the constant output (conditional) input demands:

$$x_i = \alpha_i w_i^{-\sigma} Q \text{ for } i = 1,2 \tag{20}$$

where the α_i*'s* are constants.

The supply (or unit cost) function is given by:

$$\partial\pi / \partial Q = P - \left[\beta^{\sigma} w_1^{1-\sigma} + \left(1-\beta\right)^{\sigma} w_2^{1-\sigma}\right]^{\frac{1}{1-\sigma}} = 0, \tag{21}$$

which is intrinsically nonlinear.

Translog Cost

$$\begin{aligned} \ln\left(TC\right) &= \ln\left(Q\right) + \beta_0 + \beta_1 \ln\left(w_1\right) + \beta_2 \ln\left(w_2\right) + 1/2\beta_{11} \ln\left(w_1\right)^2 \\ &+ 1/2\beta_{22} \ln\left(w_2\right)^2 + \beta_{12} \ln\left(w_1\right)\ln\left(w_2\right) \end{aligned} \tag{22}$$

Applying Shepard's lemma and some algebra results in input demands in terms of cost share equations for each input demand.

$$\mathrm{s}_1 = \beta_1 + \beta_{11}\ln\left(w_1\right) + \beta_{12}\ln\left(w_2\right) \tag{23}$$

and

$$\mathrm{s}_2 = \beta_2 + \beta_{22}\ln\left(w_2\right) + \beta_{12}\ln\left(w_1\right), \tag{24}$$

where s_i is input cost share for input i. Input share is calculated as

$s_i = w_i x_i/TC$, where $TC = w_1 x_1 + w_2 x_2$.

Several restrictions result from profit maximization. To maintain homogeneity in prices (of degree 1 in cost and degree 0 in conditional input demand), requires: $\beta_{11}+\beta_{22}+\beta_{12}=0$. Symmetry has already been imposed so: $\beta_{12}=\beta_{21}$

Estimation of CRS Cost Functions through Conditional Input Demands and Supply

Each of the constant returns-to-scale models presented above are linear in parameters. If restrictions from production theory are ignored, after appropriate data transformations, the conditional factor demands can be easily estimated using linear regression (OLS) or instrumental variable estimation (2SLS) if input prices are endogenous. For example, the translog cost parameters can be estimated using equations (23) and (24) and the Cobb-Douglas cost function can be estimated by dividing both sides of (17) by Q and estimating the transformed model in logarithms.

That is:

$$x_1 / Q = \varphi\alpha w_1^{\alpha-1} w_2^{1-\alpha} \text{ or } \ln\left(x_1 / Q\right) = \beta_1 + \alpha_1 \ln\left(w_1\right) + \alpha_2 \ln\left(w_2\right) \qquad (25)$$

where $\beta_1 = ln(\varphi\alpha)$, $\alpha_1 = \alpha - 1$, and $\alpha_2 = 1 - \alpha$.

and

$$x_2 / Q = \varphi\left(1-\alpha\right) w_1^{\alpha} w_2^{-\alpha} \text{ or } \ln\left(x_2 / Q\right) = \beta_2 + \alpha_3 \ln\left(w_1\right) + \alpha_4 \ln\left(w_2\right) \qquad (26)$$

where $\beta_2 = ln(\varphi(1-\alpha))$, $\alpha_3 = \alpha$, and $\alpha_4 = -\alpha$.

In addition, the supply (unit cost) may also be estimated using:

$$P = \varphi w_1^{\alpha} w_2^{1-\alpha} \text{ or } \ln\left(P\right) = \beta_3 + \alpha_5 \ln\left(w_1\right) + \alpha_6 \ln\left(w_2\right) \qquad (27)$$

where $\beta_3 = ln(\varphi)$, $\alpha_5 = \alpha$, and $\alpha_6 = 1 - \alpha$.

For estimation, random errors are appending to each equations to represent random factors not accounted for in the equation. Since conditional input demands and supply are interrelated, random events unaccounted for in a particular equation at a particular time are also likely to affect other equations at the same time. Hence, most often the errors across equations at any given time period are correlated, i.e. the errors across equations are contemporaneously correlated. Mathematically, contemporaneous correlation is expressed as: $E(v_{it}\ v_{jt})$ = covariance$(v_{it}\ v_{jt}) = \sigma_{ij},\ i,j = 1,2,3.$

Under the general OLS assumptions (fixed regressors, independently and identically distributed errors, model correctly specified, and no perfect multicollinearity among regressors), with contemporaneous correlation, consistent and efficient estimation is achieved using Seemingly Unrelated Regression (SUR).

In each model, two important issues must still be addressed: possible price endogenity and serial correlation. Most often, when researchers use firm-level data, all prices are assumed to be exogenous. This may also be the case when using aggregate production data when producers of the product use only a small amount of the total input production. This may well be the case for labor and some other inputs. When input prices are predetermined or exogenous, parameters are estimated using a systems estimation approach like seemingly unrelated regressions (SUR) or iterated SUR.

A researcher can test for endogenous prices using Hausman's specification test for endogenity. To conduct such tests, instrumental variables are needed for each price. Good instruments include prices for inputs sold in areas outside the geographic sample area. Serial correlation can be found in production systems and most often allowance is made for first-order serial correlation (AR1) in estimation.

One additional issue in estimation of the translog model is singularity of the covariance matrix. Since the dependent variables in the translog are cost shares, they add to one. This means that covariance matrix constructed from the second stage residuals is singular. The problem is easily overcome by dropping one equation from the estimation. Parameter estimates for the missing equation can then be reconstructed using parameter estimates from estimated equations in conjunction with parameter restrictions implied by cost minimization.

Normalized Quadratic Restricted (or Variable) Cost Function

Often we do not want to impose constant returns-to-scale on the production technology. In this case, the researcher can use functional forms similar to those already presented, but including quantity directly in the functional form. Generally it is a good idea to choose a functional form that is "flexible." That is, it is a good idea to select a functional form that can used to approximate any functional form. A number of flexible forms are generally used.

In what follows, we assume a normalized quadratic cost function with two variable inputs, x_1 and x_2, with prices w_1 and w_2, respectively. In addition, the firm uses capital, k valued at r per unit. Most often, data used in estimation are time-series. This means that, over time, firms most likely adopt new technologies that reduce cost and possibly shift optimal input usage. To account for this type of possible technological change, a time trend is also included the firms' variable cost function. This specification allows for possible Hick's non-neutral technological change.

An important feature of the normalized quadratic is that profit and cost are homogenous of degree 1 in prices and that supply and conditional input demands are homogenous of degree zero in prices. Symmetry is easily imposted by restricting $a_{ij} = a_{j}$ i. Another sometimes nice feature is that supply and conditional input demands derived from the normalized quadratic cost function are linear in parameters and variables.

Specifically the firm's cost can be represented as:

$$
\begin{aligned}
\hat{C}^*\left(Q,\hat{w}_2;k,T\right) = a_0 + a_1 Q + a_2\hat{w}_2 + a_3 k + a_4 T \\
+1/2\,a_{11}Q^2 + 1/2\,a_{22}\hat{w}_2^2 + 1/2\,a_{33}k^2 + 1/2\,a_{44}T^2 \\
+a_{12}Q\hat{w}_2 + a_{13}Qk + a_{14}QT \\
+a_{23}\hat{w}_2 k + a_{24}\hat{w}_2 T \\
+a_{34}kT,
\end{aligned}
\tag{28}
$$

where $a's$ are parameters, and T is time. Prices and cost in (28) are normalized by w_1 so $\hat{w}_2 = w_2/w_1$ and $\hat{C}^*(.) = C^*(.)/w_1$. So, $C^*(Q, w_1, w_2; k, T) = w_1\,\hat{C}^*(Q, \hat{w}_2; k, T)$. Equation

(28) admits Hicks-nonneutral technical so technological change may both reduce costs and change the optimal input mix independent of price changes.

Both supply can be derived from the profit function.

$$\begin{aligned}\Pi &= PQ - C^*\left(Q, w_1, w_2; k, T\right) - rk, \\ &= PQ - w_1\hat{C}^*\left(Q, \hat{w}_2; k, T\right) - rk,\end{aligned} \tag{29}$$

which is homogenous of degree 1 in prices.

Upstream supply is:

$$\partial \Pi / \partial Q = P - w_1 \partial \hat{C}^*\left(Q, \hat{w}_2; k, T\right) / \partial Q = 0 \tag{30}$$

Dividing by w_1 and rearranging terms yields:

$$P / w_1 = \frac{\partial \hat{C}^*\left(Q, \hat{w}_2; k, T\right)}{\partial Q} \tag{31}$$

or

$$P / w_1 = a_1 + a_{11}AQ + a_{12}Aw_2 / w_1 + a_{13}Ak + a_{14}A\ T \tag{32}$$

which is homogenous of degree zero in prices.

Variable input demands are obtained by applying Shepard's lemma:

$$x_i = \partial C^* / \partial w_i \text{ for } i = 1,2 \tag{33}$$

The input demand for x_1 is:

$$x_1 = \partial C^*\left(\cdot\right) / \partial w_1 = \partial w_1 \hat{C}^*\left(\cdot\right) / \partial w_i = \hat{C}^*\left(\cdot\right) + w_1 \partial \hat{C}^*\left(\cdot\right) / \partial w_1 \tag{34}$$

or

$$\begin{aligned}x_1 = \ & a_0 + a_1AQ + a_3Ak + a_4AT + 1/2Aa_{11}AQ^2 - 1/2Aa_{22}A\left(w_2 / w_1\right)^2 \\ & + 1/2Aa_{33}Ak^2 + 1/2Aa_{44}AT^2 + a_{13}AQAk + a_{14}AQAT + a_{34}AkAT\end{aligned} \tag{35}$$

The input demand for x_1 is homogenous of degree zero in prices. Also note that, while this equation is nonlinear in variables, it is linear in parameters. Linear estimation can still be achieved by redefining the variables.

The input demand for x_2 is:

$$x_2 = \partial C^*\left(\cdot\right) / \partial w_2 = \partial w_1 \hat{C}^*\left(\cdot\right) / \partial w_2 = w_1 \partial \hat{C}^*\left(\cdot\right) / \partial w_2 \tag{36}$$

or

$$x_2 = a_2 + a_{12}AQ + a_{22}Aw_2 / w_1 + a_{23}Ak + a_{24}AT \tag{37}$$

The input demand for x_2 is homogenous of degree zero in prices.

A long-run equilibrium condition for capital demand can also be obtained from the profit equation. In particular, the price dependent, long-run equilibrium demand for capital is:

$$\partial \prod / \partial k = -w_1 \partial \hat{C}(\cdot) \partial k. - .r = 0 \tag{38}$$

Dividing by w_1 and rearranging terms yields:

$$\mathrm{r} / \mathrm{w}_1 = - \partial \square^{*}(.) / \partial \mathrm{k} , \tag{39}$$

or

$$r / w_1 = -a_3 - a_{13}AQ - a_{23}Aw_2 / w_1 - a_{33}Ak - a_{34}AT \tag{40}$$

which is homogenous of degree zero in prices.

Model Estimation

The first step for model estimation is to append an error term to each behavioral equation in the system (equations 9a-9d). Additional assumptions are typically made concerning the error terms. Most often the system error terms are assumed to be distributed with means of zero and covariance Σ, i.e. $\varepsilon \sim (0, \Sigma)$, where ε is a 4x1 vector of error terms and Σ is an 4x4 matrix of covariance terms. Notice that no particular (say normal) distribution is required. These assumptions are later verified during the model validation stage of model construction.

Supply and conditional input demands for the firm are given by equations (32) and (40), respectively. It should be noted that endogenous variables appear on the right-hand side each of some of these equations. Hence, these supply and demand equations above cannot be reasonably estimated using OLS. Instead 2SLS or an alternative instrumental variables estimation technique would need to be used. 2SLS estimation for each equation will provide consistent parameter estimates. However, many of the same parameters appear in a number of different equations.

The entire system of equations that could be estimated includes equations 32-40. It is often useful to utilize cross-equation parameter restrictions in estimation. There are two principal advantages associated with incorporating these restrictions. First, the cross-equation restrictions provide additional restrictions that help ensure econometric identification of each equation. Second, since fewer parameters are estimated when the entire system is utilized for estimation, when compared to an equation by equation approach, statistical efficiency (smaller standard errors for the coefficients) results. This suggests the need for a systems estimation approach like 3SLS. Two additional benefits of using a systems estimation approach like 3SLS are additional statistical efficiency may result when there is contemporaneous correlation among the equations and coefficient estimates will be internally consistent. System estimation, however, requires data for every input and output price and quantity used throughout the entire system of equations. Often this data may not be available. In addition, if one equation in the system is poorly estimated, this will aversely affect coefficient estimates in the rest of the equations in the system.

Model Validation

Model validation amounts to checking if the estimated model is consistent with underlying assumptions. Assumptions maintained in model construction pertain to economic theory and the statistical assumptions used in estimation. The economic assumptions relate to those of profit maximization (and therefore cost minimization). Typically, many assumptions are simply maintained without verification, especially those relating to homogeneity and symmetry. However, others need to be carefully verified or the model is very likely to perform poorly when assessing various counter factual possibilities or making predictions of future events. Most important, the curvature of the cost function must be maintained. In fact, checking the curvature of the cost function through the second-order cost minimization conditions insures that supply is upward sloping and conditional input demands for inputs are downward sloping. The complete test requires checking to see if:

i. $C^*(.)$ is nondecreasing and concave in variable input prices, w so $\partial C^*(.)/\partial w_i > 0$ and
$\partial^2 C^*(.)/\partial w_i^{\ 2} < 0$,

ii. $C^*(.)$ is nonincreasing and convex in fixed input quantities, k (see Chambers, pp.102 & 109), and

iii. $C^*(.)$ is nondecreasing in output quantity, Q.

This is achieved by checking the matrix of second duratives in the cost function (Hessian matrix). In particular, the determinants of the matrices of second duratives of the restricted cost function with respect to variable input prices alternate in sign starting with negative and the determinates of the matrices of the second duratives of the restricted cost function with respect to quasi-fixed input quantities should be positive.

The next check is for statistical significance of important parameters. Most important are the diagonal terms just discussed. They determine whether supply is upward sloping and conditional input demands are downward sloping. For standard error estimates for the coefficients to be valid, there must not be any serial correlation or heteroskedasticity in the residuals. A number of tests are available to test for these violations in assumptions, depending on the estimation technique employed.

Calculation of Returns to Scale

Returns to scale can be defined in terms of the shape of average cost curves for homothetic production functions (Takayama, 1993, p. 158). If average cost is falling (rising) with increased output, then returns to scale are increasing (decreasing). If average cost does not change with an increase in output, we have constant returns to scale. For nonhomothetic production functions, these scale effects are actually size effects since the expansion path is not a ray line out of the origin. Returns to scale (or size) can then be defined using the derivative of average cost with respect to output. Define average cost as $\gamma(Q) \equiv C(\cdot)/Q$ where w is a vector of input prices and Q is output. Let $\gamma'(Q) = \partial[C(\cdot)/Q]/\partial Q$. The sign of $\gamma'(Q)$ then determines the nature of returns to scale (size), i.e., decreasing if positive, increasing if negative, or constant if zero.

Literature review

At the end of the eighties, the salmon aquaculture industry had been operating for a long enough time to get data that allowed empirical analysis of the firms. As Norway is the only producing country where data is systematically gathered, virtually all studies have been using Norwegian data.

In common with most production analysis, the focus was on the production process and particularly on how different input combinations could be used and on the productivity growth of the industry. A number of studies have accordingly investigated input substitution and productivity growth. The largest portion of this literature is based on primal or dual approach. Studies using the dual approach are mainly econometric studies applying cost functions of the translog functional form. These studies are applying Zellner's seemingly unrelated regression method (SUR) or non linear iterated seemingly unrelated regression method (NLITSUR) to model the cost function and cost shares. The subject of the dual approach studies are versatile and includes characterizing the structure of the industry through inspecting elasticity of substitution- and scale [Salvanes (1989) and Guttormsen (2002)], inspecting efficiency- and cost differences in the salmon production [Bjørndal and Salvanes (1991), Tveterås (1993), Kumbhakar (2001) and Roll (2008)], assessment of the presence of agglomeration externalities [Tveterås (2002)], discussion of the use of a feed price proxy [Østbye (1999)] and of potential gains from reregulation of the industry [Salvanes (1993) and Bjørndal and Salvanes (1995)].
Studies applying the primal approach are mainly preoccupied with estimation of production risk in Norwegian salmon production. Though expanding the risk framework, most of these studies use the Just and Pope framework as point of departure [Tveterås (1997; 1999; 2000), Asche and Tveterås (1999) and Kumbhakar and Tveterås (2003)] Kumbhakar (2002) estimates jointly production technology and risk preference function using first order condition of expected utility of profit maximization and the production function, while Tveterås and Battese (2006) applies stochastic frontier production function to assess agglomeration externalities.

Other formal methods have also been applied to study aspects of the salmon industry. Vassdal and Roland (1998) applies DEA analysis and Malmquist index to assess technical efficiency and technological growth in the industry. Vassdal (Asche 2006) inspect the learning curve for the industry, estimating both learning curve elasticity and learning curve slope. Tveterås (2002) applies the environmental Kutznets curve to assess environmental issues in the Norwegian salmon aquaculture industry.

Our library also contains publication without a direct application of a formal methods approach. Asche, Guttormsen and Tveterås (1999) discusses environmental effects of salmon aquaculture production and internalization of negative externalities due to feedback effects striking the farmers' own production. Asche, Bjørndal and Sissener (2003) and Asche (1997) discusses productivity growth in the salmon industry and the development of production shares among the producing countries. These articles are focusing on the effect of trade disputes on salmon producing countries using Norway as a special case. The book Havbruk:Aquakultur på norsk (Aarset and Rusten 2007) contains discussions on a wide range of subjects regarding the Norwegian aquaculture industry. This book contains contribution from economics and from other research fields.

Somewhat surprisingly, with all these productivity studies, there was no attempts to estimate the supply elasticity. Only three studies have reported such estimates; Steen, Asche and Salvanes (1997), Asche, Kumbhakar and Tveteras (2007) and Andersen, Roll and Tveterås (2008). Fortunately, despite three highly different approaches, the estimates of the long-run supply elasticity is almost identical at 1.5

Compared to the productivity studies, Steen, Asche and Salvanes is a relatively crude analysis. The authors use annual aggregate data for the Norwegian salmon industry and estimate a partial adjustment model for a supply function using a double log functional form. The fact that the study uses only a handful of observations is a main reason that it has not been published in a scientific journal. However, as it for a long period has been the only study reporting a supply elasticity, its estimates are utilised in almost all models of the salmon market where a supply elasticity is needed. The dynamic structure of the model allows the authors to report both a short-run elasticity at, which is very close to 1, and a long-run elasticity at 1.5.

Asche, Kumbhakar and Tveteras (2007) use a cost function in common with most of the productivity studies. They use the fact that a cost function is a special form of a restricted profit function to derive the associated elasticities of the profit function from the estimated cost function. They report a long-run supply elasticity of 1.5.

Andersen, Roll and Tveterås (2008) deviate form the earlier productivity studies in that a profit function is estimated. One reason for that is that the focus of the paper is on the output response to price changes, and therefore that supply must be estimated. The estimated function is a restricted profit function, treating capital as a quasi-fixed input. They therefore also report short- and long-run estimates of the supply elasticity. However, these differ conceptually from Steen, Asche and Salvanes's (1997) estimates. Steen, Asche and Salvanes (1997) estimate a time series model, and estimate the adjustment speed from short- to long-run equilibrium. Andersen, Roll and Tveterås (2008) estimate a partial equilibrium model, where the short run is when capital is fixed and the long run is when it is variable. Hence, given the tremendous increase in size of the farms, the restriction put on the farmers in the short run is much stronger. This is also reflected in the short run elasticity, as this is barely positive at 0.1, indicating very limited short run response. However, the long-run elasticity, when capital is allowed to adjust to its optimum is very similar to the two other studies at 1.5.

World Salmon supply

The global salmon supply consists of both wild and farmed salmon. As shown in **Figure 1**, supply has increased substantially during the last 25 years, from about 570,000 tonnes in 1981 to 2.5 million tonnes in 2006. In 1981, the supply was essentially wild salmon, 560,000 tonnes, while farmed production was just over 10,000 tonnes. Since then, the supply of wild salmon has grown substantially. In the last 10 years landings have varied between 700,000 and one million tonnes. However, what has driven the growth in world supply has been a tremendous increase in the farmed salmon supply that has grown to over 1.65 million tonnes in 2006. The following pages will provide an overview of farmed salmon production and consider wild salmon.

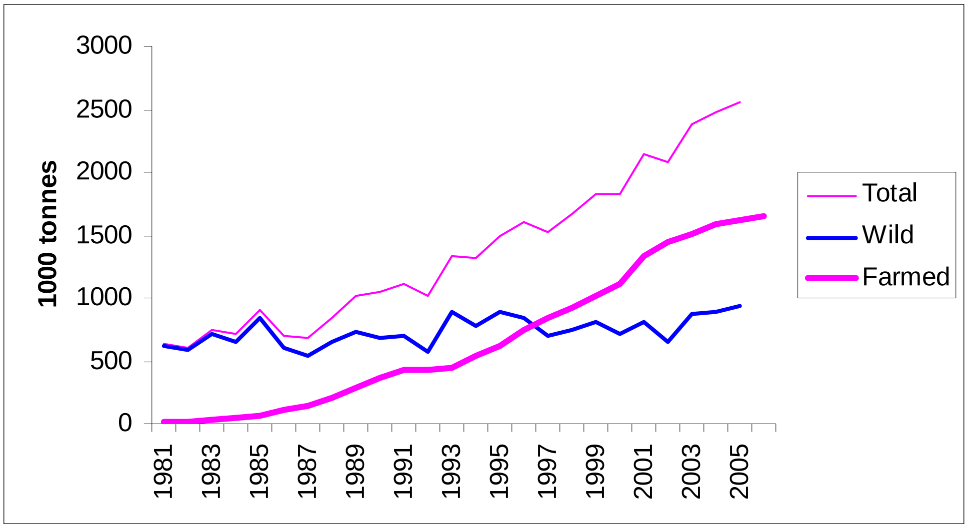

Figure 1: Global supply of salmon

Farmed Salmon Production

Production of salmon is a global industry. There is production on all continents with the exception of Africa and Antarctica. However, most of the production is concentrated in a few regions. Currently, there are two main producers, Norway and Chile, who account for 77% of production. The UK and Canada are also important, each with 7-8% of production. Accordingly, in 2006, those four countries provided over 90% of total production.

Farmed salmon production is concentrated on three species, Atlantic and coho salmon, and salmon trout (**Figure 2)**, but minor quantities of other species like chinook and cherry are also produced. Atlantic salmon is the dominant species, accounting for almost 77% of output in 2006. Atlantic salmon tends to be the most profitable species, and its production share, 64% in 1985, has steadily grown relative to all other farmed salmonides. Salmon trout follows at 14.5% in 2006, down from 23.7% in 1985. Coho's share, 7.3% in 2006, is down from 11.9% in 1985. Quantities of other species like chinook remain very limited. It is of interest to note that in two of the main production regions, Chile and the west coast of Canada, Atlantic salmon is not a native species.

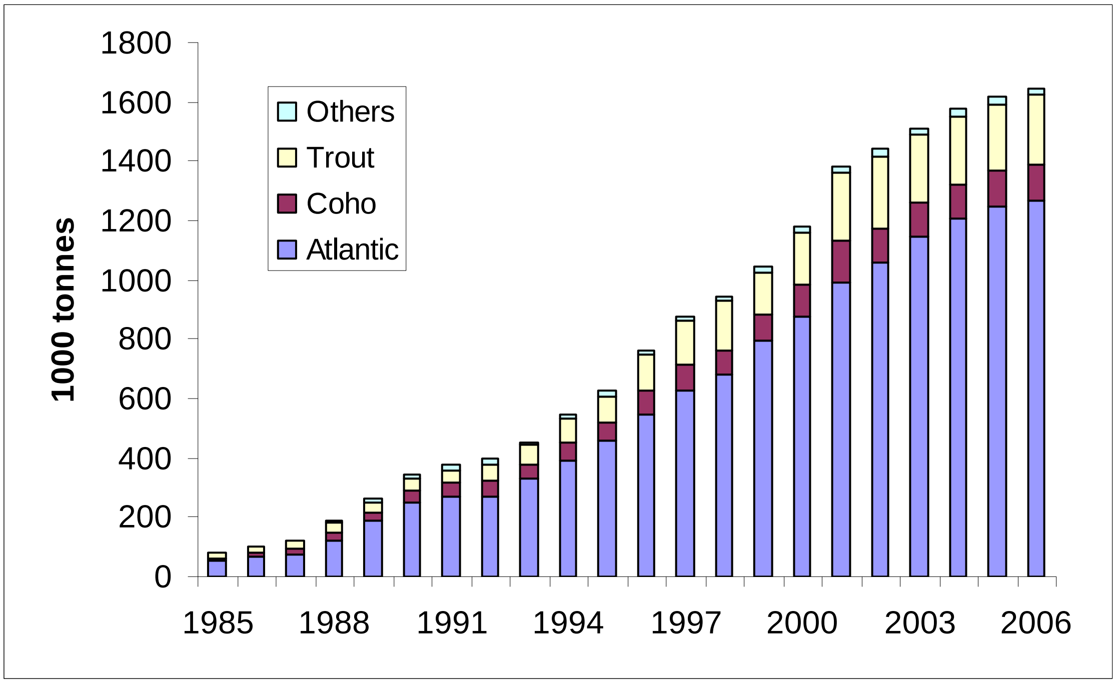

Figure 2: Global farmed salmon production 1985-2006

Norway

Norway's salmon farms are spread along its long coastline with its many fjords, inlets and islands, that in combination with relatively stable water temperatures (ranging from 4-15°C) and good infrastructure, provide a favourable environment for salmon farming. These conditions have helped make Norway the world's leading producer of farmed salmon with an estimated output of about 655,000 tonnes round weight in 2006 **(See Figure 3)**. This was comprised of 598,000 tonnes of Atlantic salmon and 57,000 tonnes of salmon trout. From 1990 to 2006 the industry nearly quadrupled its production, with an average annual growth rate of 8.8%. Production growth has been fairly steady, with brief stops in 1986 to 1987 due to severe disease problems, and in 1990 to 1992 and 2000 to 2001 due to severe problems with profitability. Salmon trout production peaked in 2002 at 77,000 tonnes and thereafter decreased to 57,000 tonnes in 2006. The primary reason for this is weaker demand in the main market for salmon trout, Japan. However, production seems set to increase again as a new market has been developed in Russia. In

2006, 186.4 million salmon smolts and 27.7 million trout smolts were released into the sea. In 2003, those numbers were 134.5 million and 18.1 million, respectively.

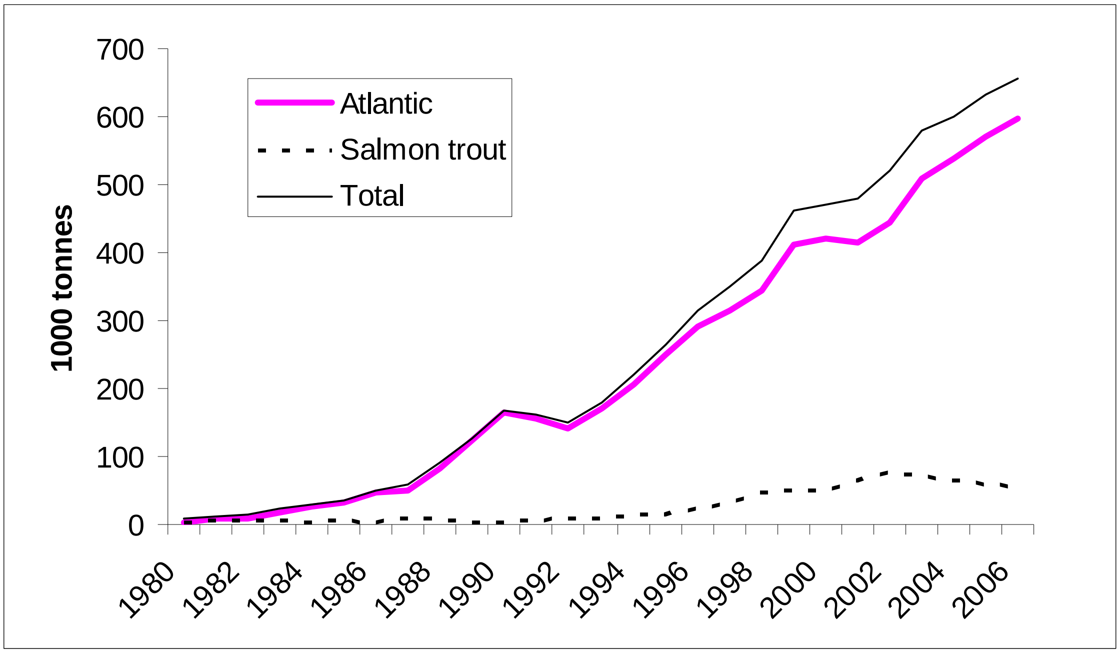

Figure 3: Production of Farmed Salmon in Norway

The tremendous growth in output throughout the 1990s has not been matched by a corresponding increase in the number of production facilities (between 1985 and 2002 no new licences were awarded) and farm level employment. Increased productivity in terms of feeding routines, as well as disease prevention, has improved the feed conversion ratios, shortened the on-growing period and lowered mortality rates. Of particular importance was the development of an effective vaccine for furunculosis in 1992. There has also been a movement in production sites from sheltered locations, where pollution can be a problem, to more exposed locations. As a result of these changes, average production costs per kilo have dropped almost continuously since the late 1980s and are in 2006 about a quarter of what they were in the mid 1980s.

In 2006 there were 26 brood stock plants, 272 smolt farms and 921 salmon farm licences (on-growing sites), including salmon trout producers. The 921 salmon licences were owned by 228 companies. In total, about 2,500 people were directly employed in the growing of salmon, counting full-time and seasonal workers. Salmon farmers constitute a highly diverse group of companies. Restrictions on ownership were lifted in 1992, and there has been an increasing tendency towards consolidation in recent years. In 2006, the four largest firms in the industry accounted for 47% of production, while the 10 largest firms accounted for about 63%. At the same time, the industry has become more international, with ownership structures across national borders. In addition to vertical integration into processing facilities, and sales offices in the EU and elsewhere, the Norwegian salmon industry has increasing ownership interests in Canadian, Chilean and Scottish salmon farming firms. A major restructuring took place in 2006 when a Norwegian company, Panfish, purchased the largest salmon producing company, Marine Harvest, as well as another major company, Fjord Seafood.

In 2006, the Norwegian industry exported salmon worth a total of 2.9 billion US dollars. That translated to roughly 18.4 billion Norwegian kroner, about 17 billion for salmon and 1.3 billion for salmon trout. Norway's most important market by far is the EU, although the EU share of exports has varied considerably. In 1985 it was 59%, more than 80% in 1995, and 76% in 2006. There are a number of factors influencing the variation in the EU market share, from economic and demand conditions to trade conflicts. In particular, it is likely that the numerous trade conflicts between Norway and the EU have led Norwegian exporters to target other markets. Within the EU, France is the largest market with about 16% of Norwegian export value. This makes France the largest importing country overall, followed by Denmark with about 13% . In some recent years Denmark has imported more than France. In contrast to France, consumption of salmon in Denmark is limited, and most of the fish is re-exported.

During the last few years Russia has become the most important destination outside of the EU. In 2005 Russia received 9% of the exports. However, this was reduced to 6% in 2006 because of import restrictions during the first half-year (After the restrictions were relaxed, import growth continued on the old trend). Russia has also become the most important destination for salmon trout, with a 45% share in 2006.

For several years in the 1990s, Japan was the largest market for Norwegian salmon. However, volumes have stagnated and the share reduced since then. Still, Japan was the second largest market outside of the EU in 2006 with a 5% share. Japan has traditionally been the main market for salmon trout with an export share of 75% in 2000. However, as exports to Russia have increased, exports to Japan have been reduced, and Japan's share in 2006 was 21%.

The US was the largest single export market for Norwegian salmon for several years in the 1980s, and in 1985 its share was 28.9%. However, this market largely disappeared following a dumping complaint in 1989.

Exports from Norway are processed in Norway to a very limited degree. Total export value of NOK 17 billion in 2006 is shown by product form in **Figure 4**. Fresh round chilled salmon made up 74% of total export value. Frozen round, fresh fillets and frozen fillets had 9, 8, and 7% of export value respectively. The importance of fresh fillets has been increasing the last decade, but it is still relatively small. Other more processed product forms make up only 2% of exports. There are several reasons for this, notably high Norwegian labour costs and higher tariffs on processed products.

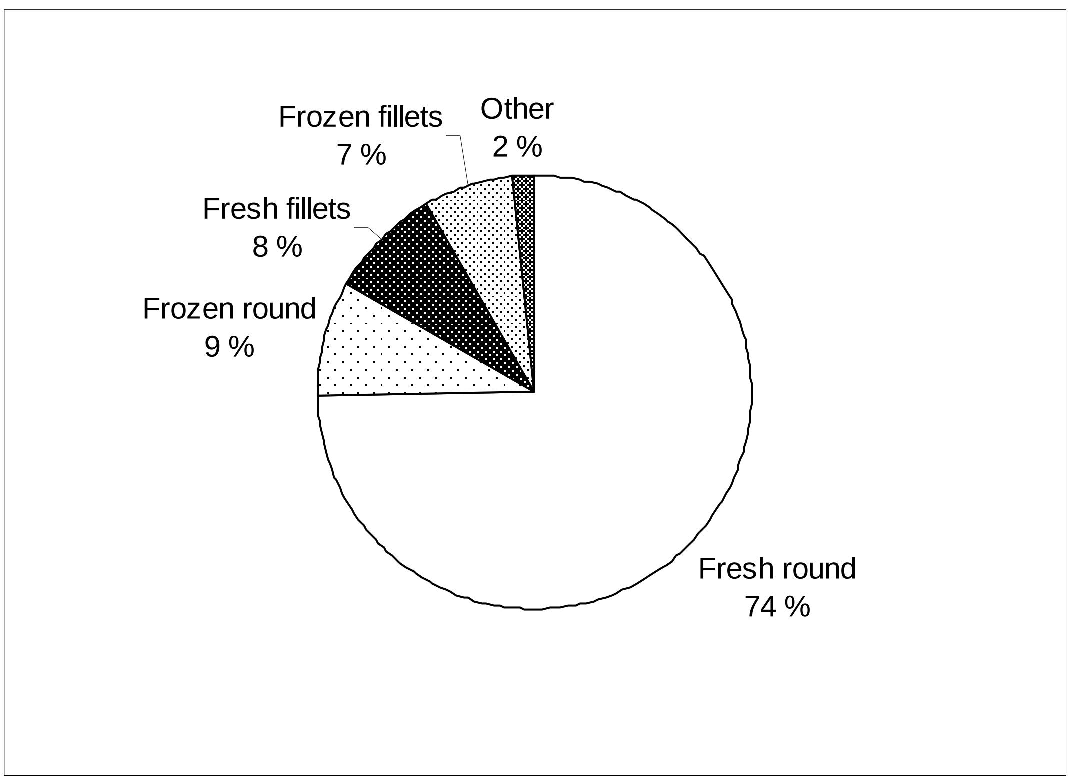

Figure 4: Norwegian production divided on product form

Outlook

Expansion during the last decade can be attributed to productivity improvements and increased output per farm, as the number of fish farm licences has remained almost unchanged since the end of the 1980s. n autumn 2002, 40 new licences were made available by the government, although only 30 were awarded. In 2003, another 50 licences were awarded. In addition, the introduction of a new system to measure capacity has increased production capacity at every site. As profitability has been good during the last few years, production should increase. However, trade tensions seem to be a constant barrier limiting production growth in Norway.

Norway has been hard hit by trade restrictions. The countervailing duty imposed by the US in 1991 on fresh/frozen salmon from Norway effectively eliminated this market for Norwegian producers and exporters. As a non-member of the European Union, Norway faces tariffs on exports to the EU. These are considerably higher for processed (smoked, marinated, ready-to-eat) products than for unprocessed products (fresh, frozen, chilled). As a consequence, processing of salmon in Norway has never become important, except for filleting. This situation is not expected to change.

Norway also faces trade restrictions with the EU, of which there has been a series following the first dumping complaint in 1989. As a consequence of dumping and subsidy complaints by Irish and Scottish fish farmers, the European Commission in 1996 initiated an investigation of Norwegian exports. A Salmon Agreement between Norway and the EU was reached in 1997 and represented a solution to "the Salmon Case", i.e., the investigation based on dumping allegations. The Agreement introduced a minimum price for Norwegian exports, indicative ceilings on Norwegian exports to the EU market, and a 3% marketing levy on the value of Norwegian salmon exports to the EU. Proceeds from the marketing levy were used for generic promotion of salmon in the EU. Because of the threat of trade measures, in 1995 the Norwegian government introduced a system of eed quotas for the production of salmon, limiting the amount of feed that may be used by a farm during one year. This contributed to limiting expansion in output.

The Salmon Agreement expired in March 2004 and was followed by new dumping accusations from Scottish farmers. As a consequence, the EU Commission introduced a temporary safeguard measure in the form of a quota, limiting imports from Norway, as well as other producers, as of August 2004. This was followed by further safeguards, and in 2005 by anti-dumping measures against only Norwegian producers. Finally a more permanent system of minimum import prices (from June 2005) was set for four years in January 2006. Hence, market access is likely to be a key factor in how the industry develops. Moreover, the challenge to the industry from Chile's competitiveness is also clear, as Norway is losing market share in all but the European markets.

Chile

The Chilean salmon aquaculture industry has expanded very rapidly since the mid 1980s. Salmon are not native to Chile, but the Chilean coast provides very similar climatic conditions to their natural habitat in the Northern Hemisphere. In particular, good climatic conditions for salmon farming exist in the southern part of the country, where the water temperature varies even less than in Europe. The Chilean salmon industry is concentrated around Puerto Montt and the Chiloé Island in Region X, about 1,000 km south of Santiago, but extends also into Regions XI and XII. Production focuses on Atlantic and coho salmon and salmon trout. Annual harvests can be seen in **Figure 5**. From 1,119 tonnes in 1985, production increased to 615,500 tonnes in 2006, including salmon trout. Coho was initially the most important species as it was thought that a Pacific species was best suited for conditions in Chile. However, it quickly became clear that most markets preferred Atlantic salmon, and coho was surpassed in production volume by Atlantic salmon in 1992. Production of salmon trout accelerated in the 1990s and surpassed coho in 1997. Smaller quantities of chinook and cherry salmon have also been farmed, but are of minor importance. In 2006, Atlantic salmon made up 60% of production, followed by 21.9% for salmon trout and 17.6% for coho.

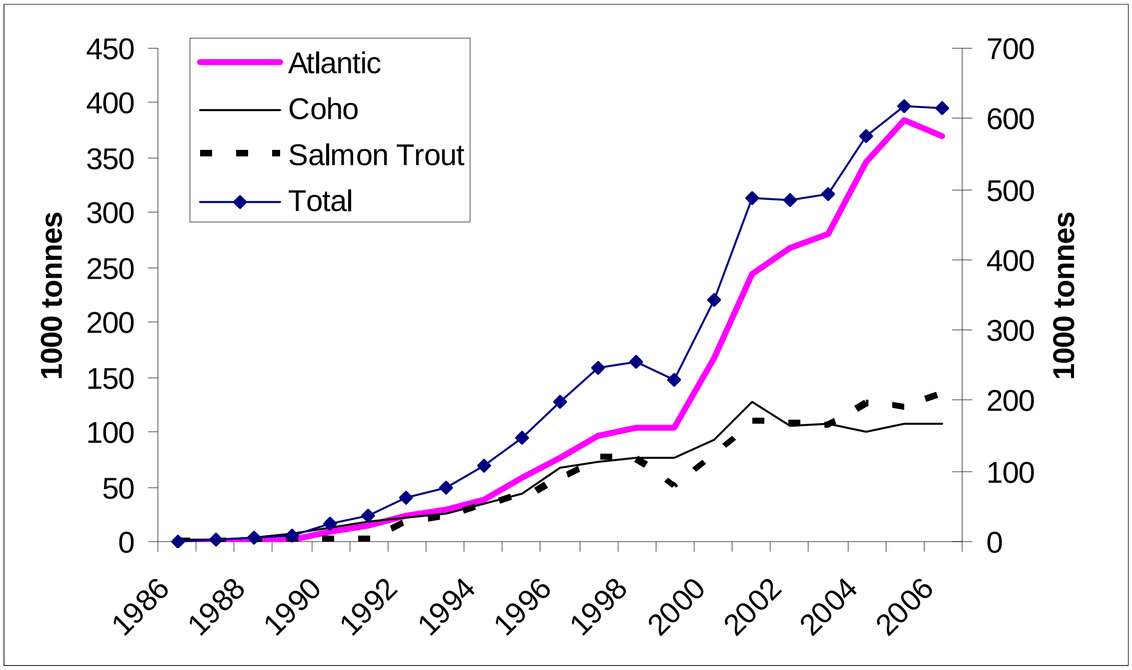

Figure 5: Production of farmed salmoids in Chile

It is interesting to note the rapid growth in Chilean salmon production, as well as the three periods when it "stopped". From 1997 to 1999 the economic crises in Asia hit the Chilean industry particularly hard. Moreover, this was the time when the first dumping complaint in the US was filed. The decrease was particularly pronounced for salmon trout, where Japan was the dominant market. The next slowdown came in 2001, a period marked by weak prices in the salmon market globally. However, it is interesting to note that Atlantic salmon production continued to grow, although at a somewhat slower rate. Production growth for coho and salmon trout not only stopped, it has not recovered since. A primary reason for this is that seafood demand in Japan, the main market for coho and salmon trout, has been stagnant. Finally, after an increase of about 100,000 tonnes from 2003 to 2005, production growth was again stagnant from 2005 to 2006. This is largely due to production problems and disease.

The Chilean salmon industry has developed with a minimum of government intervention, in the spirit of a free market economy. In addition to favourable environmental conditions, it has also benefited from low labour and feed costs, as Chile is the world's second largest producer of fish meal. The Chilean salmon industry has been developed for the most part with venture capital from large, Santiago-based companies. In addition, there are no restrictions on foreign ownership in the salmon industry, and today Canadian, Dutch, Japanese, Scottish and Norwegian farming interests are all represented through joint ventures or fully-owned subsidiaries. The degree of concentration in the industry is fairly high, with the four largest firms accounting for 58% of production in 2006, and the ten largest firms accounting for 85% of the production.

The Chilean salmon industry has been geared towards export markets since the very beginning, as domestic salmon consumption is low. The main markets are the US for Atlantic salmon, and Japan for coho and salmon trout. Most Atlantic salmon is exported fresh/chilled, but this share has declined from 89% in 1990 to about 72% in 2006. The share being exported as frozen has increased accordingly, to 28% in 2006.

The US is the main market for fresh salmon, taking 90% of exports. This provides the Chilean industry with an additional cost challenge, as the fish is shipped by air to the US. Brazil has emerged as another significant buyer of fresh Atlantic salmon, taking about 9% of exports in 2006. Japan used to be a relatively important market for fresh chilled salmon, but its share decreased from 11% in 1995 to only 0.3% in 2001. South American countries are becoming increasingly important markets, and although exports of whole fresh salmon have decreased substantially, it is the most important product form to Brazil and Argentina.

Frozen Atlantic salmon is primarily sent to the US and the EU. They took 35% and 38% of exports in 2006, respectively. However, the shares in different markets vary substantially between years, depending on market opportunities, and Russia and Eastern Europe are also important markets for frozen products in some years. During the last few years further processed product for the processing and catering industries has also become increasingly important, and the exports of salmon pieces and portions were 27.5 thousand tonnes in 2006. Again, the US (58%) and the EU (41%) were the main markets. For coho and salmon trout exports are highly concentrated on the Japanese market. Both species are primarily exported frozen, and traditionally more than 90% has been shipped to Japan. However, as is the case with Norway, Russia is an increasingly important market for salmon trout, although for Chile, Japan remains the main market.

An interesting feature of the Chilean industry is that it has developed a very large export market for salmon fillets to the US (**Figure 6**). This makes the US an even more important market in terms of value relative to other markets. In fact, the degree of processing is significantly higher in Chile than in Norway. This can be attributed at least in part to lower wages in Chile. While wage differentials have been found to have a limited effect when it comes to farming, they do appear to give Chile a competitive advantage vis-à-vis Norway when it comes to processing. However, there is also little doubt that Chile has been more market oriented than other producers. For instance, in the early 1990s, they invented the pin bone out fillet. Until then, the US farmed salmon market had primarily been a market along the eastern seaboard where whole salmon was presented in seafood counters. With the pin bone out fillets, the Chileans opened a completely new market in the Midwest, and led people, who until then barely ate fish at all, to consume substantial quantities. Figure 6 shows Chilean exports to the US by product form, and they clearly tell a story about market adaptation. Exports began with fresh coho, a species caught in substantial quantities by US fishermen. However, it was quickly discovered that Atlantic salmon was the preferred species along the eastern seaboard, where the main markets were located. Hence, in 1991 whole fresh Atlantic salmon took over as the leading species and product form. Fresh fillets were introduced in the early 1990s and quickly became a success, and by 1997 it had taken over as the leading product form by weight. At the same time, the exports of whole fresh salmon started to decline. As the market for salmon became more sophisticated, with increased processing and ready meals, but also discount sales, one can see that Chile also started exporting substantial quantities of frozen fillets.

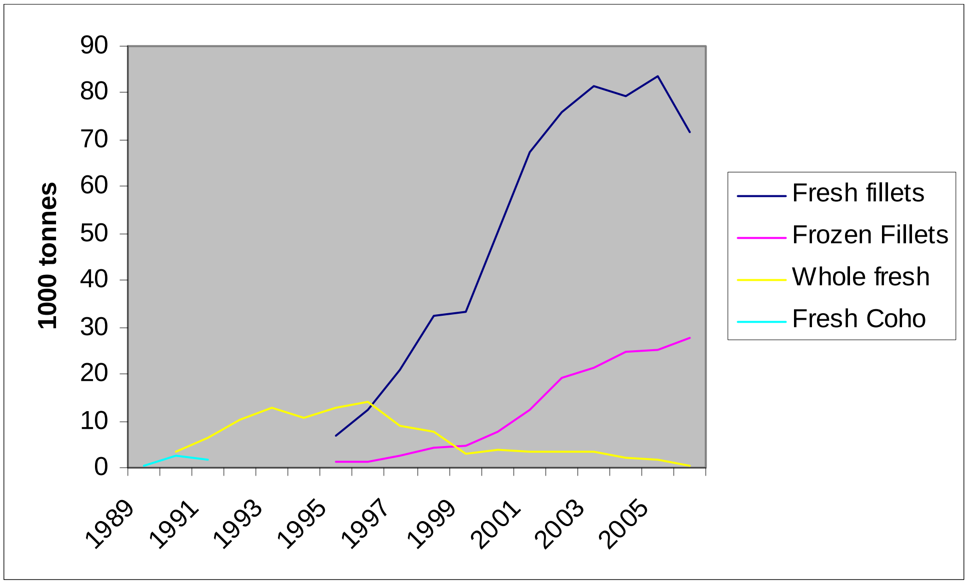

Figure 6: Chilean production divided on product form

<u>Outlook</u>

The potential for further expansion is good and the Chilean industry is expected to continue expanding at a fairly high rate. However, much of the expansion will take place in Region XI, which lacks good infrastructure. Although the industry has the potential for further cost reductions, this may to some extent be counterbalanced by greater production farther south, where cost of production is likely to be higher than in Region X (Bjørndal, 2002). Chile's production nearly surpassed Norway's in 2001 and although its growth was slower than Norway's for a few years, Chile looks set to overtake Norway on a permanent basis in the near future.

In common with Norway, Chile is very dependent on market access, and although exports to Latin America (Brazil, in particular) and the EU have been increasing, Chile is still largely dependent on two markets – Japan and the US. Chile has had its first experience with anti-dumping duties on exports to the US, and is increasingly involved in trade issues with the EU. Moreover, vaccines are used to a lesser degree in Chile than in Europe, and diseases have become a greater concern in recent years, influencing the growth rate of the industry.

The United Kingdom

Commercial farming of Atlantic salmon in Scotland, where all UK production takes place, commenced in the 1970s, following developments in Norway. Production expanded steadily throughout the 1980s and 90s and totalled 160,800 tonnes in 2003.[1] However, it declined to 120,000 tonnes in 2005 before increasing to 128,000 in 2006. The production history is shown in **Figure 7**. There are several reasons for production problems during the last decade. There have been problems with disease, but most importantly, profitability in 2001-2004 was very poor, making access to capital a problem for many producers.

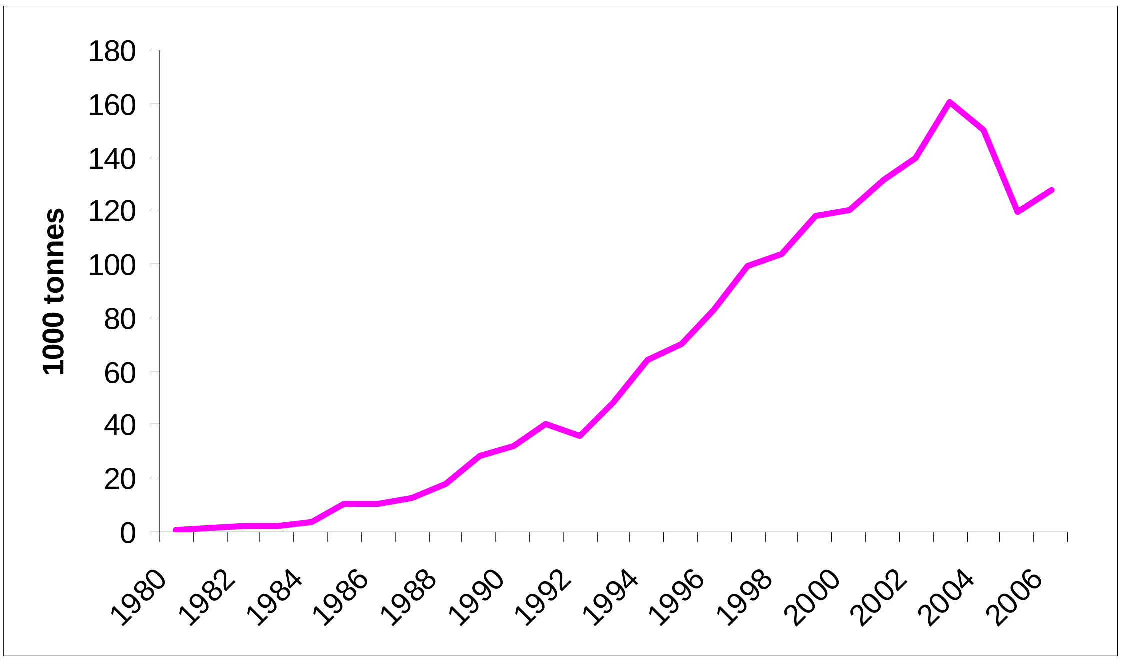

Figure 7: Production of farmed salmon in the UK

In 1968, Marine Harvest Ltd, later a part of the Unilever Group, established salmon farming in Scotland. Most of the sea sites are located on the west coast and they produce 67% of the harvest, while the remaining 33% is produced on the Orkney and Shetland Islands. As there were no restrictions on ownership in Scotland, Marine Harvest quickly became the largest salmon company in the world. The company still holds this position

[1] Different sources provide varying numbers for Scottish salmon production in 2004, and Callender-McDowell reports 162,000 tonnes.

and has obtained a large number of locations in Chile and Norway. During the 1990s, a Dutch firm, Nutreco, owned the company. In 2006 it was taken over by a Norwegian company, Panfish, although the merged company retained the name Marine Harvest.

Fish farming has become one of the most important industries in the coastal regions of Scotland. From small beginnings the industry has grown into a multi-million pound business, employing several thousand people in some of the most remote and economically vulnerable parts of Scotland. In total, some 6,500 jobs are attributed directly to the sector (SQS, 2002). In addition, there are a number of jobs in services, suppliers and processing.

There were 63 registered companies actively producing salmon in 2003, compared to 132 in 1993. This continues a trend of production being concentrated in fewer companies. A further 18 companies were registered as active but producing no fish for harvest in 2003, an increase from only one company in 1999. These 81 companies have 326 registered active sites, although only 202 sites were producing fish in 2003. The industry in Scotland is highly concentrated, with the four largest companies having 88% of production in 2006.

The organisation of the Scottish salmon industry underwent a radical transformation in January of 2000. Concentration of power within the sector required a review of the role of the four main bodies then present, the Scottish Salmon Growers Association, the Scottish Salmon Board, Scottish Quality Salmon and the Scottish Salmon Producers Organisation. The organisation emerging from this review, Scottish Quality Salmon (SQS), represents an amalgamation of the first three organisations and leaves the Scottish Salmon Producers Organisation to function as a producer organisation.

The SQS is intended to operate as a market oriented organisation for the industry whereby the product is certified to have attained a certain standard of specifications. These standards are enforced through Food Certification Scotland and are communicated to the market via the Tartan Quality Mark through a variety of promotional instruments.

The SQS is reported to account for 65% of Scottish production volume and a similar proportion of smoked output.

The emphasis of the SQS is upon the quality of the Tartan Quality Mark, and this has supported some degree of product and price differentiation in the market. The most notable manifestation of this has been the award of the Label Rouge in France, a highly regarded recognition of quality attainment awarded to only a select range of products. Scottish salmon was the first fish and the first non-French product to achieve this status, and this has helped to ensure primacy within the French market and elsewhere.

Scotland is the only major producer of farmed salmon with a large domestic market. Nevertheless, exports are also considerable and represent roughly 50% of output. Farmed salmon accounts for some 40% of all Scottish food exports (SQS, 2002). Most products are exported fresh or chilled, with continental Europe, and France in particular, as the main market. However, small volumes are sent to a number of countries to serve niche markets, and the US is more than a niche market as it imports several thousand tonnes. Exports of cured products are also important, particularly as they are high value products.

Outlook

Potential sites for salmon farming in Scotland appear to have been exhausted. Thus, increased production will have to come from productivity improvements, unless new offshore technology should become economically viable. The scope for productivity improvement is, however, substantial as Scotland has been badly affected by diseases and other production problems for a number of years.

It has proved difficult for Scottish farmers to compete with Norwegian farmers on the basis of price. The Scottish product has increasingly orientated itself to an emphasis on quality, rather than high volume with a lower price. The limitations on Scottish output, especially compared to Norway, inhibit its ability to compete on price and there seems no reason for any change in this. The emphasis upon quality has permeated the supply chain, and even the more stringent health controls are benefiting quality. However, poor profitability has been a challenge, and marginal locations may face serious problems. Declining production after 2003 also indicates an industry with challenges in the future, even if profitability increases.

Canada

Salmon farming in Canada started in British Columbia (west coast) in the early 1970s and later developed in Eastern Canada. Initially it focused on chinook (of which Canada is the largest aquaculture producer with about 15,000 tonnes in 2005, but only 7,000 tonnes in 2006).[2] However, as in other larger producing countries, Atlantic salmon eventually became the most important species. Total output reached 125,000 tonnes in 2006, of which 117,000 tonnes was Atlantic salmon. The develoment in Atlantic salmon production is shown in **Figure 8.** In recent years, British Columbia has about 65% and New Brunswick 29% of Canadian production.

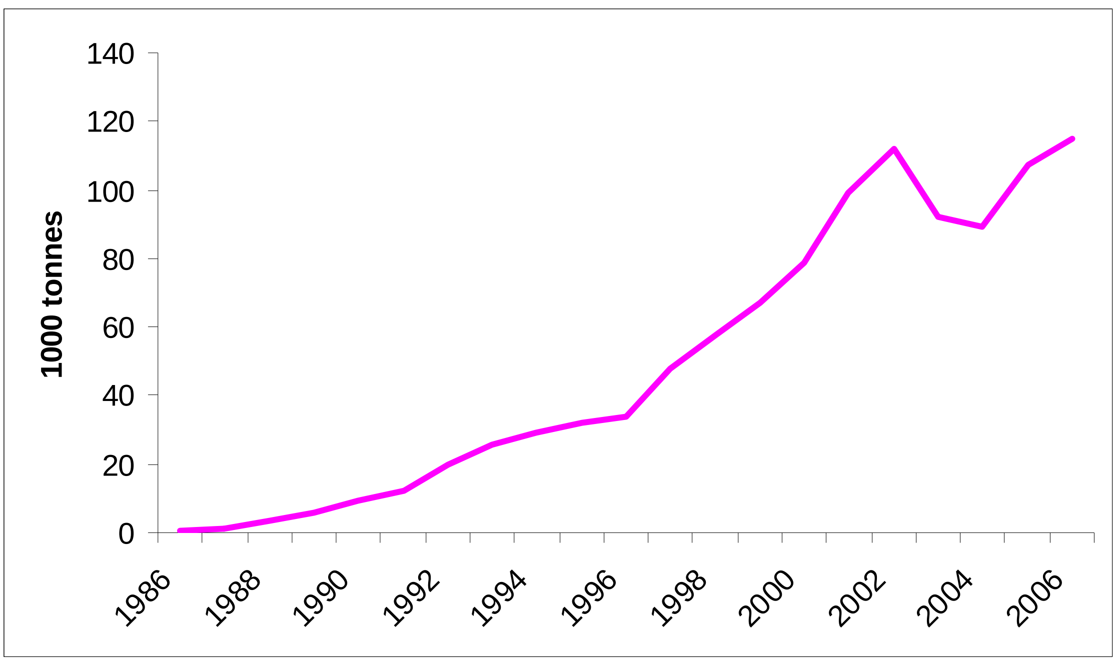

Figure 8: Production of farmed salmon in Canada

[2] New Zealand is the only other important Chinook producer, with 9,300 tonnes in 2005.

When salmon farming developed in British Columbia, only two Pacific species, coho and chinook, were reared. Atlantic salmon was introduced at the end of the 1980s (Bjørndal, 1990). Subsequently, Atlantic salmon became the preferred species, having 86% of British Columbia's output in terms of volume in 2001. No Pacific salmon is farmed in New Brunswick, Nova Scotia or Newfoundland. The Canadian industry is highly concentrated, with the four largest companies accounting for about 92% of production in 2006.

Canadian salmon is primarily exported in a round fresh or chilled form to the United States, with the domestic market as the second most important market. It is of interest to note that in contrast to Chile, Canadian salmon is primarily shipped as round. This indicates that, to some extent, the Canadian producers are serving different market segments than the Chilean producers.

Outlook

The scope for increased farmed salmon and salmon trout production in New Brunswick and Newfoundland is very limited for reasons of site availability and unfavourable biological conditions. There is room for some expansion in Nova Scotia and, in theory, for substantial growth in British Columbia. As a result of strong opposition to salmon farming from environmental and native groups, fishermen and residents, a moratorium on the issuance of new salmon farming licences was imposed in 1995. The moratorium was lifted in September 2002, but given continued public opposition to the industry, it is likely that the government will proceed cautiously in granting new licences. Under the circumstances, it is difficult to predict future Canadian production. Expansion on the East Coast will be limited for geographical and biological reasons. On the West Coast, hostile public opinion will probably continue to hinder industry growth.

Other Farmed Salmon Producers

In addition to the four main producers, there is substantial production of farmed salmon in a number of countries. We will take a quick look at some of them here. However, it is worthwhile to note that with the possible exception of the Faroe Islands, these countries are likely to see their share of total production decrease, and in many cases their industries will only serve local or niche markets. It is interesting to note in **Table 1**, which shows production at five-year intervals for five selected countries, that production was reportedly highest in 2000.

Table 1 Production of farmed salmon, other countries

	1985	1990	1995	2000	2005	2006
USA	0	2	17	22	10	10
Ireland	2	7	12	19	12	15
Faroe Islands	1	13	8	30	17	12
Japan	9	24	16	13	12	10
Finland	7	15	17	15	13	15

In the early 1980s, Japan was the second largest producer of farmed salmon in the world, primarily producing coho. Production increased steadily from 1,855 tonnes in 1980 to a peak of 25,730 tonnes in 1991. Subsequently, production has been decreasing. In 2003, output was 12,000 tonnes, and in 2006, about 10,000 **(Table 1).** Because of water temperature the growing season in Japan is fairly short, meaning that fish tend to weigh less than in Chile. Moreover, production is small scale and not as industrialised as in Chile. For these reasons, it has been difficult for Japanese farmers to compete with their Chilean counterparts.

Other producers of farmed Atlantic salmon are Ireland, the Faroe Islands, Iceland, Australia and the US (**Table 1).** Irish production grew to a peak of 23,700 tonnes in 2001, but has subsequently declined to 14,500 tonnes in 2006. Irish output is increasingly becoming a niche product with a strong focus on ecologically farmed salmon. The Faroe Islands increased their production substantially, to 47,000 tonnes in 2003, taking advantage of the fact that Norwegian production was limited by feed quotas. However, severe financial problems have stopped production at a number of sites, and production in 2006 was only 11.900 tonnes. As prices improve, it is expected that Faroese production will increase. Icelandic production is small and takes place in land-based facilities. The potential for increased production is limited. In Australia, where Tasmania is the centre of salmon farming, production has levelled off in recent years. In the United States, Atlantic salmon is farmed in Maine and the state of Washington. Production is not expected to increase, as new sites are not likely to become available, particularly due to environmental constraints.

Table 1 also shows salmon trout production in Finland. In 1985 Finland took over from Norway as the largest producer of salmon trout, and kept the leading position until 1993, when Chile supplanted it. Production peaked in 1991 at 19,100 tonnes and decreased steadily after that to a low of 12,000 tonnes in 2004. It has picked up again during the last few years. However, in contrast to Chile and Norway, Finnish production has primarily been sold in the domestic market with only limited exports. Production diminished after the domestic market was opened to competition from Norwegian salmon and salmon trout. The fact that production has picked up during the last few years is encouraging, as it indicates that the industry is becoming more competitive.

Wild Salmon Production

There are wild commercial harvests of seven salmon species: pink (*Oncorhynchus gorbuscha)*, chum (*Oncorhynchus keta)*, sockeye (*Oncorhynchus nerka)*, coho (*Oncorhynchus kisutch*), chinook (*Oncorhynchus tshawytscha*), masu (*Oncorhynchus masou*) (all genues *oncorhyncus)*, and Atlantic salmon (*Salmo salar).* Wild commercial harvests of masu salmon and Atlantic salmon are very small and we will not consider them further i

Figure 9 illustrates trends in world wild salmon harvests by species for 1980-2006. Total salmon harvests rose during the 1980s and early 1990s, from just over 500,000 tonnes to a peak of almost one million tonnes in 1995, but fell to 800,000 tonnes by 2000. Pink, chum and sockeye in that order, account for most commercial production. Both sockeye and chum salmon harvests rose during the 1980s and early 1990s, before declining in the late 1990s. Pink salmon harvests were sharply higher in the 1990s than in the 1980s, but variy substantially between years. A substantial share of increased wild salmon landings is due to hatcheries. They are prevalent in Alaska, as well as Japan and Canada and primarily supply chum and pink salmon.

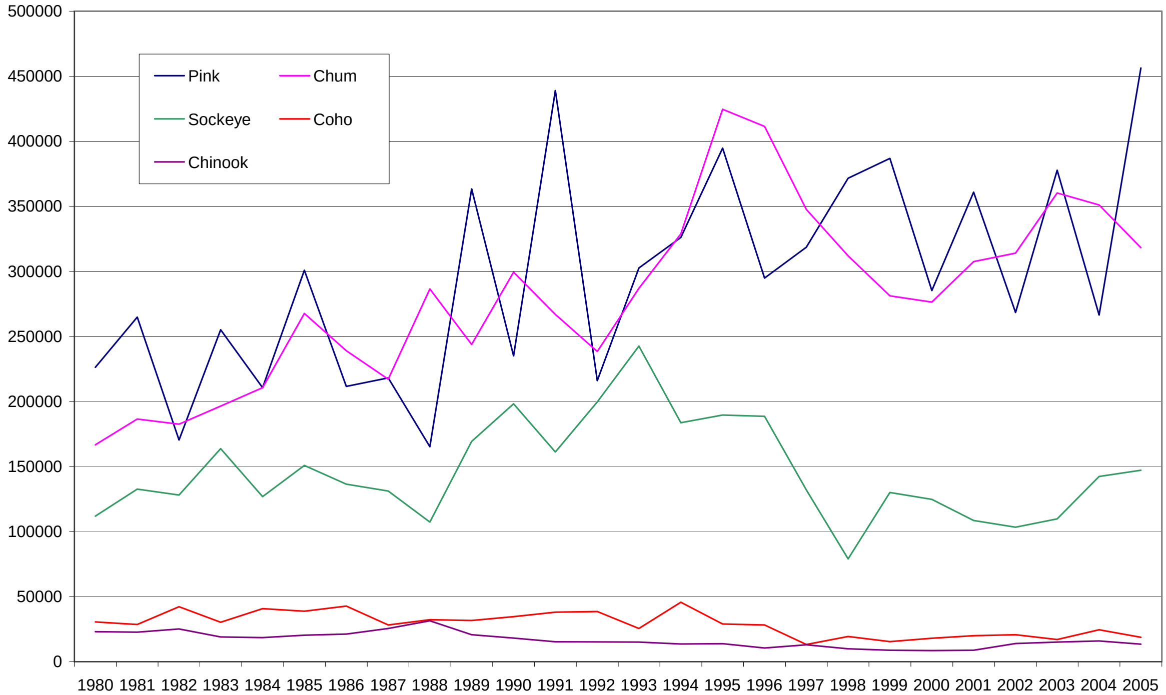

Figure 9: Harvest of wild salmon

Figure 10 shows the distribution of wild salmon landings between the four main harvesting countries. The United States leads, accounting for about 41% of the total global catch over the period 1980-2005. Over the same period, Japan accounted for 29%, Russia 21%, and Canada 9%.

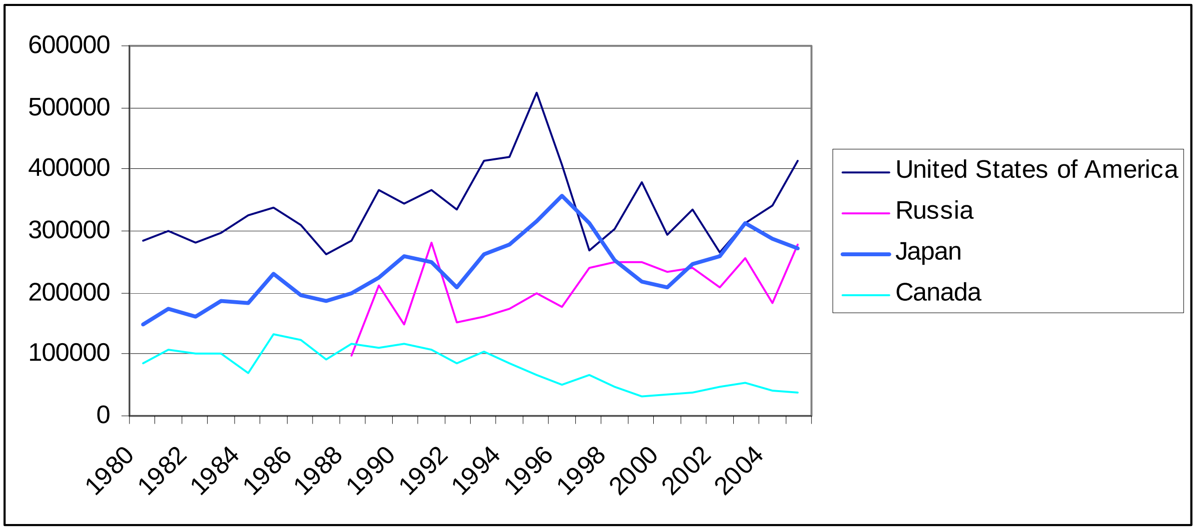

Figure 10: Wild salmon harvest divided by country.

The importance of the different Pacific salmon species differs amongst countries. The US catches mainly pink and sockeye salmon, but chum has gained in relative importance in recent years, while sockeye catches have decreased. Over 80% of the Japanese catches are chum. Russia catches mostly pinks, while Canada lands mostly pinks and sockeye. It is of interest to note that Russian salmon has had a substantial impact on the Japanese market in the 1990s. This is due to the fact that the old Soviet Union did not export salmon, but after the collapse of communism, Russian fishermen preferred selling to the higher paying Japanese market. Japanese vessels that buy Russian quotas also land some of the Russian salmon.

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Equilibrium Displacement Modeling: A Literature Review with Special Reference to Salmon*

by

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Equilibrium Displacement Modeling: A Literature Review with Special Reference to Salmon

Piggott (1992, p. 117) defines equilibrium displacement modeling as "comparative static analysis of general function models." The EDM method has been used by economists to evaluate policy issues at least since Hicks (1932). The purpose of this paper is to highlight important developments in the EDM literature, and to illustrate how the method has been applied to gain insight into important issues affecting the salmon industry.

The exercise is useful for two reasons. First, EDM models are increasingly being used to evaluate the effects of trade policies, technical change, market power, R&D, promotion, and other factors affecting producer and consumer welfare in multistage production systems (see Zhao, Mullen, and Griffith (2005) and the references cited therein). Thus, it is of some interest to be aware of the technique and how it has been refined over time to address these issues. Second, the literature review provides necessary background for the EDM to be developed for the "Salmon Market Analysis Modules" project. Innovations in the technique with respect to incorporating uncertainty into the modeling framework will be of special interest.

We begin with a brief description of the technique. A sketch of the theoretical literature is then provided, following by a summary of empirical findings with respect to salmon. The paper closes with some concluding comments.

EDM in a Nutshell

As noted by Piggott (1992), equilibrium displacement modeling is a procedure involving three basic steps:

1) A particular market situation is characterized by a set of supply and demand (and perhaps other) functions that are general in the sense that no particular functional forms are assumed.
2) The market is disturbed by a change in the value of some exogenous variable, and

3) The impacts of the disturbance are approximated by functions that are linear in elasticities.

To illustrate, consider the following model of an isolated market:

(1) $D = D(P,Y)$ (domestic demand)

(2) $X = X(P)$ (export demand)

(3) $S = S(P)$ (supply)

(4) $S = D + X$ (market clearing)

where *D*, *X*, and *S* are domestic consumption, exports, and domestic production, respectively, *P* is market price, and *Y* is consumer income. The model has four endogenous variables (*D*, *X*, *S*, and *P*), and one exogenous variable (Y). Equations (1) - (3) are in general function form. The endogenous variables in the equations are interpreted as values that obtain in the *initial* equilibrium, i.e., before the disturbance caused by a change in *Y*. Other exogenous variables that affect supply and demand are suppressed.

To evaluate the effects of an increase in income we first totally differentiate (1) - (4) and convert the partial derivatives to elasticities to yield:

(5) $d\ln D = \eta_d\, d\ln P + \delta\, d\ln Y$

(6) $d\ln X = \eta_x d\ln P$

(7) $d\ln S = \varepsilon\, d\ln P$

(8) $d\ln S = k_d\, d\ln D + k_x\, d\ln X$.

Equations (5) - (8) is the structural model in EDM form. All variables are expressed as proportionate (or percentage) changes. The parameters are either elasticities or quantity shares. Specifically, η_d (< 0)and η_x (< 0) are domestic and export demand elasticities with respect to price, δ (> 0) is the income elasticity, ε (> 0) is the domestic supply elasticity, $k_d = D/S$ is the domestic quantity share, and $k_x = X/S$ is the export quantity share.

Comparative static analysis is done by first solving the model for the reduced from. For this purpose, we begin by deriving the export supply relation. Deleting equation (6) (to treat price as temporarily exogenous) and solving the remaining equations simultaneously yields:

(9) $$d\ln X = \varepsilon_x \, d\ln P - \left(\frac{k_d \, \delta}{k_x} \right) d\ln Y$$

where $\varepsilon_x = (\varepsilon - k_d \, \eta_d)/k_x$ is the export supply elasticity. Under the assumed parameter values the export supply curve is upward sloping ($\varepsilon_x > 0$), and an increase in income shifts the export supply curve to the left. The magnitude of the supply shift increases with the domestic consumption share, and with the income elasticity. (With price constant supply response is nil, so exports must decrease to accommodate the increase in domestic consumption caused by an increase in income.)

Setting export supply equal to export demand [equation (9) = equation (6)] gives the reduced-form equation for price:

(10) $$d\ln P = \left(\frac{k_d \, \delta}{k_x(\varepsilon_x - \eta_x)} \right) d\ln Y \, .$$

From equation (10) an increase in income always increases price. The one exception is when the country in question is a small-nation exporter ($\eta_x = -\infty$). In this instance, an increase in income results in an increase in domestic consumption with a counterbalancing decrease in exports. This can be seen by substituting (10) into (5) and (9) to get the reduced-form equations for domestic consumption and exports:

(11) $$d\ln D = \left(\frac{\delta(k_d \eta_d + k_x(\varepsilon_x - \eta_x))}{k_x(\varepsilon_x - \eta_x)} \right) \delta \, d\ln Y$$

(12) $$d\ln X = \left(\frac{k_d \, \delta \eta_x}{k_x(\varepsilon_x - \eta_x)} \right) d\ln Y \, .$$

Comparing equation (11) and (12), when price is permitted to adjust, an increase in income always causes exports to decrease. The general-equilibrium response of domestic consumption to an increase in income, however, is indeterminate. The reason is that the price rise associated with the demand shift causes a reduction in quantity demanded. This price effect works in opposition to the income effect, and could be large enough to offset the income effect resulting in a decrease in consumption.

Setting $\eta_x = -\infty$ reduces equations (11) and (12) to:

(11a) $$d\ln D = \delta\, d\ln Y \Rightarrow \frac{dD}{d\ln Y} = D \cdot \delta$$

(12a) $$d\ln X = \left(\frac{-k_d\,\delta}{k_x}\right) d\ln Y \Rightarrow \frac{dX}{d\ln Y} = -D \cdot \delta\,.$$

Thus, if the country is a small exporter, the increase in domestic consumption associated with an increase in income is exactly offset by a decrease in exports. The reason, of course, is that price and thus production is fixed, which means exports have to decrease to accommodate the demand shift.[1]

As the foregoing illustration demonstrates, EDM in essence is comparative static analysis. The main difference is that changes in variables are expressed in percentage (rather than absolute) terms, and parameters are expressed in terms of elasticites rather than derivatives.

Equilibrium displacement modeling is sometimes referred to as "Muth modeling" in recognition of Richard F. Muth's seminal contribution "The Derived Demand Curve for a Productive Factor and the Industry Supply Curve" published in 1964. In the trade literature the technique is sometimes referred to as "hat calculus modeling" due to the use of the carrot symbol to denote proportionate changes, as in $\hat{x} = d\ln x$ (Bhagwati, Panagariya, and Srinivasan, 2001, Chapter 9).

Literature Sketch

[1] The implication of this analysis for generic advertising is clear: in a small, open economy increases in domestic demand are exactly offset by decreases in exports, rendering the program unprofitable *a priori*. The same is true for export promotion. That is, an advertising-induced increase in export demand is exactly offset by reduced domestic consumption when price is not affected by the demand shift, rending export promotion unprofitable *a priori*.

In this section we trace the evolution of equilibrium displacement modeling, starting with Hicks's original contribution.

<u>Hicks (1932)</u>

Uses a log differential model to assess the effects of technical change on labor's share of the cost of production. Generally considered the first application of the EDM approach.

<u>Muth (1964)</u>

Extends Hicks framework to include supply schedules and equilibrium in input markets. Derives "general equilibrium" output supply and input demand curves for a competitive industry that uses two inputs to produce a single output under constant returns to scale.

<u>Floyd (1965)</u>

Applies Muth's model to determine the effects of farm price supports on the return to land and labor in agriculture.

<u>Gardner (1975)</u>

Applies Muth's model to determine the effects of shifts in farm supply, marketing services supply, and retail demand on the farm-retail price spread.

<u>Alston and Mullen (1992)</u>

Develops a dual version of Muth's model to evaluate costs and benefits associated with industry R&D for a traded good (open-economy model).

<u>Piggott (1992)</u>

Discusses strengths and weaknesses of EDM for policy analysis. One of the first papers to define "equilibrium displacement modeling" and promote its use.

<u>Alston, Norton and Pardey (1995)</u>

A 585 page book entitled *Science Under Scarcity* that elucidates the application of Muth-type models for evaluating the returns to agricultural research. The "Bible" for EDM practitioners.

<u>Perrin (1997)</u>

Extends Muth's framework to the *n*-input case and generalizes the specification of technical change. Technology-induced shifts in farm supply are shown to equal the rate of technical change plus the share-weighted induced change in input prices.

Holloway (1991), Azzam (1998), Kinnucan (2003)

Extends the Muth/Gardner model to include oligopoly power in the output market and oligopsony power in the farm market.

McCorriston, Morgan, and Rayner (1998, 2001), Weldegebriel (2004)

Extends the Muth/Gardner model to include imperfect competition and non-constant returns to scale.

Chung and Kaiser (1999) (see also Wohlgenant (1993, 1999))

Developed EDM-based methods to measure welfare effects when demand and supply shifts are not parallel.

Davis and Espinoza (1998), Zhao *et al*. (2000), Piggott (2003)

Develop methods to incorporate parameter uncertainty into EDMs. Bayesian procedures and Monte Carlo integration are used to calculate confidence intervals to indicate the precision of simulated effects, and to test whether welfare effects implied by the EDM are significant in a statistical sense.

Harrington and Dubman (2008)

Extends equilibrium-displacement methods to include mathematical programming. An aggregate model of the US farm sector is developed to illustrate procedures, and to indicate sectoral adjustments to exogenous shocks that may occur under alternative markets structures (perfect competition, monopoly/monopsony, and mixed competition).

Applications to Salmon

Here we summarize the key findings of studies that use equilibrium displacement models to analyze policies of importance to the salmon industry. The studies are organized chronologically by subject matter (marketing, exchange rates, tariffs, and supply expansion and control).

Marketing

Kinnucan and Myrland, *ERAE*, 2000

Uses an EDM to determine the optimal advertising intensity for a competitive industry that produces large tradable surpluses and raises funds for promotion through a per-unit assessment on farm output or, alternatively, on exports.

Results suggest that, owing to the ability to shift part of the advertising cost onto foreign consumers, an export levy in general is more profitable from the domestic producer perspective than a levy on farm output. In addition, domestic consumers prefer an export levy because, holding constant the advertising effect, it lowers (rather than raises) domestic price.

Applying the model to the 1997 Norway-EU Salmon Agreement, results suggest the Agreement was welfare increasing from the domestic (Norwegian) producer perspective in that the optimal export levy of between 3.5% and 5.8% was well above the pre-agreement levy of 0.75%.

Kinnucan and Myrland, *MRE*, 2002

Uses an EDM to determine the importance of international price linkages on the optimal promotion expenditure. Results suggest an inverse relationship between the price transmission elasticity and optimal intensity. The reason for this somewhat surprising result is that a smaller price transmission elasticity implies less sensitivity of foreign demand to advertising induced increases in market price. Applying the model to Norway's salmon promotion program results suggest observed intensity of 1.54 percent is well below the economic optimum by a factor of at least two. Market-specific optimal intensities are higher for Norway (5.4), Japan (3.8), and ROW (3.8) than for EU (2.1). This suggest producer returns could be increased by diverting funds from the EU market to other markets, especially the domestic market.

Kinnucan and Myrland, *MRE*, 2002

Uses an EDM to determine the optimal seasonal allocation of a fixed promotion budget when substitution effects are important and prices are determined under competitive conditions.

Decision rules depend on elasticities of supply and demand, advertising elasticities, and consumer expenditure shares, all of which can vary seasonally.

Applying the rules to Norwegian salmon promotion in France, results suggested that a smooth expenditure pattern in general is more profitable than pulsing. Specifically, the actual quarterly allocation of 4%, 52%, 17%, and 27% was inefficient in that the optimal allocation of 23%, 26%, 20%, 31% would have enhanced producer profits by 27%.

Ignoring product substitution distorts the allocation rule, causing optimal expenditures in the second quarter to be overstated by 36% with corresponding reductions in the remaining quarters.

Kinnucan and Myrland, *Agribusiness*, 2003

An EDM is used to determine the free-rider effects of salmon promotion sponsored by the Norwegian Seafood Export Council.

Results suggest promotion intensification funded by an increase in the levy on Norwegian salmon sold in the EU would have a positive effect on producer surplus worldwide. However, the distribution of gains is uneven, with most of the benefit (47%) accruing to producers in the United Kingdom. Norway, with a 47% market share, receives only 23% of the incremental gain.

The reason for the uneven distribution is tax shifting. Specifically, the heighted EU export tax used to fund the promotion increment raises the price EU producers receive for salmon sold in the EU, which augments the gain they receive from the demand shift. The same tax lowers the price Norwegian producers receive for their EU sales, which attenuates their from the demand shift.

Exchange Rates

Kinnucan and Myrland, *JAE*, 2002

Uses an EDM for the Norwegian salmon sector to test Houck's assertion that "exchange rate movements can easily swamp or obscure the desired price, trade, or production effects of any specific agricultural commodity policy."

Results were affirmative in that the three most important variable to affect the farm price of salmon in Norway were:

1) the euro/kroner exchange rate ($p^*/Z_E^* = -0.76$)
2) feed quota ($p^*/F^* = -0.38$)
3) the US$/kroner exchange rate ($p^*/Z_R^* = -0.17$).

By way of comparison, the largest advertising effect was $p^*/A_E^* = 0.017$ and the largest levy effect was $p^*/T_E^* = -0.008$, which means that kroner strengthening or feed quota relaxation could easily neutralize the effect of the levy *cum* advertising on farm price.

Similarly, the largest transportation cost effect was $p^*/C_E^* = -0.04$, larger than the advertising effect, but substantially smaller than exchange rate effects.

Tariffs

<u>Kinnucan and Myrland, *App. Econ.*, 2005</u>

Uses an EDM to determine the effects of tariffs and income growth on the world salmon market.

Results suggest the total income elasticity in world trade for salmon is about one, which means imports worldwide will grow at about the same pace as world income.

However, owing in part to policies that restrict supply response, not all exporters will share evenly in this growth, with UK producers benefiting the most and Norwegian producers the least.

US tariffs on imports from Norway and Chile are counterproductive in that they reduce world salmon imports with little effect on the US price. The reason is that import demand is more elastic than export supply when tariffs are targeted, which means most of the tariff's incidence falls on producers in the exporting country rather than consumers in the importing country.

Norway's feed quota (biomass limit) reduces the efficacy of US tariffs, makes imports less responsive to income, and increases price volatility. Hence, quota elimination may yield producer benefits in excess of producer losses associated with a lower world price.

Kinnucan, and Myrland, *JAE*, 2006

Uses an EDM to determine the price effects of safeguard tariffs on salmon imports from Norway, Chile, and Faroe Islands contemplated by the European Commission.

Results suggest the tariffs lack efficacy in that most of the tariffs' incidence falls on producers in the exporting countries with little benefit for producers in the importing country. For example, a 6% tariff on imports from Norway reduces the Norwegian price 5.5% and raises the UK price a mere 0.5%. The combined effects of a 6%, 30%, and 22% tariffs on imports from Norway, Chile, and Faroe Islands, respectively, on the UK price is a mere 6.6%.

The reason the tariffs are ineffective is that export supply is less elastic than import demand on a bilateral basis, which means most of the tariff is borne by targeted producers rather than EU consumers. The incidence problem is exacerbated by feed quota (biomass limit) that Norway uses to limit its production.

A marketing fee that expands demand is shown to be less distortionary than its tariff equivalent, and thus may be preferred from a second-best perspective.

Supply Expansion and Control

Kinnucan and Myrland, *JIATD*, 2006

Uses an EDM to determine the effects of increased supplies of farm salmon from Chile on world salmon prices, trade flows, and producer welfare.

Results indicate that the 71% increase in exports from Chile between 2000 and 2002 generated a total surplus gain of $1.3 billion. Most the gain ($1.03 billion) accrues to Chilean producers, as might be expected since the implied cost reduction (58%) far exceeded the associated price decline (11%). With the lower prices consumers gain $771 million, and Chile's international competitors lose $525 million. Most of this loss

($381 million) is absorbed by Norwegian producers, thanks in part to the feed quota that makes Norwegian supply less elastic.

Removal of the feed quota leaves the total welfare gain from Chile's supply expansion unchanged at $1.30 billion but shifts the incidence in favor or producers. Specifically, removal of the feed quota causes the producer incidence of the welfare gain to rise from 41% to 54%. The producer gain rises because quota removal makes Norwegian supply more elastic, which attenuates the price decline associated with Chile's supply expansion.

Overall, results indicate the general equilibrium demand curve for salmon in world trade is elastic at -1.2. This suggests feed quotas, tariffs, or other trade restrictions are not an effective instrument for assisting salmon producers.

Concluding Comments

As this review suggests, equilibrium displacement modeling has a rich intellectual history, and has proved useful in applied policy analysis. We now know, for example, why anti-dumping and safeguard duties are not apt to be effective in raising the import price of salmon. In most instances, import demand is more elastic than export supply, which means most of the tariff is borne by the foreign producer rather than the domestic consumer. We have also learned that attempts to adapt salmon supply to market conditions via restrictions on feed use or biomass can have unintended consequences in that such restrictions reduces the export supply elasticity. This increases price volatility, reduces consumer incidence of salmon tariffs, and magnifies declines in world price associated with productivity-based increases in supply from countries that do not restrict output.

Marketing applications have been useful in assessing whether promotion is an effective instrument for resolving trade disputes, and in identifying the optimal rate of assessment. They have also shed light on the free-rider problem associated with industry-sponsored promotion efforts. For example, if international promotion is funded by an export tax, as is true of Norway's salmon promotion program, then foreign producers who do not contribute to the promotion effort receive a double benefit: once from the higher world price associated with the tax, and again from any price increase associated with the demand shift.

An EDM model of the world salmon market confirmed Houck's thesis that movements in exchange rates can easily swamp or obscure the price, trade, and production effects of sector-specific policies. For example, a one percent movement in the Norway-EU exchange rate was found to have three times the effect on the farm price of Norwegian salmon as a one percent change in the feed quota.

As noted by Piggott (1992) and by Harrington and Dubman (2006), EDMs have their limitations. These include:

- Displacements are restricted to the neighborhood of the initial equilibrium.
- Paths of adjustment are ignored. (This weakness can be overcome to some extent by repeated applications of the procedures for different lengths of run.)
- Structural parameters (elasticities) are assumed to be fixed. (The Lucas critique.)
- Technology is assumed to be known and fixed.
- Responses are assumed symmetric. That is, a one percent increase in an exogenous variable has the same proportionate effect on endogenous variables as a one percent decrease.

Some of these limitations can be overcome, or at least mitigated, through appropriate modification of the model, or simulation procedure. For example, if advertising response is asymmetric, as suggested by the advertising elasticity can be changed between simulations to indicate the differential effects of an increase versus decrease in advertising expenditure.

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Cost Functions in Analysis of Tariff and Technology Changes[1]

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"Equilibrium Displacement Model", or EDM, is a term often used for comparative statics models that are expressed in log-linear form, especially in agricultural and natural resource economics. Rather than relying solely upon simple demand and supply matrices to establish market equilibrium adjustments, EDM models generally use characteristics of the production function, combined with optimal behavioral conditions with respect to it, to provide a more detailed characterization of equilibrium displacements resulting from changes in policies or technologies.

Production technology can be characterized as readily with a cost function as a production function, with some benefit in relating technological parameters to market behavior (Perrin, 1997.) Given the interest of this conference in EDMs for technical change, and given the EDMs previously developed by Kinnucan and Myrland (2005, KM05 henceforth) for the Norwegian salmon industry, my comments will demonstrate the use of a cost function in a log-linear displacement model of the effects of technical change, a tariff, and world income (a demand shifter.) This model is a variant of one I have earlier published (Perrin, 1997, available at http://digitalcommons.unl.edu/ageconfacpub/ .

[1] Prepared for the research conference on Salmon Market Analysis Modules, Longyearbyen, Norway, Sept 25-26, 2008 . Thanks to Lilyan Fulginiti for helpful comments on this paper and collaboration in development of these models.

A cost function applicable to the Norwegian salmon industry

Start by defining the industry-level technology in terms of a cost function. We can reasonably assume that in the vicinity of the equilibria, the technology is continuous and convex, and exhibits constant returns to scale (this can be relaxed, as I've shown in a 1997 article.) Here I will posit three unspecified inputs, such as materials, labor and capital. A cost function such as this could possibly be estimated for the Norwegian salmon industry by regressing total expenditures on input prices, output and an indicator of technology as simple as a time trend.

$C(\mathbf{w}, y, \tau) \equiv \min_{x}\{\mathbf{wx} \mid (\mathbf{x}, y) \in \mathrm{T}_{\tau}\}$, where

$\mathbf{x}$ is an nx1 vector of inputs,

$\mathbf{w}$ is a 1xn vector of input prices,

(1) y is salmon production,

τ is an index of technical change

T_{τ} is the technology set τ, such that $d\mathrm{T} / d\tau$ represents some discrete change in technology

To represent change in this technology, we evaluate first- and second-order derivatives with respect to τ (which will appear in the differentiation of the equilibrium equations.) Given an estimate of a cost function with a specific functional form, these derivatives would have numerical values, but it is also useful to convert derivatives of the cost function into generalized share and elasticity parameters. For that purpose, the following notation and derivations are useful:

$\mathbf{H} \equiv (\tilde{\mathbf{x}})^{-1} C_{\mathbf{ww}}(\mathbf{w}, y, \tau)\tilde{\mathbf{w}}$, nxn output-constant input demand elasticity matrix, where subscripts indicate derivatives and $\tilde{\mathbf{x}}$ and $\tilde{\mathbf{w}}$ designate matrices with $\mathbf{x}$ and $\mathbf{w}$, respectively, on the diagonal;

(2)

$\mathbf{s} \equiv C_{\mathbf{w}}(\mathbf{w}, y, \tau)(\tilde{\mathbf{x}})^{-1}$, a $1xn$ vector of input shares;

$\delta \equiv -C^{-1}C_{\tau} = -d\ln C / d\tau$, the rate of technical change;

$\mathbf{B} \equiv (\tilde{\mathbf{x}})^{-1} C_{\mathbf{w}\tau} + \mathbf{i}\delta$, $nx1$ bias vector of technical change, measuring the percentage change in shares at constant prices, where $\mathbf{i}$ is a $nx1$ unit vector.

If the technical change has no biases, the output-constant derived demand for all inputs falls by δ, the rate of technical change. The share-weighted sum of biases (as defined here) must equal zero, so if the technical change is biased toward one input, it must be biased against one or more other inputs. These biases change input shares, but do not affect change in cost, δ.

Equilibrium conditions

Now define equilibrium equations in the salmon industry output and input markets, all of which are assumed here to be perfectly competitive (alternative assumptions are also feasible.) Specify, similar to KM05, that net demand for salmon exports is a function of the world price, p^w, and world income, *Y,* implying that Norway is not a small country in the farmed salmon market. The "world" imposes an ad valorem tariff on their salmon imports, a price wedge equal to *t* times the Norwegian domestic price, *p*. Following KM05, I assume zero domestic demand, though that could easily be relaxed. I assume zero profits in the salmon industry, which simply implies that all revenues are paid out to owners of inputs (equation c below.)

The system of equilibrium equations is:

(3)
a. net export demand: $y = f(p^w, Y)$
b. foreign ad valorem tariff: $p^w = p(1+t)$
c. zero industry profit: $py = C(\mathbf{w}, y, \tau)$
d. optimal **x**: $\mathbf{x} = C_{\mathbf{w}}(\mathbf{w}, y, \tau)$
e. supply of **x**: $\mathbf{x} = S(\mathbf{w})$

Given that there are *n* inputs, this equilibrium system involves 2*n*+3 equations, 2*n*+3 endogenous variables (production, world price, domestic price, *n* input prices and *n* input quantities) and three exogenous variables, world income *Y*, world tariff *t*, and technology, τ .

[Note something a bit peculiar here. I have characterized *firm* behavior in input and output markets with respect to characteristics of the *industry-level* cost function. Alternatively, the model can be extended slightly to represent *N* identical firms responding to a common firm-level technology (see Perrin, 1997), but it is simpler in the present version and conceptually defensible.]

Log-differentiation of the equilibrium system

Following comparative statics logic, next steps are to totally differentiate each of the equilibrium equations, then solve the system to describe changes in endogenous variables in response to changes in exogenous variables. Expressing these differential equations in terms of logarithms of variables ("log differentials"), along with the following elasticity definitions, will allow us to express the log differentials of these equations efficiently. Define:

$\eta \equiv d\ln y / d\ln p$, price elasticity of world demand;

(4) $\varepsilon \equiv d\ln y / d\ln Y$, income elasticity of world demand;

$\Sigma \equiv$ *nxn* input supply elasticity matrix;

To proceed with the comparative statics, log differentials of equilibrium equations can now be derived as:

a. $d\ln y = \eta d\ln p^w + \varepsilon d\ln Y$

b. $d\ln p^w = d\ln p + dt$

(5) c. $d\ln p = \mathbf{s} d\ln \mathbf{w} - \delta d\tau$

d. $d\ln \mathbf{x} = \mathbf{H} d\ln \mathbf{w} + \mathbf{i} d\ln y + (\mathbf{B} - \mathbf{i}\delta) d\ln \tau$

e. $d\ln \mathbf{x} = \Sigma d\ln \mathbf{w}$

The results in (5c) and (5d) follow from substituting definitions in equation (2) above, where derivatives of the cost function appear. Re-arranging these equations with endogenous variables on the left, exogenous on the right, in detached coefficient matrix format, the system of equations (5) can be written as:

(6)
$$\begin{bmatrix} -\eta & 1 & 0 & \mathbf{0} & \mathbf{0} \\ 1 & 0 & -1 & \mathbf{0} & \mathbf{0} \\ 0 & 0 & 1 & -\mathbf{s} & \mathbf{0} \\ \mathbf{0} & -\mathbf{i} & \mathbf{0} & -\mathbf{H} & \mathbf{I} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & -\Sigma & \mathbf{I} \end{bmatrix} \begin{bmatrix} d\ln p^w \\ d\ln y \\ d\ln p \\ d\ln \mathbf{w} \\ d\ln \mathbf{x} \end{bmatrix} = \begin{bmatrix} \varepsilon \\ 0 \\ 0 \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix} d\ln Y + \begin{bmatrix} 0 \\ 1 \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix} dt + \begin{bmatrix} 0 \\ 0 \\ -\delta \\ \mathbf{B} - \mathbf{i}\delta \\ \mathbf{0} \end{bmatrix} d\tau$$

A numerical solution to this system provides impact elasticities with respect the exogenous changes $dlnY$, dt and $d\tau$. A numerical solution can be readily obtained by using a spreadsheet to multiply both sides of (6) by the inverse of the initial matrix, as is demonstrated a subsequent section.

Welfare implications

We can approximate welfare changes for consumers and producers as changes in consumer and producer surplus. It is convenient in the context of this model to express surplus measurements as a fraction of the initial market value of the commodity (price times quantity.) Given changes in quantities and prices from equation (6), the elasticity of this measure of surplus with respect to the shocks can be readily calculated as:

$$(7) \qquad \begin{aligned} & d\ln CS \equiv dCS / p^w y = d\ln p^w (1 + 0.5 d\ln y), \text{ and} \\ & d\ln PS_i \equiv dPS_i / w_i x_i = d\ln w_i (1 + 0.5 d\ln x_i), \text{ for } i = 1,..n. \end{aligned}$$

This measure of change, a fraction of the initial value of the commodity, is often more easily comprehensible than money metric values, since a change in consumer surplus equal to 20% of the commodity's value, for instance, may be more easily evaluated than a number such as $250 million.

A numerical example

Below is an example for a three-input technology with technical change that is biased in favor of the first. The spreadsheet for this problem is shown in Figure 1, and graphic representations are shown in Figure 2.

For world demand elasticities, I've used -1.3 for price elasticity and 1.2 for income elasticity, which approximate those used by Kinnucan and Myrland.

To illustrate bias in technical change, I specify a *rate* of technical change of 0.1 (unit cost falls by 10% if input prices remain constant), but with a *bias* of +0.1 for the first input (its cost share would increase by 10% if prices did not change), -0.1 for the second, and no bias for the third. (Biases defined in this manner must sum to 1.0 when weighted by factor shares.) For an unbiased technical change, if there are no input price changes and output remains constant, optimal levels of all inputs would fall by the rate of technical change (10% for the rate of change posited here), whereas equation (8) indicates that under this biased techncical change, x_1 would remain constant and x_2 would decline by twice the rate of technical change. In order to more completely contrast the implications of the bias effects for the two biases, I've specified equal initial shares (0.3) and equal supply elasticities (1.0) for the first two inputs. I've specified an inelastic supply for the third input (0.25), as might be appropriate for a more fixed input such as salmon facilities.

The derived demand functions in this model (rows d1-d3) are Hicksian demands, as they hold output constant. As such, the elasticity values I use here conform to standard Hicksian homogeneity and reciprocity (symmetry) conditions. (Given those six constraining conditions, note that there are only three degrees of freedom in specifying or estimating the nine elements of the derived demand elasticity matrix.)

The resulting numerical implementation of equation (6), with row identifications corresponding to equations in the equilibrium system (5) is:

$$
(8)\quad
\begin{matrix} a. \\ b. \\ c. \\ d1. \\ d2. \\ d3. \\ e1. \\ e2. \\ e3. \end{matrix}
\begin{bmatrix}
1.3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & -.3 & -.3 & -.4 & 0 & 0 & 0 \\
0 & -1 & 0 & -.10 & .02 & .08 & 1 & 0 & 0 \\
0 & -1 & 0 & .02 & -.10 & .08 & 0 & 1 & 0 \\
0 & -1 & 0 & .06 & .06 & -.12 & 0 & 0 & 1 \\
0 & 0 & 0 & -1 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & -.25 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix} d\ln p^w \\ d\ln y \\ d\ln p \\ d\ln w1 \\ d\ln w2 \\ d\ln w3 \\ d\ln x1 \\ d\ln x2 \\ d\ln x3 \end{bmatrix}
=
\begin{bmatrix} 1.2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} dY +
\begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} dt +
\begin{bmatrix} 0 \\ 0 \\ -.1 \\ 0 \\ -.2 \\ -.1 \\ 0 \\ 0 \\ 0 \end{bmatrix} d\tau
$$

When solved with a spreadsheet, the solution provides these impact elasticities:

$$
(9)\quad
\begin{bmatrix} d\ln p^w \\ d\ln y \\ d\ln p \\ d\ln w1 \\ d\ln w2 \\ d\ln w3 \\ d\ln x1 \\ d\ln x2 \\ d\ln x3 \end{bmatrix}
=
\begin{bmatrix} 0.74 \\ 0.23 \\ 0.74 \\ 0.11 \\ 0.11 \\ 1.70 \\ 0.11 \\ 0.11 \\ 0.49 \end{bmatrix} d\ln Y +
\begin{bmatrix} 0.19 \\ -0.25 \\ -0.81 \\ -0.12 \\ -0.12 \\ -1.84 \\ -0.12 \\ -0.12 \\ -0.46 \end{bmatrix} dt +
\begin{bmatrix} -0.08 \\ 0.11 \\ -0.08 \\ 0.12 \\ -0.11 \\ 0.04 \\ 0.12 \\ -0.11 \\ 0.01 \end{bmatrix} d\tau
$$

The interpretation of these elasticities is straightforward. From the first row for instance, the percentage change in equilibrium level of p^w with respect to a one percent change in income is 0.74; with respect to an ad valorem tariff of one percent it is 0.19; and with respect to a one-unit change in technology it is -0.08.

With respect to technical change, note that although x_1 and x_2 have identical initial shares, and identical derived demand elasticities and supply elasticities, the equilibrium price and quantity of x_1 increase, whereas those of x_2 decrease because of the bias in the technical change.

The welfare impacts described in equation (7), also depicted in the diagrams of Fig 2., are presented in Table 1 below.

Table 1. Welfare impact elasticities, measured as percent change in the ratio of economic surplus to market value

		Exogenous variable		
Agent	Measured as	*dln Y*	*dt*	$d\tau$
Consumer	$\Delta CS^y / y^0 p^{w,0}$	-	-0.17	0.09
Tariff revenue	$tax / y^0 p^{w,0}$	-	0.75	-
Producers of x_1	$\Delta PS^1 / x^{1,0} w^{1,0}$	0.11	-0.11	0.12
Producers of x_2	$\Delta PS^2 / x^{2,0} w^{2,0}$	0.11	-0.11	-0.10
Producers of x_3	$\Delta PS^3 / x^{3,0} w^{3,0}$	2.06	-1.42	0.04

A tariff equal to one percent of import price will reduce (foreign) consumer surplus by 0.17 percent of the value of salmon purchases, will generate tariff revenue equivalent to 0.75 percent of that value, and will reduce producer rents to the residual claimants (owners of x_3) by 1.42 percent of the initial market value of input three.

The technical change will increase consumers' surplus by 9% of the value of the salmon crop; and will increase input producers' surplus by 0.12 for x_1 (toward which the technical change was biased); reduce it by 10% for producers of x_2 (against which the technical change was biased); and increase it by 4% for producers of x_3 .

Comments

On the linearity of this model

A log linear model such as this is definitely linear: simulated market supply and demand responses are straight lines along which arc elasticities are constant, and there are no interactions between the effects of various exogenous shocks. Approximation errors will arise if the true market relationships are not linear. It is perfectly possible here that responses predicted from an exogenous shock would result in negative quantities or negative prices. Linearity may be a serious limitation in some contexts, not at all in others. A linear model such as this offers the advantage of simplicity and transparency, which may or may not offset the limitations as compared with methods of solving systems of non-linear equations.

Problems of non-linearity can in some cases be reduced by recursive application of the model, with very small steps in the exogenous variable combined with re-calibration of shares and perhaps elasticities after each step.

On the use of the cost function to represent technology

Use of the cost function in EDMs has an advantage over the production function in that it translates technology characteristics directly into behavior characteristics. Furthermore, it allows one to easily impose appropriate cost function constraints on the derived demand matrix, whether that matrix is estimated from empirical data or postulated from thin air, as I have done in the numerical example above. It is of course true that in some cases it may be more feasible to estimate a production function than a cost function from available data. In that case, Muth's model would be more directly applicable. Even then, using duality relationships one can obtain point estimates of the elasticities of the cost function. Depending on the functional form estimated, it may or may not be a simple matter to derive the cost function dual to the production function.

Estimation of technical change parameters can be simple in some cases. If one wishes merely to extrapolate trends from past technical change, it would be simple to do so by estimating a cost function from historical data, including the appropriate first and second-order time trend terms. For ex-ante evaluation of technical change, a rough estimation of parameters can be extracted from experimental data that includes a control treatment (representing old technology) and another treatment that one is willing to accept as approximately optimal for the new technology. For current input prices, the rate of technical change is estimated as the reduction in unit cost from the old to the new technology, and biases are estimated as the changes in input cost shares from the old to the new technology. Obviously, these simple expedients will not be appropriate in all cases.

Our extensions of this model

We (Lilyan Fulginiti and I) have previously extended the above model in a number of ways. This includes extension to *m* outputs and *n* inputs using cost or profit functions, to general equilibrium, to the case of N firms, to the case of variable returns to scale and non-homothetic technology, to both open and closed economies, and to include various welfare measures of technical change and waste due to quotas or taxes.

The following is a cryptic guide to articles in which various of these extensions are developed. All of these papers are available through the Digital Commons at http://digitalcommons.unl.edu/ageconfacpub/ .

1993. "Measures of Waste Due to Quotas": general equilibrium closed economy model using profit functions, evaluating Compensating Variation and Allais-Debreu welfare measures of loss due to quotas (application to U.S. tobacco quotas);
1994. "Interventions and Production Sector Waste in LDC Agriculture": partial equilibrium open economy model using profit functions, evaluating Allais-Debreu profit loss due to export taxes in LDC agriculture;
1995. "An Allais Measure of Production Sector Waste Due to Quotas": partial equilibrium closed economy model using profit functions, evaluating a Diewert measure of welfare loss due to quotas (application to tobacco);

1996. "Productivity Measurement in the Presence of 'Poorly-Priced' Goods": general equilibrium closed economy model using profit functions examining the effect of market failure and price distortions productivity change on Equivalent Variation measure of welfare gain from biased technical change;

1997. "The Impact of Technological Change on a Competitive Industry": partial equilibrium model using a single-output cost function for technology that is non-homothetic, examining the price and quantity effects of biased technical change;

2001. "Technological Change and Welfare in an Open Economy with Distortions": a general equilibrium open economy model using profit functions, to evaluate how tax distortions cause the Equivalent Variation welfare impact of technical change to diverge from the rate of technical change.

2005. "Productivity and Welfare": general equilibrium model using profit functions to characterize an Allais welfare measure of technical change, as a function of rate and biases of technical change, and market failure parameters for taxes and subsidies, quotas and rationing, imperfect competition in final and intermediate markets and "poorly priced" goods (for example environmental bads).

In most cases, the above analyses obtain analytical solutions (positive and normative), rather than numerical solutions to the equilibrium equations, though empirical examples or simulations are included.

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Figure 1. Spreadsheet layout for solving equation (8).

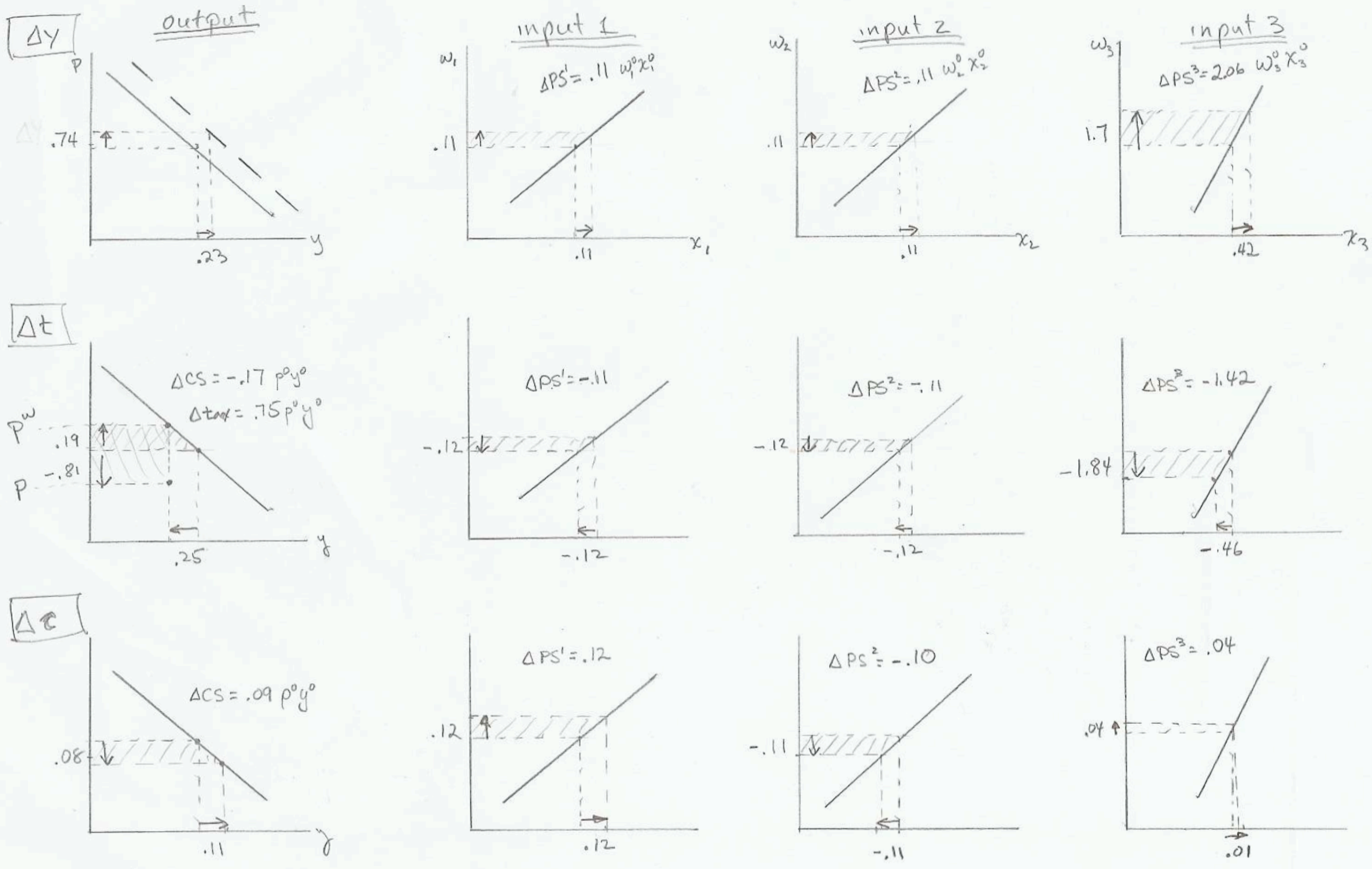
	$d\ln p^w$	$d\ln y$	$d\ln p$	$d\ln w^1$	$d\ln w^2$	$d\ln w^3$	$d\ln x^1$	$d\ln x^2$	$d\ln x^3$										
a.	1.3	1	0	0	0	0	0	0	0	$d\ln p^w$		1.2		0		0			
b.	1	0	-1	0	0	0	0	0	0	$d\ln y$		0		1		0			
c.	0	0	1	-0.3	-0.3	-0.4	0	0	0	$d\ln p$		0		0		-0.1		0.1	delta
d1.	0	-1	0	-0.100	0.020	0.080	1	0	0	$d\ln w^1$		0		0		0		0.1	=b1
d2.	0	-1	0	0.020	-0.100	0.080	0	1	0	$d\ln w^2$	=	0	$d\ln Y$ +	0	$d\ln t$ +	-0.2	$d\ln \tau$	-0.1	=b2
d3.	0	-1	0	0.060	0.060	-0.120	0	0	1	$d\ln w^3$		0		0		-0.1		0	=b3, fixed
e1.	0	0	0	-1	0	0	1	0	0	$d\ln x^1$		0		0		0			
e2.	0	0	0	0	-1	0	0	1	0	$d\ln x^2$		0		0		0			
e3.	0	0	0	0	0	-0.25	0	0	1	$d\ln x^3$		0		0		0			

0.619	0.195	0.195	0.026549	0.0265	0.56637	-0.03	-0.03	-0.57	$d\ln p^w$		0.74		0.19		-0.08	
0.195	-0.25	-0.25	-0.03451	-0.0345	-0.7363	0.035	0.035	0.74	$d\ln y$		0.23		-0.25		0.11	
0.619	-0.81	0.195	0.026549	0.0265	0.56637	-0.03	-0.03	-0.57	$d\ln p$		0.74		-0.81		-0.08	
0.088	-0.12	-0.12	1.143403	0.007	-1.0619	-1.14	-0.01	1.06	$d\ln w^1$		0.11		-0.12		0.12	
0.088	-0.12	-0.12	0.007039	1.1434	-1.0619	-0.01	-1.14	1.06	$d\ln w^2$	=	0.11	$d\ln Y$ +	-0.12	$d\ln t$ +	-0.11	$d\ln \tau$
1.416	-1.84	-1.84	-0.79646	-0.7965	3.00885	0.796	0.796	-3.01	$d\ln w^3$		1.70		-1.84		0.04	
0.088	-0.12	-0.12	1.143403	0.007	-1.0619	-0.14	-0.01	1.06	$d\ln x^1$		0.11		-0.12		0.12	
0.088	-0.12	-0.12	0.007039	1.1434	-1.0619	-0.01	-0.14	1.06	$d\ln x^2$		0.11		-0.12		-0.11	
0.354	-0.46	-0.46	-0.19912	-0.1991	0.75221	0.199	0.199	0.25	$d\ln x^3$		0.42		-0.46		0.01	

Welfare impact elasticities:

$\Delta CS^y / y^0 p^{w,0}$	-	-0.17	0.09
$tax / y^0 p^{w,0}$	-	0.75	-
$\Delta PS^1 / x^{1,0} w^{1,0}$	0.11	-0.11	0.12
$\Delta PS^2 / x2^{,0} w2^{,0}$	0.11	-0.11	-0.10
$\Delta PS^3 / x3^{,0} w3^{,0}$	2.06	-1.42	0.04

Figure 2. Sketch of numerical example (8)



Summary report of project activities and Svalbard Workshop

by

Sverre Braathen Thyholdt

and

Øystein Myrland

Introduction

The project group has coordinated a field trip to document and learn how other commodities and industries use and utilize different market analysis systems as a part of their industrial economics. The main focus was to study the integration of research and industry use of international trade and price formation models. The project group identified Food and Agricultural Policy Research Institute (FAPRI) to have a really interesting approach for analyzing the agricultural sector, and the project group visited FAPRI earlier this year. FAPRI has since 1984 done production and price projecting for the U.S. agricultural sector and the international commodity markets. The institute has a unique bilateral research program between Iowa State University and University of Missouri, as well as having Arizona State University, University of Arkansas, Texas Tech University, and Texas A&M University as research partners in the FAPRI consortium. An overview of FAPRI, how they are organized, funded and their modeling structure will be presented in this paper

Agricultural Policy Analysis Center (APAC) at University of Tennessee and their Policy Analysis System (POLYSYS) was also identified as an institute we would like to take a closer look on. Unfortunately, the project group was not able to visit the institute, but we have conducted a literature study of their approach which will give an overview of how APAC are analyzing the U.S. agricultural sector, which will be presented in this paper.

The project group visited NCCC-134 Committee's annual meeting in April. The meeting emphasize on research on applied commodity price analysis, forecasting and market risk management. This was presented and discussed by academics and industry professionals from across the US and the globe. This meeting gave the project group a unique opportunity to be updated on the latest research in applied economics, as well as interact with other researchers who are doing similar research as this project plans to do.

The project group also arranged a workshop in September at Longyearbyen. The overall aim of the workshop was to discuss and further develop the models and the applied knowledge base of this project. Several key representatives were present at the workshop and then especially Professor Richard K. Perrin from University of Nebraska and Dr. Amani Elobeid and Dr. Fengxia Dong from FAPRI. Other attendees were from academic institution in the U.S. and Norway as well as representatives from the salmon industry. The workshop was divided in two parts. First, there was formal presentation from FAPRI, Professor Frank Asche from University of Stavanger, Professor Atle Guttormsen from Norwegian University of Life Sciences, Professor Henry Kinnucan from Auburn University, and Professor Richard K. Perrin from University of Nebraska. Second, there was a panel discussion where globalization of market information and the use of global market models that was relevant for this project was discussed and identified. A report from the workshop will be presented in this paper, along with abstracts and presentations of the attendees. The contribution from Professor Atle Guttormsen, Professor Frank Asche, Professor Henry Kinnucan, and Professor Richard K. Perrin is considered as independent papers.

Food and Agricultural Policy Research Institute (FAPRI) and Agricultural Policy Research Centre (APAC) both use an approach that can be conceptualized as an equilibrium displacement modelling (EDM). An equilibrium displacement modelling is particularly relevant in cases where (1) sufficient data of econometric modelling may be unavailable, (2) where data are unreliable, or (3) where "good" data and extensive prior research results and experience are available to develop large-scale models of complex relationships. The latter describes the objective and setting for the SMAM project; an international model of the salmon aquaculture is understandably large and complex. The partial equilibrium framework of an EDM involves linear approximation of changes in prices and quantities of inputs and outputs. The impact of any exogenous change to the system, such as new technology or promotion campaign, is modelled as a shift in demand or supply from the initial equilibrium.

To estimate equilibrium displacement models, it requires base equilibrium price, quantity data and Marhallian elasticity values. FAPRI prepares a baseline projection each year for the U.S. agricultural sector and international commodity markets, which is used as a starting point when evaluating supply, demand, and policy factors that influence short-term and long-term trade prospects and patterns. APAC, however, does not prepare a baseline projection, but anchor their simulations to a baseline of projections such as those estimated by FAPRI. The SMAM project need to establish a baseline projection each year, similar to what FAPRI does, which again can be used as the base equilibrium price in the EDM.

The SMAM-project will have the same approach and use the same methodology that is used by other commodities. Equilibrium displacement modelling is one of the most frequently tools used in agricultural economics, and this approach can be transferred to analyze salmon aquaculture. The knowledge obtained from APAC and FAPRI will be utilized when doing simulations that effects supply, demand, and policy factors in an EDM framework. The knowledge obtained from FAPRI will be particularly relevant when we are establishing baseline projections to be used as the base equilibrium price as an anchor to these simulations.

Food and Agricultural Policy Institute (FAPRI)

Introduction

Food and Agricultural Policy Research Institute (FAPRI) was established in 1984 by a grant from the U.S. Congress. FAPRI is today funded by the U.S. Congress and other governmental agencies as well as by specific project financing. FAPRI was established with the following objectives

1) Prepare baseline projections for the U.S. agricultural sector and international commodity markets
2) To examine major commodity markets and analyze the alternative policies and external factors for implications on production, utilization, farm and retail prices, farm income and government costs
3) To aid development of effective risk management tools for crop and livestock producers, and to analyze how government policy affects risk management strategies.

FAPRI prepares baseline projections each year for the agricultural sector and international commodity markets. The multi-year projections are published as FAPRI Outlooks, which provide a starting point for evaluating and comparing scenarios involving macroeconomic, policy, weather and technology variables. These projections are intended for use by farmers, government agencies and officials, agribusinesses, and others who do medium-range and long-term planning.

Organization

FAPRI is a dual-university research program, with research centers at Center for Agricultural and Rural Development (CARD) at Iowa State University and the Center for National Food and Agricultural Policy (CNFAP) at University of Missouri. Other research partners in the FAPRI consortium are at Texas A&M University, the University of Arkansas, Arizona State University, and Texas Tech University. FAPRI-Iowa maintains the international modeling structure for grains, oilseeds, livestock, dairy, and sugar and U.S. crop insurance model. FAPRI-Missouri maintains the U.S. modeling structure for grains, oilseeds, livestock, and dairy, along with models for the international cotton sector and the European Union. In general FAPRI-Iowa is emphasizing on the international commodity markets, and FAPRI-Missouri is emphasizing on the U.S. agricultural sector.

Commodities being analyzed

The commodities FAPRI are analyzing are divided into six major groups, dairy, livestock, grains, oilseed, sugar, and cotton. Below is a list of all commodities that are being analyzed in each group

Dairy:	fluid milk, butter, cheese, nonfat dry milk and whole milk powder
Livestock:	beef and veal, pork, and poultry meat
Grains:	wheat, corn, barley, sorghum, and rice
Oilseed:	soybean, sunflower seed, palm, and peanut
Sugar:	sugar
Cotton:	cotton

FAPRI is constantly developing and expanding the commodities being analyzed. The University of Arkansas, FAPRI-Missouri and FAPRI-Iowa have developed and are further refining models of the United States and world rice sectors. In addition, through combined efforts between FAPRI-Missouri and Arizona State University, an international model of the fruit and vegetables industry is being developed. FAPRI has also recently included modeling of the biofuels sector with analyses of ethanol and biodiesel, which has attracted a lot of attention even outside the agricultural sector.

Modeling

FAPRI has created one module for each group of commodities that are all linked together, and although there are minor differences between the modules for each commodity, all modules are a partial equilibrium model, econometric, non-spatial policy model. That is, all other sectors of the economy outside of the relevant commodities are considered as given; parameters in the model are either directly estimated, surveyed from literature, or obtained from consensus of expert opinion; and country sources and destinations of trade are not monitored. The models strive to capture policy instruments that influences the incentives faced by economic agents. This includes domestic policies (i.e. price support) and border policies (i.e. duties, tariff rate quotas, export subsidies). Other policies that are difficult to represent quantitatively, such as environmental regulations, are accounted for exogenously.

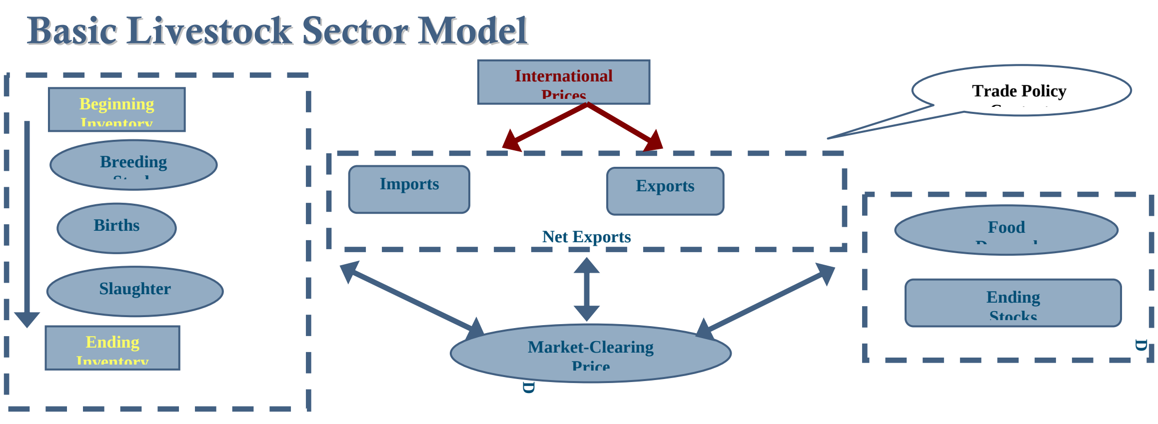
Of all the commodities that FAPRI are analyzing, the livestock approach is perhaps the one which has most similarities with the approach for salmon, and we will here take a closer look on the livestock model.

Livestock module

The specification of the model is based on five principles. The first is a clear differentiation of stock and flow variables. Animal inventory is an example of a stock variable, while animals slaughtered is an example of a flow variable. Second, in the specification of the model, except for the breeding herd, all stock variables are derived in an accounting identity from the changes in the flow variable. Third, flow variables are generally the only ones with behavioral specification representing economic decisions of significant agents in the sector. Fourth, flow variables are specified in terms of rates rather than levels. Finally, price determination in individual country submodels is specified as either price transmission from the world price or market clearing when there are significant restrictions in trade flow. The entire model solves with a market-clearing world price that balances world trade and equates supply and demand in individual countries.

The same approach will be useful in terms of modeling salmon, and then especially the clear differentiation of stock and flow variables, animal inventory and animals slaughtered. The flow variables in salmon, salmon slaughtered, are in the salmon case also generally the only ones representing economic decisions of significant agents in the sector.

An overview of the livestock model can be seen in the figure below



Data

FAPRI uses several different sources to collect data to their models.

Data about production, supply and distribution for the US is collected from the Economic Research Service (ERS) of United States Department of Agriculture (USDA). For the livestock sector these data are collected twice a year, in April and November, and for all other commodities the data is collected from the December releases.

For other countries similar websites/statistics which are published by the official government is collected. Statistics from Food and Agricultural Organization of the United Nations (FAO) is also an important data source. FAOSTAT provides time series data relating to food and agriculture for some 200 countries, which provides trade and production statistics.

Historical macro data is collected each December from International Financial Statistics, and global projection on macro data is collected in December from Global Insight. Demographic data is collected from International Data Base U.S. Bureau of Census in December.

FAPRI Outlook

FAPRI prepares baseline projections each year for the agricultural sector and international commodity markets. The multi-year projections are published as FAPRI Outlooks, which provide a starting point for evaluating and comparing scenarios involving macroeconomic, policy, weather and technology variables. In estimating the projections, FAPRI begins with a preliminary baseline that is first submitted to a review process before a panel of experts, which includes employees of different governmental agencies and international organization, as well as industry experts. Their comments and suggestions are taken into consideration in the final baseline, which is used for policy analysis throughout the rest of the year. The FAPRI Outlook Database publish own-price elasticities for supply and demand, agricultural policy effects for each commodity, and different data, like ending stocks, beginning stocks, production, net exports, etc., for each commodity.

Target group

FAPRI are principal economic policy analysts for leading industry groups such as National Pork Producers Council, U.S. Grains Council, National Corn Growers Association, American Soybean Association, National Milk Producers Federation, and American Farm Bureau Federation. The user group also consists of significant policy makers in the U.S. Congress and United States Department of Agriculture (USDA). FAPRI provides information to legislators, trade organizations, international organizations, agricultural business, local and regional watershed associations, and individuals. The system FAPRI has got is created to estimate the state and farm-level implications of developments in policy or markets, and in addition does FAPRI specialized research to address local importance. Their analyses are intended for use for all actors in the agricultural sector, from the individual farmers to governmental agencies to agribusinesses and industry groups.

The Agricultural Policy Analysis Center (APAC)

A description of the Policy Analysis System (POLYSYS)

Introduction

The Agricultural Policy Analysis Center (APAC) was created in 1992 at University of Tennessee. The APAC's research program is structured around the Chair of Excellence in Agricultural Policy at University of Tennessee, and along with Economic Research Service (ERS) of United States Department of Agriculture (USDA) and University of Oklahoma, they have developed the Policy Analysis System (POLYSYS) modeling framework. POLYSYS was developed to simulate changes in policy, economic or resource conditions and estimate the resulting impacts for the U.S. agricultural sector. These analyses are intended for use by farmers, policy makers, analysts, and other interested in and affected by agriculture-related policies.

Commodities being analyzed

The commodities that the core POLYSYS modules endogenously consider are divided into two major groups; crops and livestock.

Below is a list of all commodities that are being analyzed in each group

Crops:	corn, soybeans, wheat, cotton, sorghum, oats, barley, and rice
Livestock:	beef, pork, poultry, lamb and mutton, eggs, and milk

POLYSYS also does analyses on crops which may be of regional significance, but whose market impacts are not endogenous in the modeling system. These crops may be tobacco, peanuts, alfalfa hay, other hay, and switch grass, among others.

Modeling

The POLYSYS framework is designed to anchor its analyses to a published baseline of projections. Generally, the benchmark for POLYSYS simulation is U.S. Department of Agriculture (USDA), Food and Agriculture Policy Research Institute (FAPRI), or U.S. Congressional Budget Office (CBO) national baseline projections and related assumptions.

Using a baseline as a starting point, POLYSYS can introduce a wide variety of exogenous shocks and simulate the resulting impacts for crop and livestock supply and demand and agricultural income. The analyses are anchored to the published baseline, which again allows POLYSYS to focus on variables of interest.

The POLYSYS modeling framework can be conceptualized as a variant of equilibrium displacement model (EDM). In general, to estimate EDMs, it requires a base equilibrium price, quantity data, and Marshallian elasticity. The values of the structural parameters in POLYSYS' EDM are generally estimated, surveyed from relevant studies or assumed to be known. The modules use a combination of models and identity to estimate crop and livestock supply, demand and prices. POLYSYS then takes the EDM structure one step further and tracks supply, demand, government program, price, and cost variables to calculate agricultural income variables. The POLYSYS structural models can be thought as a system of demand and supply equations for the livestock and crop sectors and an equilibrium condition in each sector.

Data

The POLYSYS framework uses several different sources for data. Since the POLYSYS framework is anchored to a published baseline of projections, and the three published baseline which is most commonly used for POLYSYS include the baseline of USDA, FAPRI and U.S. Congressional Budget Office (CBO), POLYSYS use the data and the general assumptions for each baseline projection. In addition, data about production, supply and distribution is collected from the Economic Research Service of USDA. Demographic data is collected from U.S. Bureau of Census

APAC Databook and Data Manager

Most of the data APAC routinely use in their models is available for other interested parties in the APAC Databook. In addition, APAC also offer software, the Data Manager, which allows you to view, compute, and export data series. Their APAC Databook publish own-price and cross-price elasticities for supply and demand, and agricultural policy effects for each commodity. In addition, APAC publish newsletters and presentation in an Agricultural Outlook Forum so interested parties can always be updated on the latest information.

Target group

APAC provides information to legislators, agricultural businesses, trade organizations, local and regional interest groups, and individual farmers. APAC conduct several research projects to examine the local and regional effects of policy implications. This means that individual farmers and local and regional association is one major user group of APAC's analyses. In addition do they also conduct research projects where they examine the policy effects on one particular commodity, and then especially tobacco, and for that reason tobacco farmers and tobacco associations is a big user group for APAC

Report from SMAM Roundtable Conference, Sept 2008

In connection with the Salmon Market Analysis Modules (SMAM) pre-project, there was arranged a roundtable conference to present the findings from the pre-project to relevant academic and industry partners. The roundtable conference was arranged on September 24 – 26 this year. The presentations were divided into three parts. a) Food and Agriculture Policy Research Institute (FAPRI) gave an overview of their institute and how FAPRI runs and what kind of analyses FAPRI perform in the agricultural sector. b) An introduction to market and production development in farmed fish, and c) a presentation of the equilibrium displacement model (EDM) for the global salmon market, its advantages and analyses possibilities. After the formal presentations, the workshop implemented a panel discussion where the feasibility and challenges for the main project was discussed.

The following topics were presented at the conference

FAPRI;

Dr. Fengxia Dong and Dr. Amani Elobeid were presenting an overview of the Food and Agricultural Policy Research Institute (FAPRI) at Iowa State University. FAPRI is policy and academically driven, with a modeling intensive approach. Their analyses are globally oriented and connected to a rich intellectual resource base. The overview included the modeling structure, how the models are built-up and what lies behind their models. The presentation also included a thorough review of the process of preparing a baseline projection each year, and what type of analyses that they execute based on this baseline in the agricultural sector. In estimating the projections, FAPRI begins with a preliminary baseline that is first submitted to a review process before a panel of experts, which includes employees of different governmental agencies and international organization, as well as industry experts. Their comments and suggestions are taken into consideration in the final baseline, which again is used for policy analysis throughout the rest of the year. FAPRI also gave an insight to their future model expansions, how the models are further developed and the process by making new models to do research in new fields. FAPRI has recently included modeling of the biofuels sector with analyses of ethanol and biodiesel, which is linking agriculture to energy markets. This model has attracted a lot of attention even outside the agricultural sector, and the presentation gave an insight in how this model was developed. Further model extensions FAPRI prepare is dividing urban and rural demands, environmental factors on regional

supplies and demands, and impact of government investments in productivity growth, i.e. impact of research expenditures on yields, and impact of irrigation investments on yield, cropping patterns, and water use.
In addition they also presented the history of the institute and how the institute is organized and funded. The presentation of FAPRI is enclosed in the appendix of this report.

Professor Frank Asche;
from University of Stavanger gave an overview of the development in aquaculture production during the last decades, and then focused on the market driven part of this development. Special attention was given to the development of salmon. In the 1970s a revolution occurred with respect to aquaculture technology, as better control with the production process allowed technologies largely from agriculture to be applied also in aquaculture. One may say that one started farming the sea. The tremendous degree of productivity growth in salmon aquaculture from the late 70's, has resulted that real prices have rapidly declining, since productivity growth has been faster than market growth. The market for salmon is today a global market. Today is the markets in EU, Japan and USA the most attractive buyers because of their ability to pay. South East Asia, China and Russia are emerging markets that will be increasingly important in the future. The high productivity growth has resulted in a market growth which again has resulted in an expansion of the geographical market and the expansion of product forms. The retailing sector and logistics is changing since the buyers of salmon products is more and more retail chains, and they outsell traditional outlets and fish mongers. The retail chains are demanding customers that increase the importance of being competitive for the salmon producers. The product is no longer the physical seafood product, but also a set of services for the industrial buyers related to volume, timing and frequency, flexibility, cost efficiency in distribution, and food safety. The set of extra services increase the complexity of the composite product that a supplier is providing. But since there is a substantial lag from when the decision to produce is made until the product is ready for the market, there will be cycles in profitability. These cycles can also be created by an uneven market growth. Since the market is truly international gives an additional potential for problematic issues as production practices and regulatory conditions vary. Cycles in profitability, producers located outside the main markets and fast productivity growth which again leads to substantial reduction in prices and a decrease in the production can be the main reasons for trade problems, and the aquaculture industry is highly exposed to trade problems. The presentation of Professor Frank Asche is enclosed in the appendix of this report.

Professor Atle Guttormsen;
from Norwegian University of Life Sciences gave a presentation of the productivity development in aquaculture with focus on salmon. Although market growth has been important for the most successful species, there is no doubt that it is productivity growth that has been the main engine. For all successful species, real prices have declined significantly, making the product more competitive. This has resulted in a geographically expansion of the market as well as a development of more product forms. The control in the production process has allowed a number of innovations in the supply chain, i.e. large scale air-freight of seafood, just-in-time delivery, and substantial product innovation. One started in the traditional fresh fish counter, with unprocessed products, and continued with fresh packed products, branded products, and today has an increased number of ready meals and inconvenience food based on salmon. Chile has partly overcome long distances to the main markets with innovative product development, and has been leading on the development in the last decade. Since it is the total cost of the product that matter innovations in the supply chain is as important as innovations in retail and production. Productivity growth makes aquacultural products increasingly competitive, and for successful species market is expanded in product space as well as geographical space, and species that do not have production processes with these characteristics will not succeed as large volume species. The presentation of Professor Atle Guttormsen is enclosed in the appendix of this report.

Professor Henry Kinnucan;
from Auburn University was presenting the theory, method and specification for an equilibrium displacement model (EDM) for the global salmon market. Equilibrium displacement modelling is a procedure involving three steps: 1) a particular market situation is characterized by a set of supply and demand functions that are general in the sense that no particular functional forms are assumed. 2) The markets are disturbed by a change in the value of some exogenous variable, and 3) the impacts of the disturbance are approximated by functions that are linear in elasticities. EDM in essence is comparative static analysis. The main difference is that changes in variables are expressed in percentage terms, rather than absolute terms, and parameters are expressed as elasticities rather than as derivatives. Hicks approach from 1932 where he uses a log differential model to assess the effects on technical change on labor’s share of the cost of production is generally considered the first application of the EDM approach. In the 60s Muth expanded Hicks framework to include supply

schedules and equilibrium in input markets. The model was first defined as the equilibrium displacement modelling by Piggott in 1992, and the model has since then been further developed. The equilibrium displacement modelling has a rich intellectual history and has proved useful in applied policy analysis. The presentation of Professor Henry Kinnucan is enclosed in the appendix of this report.

Professor Richard K. Perrin;

from University of Nebraska.

Equilibrium Displacement Model (EDM) is a term often used for comparative statics models that are expressed in log-linear form, especially in agricultural and natural resource economics. Rather than relying solely upon simple demand and supply matrices to establish market equilibrium adjustments, EDM models generally use characteristics of the production function, combined with optimal behavioural conditions with respect to it, to provide a more detailed characterization of equilibrium displacements resulting from changes in policies or technologies. Production technology can be characterized as readily with a cost function as a production function, with some benefit in relating technological parameters to market behaviour; his comments demonstrated the use of a cost function in a log-linear displacement model of the effects of technical change, a tariff, and world income (a demand shifter.)

A log linear model such as the one defined in the presentation of Perrin, is definitely linear: simulated market supply and demand responses are straight lines along and the elasticities are constant, and there are no interactions between the effects of various exogenous shocks. Approximation errors will arise if the true market relationships are not linear. A linear model offers the advantage of simplicity and transparency. Use of the cost function in EDMs has an advantage over the production function in that it translates technology characteristics directly into behaviour characteristics. The presentation of Professor Richard K. Perrin is enclosed in the appendix of this report.

The panel discussions

The salmon aquaculture sector is highly dynamic, and the researchers need to adopt. There are now an increasing number of specialized services that is supplying the salmon producers, which again indicates that the salmon industry is now a more sophisticated industry. There is now a global perspective of salmon production and trade and the sector is now so big that it is possible to carry out a systematic collection and adaption of production and market data, similar to what have been done in several decades in the agricultural sector. Norway is the second biggest exporter of seafood products in the world. The aquaculture of salmon and trout is Norway's biggest seafood sector with an export value of 18.8 billions NOK in 2007. About 95 percent of all production in salmon and trout is exported to over 100 different countries. The prices of salmon has been extremely volatile, with an increased difference of about 150% between 2003 and 2006, and a reduction with about 40% the following year. This variation in the prices is an expression of the changes in the production and market relationships at both the demand and the supply side. The changes in these relationships are therefore strategically important for the participants in the industry.

A big industry is put together with many participants who have different agendas, and it can be difficult for a model to be everything for all people. Official government, legislators and interest organization wants to know the impact of policy adjustments. Trade organizations want to know the effects of changes in market and production relationships, and individual salmon producers want to know the future price and the effect of changes in the interest and exchange rate. To establish such a model, the model needs to be fairly simple and easy to expand. An equilibrium displacement model is relative easy to estimate, and can easily be expanded to broaden the model's capability. The model needs to be reliable and produce an outcome that is useful. The project need to produce data that is publishable in scientific journals, since it demonstrates that it is holding scientific standards, which again indicates that the data has quality and is trustful.

There is a need for research of the consequences of policy making in the salmon industry. The effect of the regulations to limit the size, like the feed quota regime and the new maximum allowed biomass regulation has hardly been done any research on. Other policy factors as the license system have neither been researched on. This modelling framework can make it easier to estimate the impacts of policy in the aquaculture sector. This modelling framework can also show the most efficient way to impose a policy to the aquaculture sector. If the government agencies want to restrict the output, this modelling framework can indicate the most efficient way to restrict the output. The same modelling framework can project future price, trade patterns and the impacts for the industry of changes in the exchange and interest rates. This modelling framework will give all the participants in salmon aquaculture more knowledge.

The salmon sector has different questions they want answers on, and models help address the important questions. This modelling framework will give farmers, government agencies and officials, and aquaculture business deeper and improved strategic information about policy implications, supply and market changes, and future price development for the salmon aquaculture.

The basic research idea for this project is to add the simultaneity principle in the analysis of the global salmon market, where we conduct empirical demand and supply analysis in a joint framework. These types of equilibrium models have been particularly applicable to modelling different factors that affect the price formation of the global salmon market. This methodical approach will give a deeper insight in the price formation of salmon, which again will give participants in the global salmon market new and better tools for strategically planning and knowledge about the market.

Appendix

The attendees at the SMAM roundtable conference were:

Øystein Myrland	University of Tromsø
Frank Asche	University of Stavanger
Atle Guttormsen	Norwegian University of Life Sciences
Henry Kinnucan	Auburn University
Richard K. Perrin	University of Nebraska
Lilyan E. Fulginiti	University of Nebraska
James Anderson	University of Rhode Island
Cathy Roheim	University of Rhode Island
Kristin Roll	University of Stavanger
Jinghua Xie	University of Tromsø
Jingjie Chu	University of Rhode Island
Thomas Larsen	University of Tromsø
Atle Øglend	University of Stavanger
Fengxia Dong	FAPRI
Amani Elobeid	FAPRI
Sverre Braathen Thyholdt	University of Tromsø
Leiv Grønnevet	Sintef MRB
Dag Eivind Opstad	Capia AS
Arne Erling Karlsen	Capia AS
Jan Trollvik	Norwegian Seafood Export Council

Program SMAM Roundtable Conference

Thursday 25 September 2008

09.00 – 12.00 h

Opening

FAPRI

A presentation of FAPRI

Professor Frank Asche

Market driven part of the development in aquaculture

Discussions

12.00 – 13.00 h **Lunch**

13.00 – 16.00 h

Professor Atle Guttormsen

Productivity development in aquaculture

Professor Henry Kinnucan

A presentation of the Equilibrium Displacement Model (EDM)

Professor Richard K. Perrin

How to use a cost function as a demand shifter in the EDM

Discussions

Friday 26 September 2008

09.00-12.00 h

Opening

Roundtable desk with discussions;

led by Project Leader Prof. Myrland

Conclusion and closure address

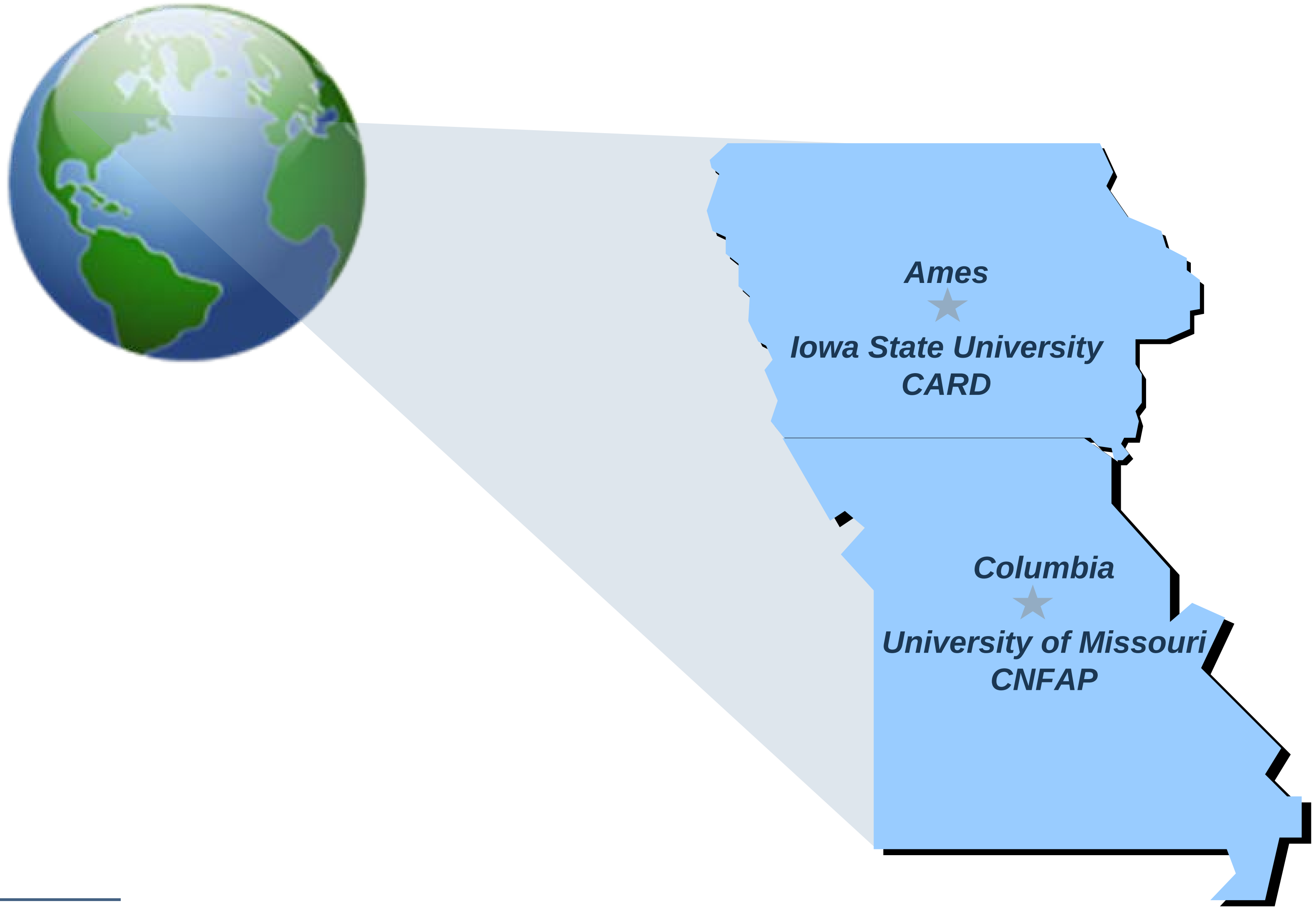
Overview of the FAPRI Modeling System and Outlook Project

FAPRI
Food and Agricultural
Policy Research Institute

Iowa State University

FAPRI Modeling System

- Established in 1984 by a grant from the U.S. Congress with the following objectives
  - To prepare baseline projections for the U.S. agricultural sector and international commodity markets
  - To examine the major commodity markets and analyze alternative policies and external factors for implications on production, utilization, farm and retail prices, farm income, trade, and government costs
  - To aid development of effective risk management tools for crop and livestock producers, and to analyze how government policy affects risk management strategies
- Development of FAPRI since 1980s
  - Expanded commodity coverage
  - Expanded country coverage
  - Added biofuels models


Ames
Iowa State University
CARD
Columbia
University of Missouri
CNFAP

Other Consortium Members

- World Rice
  - University of Arkansas: Arkansas Global Rice Project
- U.S. Fruits and Vegetables
  - Arizona State University: National Food and Agricultural Policy Project
- U.S. Farm-Level Analysis
  - Texas A&M: Agricultural and Food Policy Center
- World Cotton
  - Texas Tech University: Cotton Economics Research Institute

Organization of FAPRI at CARD

Center for Agricultural and Rural Development (CARD)

- Trade and Agricultural Policy Division
  - FAPRI
- Food and Nutrition Policy Division
- Resource and Environmental Policy Division
- Agricultural Risk Management Policy Division
- Science and Technology Policy Division

Funding

- Congress
- Grants
  - Environmental Protection Agency
  - U.S. Department of Agriculture
  - National Research Initiative (NRI)
  - Other funding sources

FAPRI Staff

Bruce Babcock
CARD Director

Dermot Hayes and Jacinto Fabiosa
FAPRI Co-Directors

- Jacinto Fabiosa — Livestock Analyst
- Amani Elobeid — Sugar & Ethanol Analyst
- Fengxia Dong — Dairy Analyst
- Karen Kovarik — Systems Support Specialist
- Edward Yu — Oilseed Analyst
- Simla Tokgoz — Grain & Ethanol Analyst
- Ed Chavez (UA) and Seth Meyer (MO) — Rice and Cotton Analysts

Research Comparative Advantage

- Policy and Academically Driven
- Modeling Intensive
- Globally Oriented
- Connected to a Rich Intellectual Resource Base
- More transparent (more feedback from users)
- Continuing model development
  - Emergence of biofuels; modeling DDG; environmental impacts; land use; linking agriculture to energy markets
  - Challenges
    - Data availability
    - Policy issues
    - Questions of aggregation (regional and commodity)

Other Institutions Doing Similar Work

- Organisation for Economic Co-operation and Development (OECD)
- United States Department of Agriculture (USDA)
- Food and Agriculture Organization (FAO) of the United Nations
- European Union (EU) Commission
- Australian Bureau of Agricultural and Resource Economics (ABARE)

FAPRI Model Development

Input

Database	Theory	Econometric
PSD	Demand	
OECD	Supply	
FAO	Market	
USDA	Equilibrium	
UN		
Country		

Process

Data → Specification → Estimation → Validation → Simulation

Output

Projections of production, consumption, net trade, stocks and prices

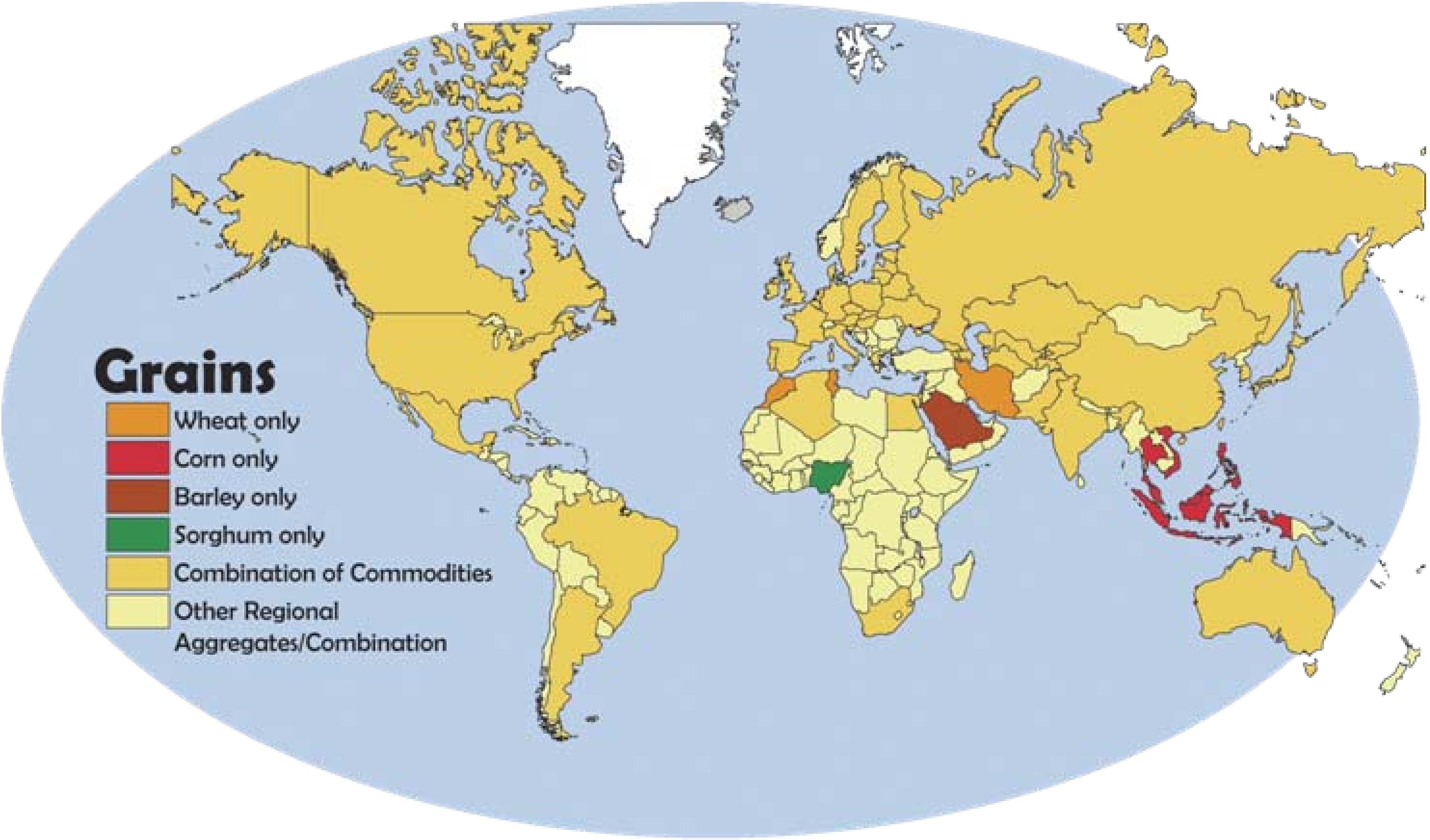
Data

- USDA/ERS – PS&D View commodity data
  - Livestock (April/November releases)
  - All Other Commodities (October/December releases)
- USDA Foreign Agriculture Service Attaché Reports
  - Biofuels
- International Financial Statistics
  - Historical macro data (October/December issues)
- Global Insight
  - Global projection macro data
- FAO
- Official government websites/statistics
- International Data Base U.S. Bureau of census
  - http://www.census.gov/ipc/www/idbnew.html
  - Downloadable in spreadsheet format

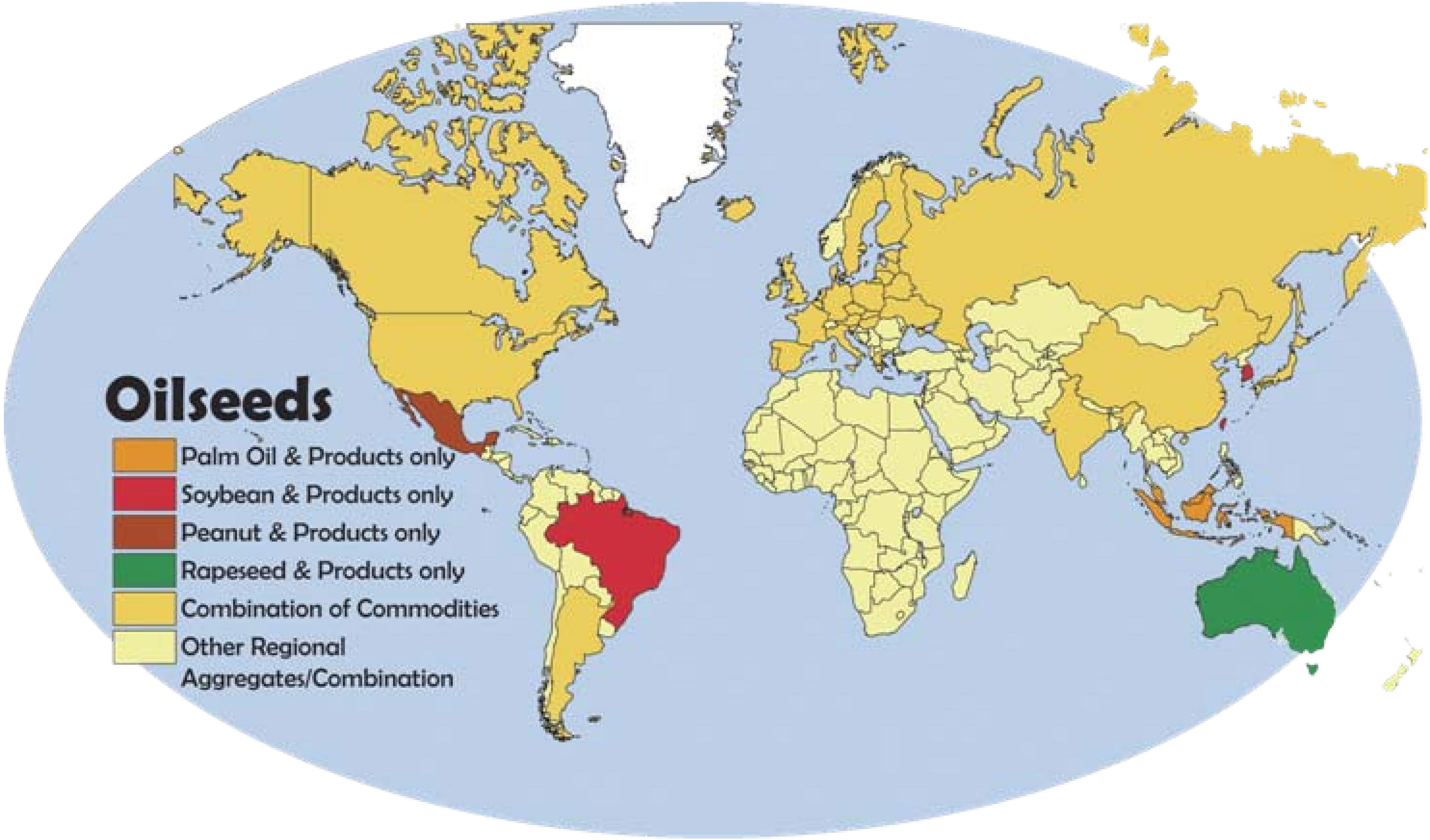
U.S. and International Models Commodity Coverage

Grains	Oilseeds	Cash Crops	Livestock	Dairy	Biofuels
Wheat	Soybeans	Sugar	Beef	Milk	Ethanol
Rice	Rapeseed		Pork	Butter	Biodiesel
Corn	Sunflower Seed		Mutton	Cheese	
Barley	Ground Nuts		Poultry	Non-fat Dry Milk	
Sorghum	Palm		Eggs	Whole-fat Dry Milk	

Country Coverage by Commodity



Country Coverage by Commodity



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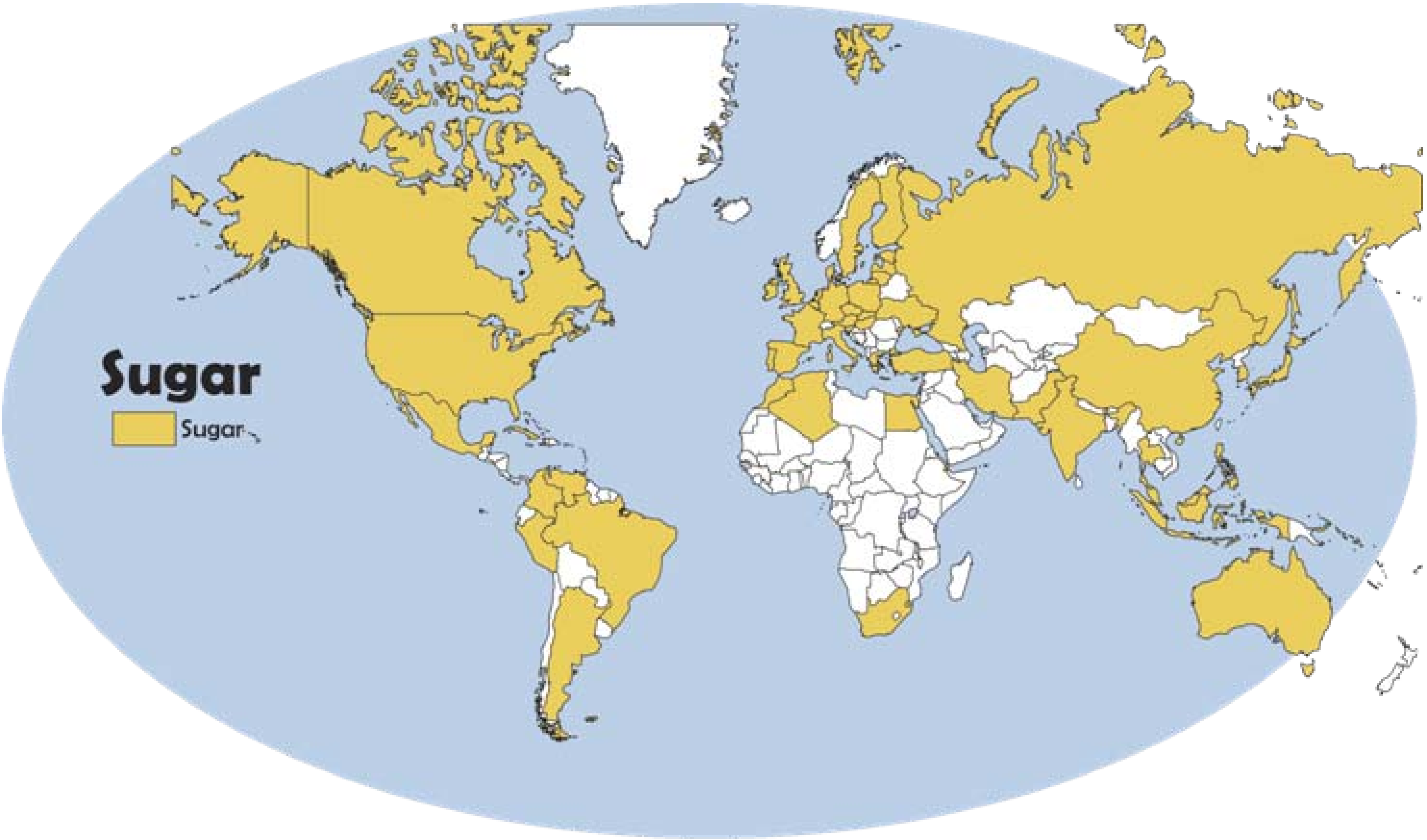

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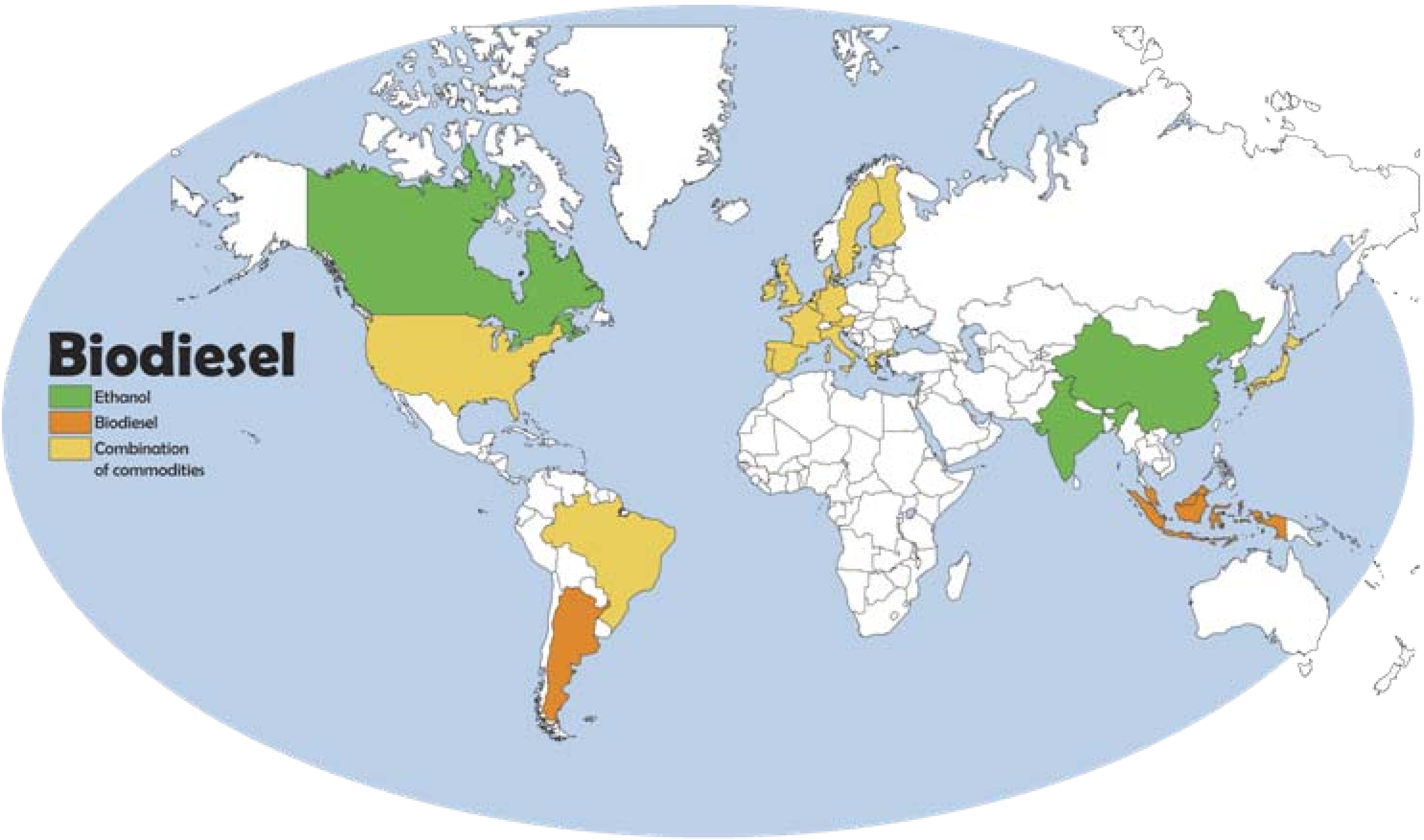

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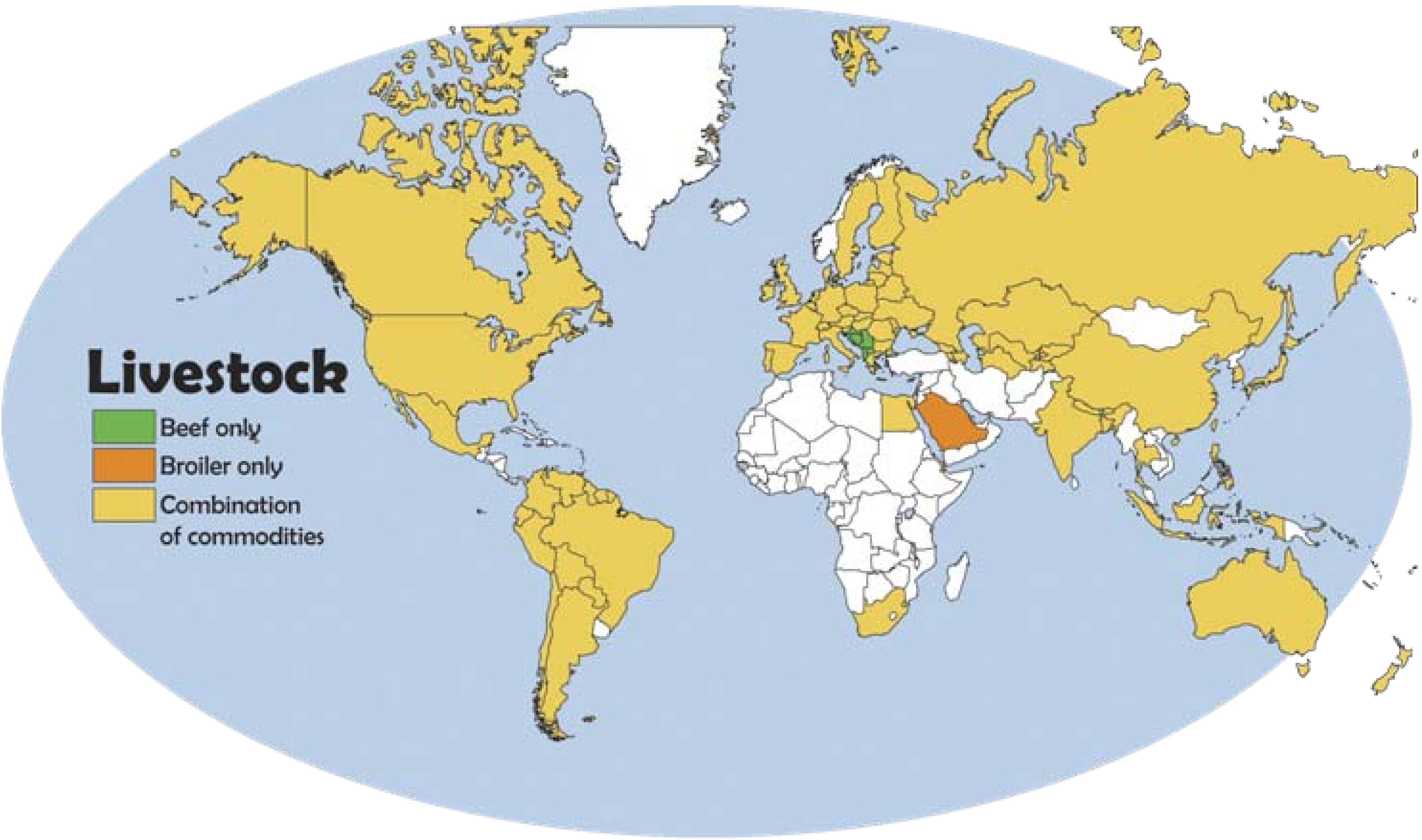
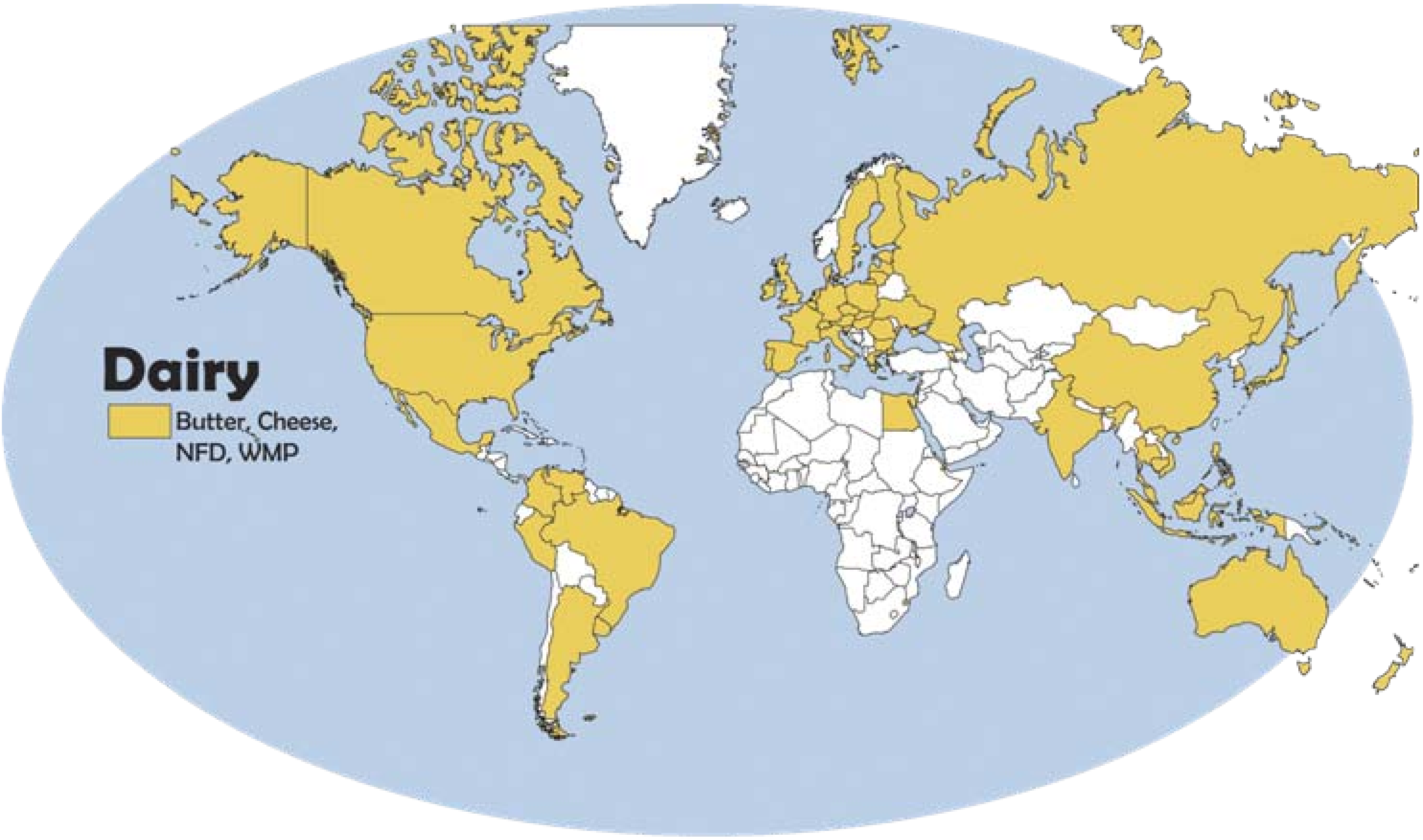
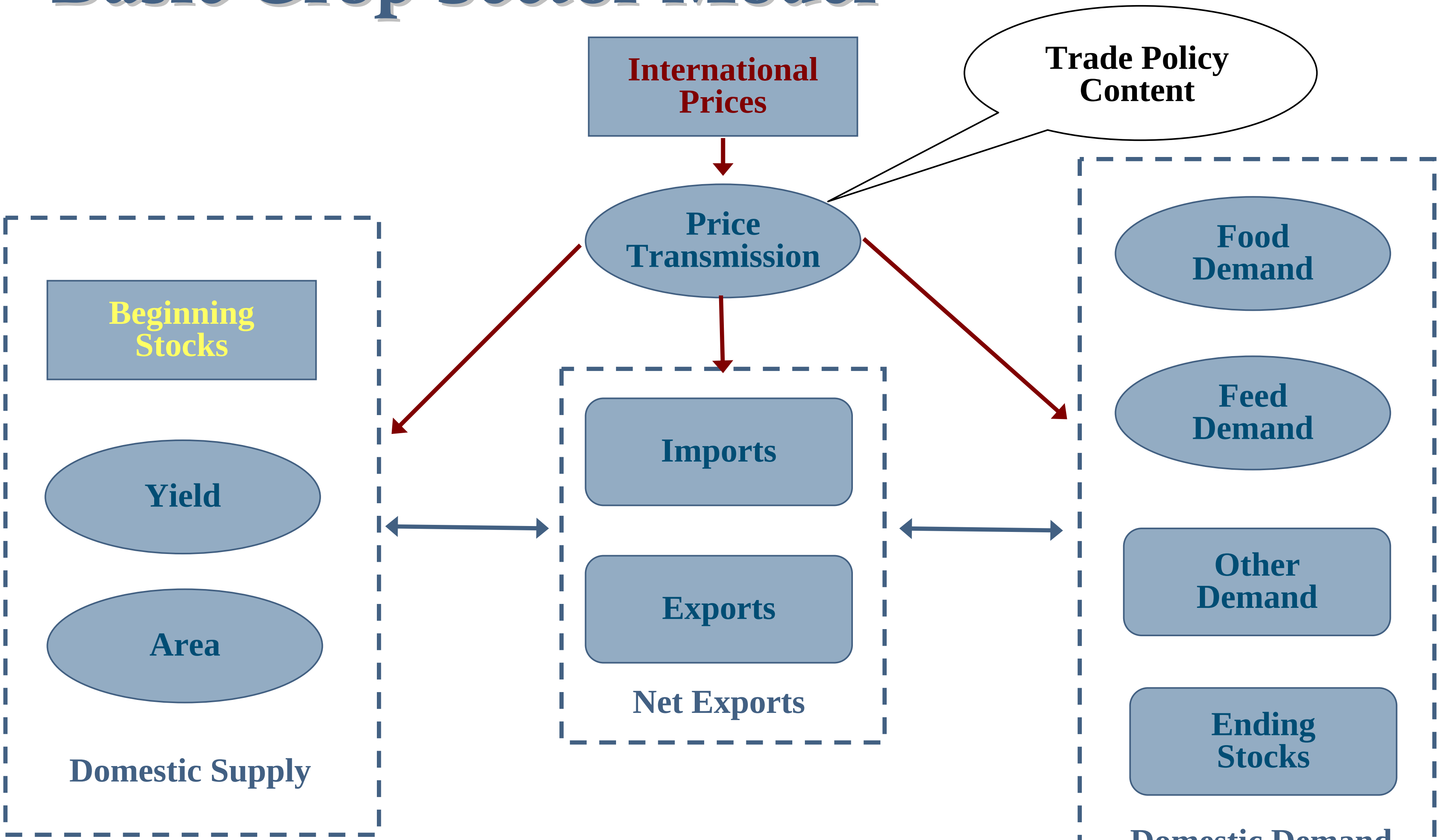


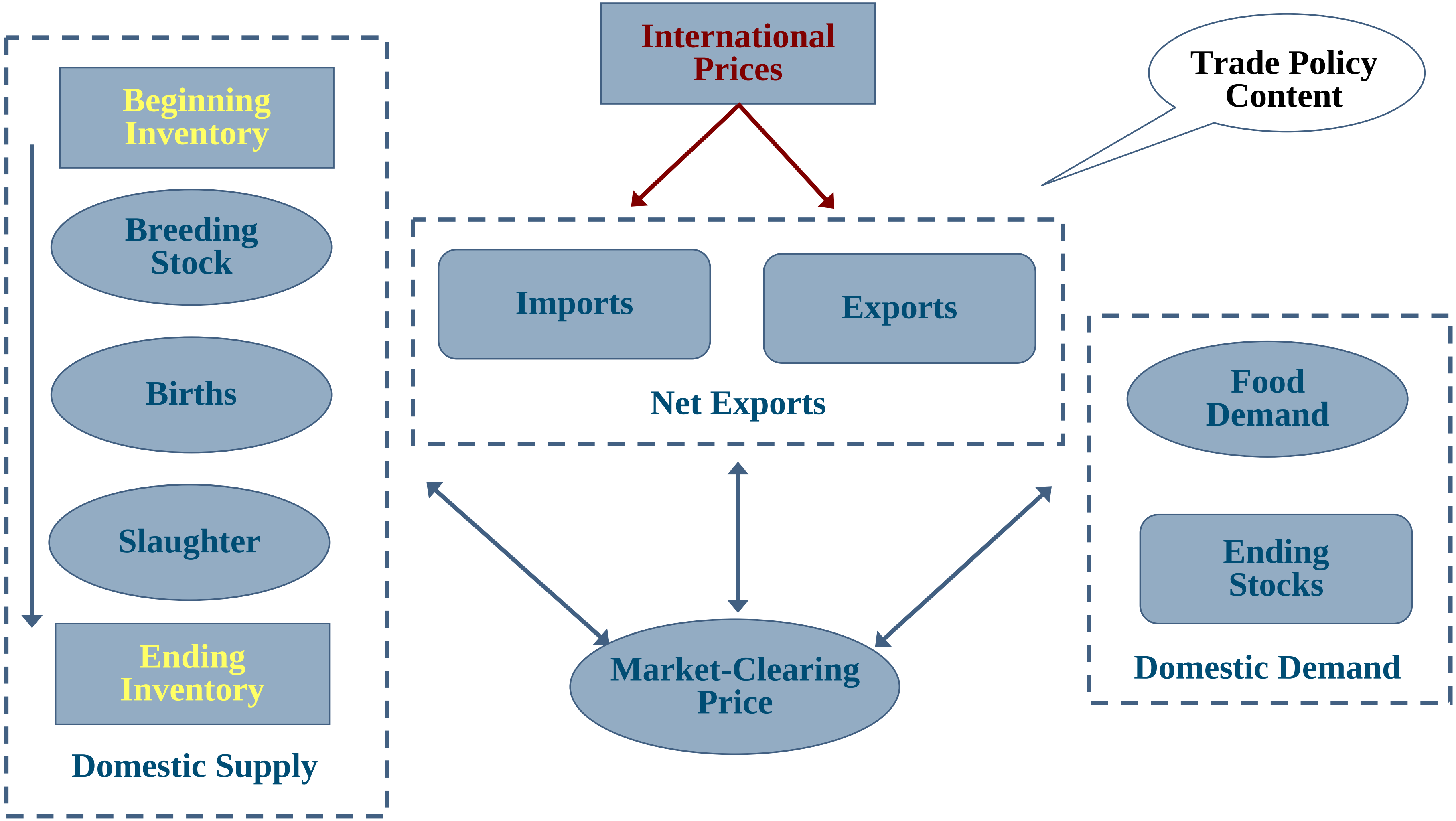
Country Coverage by Commodity



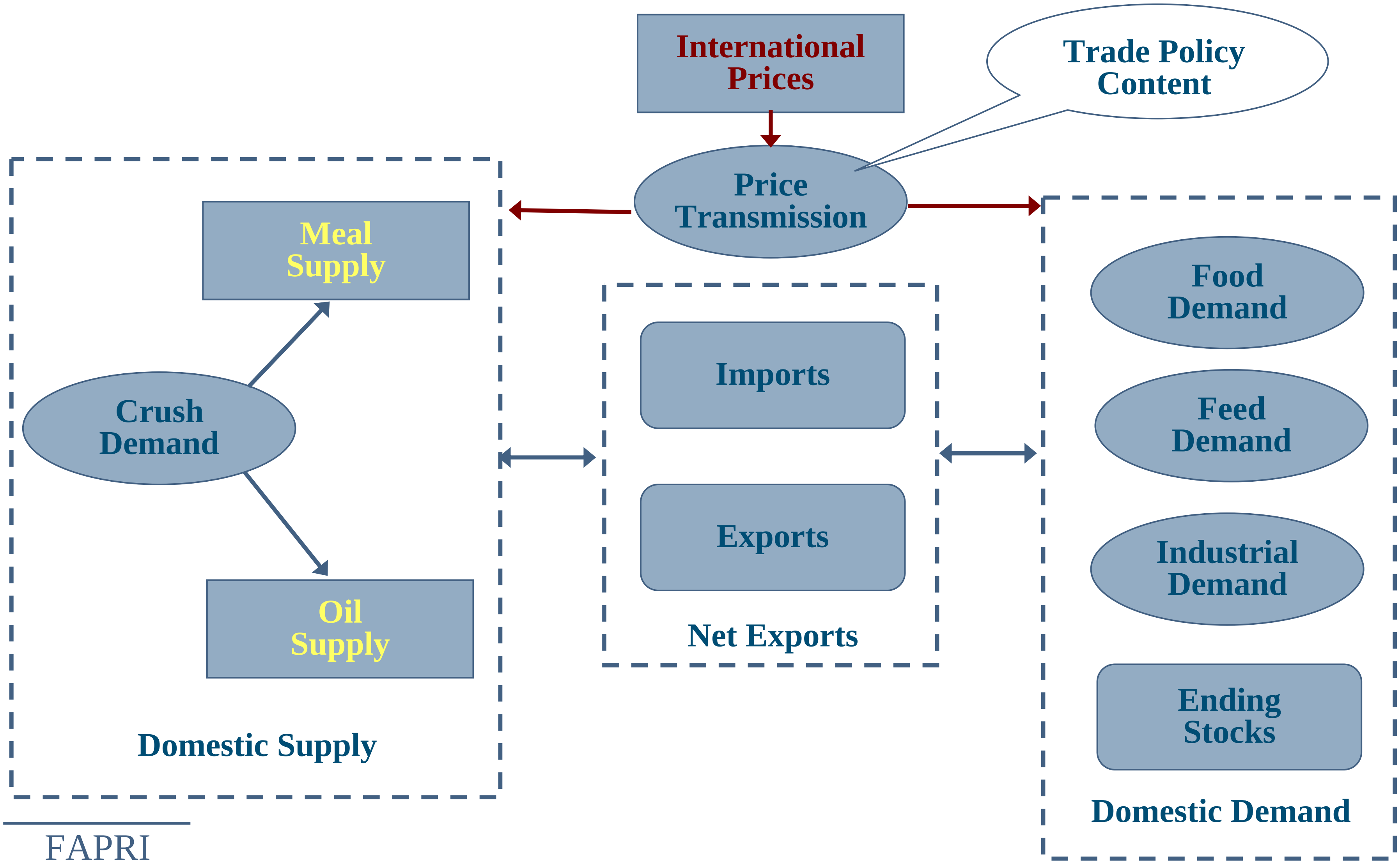
Basic Crop Sector Model



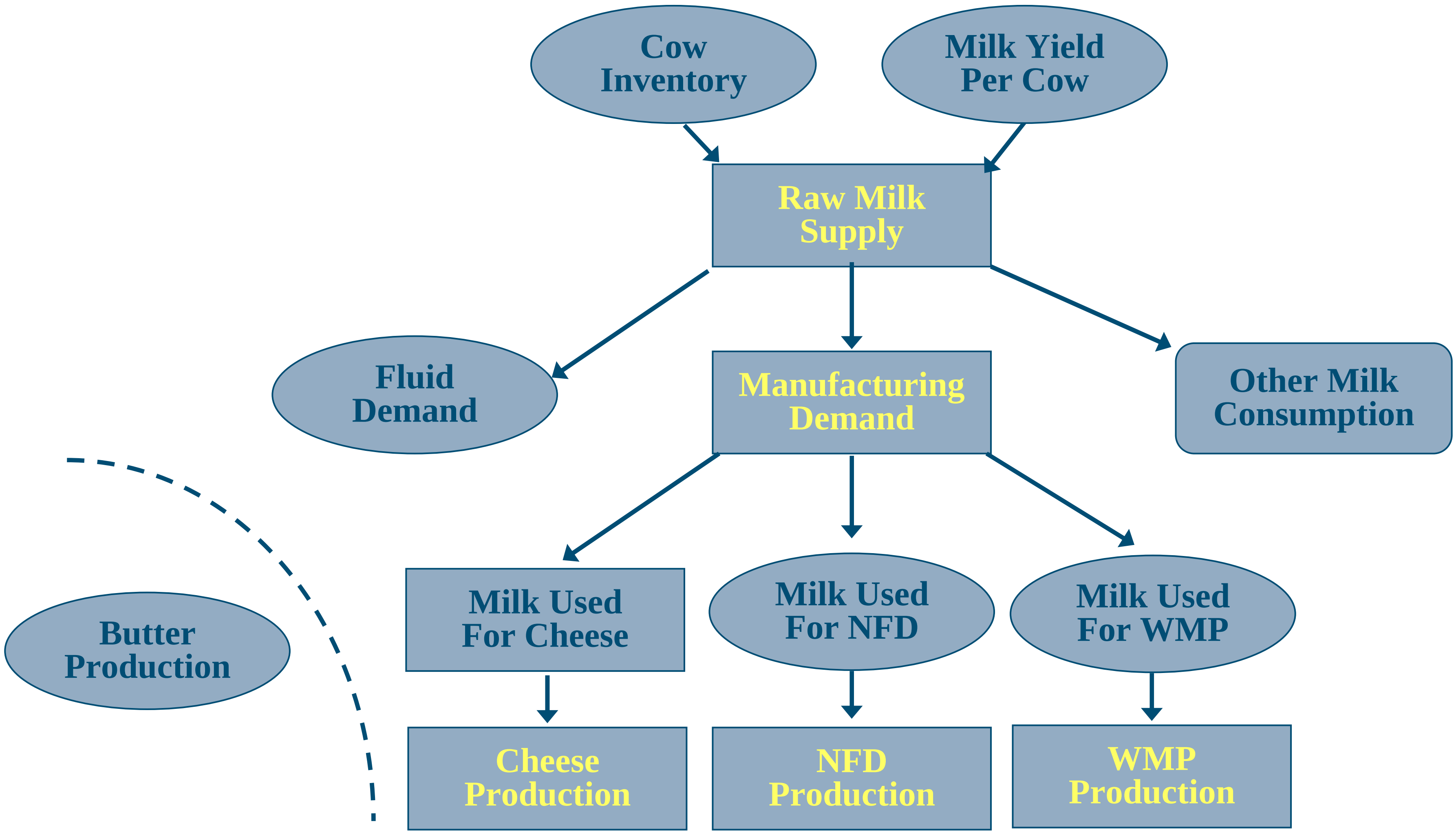
Basic Livestock Sector Model



Derived Product Model: Oilseeds

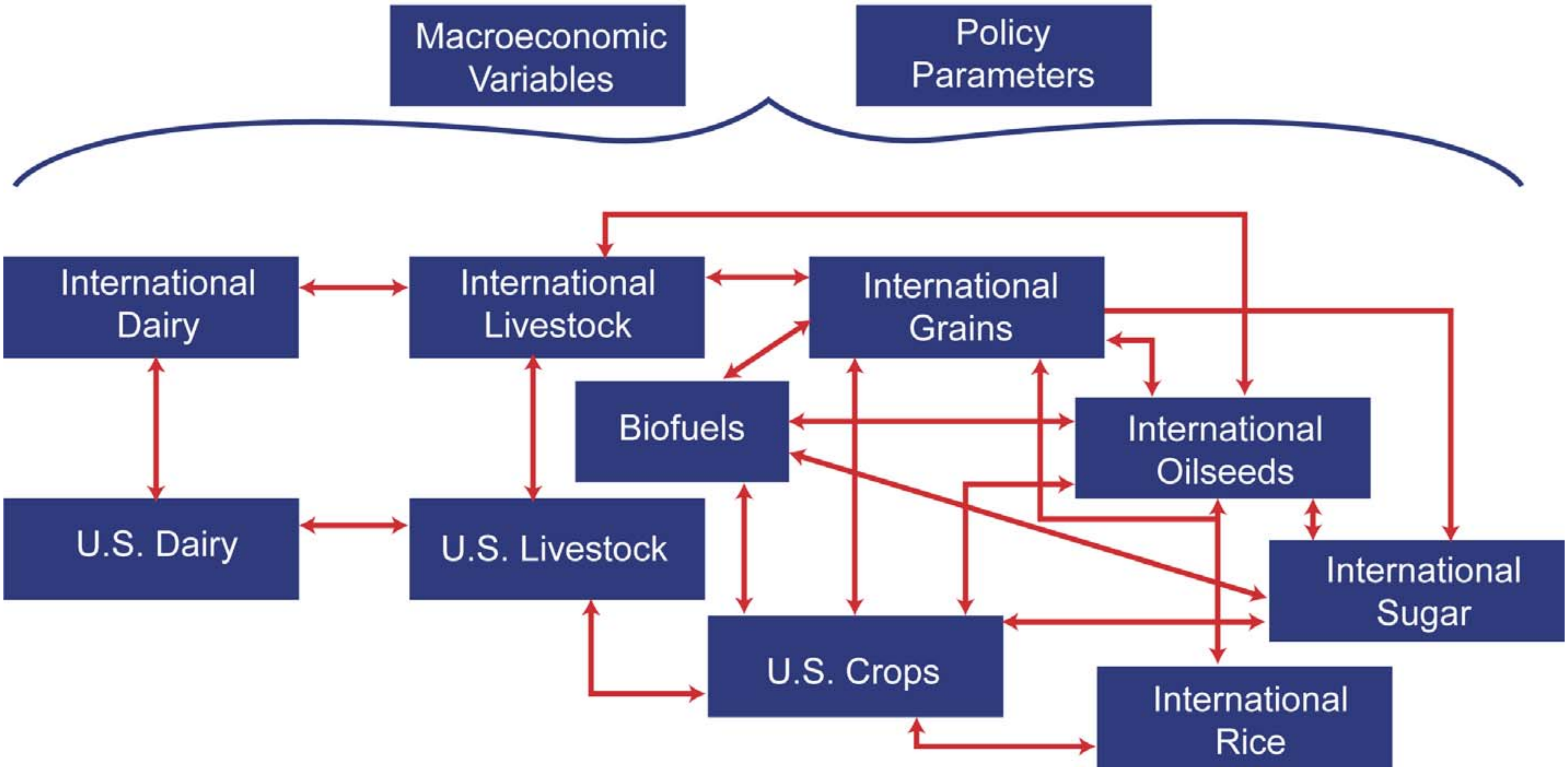


Dairy Product Supply

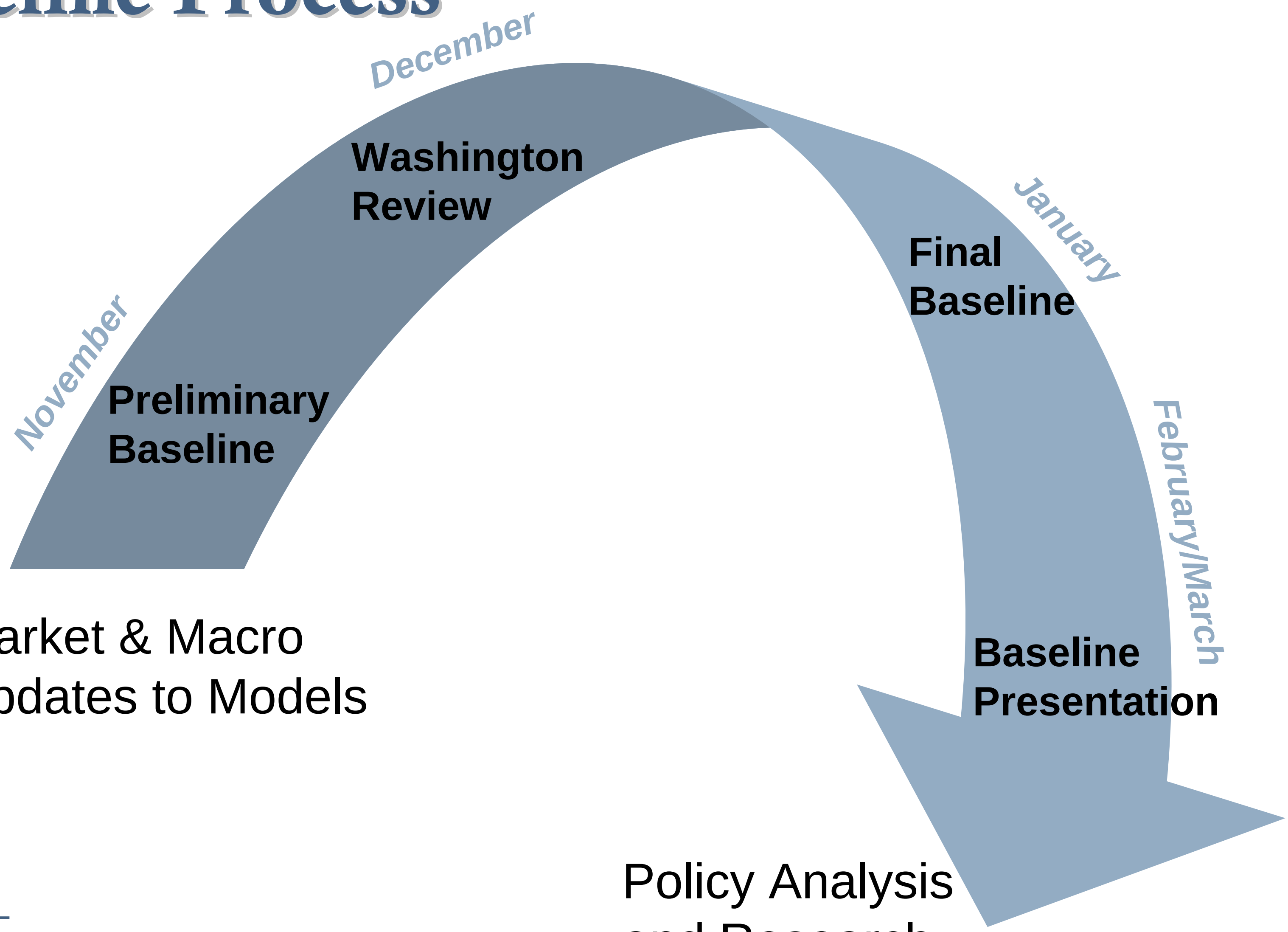


Model Interactions

Trade, Prices, and Physical Flows



Baseline Process



Market & Macro Updates to Models

Policy Analysis and Research

Core Products

- Baseline
  - FAPRI Briefing book and press release
  - FAPRI Outlook book
  - Web page: http://www.fapri.iastate.edu/
  - Database
- Analysis
  - Working papers
  - Journals/Papers/IA Ag Review

FAPRI Projects and Analyses

- Multilateral Trade and Agricultural Policy Reforms in Sugar Markets
- Modeling World Peanut Product Markets: A Tool for Agricultural Trade Policy Analysis
- U.S. Farm Policy and the World Trade Organization: How Do They Match Up?
- Analysis of Doha Round Proposals
- Asian Dairy Markets
- Impacts of Eastward Enlargement of the European Union
- An Analysis of the Link between Ethanol, Energy, and Crop Markets
- The Long-Run Impact of Corn-Based Ethanol on the Grain, Oilseed, and Livestock Sectors
- Removal of U.S. Ethanol Domestic and Trade Distortions: Impact on U.S. and Brazilian Ethanol Markets

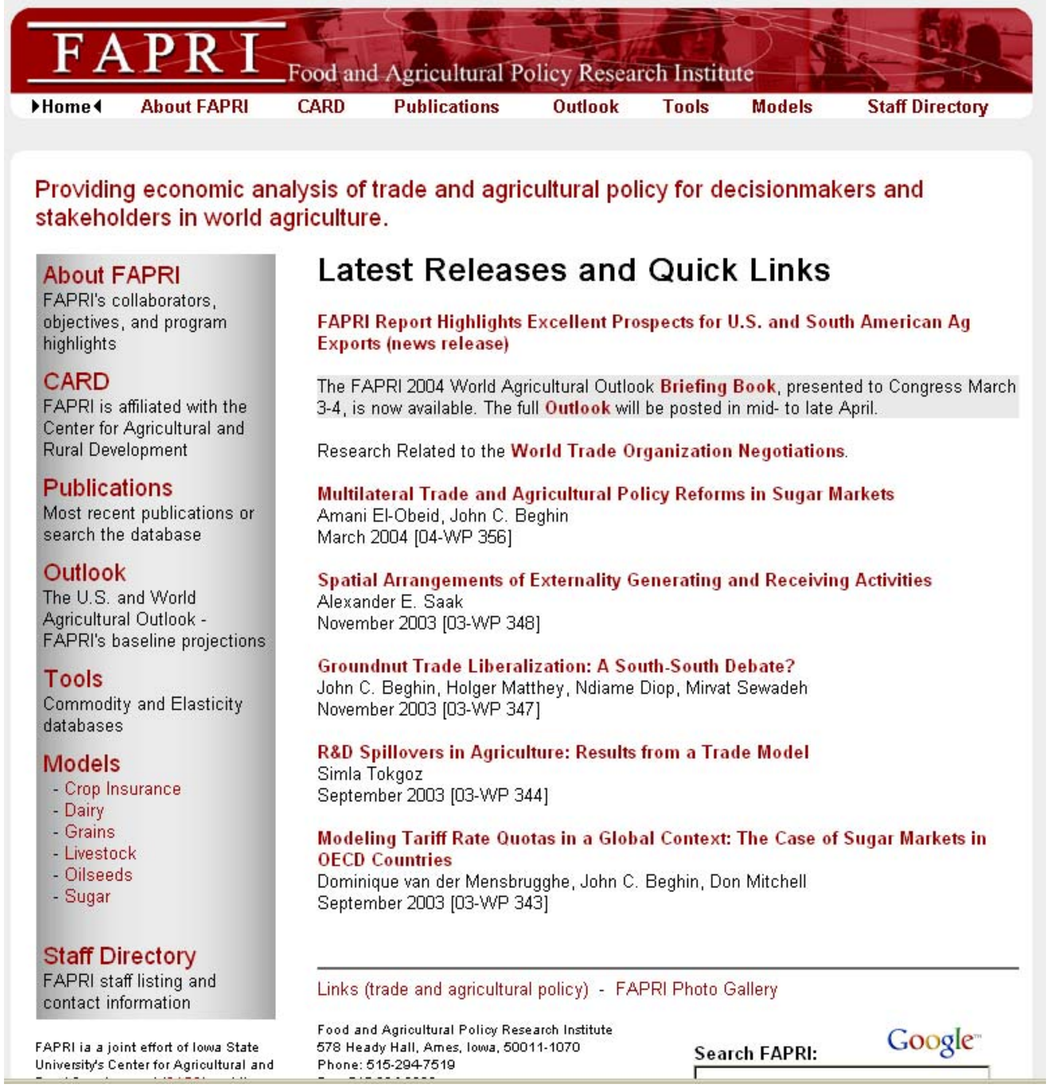
Record of Excellence and Relevance

- FAPRI researchers are principal economic policy analysts for:
  - Leading Industry Groups
    - National Pork Producers Council
    - U.S. Grains Council
    - National Corn Growers Association
    - American soybean Association
    - National Milk Producers Federation
    - American Farm Bureau Foundation
  - Significant Policy Makers-Congress and USDA

Future Model Extensions

- Urban and Rural demands
- Regional Supplies and Demands
  - Environmental Factors
  - Varied Cropping Patterns and preference structures
- Backyard and Commercial Livestock Supplies
- Explicit Incorporation of Government Investments in Productivity Growth
  - Impact of research expenditures on yields
  - Impact of irrigation investments on yields, cropping patterns, and water use
- Non-Agricultural Economic Sector Effects
- Bilateral/Regional Trade Flows

www.fapri.org



Thank you

Aquaculture: Control with production gives the opportunity to work systematically with the market

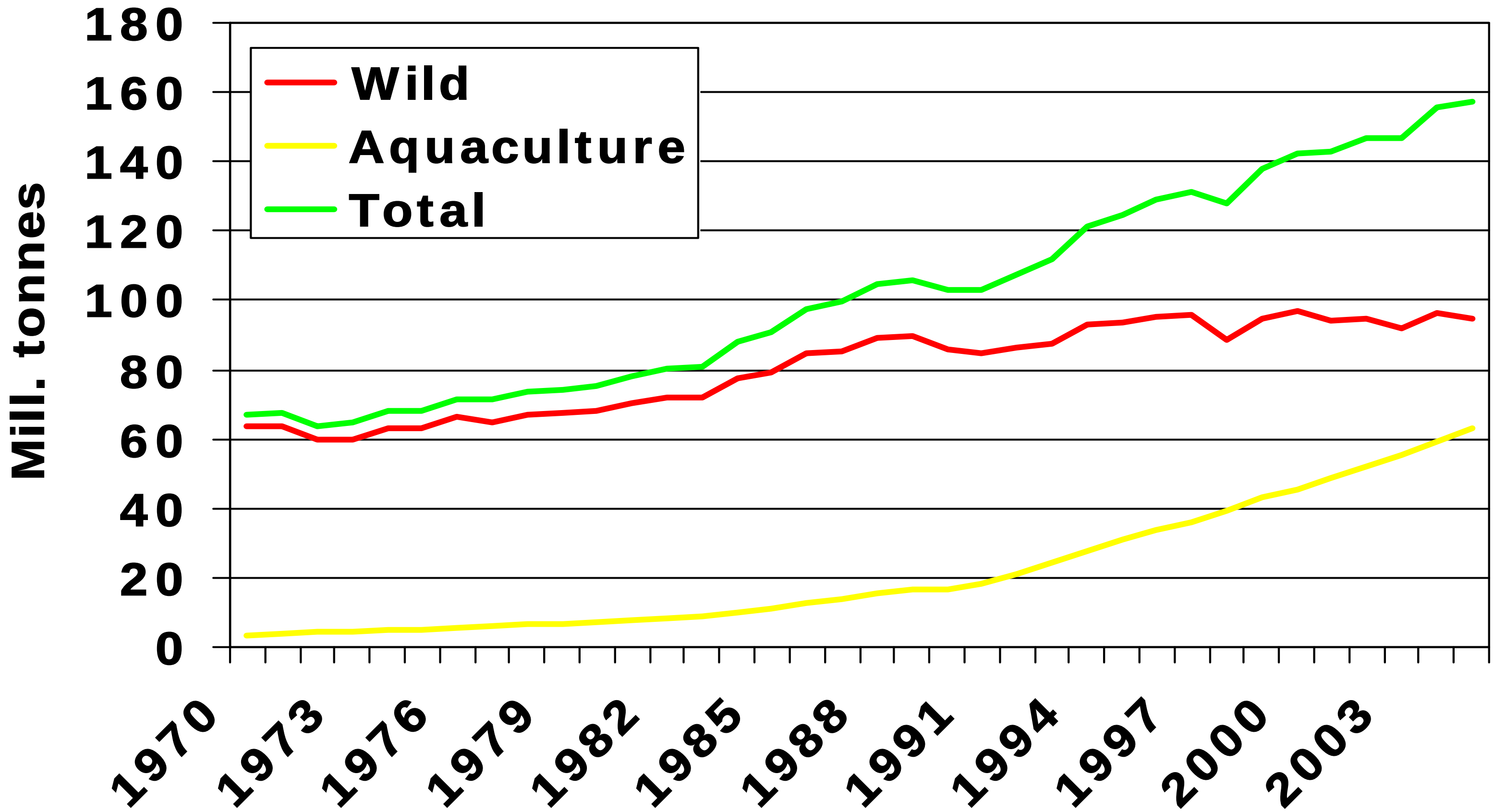
Frank Asche

University of Stavanger

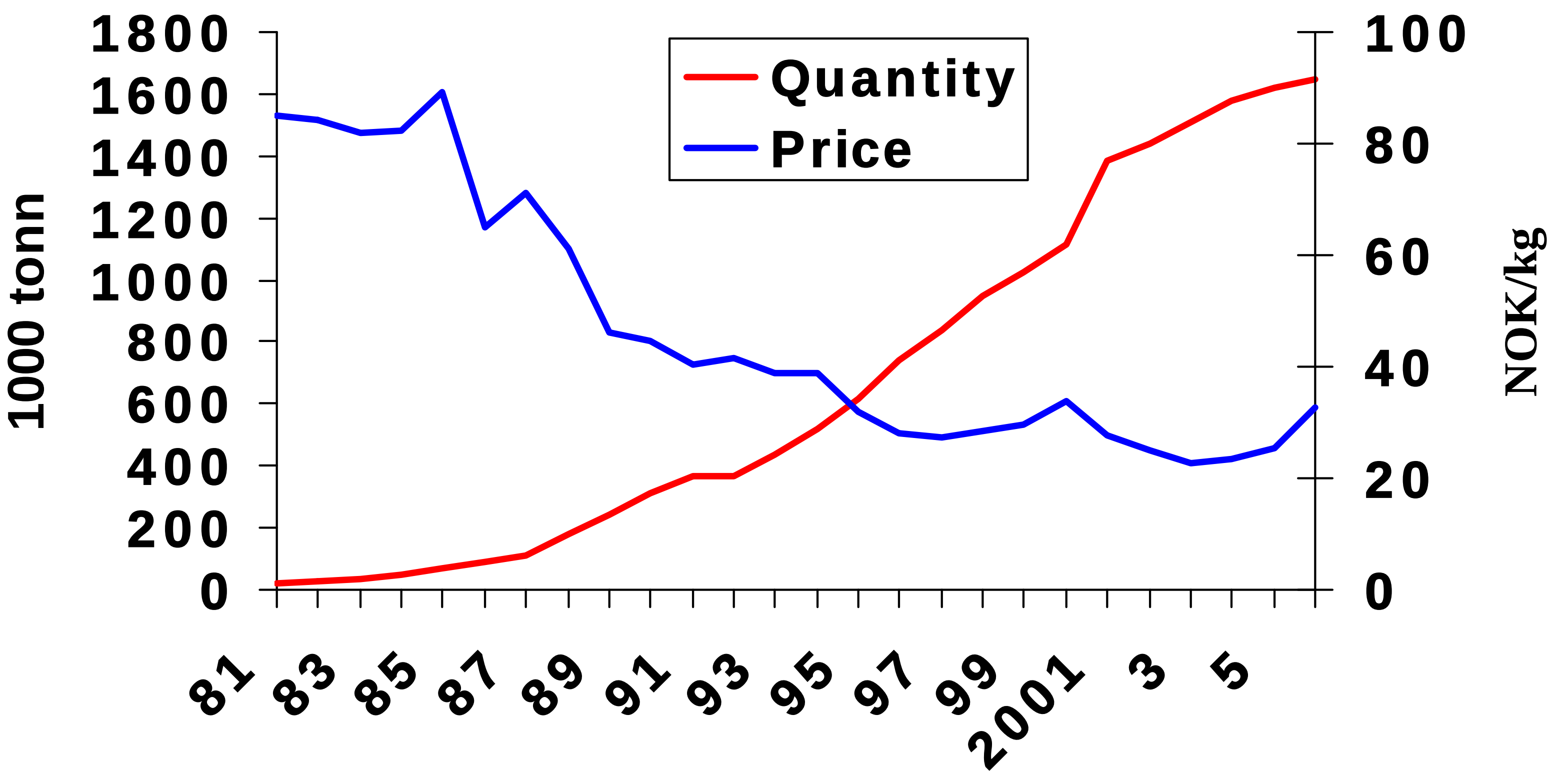
Aquaculture

- Human cultivation of organisms in water
- Fish farming, fish culture, marine culture or mariculture, sea ranching
- Farming, not hunting and gathering as fisheries is still an example of
- Had its origins in China more than thousand years ago
- A revolution occurred in the 1970s, that gave humans a much higher degree of control with the production process

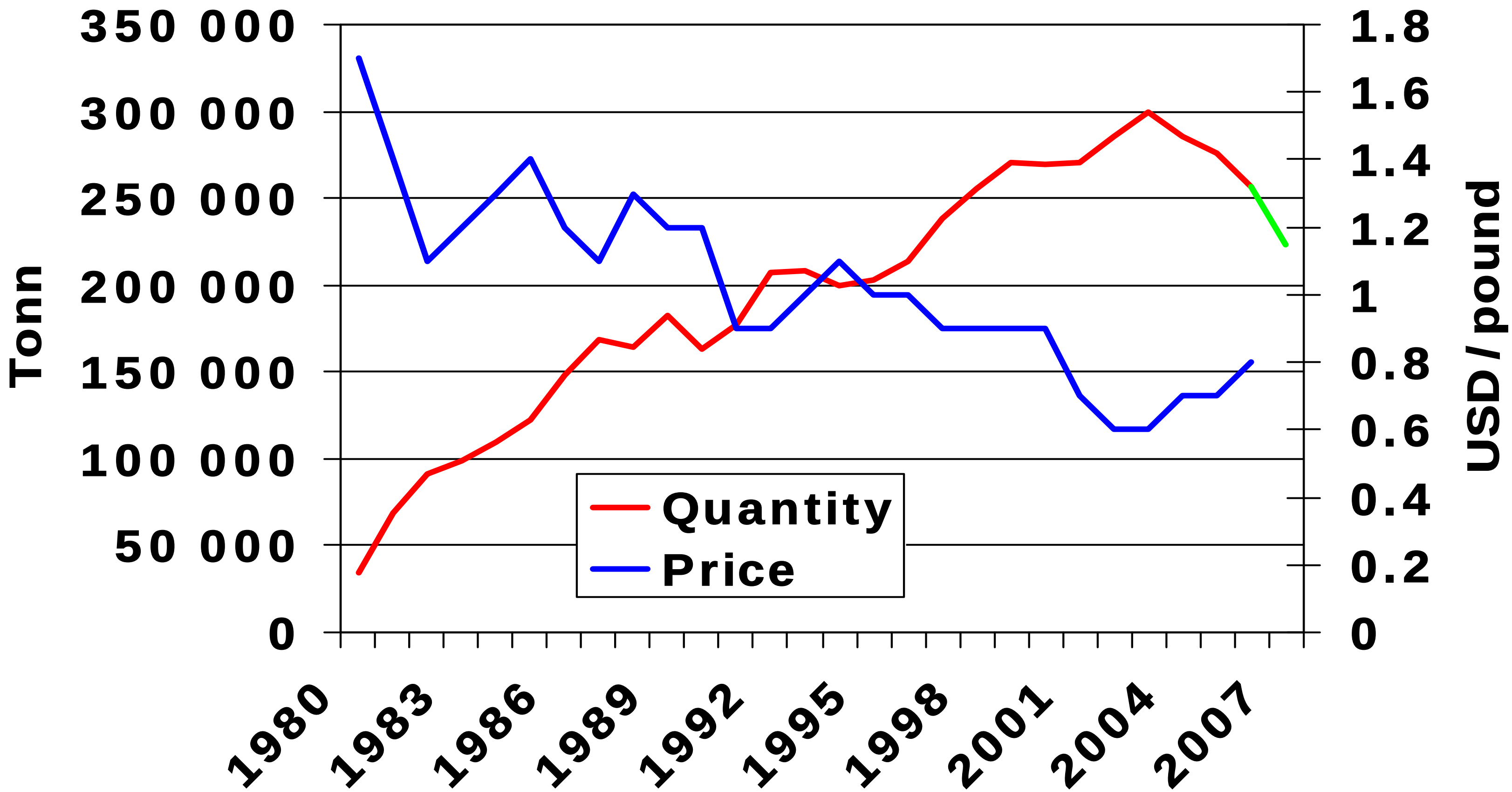
Global seafood production



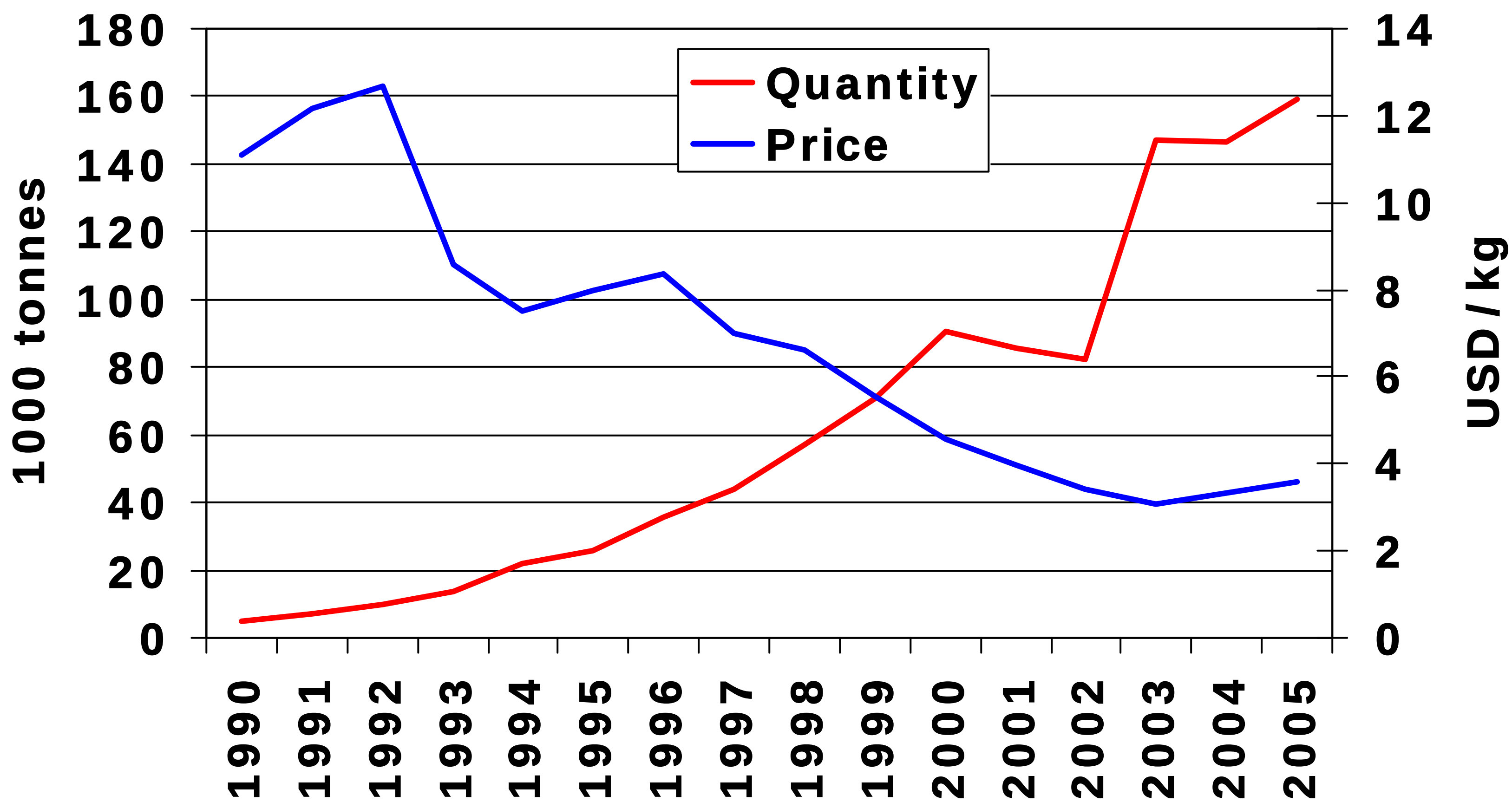
Global production of farmed salmon and real Norwegian export price, 1981-2006



US catfish production and real producer price (2006=1)



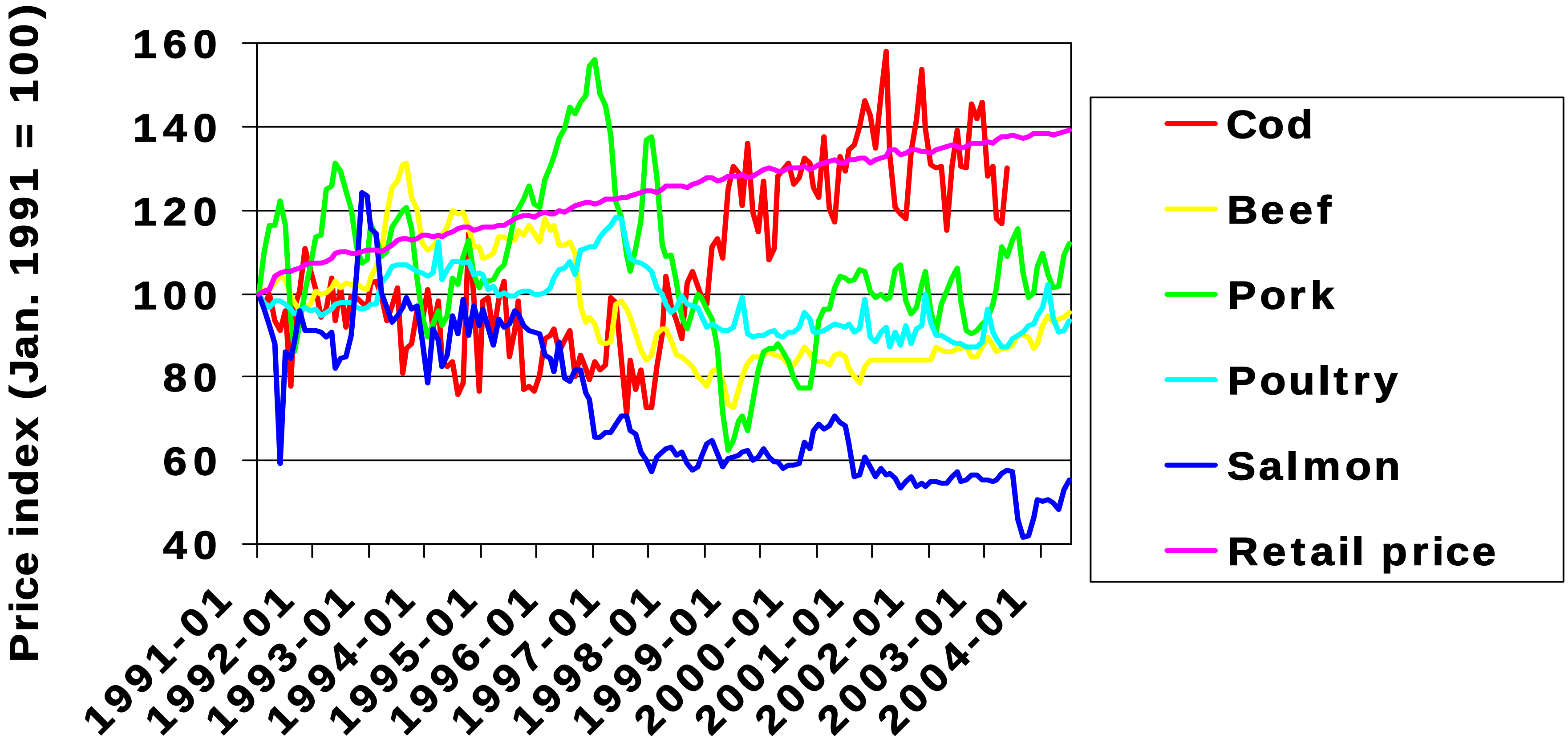
Production of Sea bream and real unit price (2005=1)



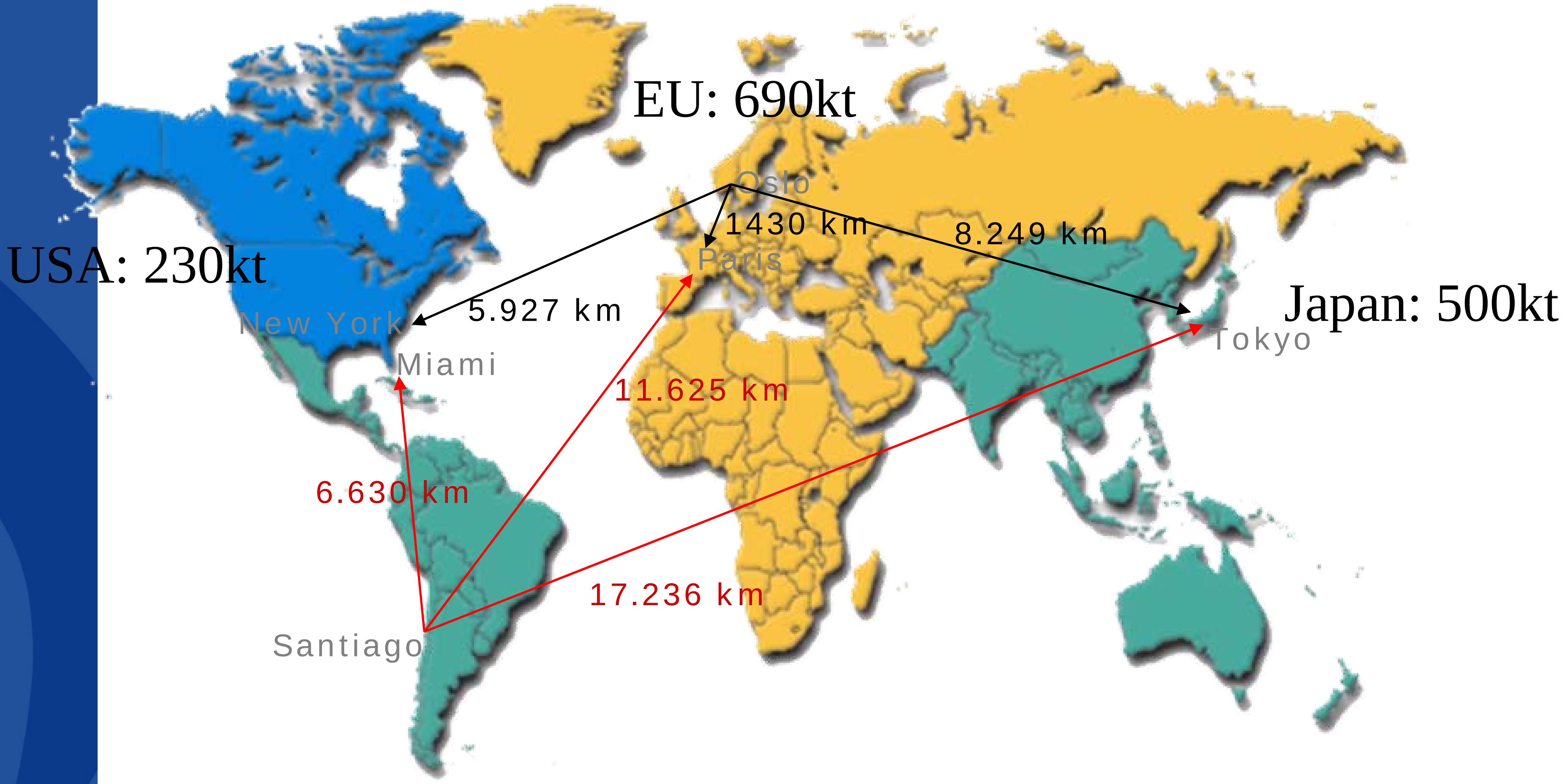
University of Stavanger

- There has been a tremendous degree of productivity growth in aquaculture
- Real prices has been rapidly declining
  - Production growth has been faster than market growth

Salmon (and other aquaculture products with declining prices) is competitive:
Retail prices on selected food products and retail price index in UK



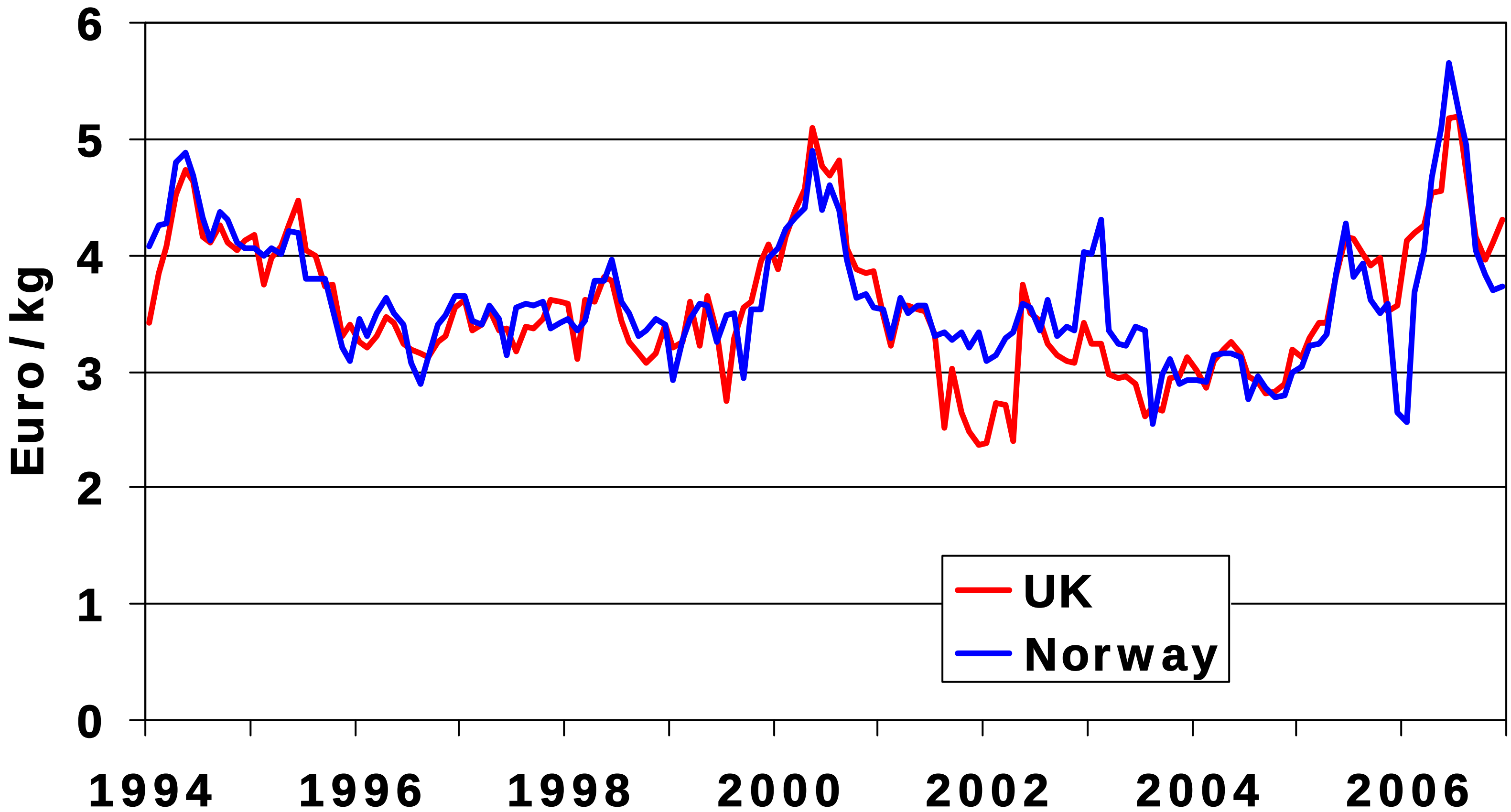
The market for salmon has become global



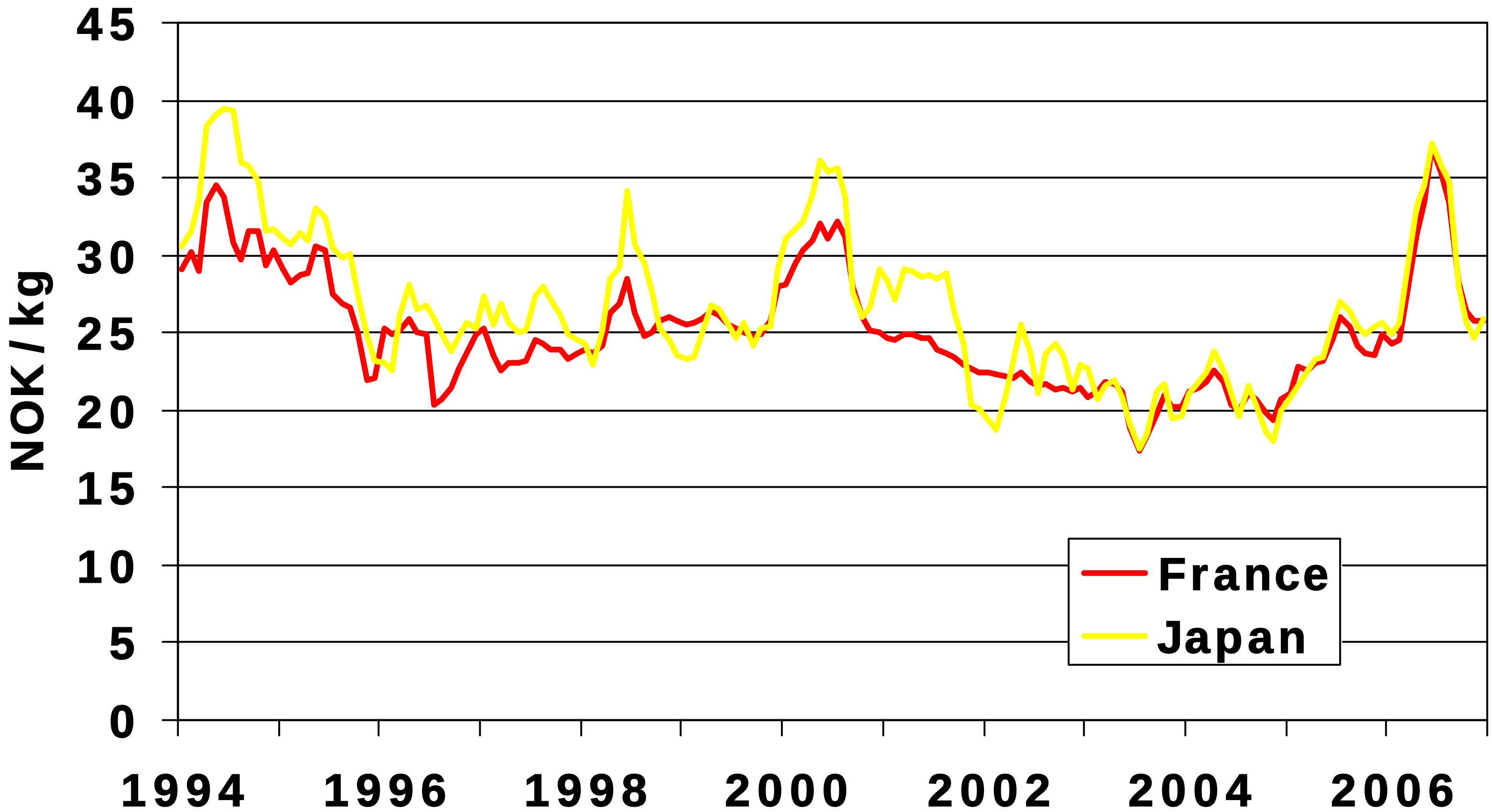
Market size

- EU
  - Total import value €2.2 billion for 507k tonnes
  - In addition, 70k Scottish tonnes consumed in Scotland worth € 250 million
  - France, Germany, UK and Denmark and Poland
- USA
  - 230kt + 50kt canned
- Japan
  - 500kt, of which half is imported
- As for seafood, these three markets are the most attractive because of their ability to pay
- South east Asia, China and Russia are very interesting markets

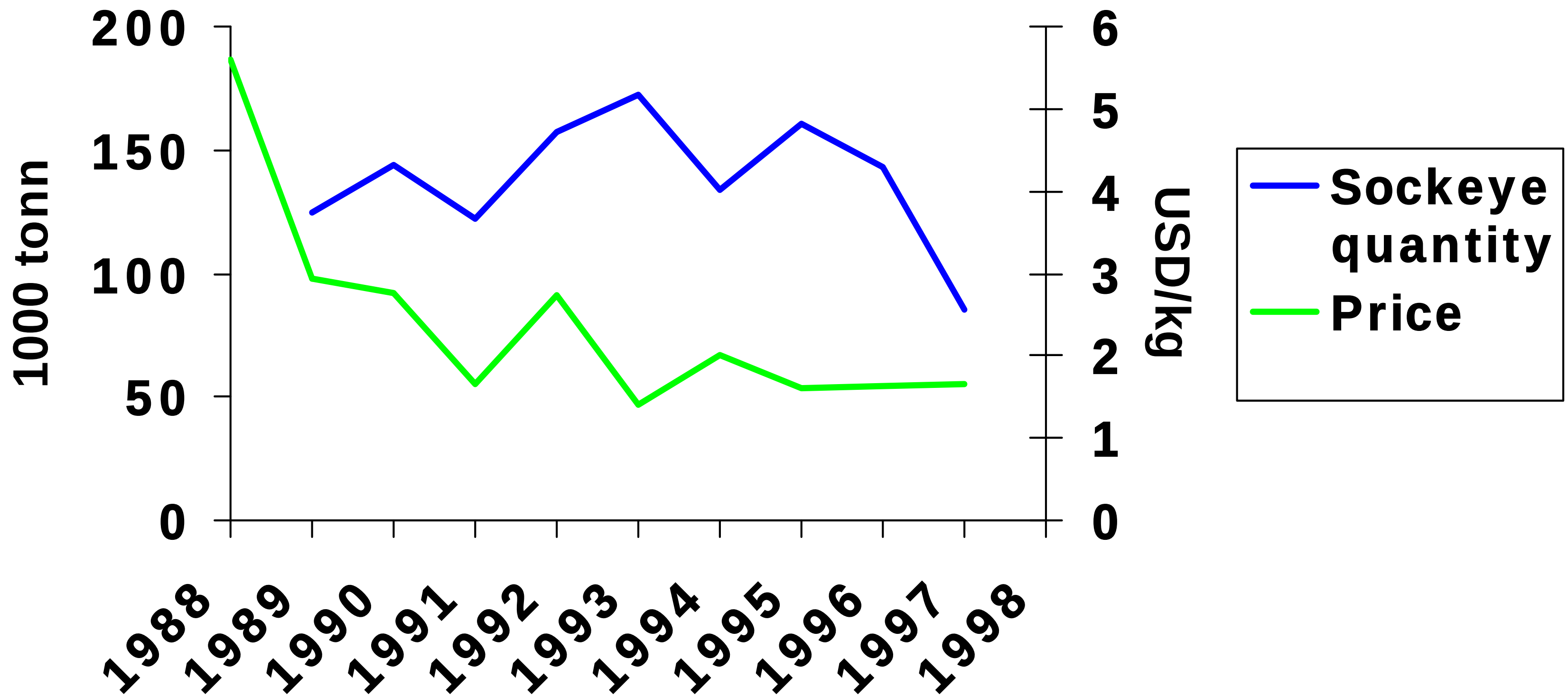
There is a global market: French import prices of salmon



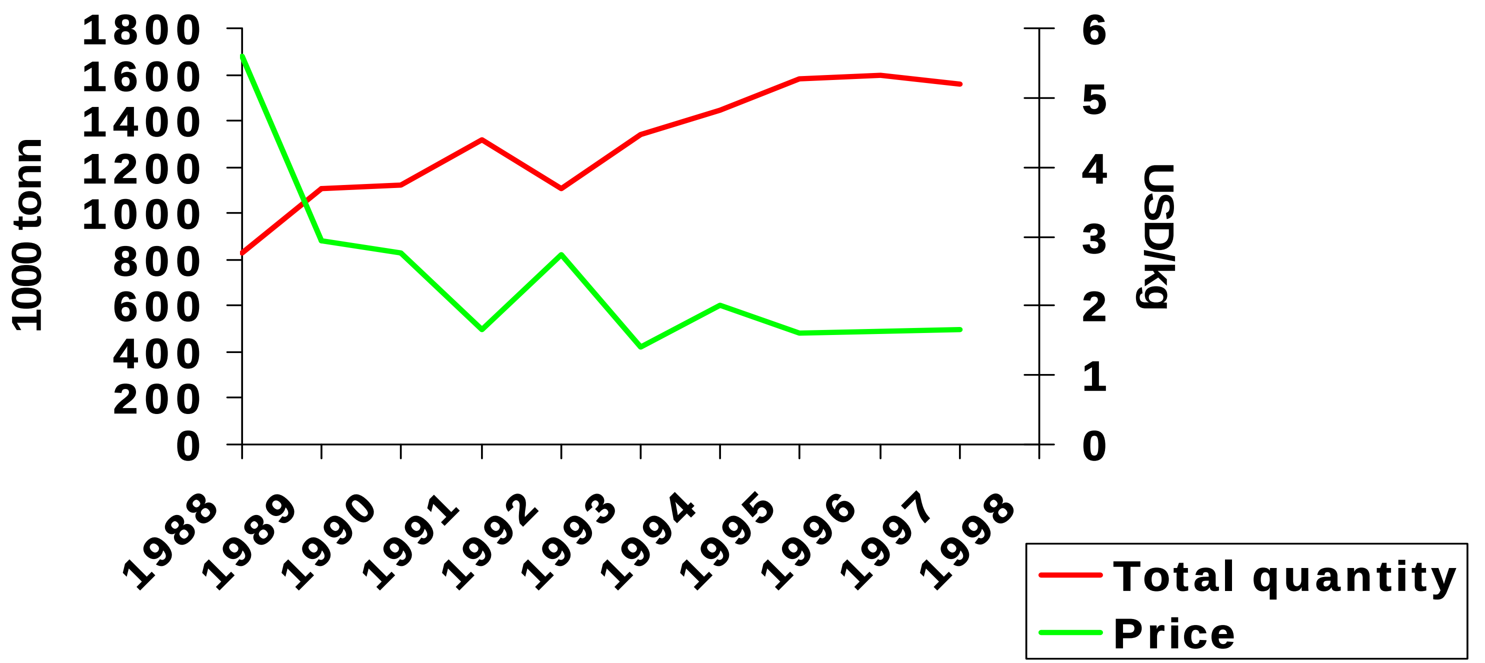
There is a global market: Norwegian export prices for fresh salmon



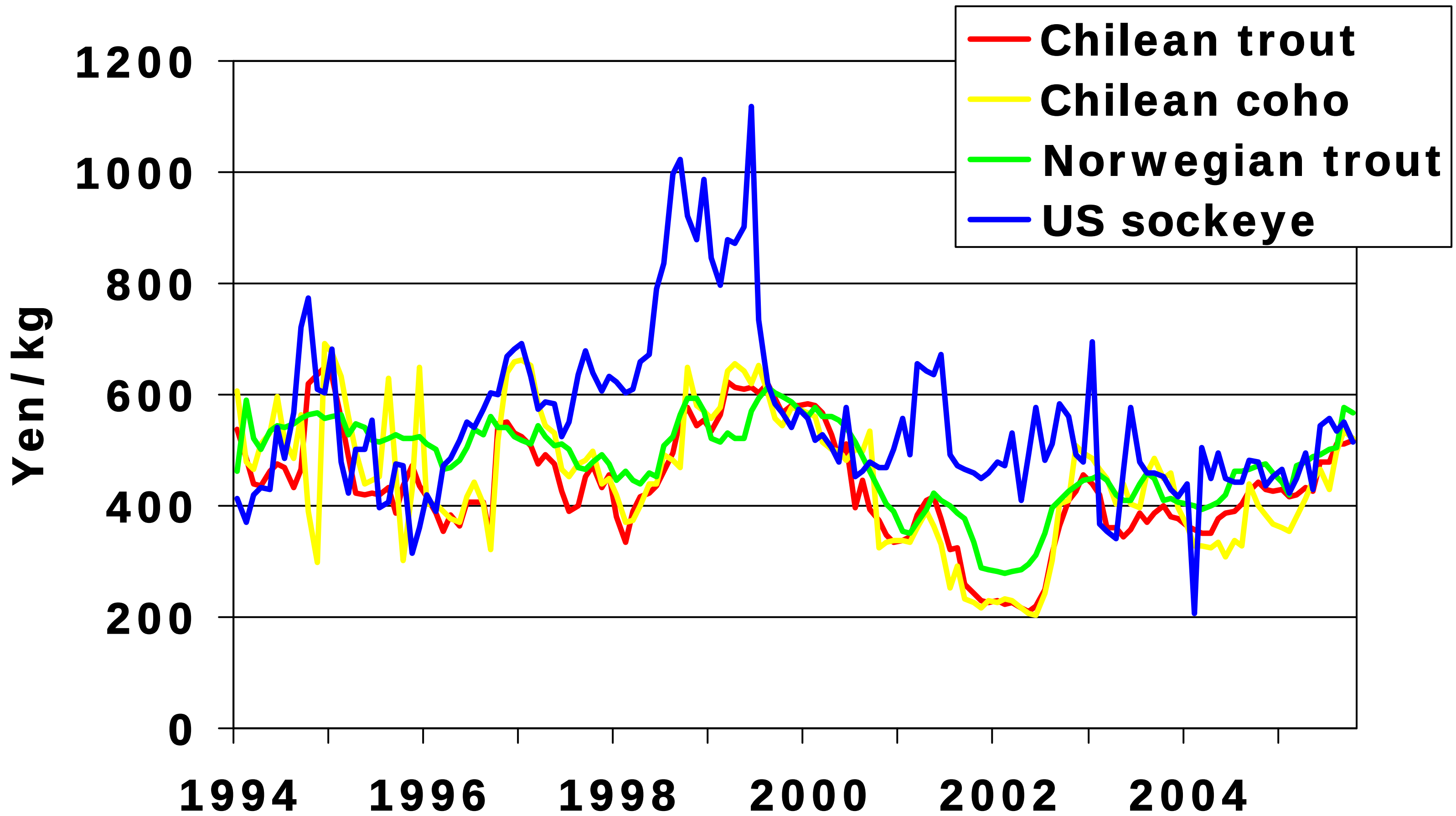
Quantity landed and sockeye price



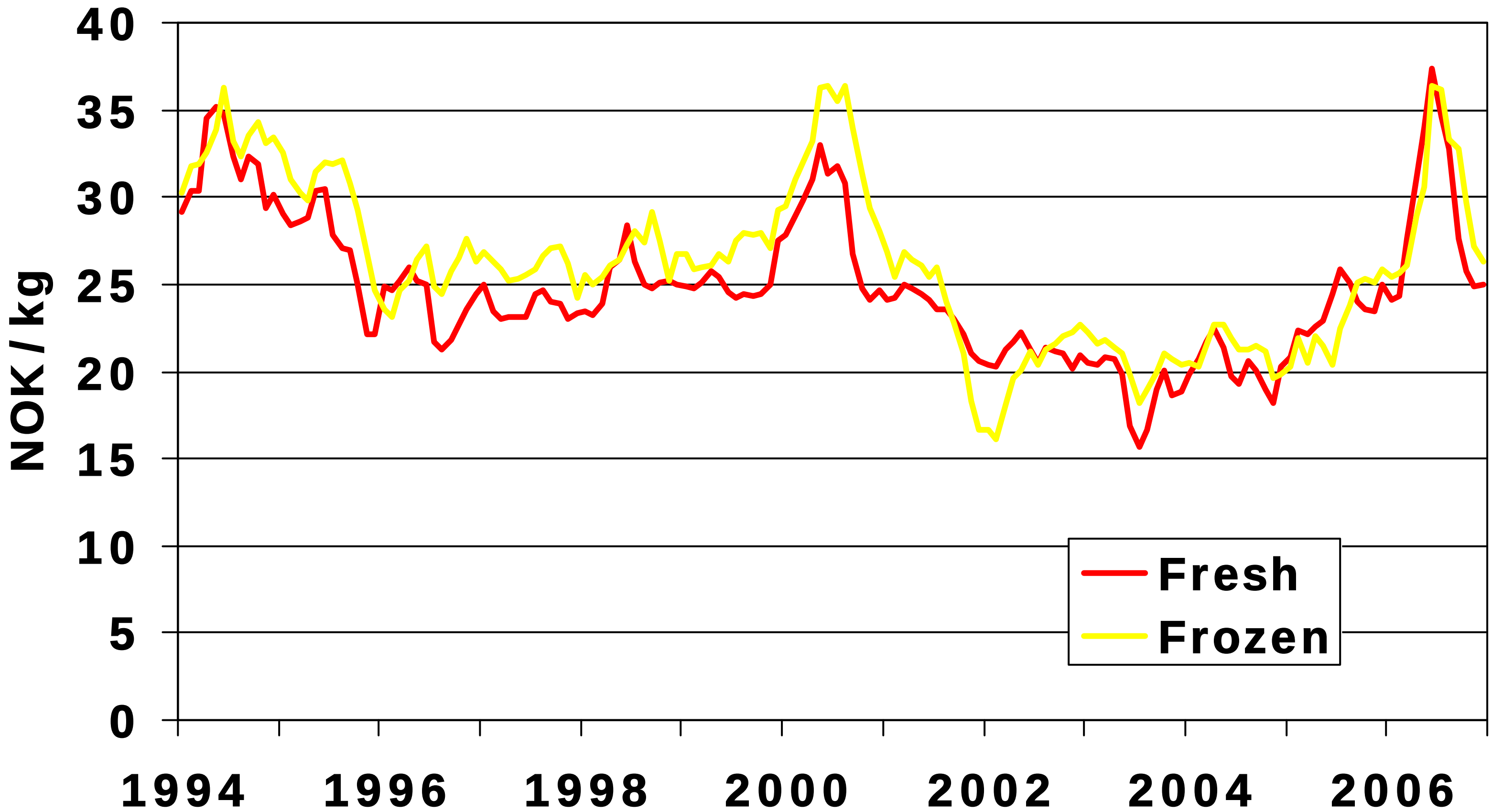
Total quantity salmon and sockeye price



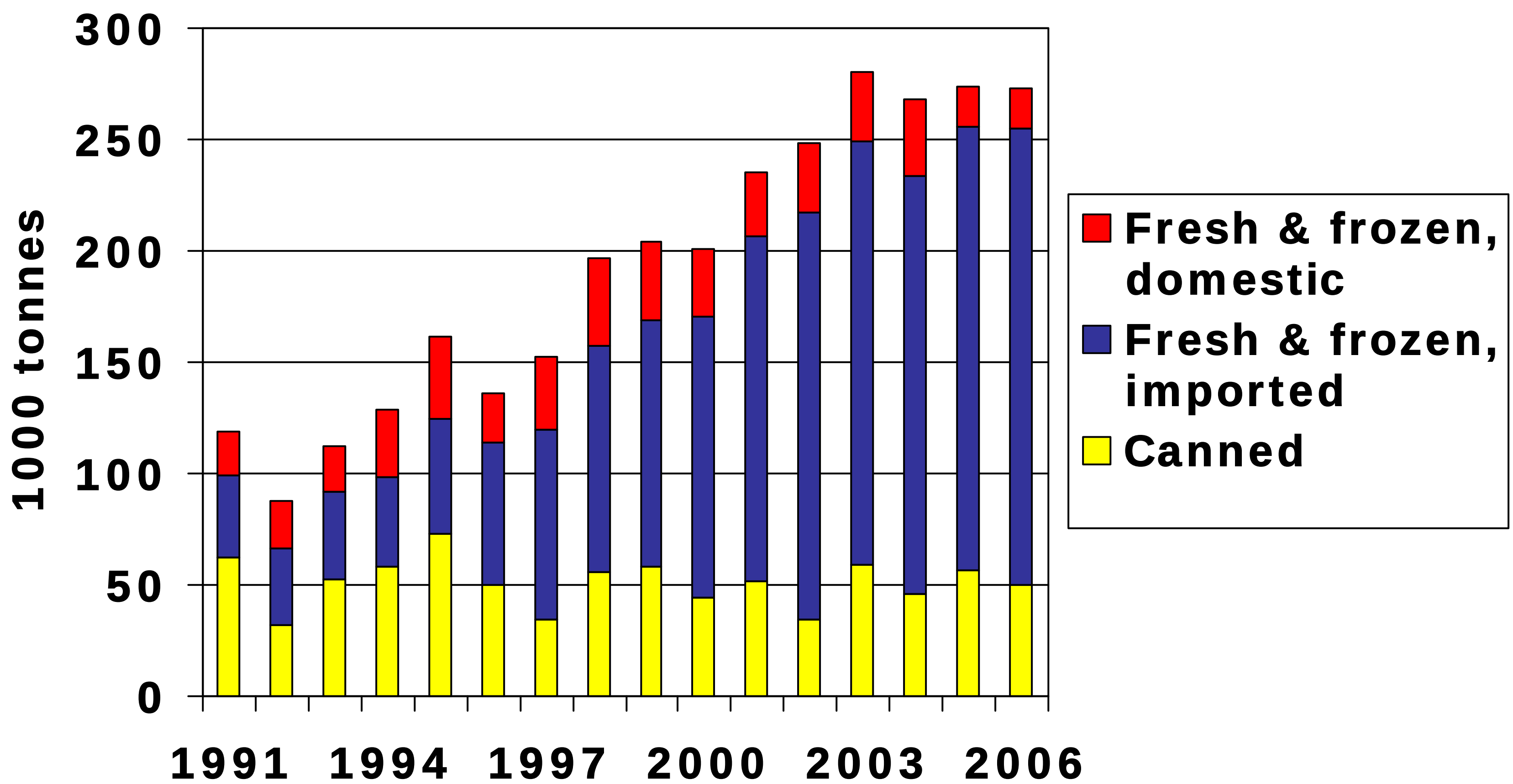
Japanese import prices



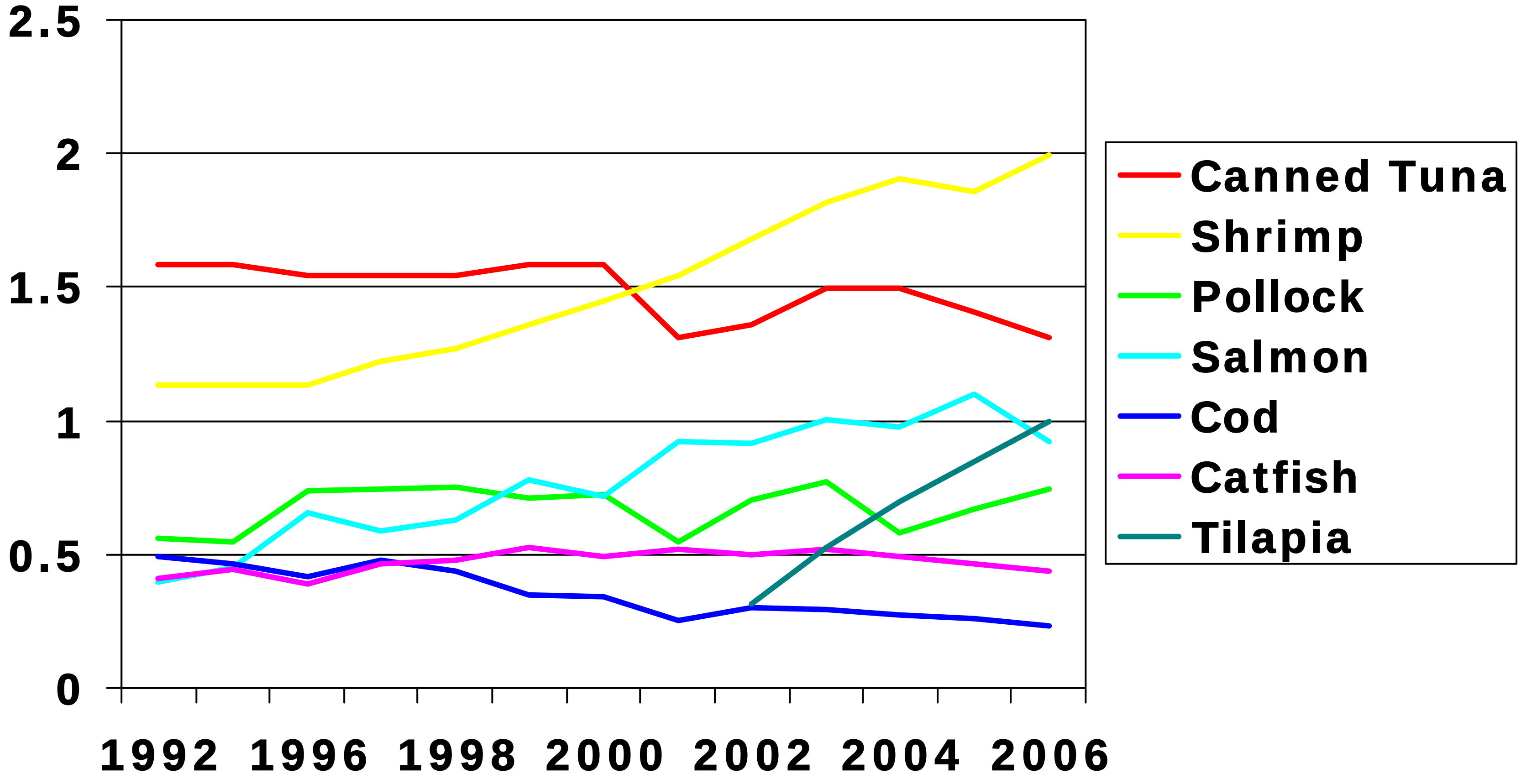
Norwegian export prices



US consumption by product form



US per capita consumption, leading species



A brief history of the development of the salmon market

- Pacific salmon
- Wild Atlantic salmon
- Farmed salmon in the early days
- Geographical expansion of the market
- More product forms

Innovations in logistics and marketing

- The control in the production process has allowed a number of innovations in the supply chain
  - E.g. large scale air freight of seafood, just-in-time delivery, and substantial product innovation

- One started in the traditional fresh fish counter, with unprocessed products....

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- ..and continued with fresh packed product, branded products..

- ..and one see an increased number of ready meals and convenience food based on salmon

- Product specter has developed significantly
  - Finer cuts
  - And specialiced products for the cut offs
    - Sausages

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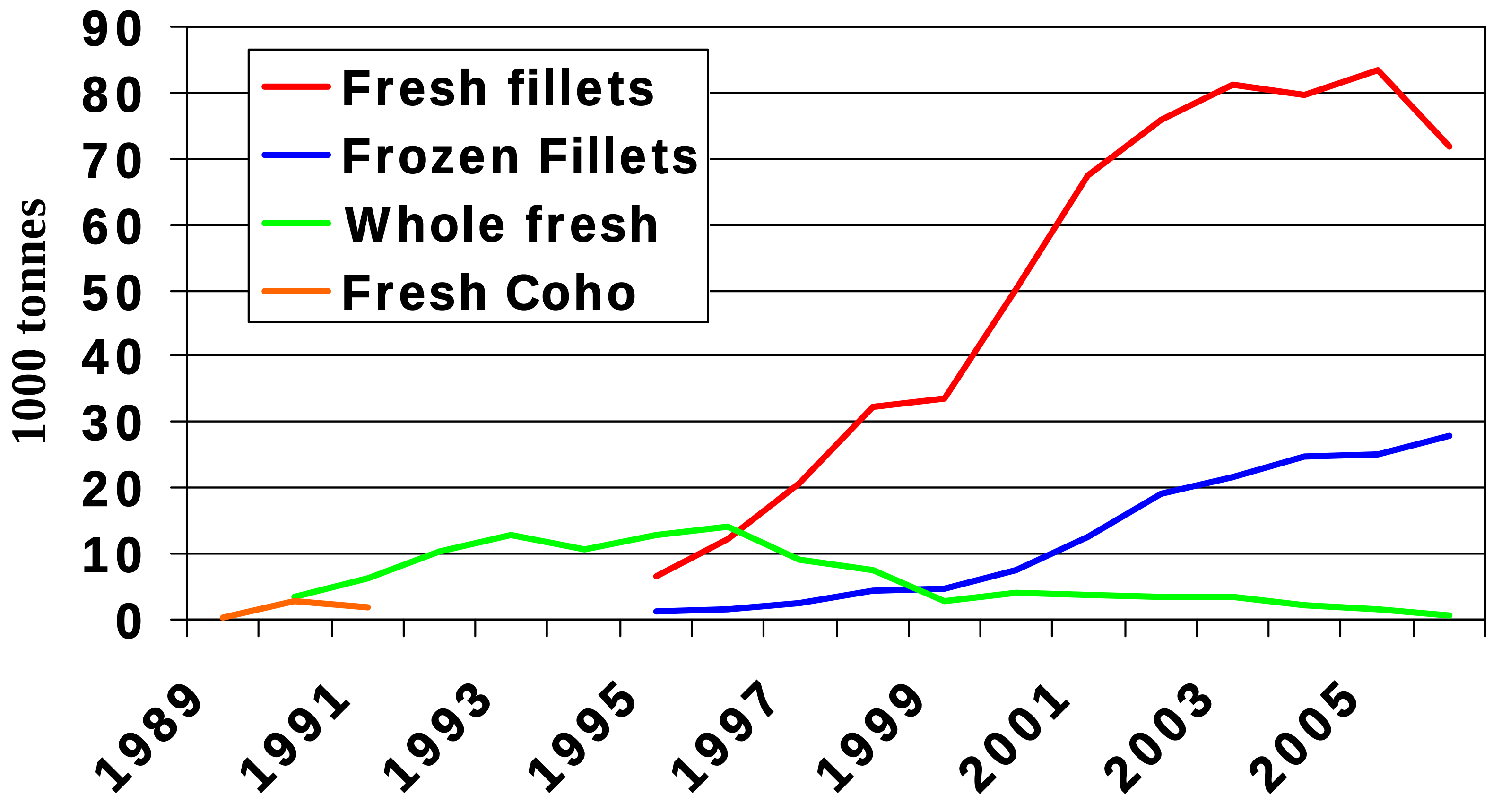
Product development in Chile

- Chile has partly overcome long distances to the main markets with innovative product development, and has been leading on the development during the last decade

- Exploit local competitive advantages in processing, which increase value and reduce transportation cost

- ”pinbone out” fillets opened up markets in the USA where fish normally were not consumed

Chilean salmon exports to the US



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From Tesco-advertisement in the UK…

Salmon fillet at NOK 76/kg

	Was Price*	Now Price	SAVE
Tesco Butchers Choice 8 Sausages 454g	£1.69	£1.38	31p
Tesco Healthy Eating Chicken Mini Fillets 240g	£2.39	£1.99	40p
Tesco Healthy Eating Diced Chicken Breast 400g	£3.99	£2.97	£1.02
Tesco Pork Steaks x 2	£5.49/kg	£4.80/kg	69p
Tesco Sparerib Chops x 2	£3.99/kg	£3.68/kg	31p
Tesco Salmon Fillets	£7.97/kg	£5.99/kg	£1.98
Tesco Baby New Potatoes 750g	£1.09	67p	42p
Tesco Baking Potatoes 2.5kg	£1.78	£1.49	29p
Tesco Value Apple Bag	£1.08	87p	21p
Tesco Value Bananas 1.5kg	£1.09	99p	10p
Tesco Value Pears Pack	£1.19	87p	32p
TOTAL	£31.75	£25.70	£6.05

...and Tesco-advertisement in Polen

Salmon fillet at NOK 28,80/kg

The retailing sector and logistics is changing

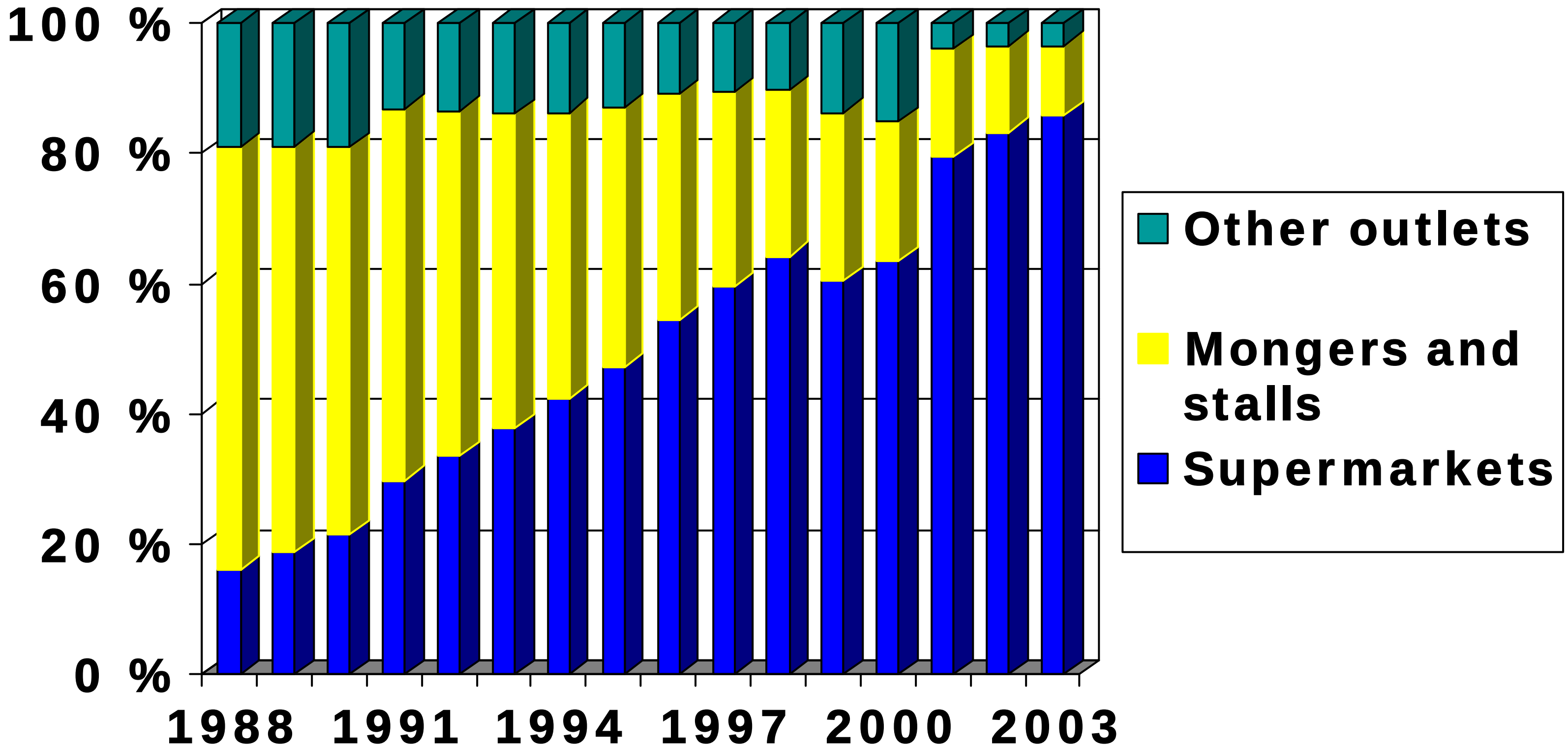
- And that is good for aquaculture

- Retail chains allows for economies of scale and scope in marketing, retailing, logistics and distribution

- Few seasonal products and smallscale suppliers get access to the shelves because that gives higher cost

- In most European countries retial chains make up more than 80% of retail sales
  - Murray and Fofana, Guilotreau et al
  - Traditional outlets like fish mongers disappear

Market share for seafood by outlet in the UK



The retail chains are demanding customers

I. **Price**: (a) Price level, (b) linkage to market prices, (b) quantity discounts.

II. **Volume and timing**: (a) Total volume, (b) regularity of deliveries, (c) flexibility in deliveries, e.g. in relation to ”normal” volumes and times of delivery.

III. **Raw material attributes**: (a) Size distribution, e.g. fillets, (b) quality attributes, e.g. colour, fat, texture, taste, (c) fresh vs frozen, (d) uniform quality, (e) shelf life.

IV. **Product range and differentiation**: (a) Fish species, (b) Product varieties, e.g. easy-to-cook, ethnic foods, healthy foods, (c) private labels / brands, (d) consumer advertising.

V. **Production process**: (a) Raw materials in feed, (b) environmental effects of production, (c) animal welfare, (d) third party certification, e.g. ISO, EMAS, (e) traceability.

VI. **Transaction costs**: (a) Negotiation, (b) planning, (c) control and enforcement, (d) transportation og (e) storage.

The product is not only the physical seafood product…

...but also a set of services for the industrial buyers related to:

- **Volume**
- **Timing and frequency**
- **Flexibility**
- **Cost efficiency in distribution**
- **Food safety**
- **etc.**

The retail chains are demanding customers

- The set of extra services increase the complexity of the composite product that a supplyer is providing

- In addition to productivity growth, this increase the competitiveness of (salmon) aquaculture because it is less costly to provide the added services

The supply chain

- Since it is the total cost of a product that matter, innovations in the supply chain is as important as innovations in retail and production

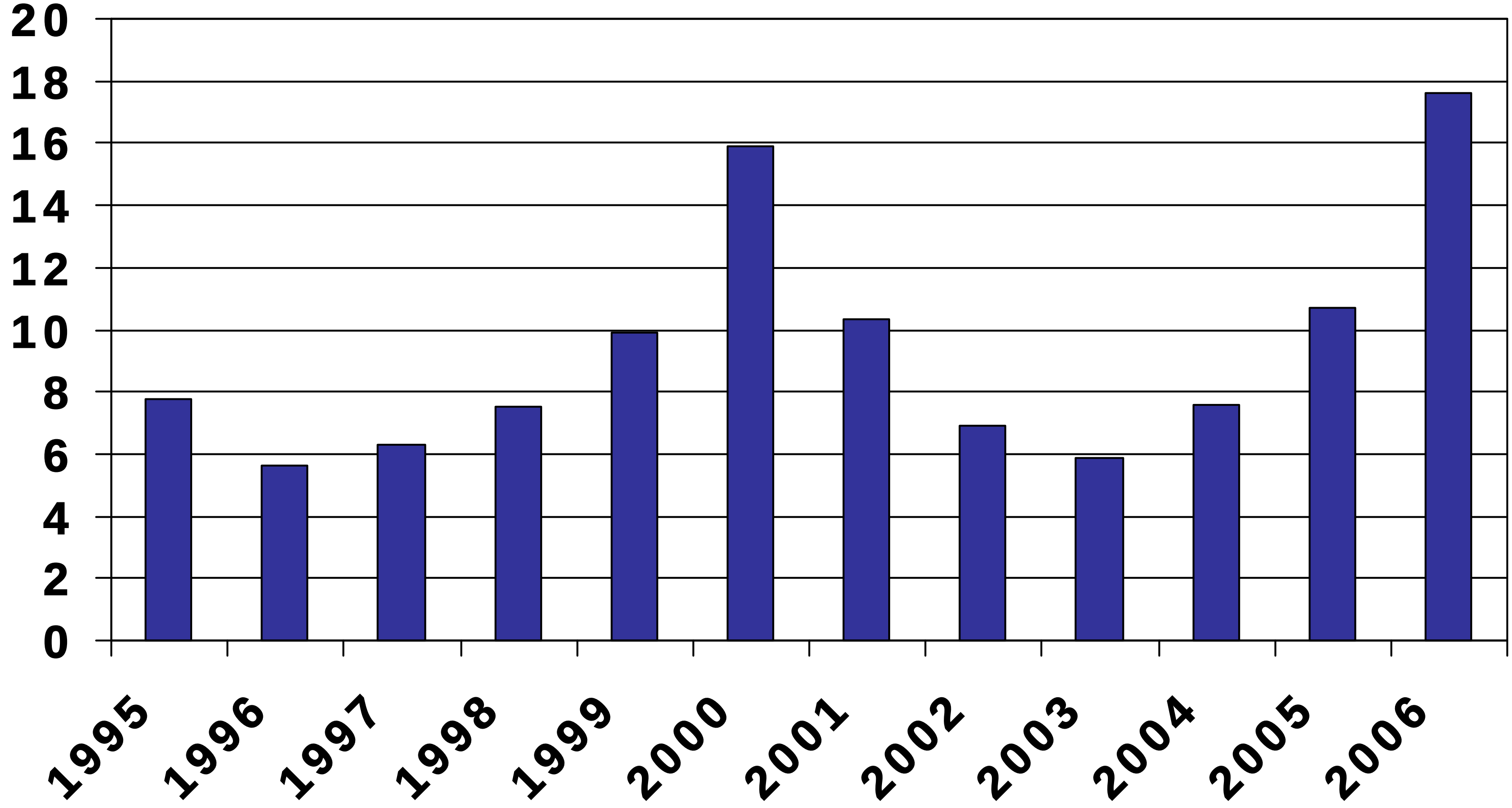
- Salmon in Europe is in a shop less then 3 days after it came out of the sea, and is freighted by car
  - First species with reliable delivery of good quality fresh fish independent of distance
  - Air freight (USA, Japan)
  - Icelandic cod

Cycles in profitability

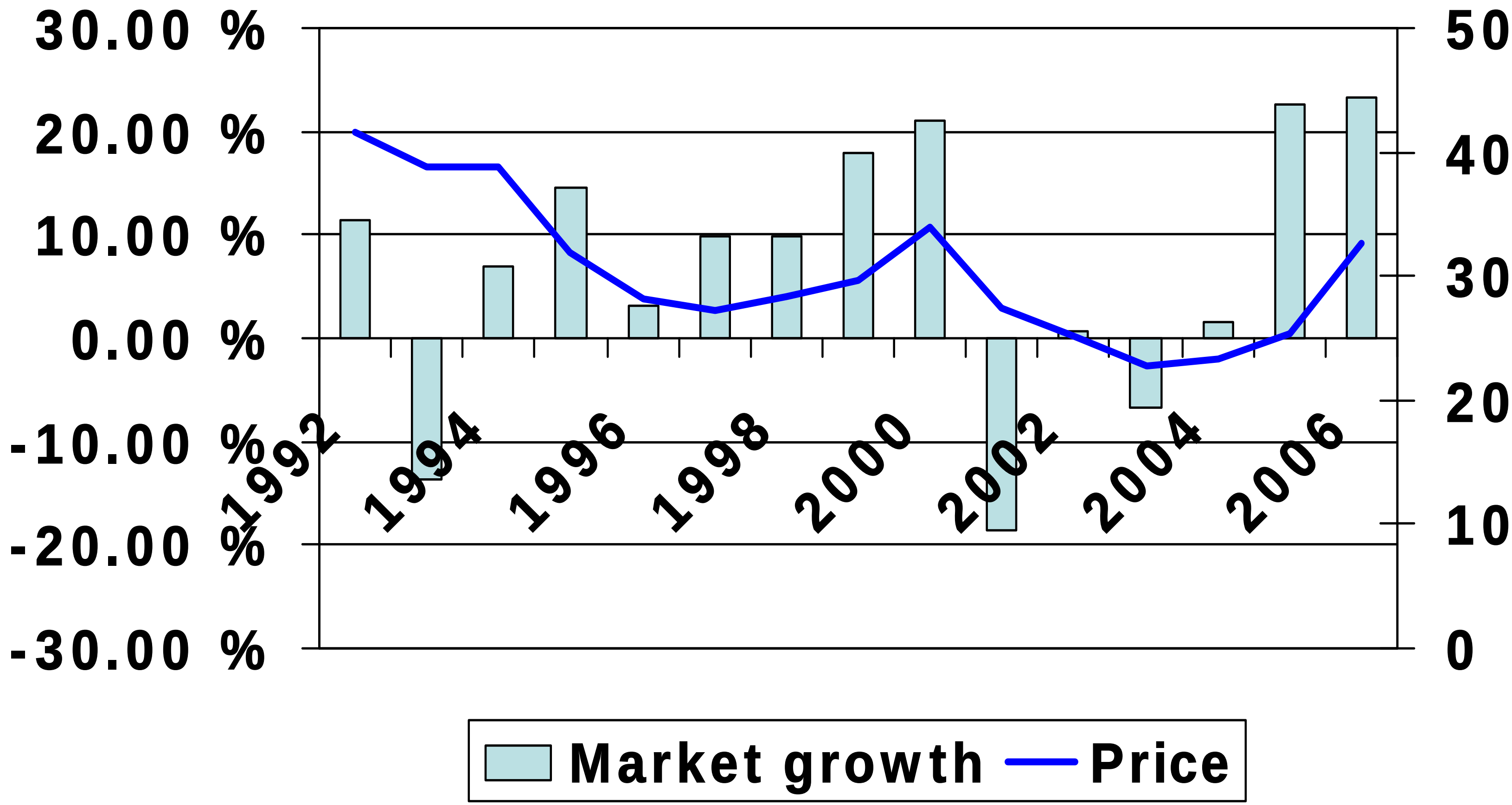
- Because there are a substantial lag from when the decision to produce is made until the product is ready for the market, there will be cycles in profitability

- Cycles can also be created by uneven market growth

Norwegian unit margin



Uneven market growth in the EU



This is pretty much the same story as for chicken

- And that is not accidental
- There are certainly a number of challenges, but the main drivers are similar
- That the market is truly international makes gives an additional potential for problematic issues as production practices and regulatory conditions vary
- Health is an additional argument for market growth
- Demand is becoming less elastic

Concluding remarks

- Productivity growth makes aquacultural products increasingly competitive

- For succesful species, the market is expanded in product space as well as geographical space

Concluding remarks

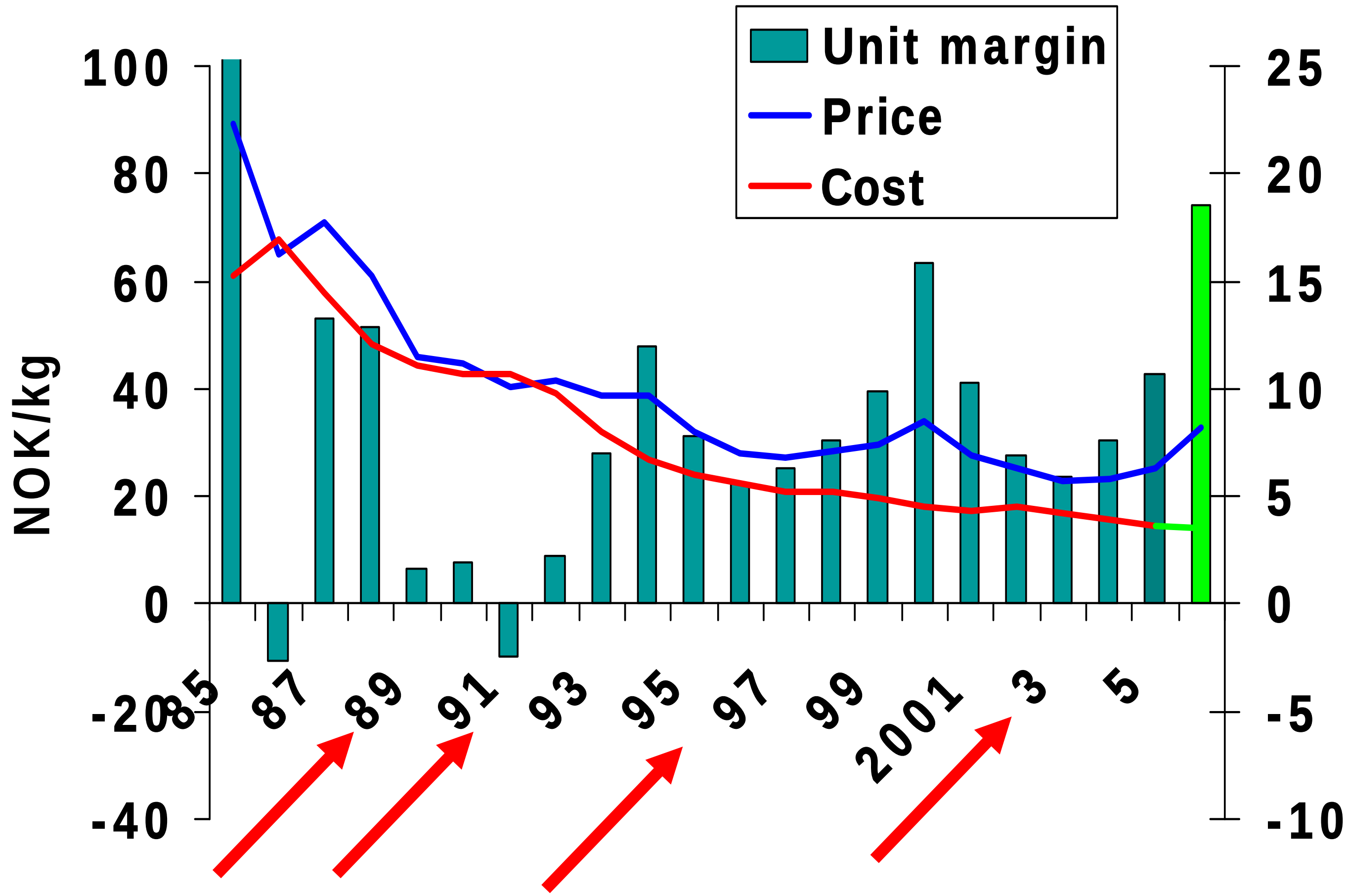
- Species that does not have production processes with these characteristics, will not succeed as large volume species
  - In the intermediate term, there will be relatively many species exploring new technology
  - In the long term there will be few large ones with clear cost advantages in their categories
    - In agriculture there are four – beef, chicken, pork and lamb
  - There will also be significant niche markets both in the high and the low end

- Challenges with respect to trade and environmental concerns

Trade issues

- Two main reasons for trade problems
  - Fast productivity growth leading to substantial reductions in prices and increases in production
  - Cyles in profitability

Norwegian export price, unit cost and unit margin 1985-2006 (2006=1)



Trade restrictions

- Due to the GATT and WTO agreements, general tariffs has been substantially reduced since the mid 1980s
- Explosion in the use of anti-dumping and other temporary trade restricting measures
- Although measures are based on complaints, the plaintiff win in most cases

Seafood

- Farmed products most exposed
- US:
- Anti-dumping: Salmon (Norway and Chile), crawfish (China), Shrimp (China,
- Equador, Vietnam etc), Catfish (Vietnam)
- Health/quality issues (primary shrimp)
- Ecolabeling, dolfin safe tuna etc.
- EU:
- Anti-dumping, salmon, trout, shrimp etc.
- Safeguard measures.
- Health/quality
- Voulentary trade restraints

Trade restrictions for salmon

- USA
  - Dumping complaints against Norway, tariffs from 1991
  - Dumping complaints against Chile in 1997

- EU
  - Dumping complaints against Norway in 1989,1991,1996,2003
  - Minimum import prices in a number of periods for Norwegain salmon, Atlantic salmon and all salmon
  - Safeguard measures (quotas)
  - The salmon agreement in 1997-2003
  - Safeguards, 2004-2006, anti-dumping, 2006-2008

Trade restrictions for salmon in the USA

- Following the complaint in 1989, a tariff on average of 26% where imposed on Norwegian salmon
- Norway's market share in the US went from over 50% to basically zero in three years
- US prices did not change relatively to prices in other markets
- No benefits for US producers, only a reallocation of trade patterns where Canada and Chile took over Norway's shares
- Following the complaint in 1997, Chilean producers got a tariff on average of 5%, which was removed in 2002
- The recent experience with shrimp is similar

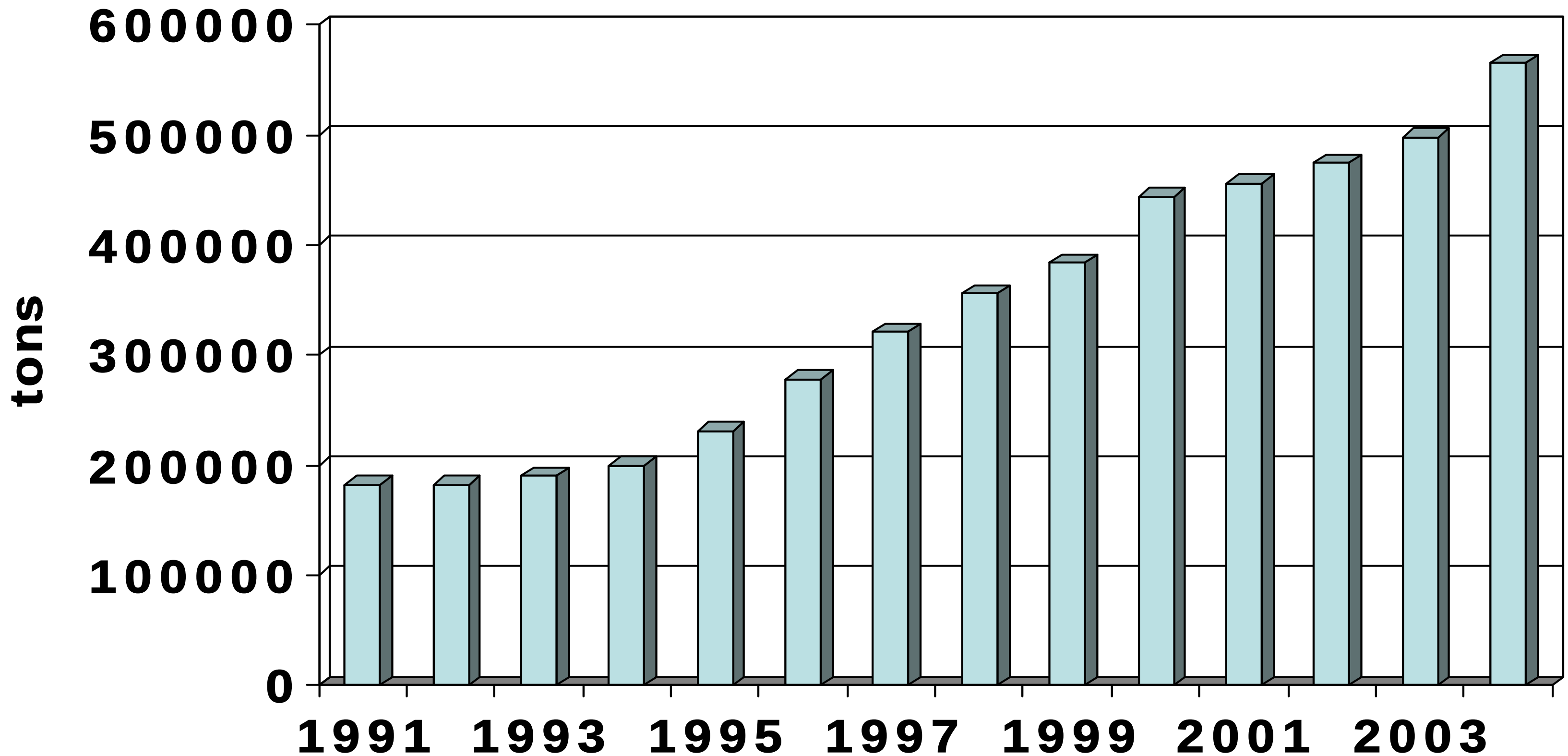
Trade restrictions for salmon in the EU

- Since 1990, there has been restrictions on market access to the EU for salmon about two thirds of the time

- Most of the time they come in the form of minimum import prices and quotas

- Hence, while they can potentially have a sever impact, they need not have much impact

Salmon consumed in the EU15



Trade restrictions in the EU

- Since 1990, there has been restrictions on market access to the EU for salmon about two thirds of the time
- Most of the time they come in the form of minimum import prices and quotas
- Hence, while they can potentially have a sever impact, they need not have much impact
- And they seem to have had a strong impact only for shorter periods of time, although they have increased transaction costs somewhat
  - Makes the Irish industry survive?

Concluding remarks trade

- For salmon, the US restrictions on Norwegian salmon provides the clearest example of how little impact can have to exclude a major supplier

- In the EU, it is much harder to assess the impact
  - The measures are weaker
  - Their strength varies

- There is little doubt that cost has been increased for importers
- But imports have continued to increase and prices to decrease

Concluding remarks trade

- The aquaculture industry is highly exposed to trade problems because of fast production growth, producers located outside of the main markets and cycles in profitability

- WTO prevents general measures, and accordingly there are named countries that are restricted

- Leaves the market open to other producers

- So far domestic producers has received small benefits from trade conflicts
  - They do influence where production takes place and trade patterns

Concluding remarks trade

- Trade restrictions also increase risk with respect to export oriented investments
- Reduce product development
- Reduce degree of processing
- Influence which species will succeed
- Trade restrictions together with environmental concerns can harm US consumers, but will have little impact on aquaculture development


coop
SEIBIFF med løk
panerte seistykker
530g
6 stk
dypfryst
We Care to be Fair.
Til deg
som velger med omhu
Har vi produsert denne Pangasius fileten med respekt for naturen og omtanke for mennesker
BENFRI FISK • RIK PÅ OMEGA-3
PANGASIUS FILET
300 g
Koktorsk
Kogetorsk
600 g
4-6
400

SALMON PRODUCTION
Modeling supply

Professor Atle G. Guttormsen

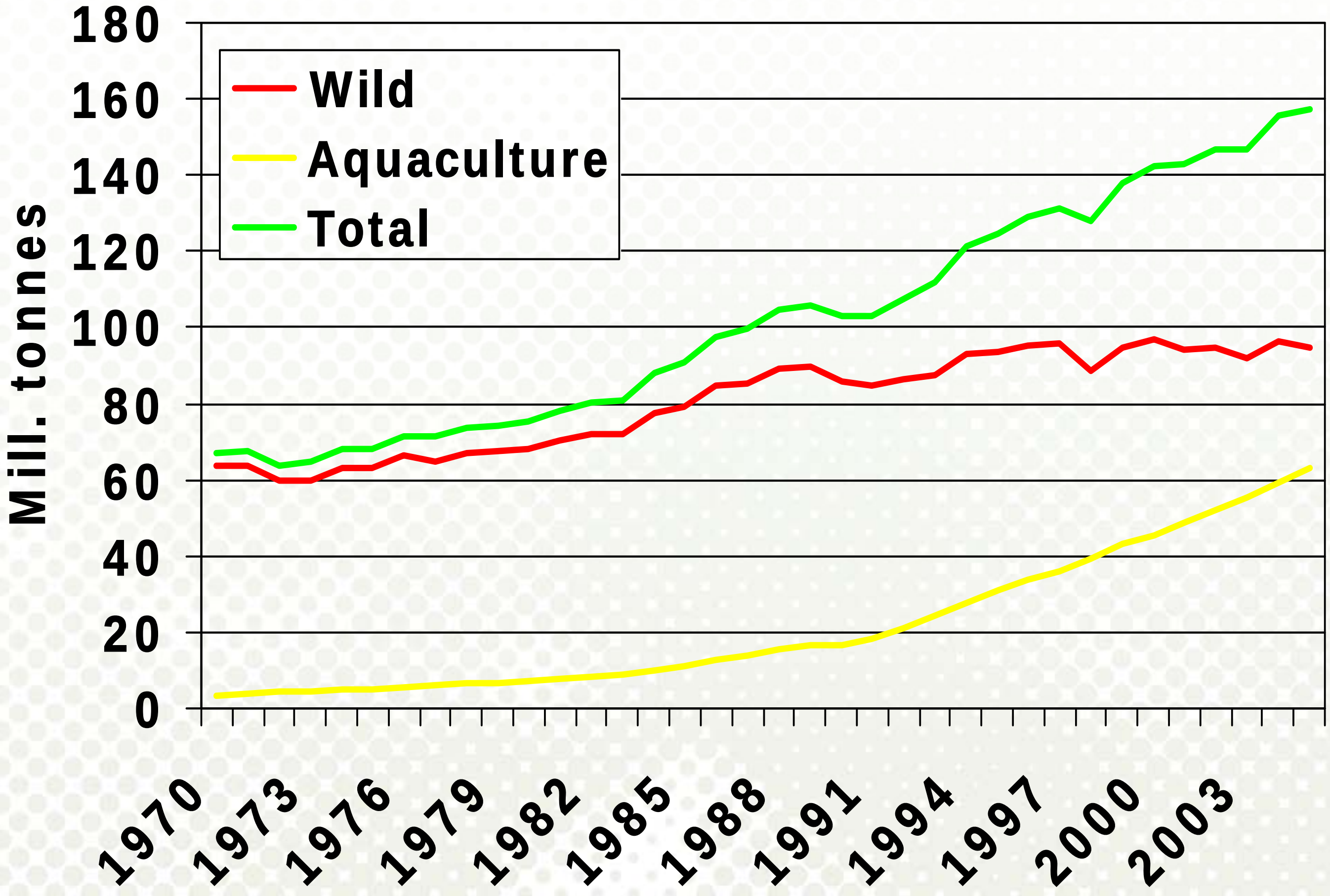
NORWEGIAN UNIVERSITY OF LIFE SCIENCES
MDCCCLIX

ATLE G. GUTTORMSEN
NORWEGIAN UNIVERSITY OF LIFE SCIENCES

AQUACULTURE

- Human cultivation of organisms in water
- Fish farming, fish culture, marine culture or mariculture, sea ranching
- Farming, not hunting and gathering as fisheries is still an example of
- Had its origins in China more than thousand years ago
- A revolution occurred in the 1970s, that gave humans a much higher degree of control with the production process

GLOBAL SEAFOOD PRODUCTION



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PRODUCTION GROWTH AND PRICES

- We have seen that production growth has been significant in aquaculture, and for salmon
- A key feature for all successful species are that prices have also declined significantly
- This is so because the main argument to get more consumers to buy a species, is to make it more competitive relatively to other foodstuffs. This entails reducing the price

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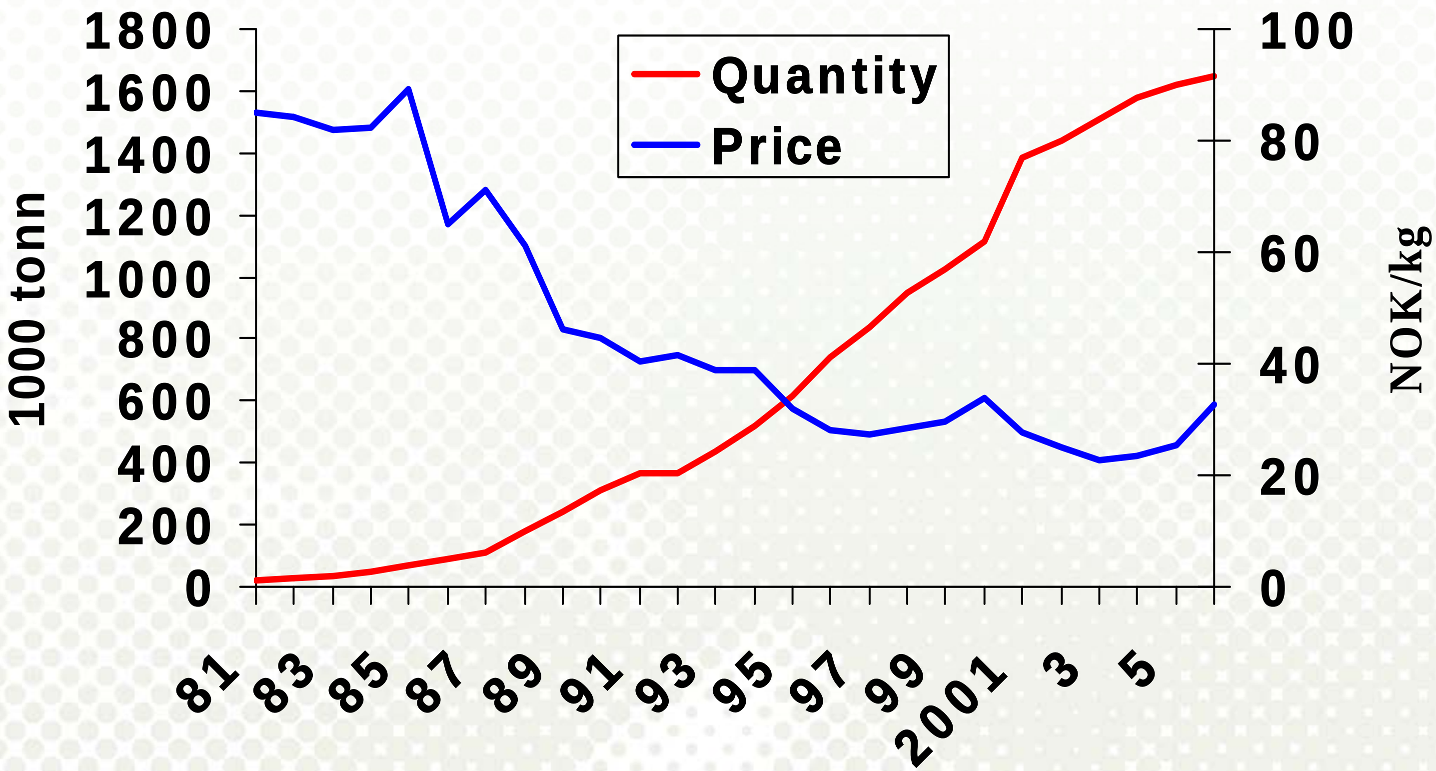
GLOBAL PRODUCTION OF FARMED SALMON AND REAL NORWEGIAN EXPORT PRICE, 1981-2006



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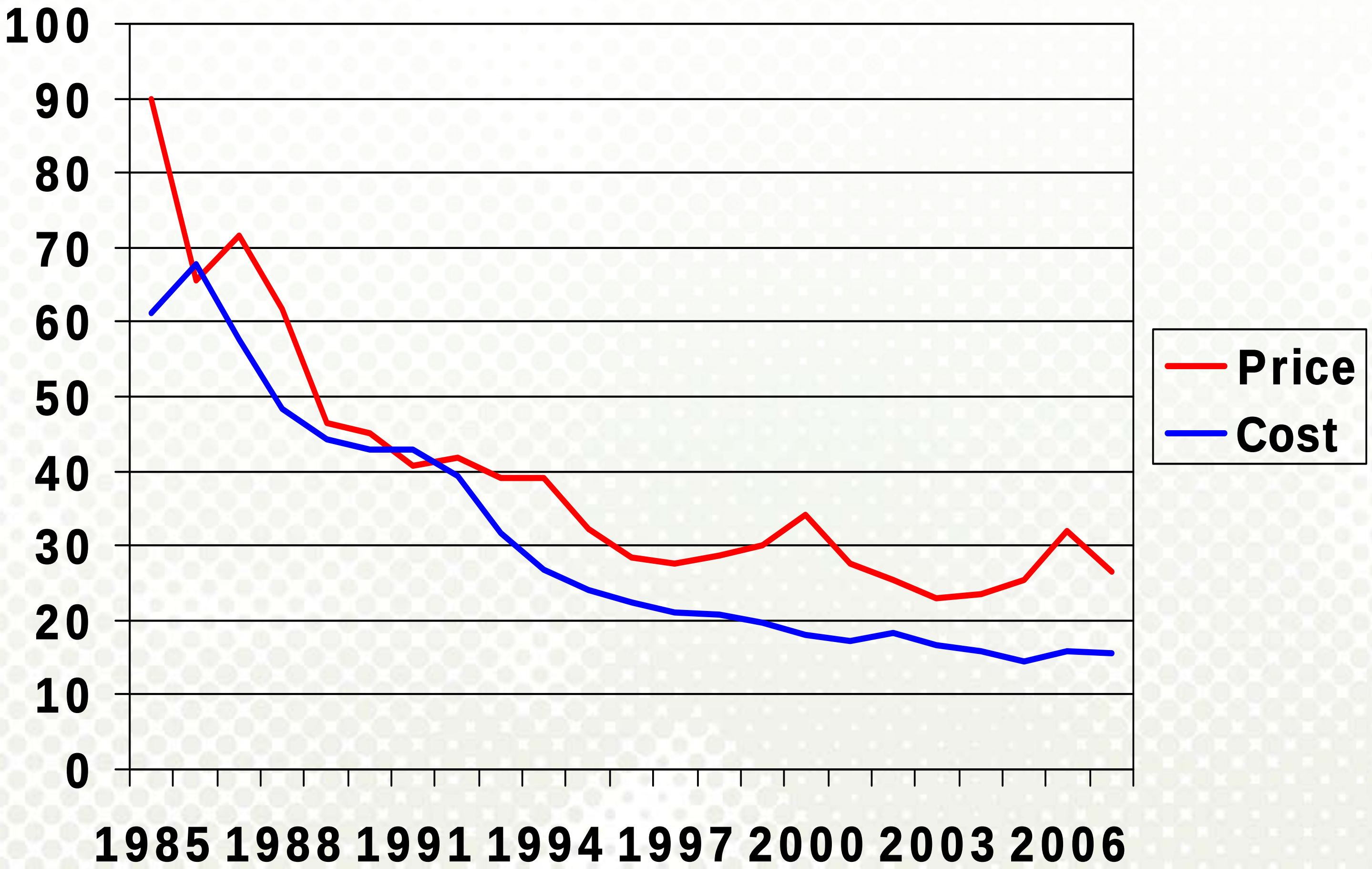
REAL NORWEGIAN EXPORT PRICE AND PRODUCTION COST (2007=1)



Continuous productivity improvement is a challenge when modeling supply !

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CONTROL

- Control is important because it allow systematic gathering of knowledge, leading to innovation and scientific research
- Closing the production cycle (ie keeping a confined brood stock) so that one are independent of wild stocks for reproduction is necessary for breeding
  - 1985: From smolt to harvestweight 24 months
  - Today. From smolt to harvestweight 14 months
- Formula based feed is necessary for research into feed recepies and automated feeding systems

Better control is the main reason for productivity growth !

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SALMON DATA

- The Norwegian salmon farm dataset
  - Unbalanced panel data based on annual data collected by the norwegian directorate of fisheries since 1982.
- Covers more than 50% of total salmon industry in most years
- About 80 variables is reported
- Used in a number of Phd-theses: Salvanes (19xx), Tveterås (1998), Guttormsen (2002), Roll (2008) and more than thirty per rewieved articles

Source: Roll K.H. (2008)

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STUDIES ON PRODUCTION

(A rich source of literature discussing several aspects of the **norwegian** salmon industry)

- Asche, F. (1997). "Trade Disputes and Productivity Gains: The Curse of Farmed Salmon Production?" Marine Resource Economics **12**(1): 67-73.Asche, F. (2006). Primary industries facing global markets: the supply chains and markets for Norwegian food and forest products. Oslo, Universitetsforl.Asche, F., T. Bjorndal, et al. (2003). "Relative Productivity Development in Salmon Aquaculture." Marine Resource Economics **18**(2): 205-10.Asche, F. and A. G. Guttormsen (2001). "Patterns in the Relative Price for Different Sizes of Farmed Fish." Marine Resource Economics **16**(3): 235-47.Asche, F., A. G. Guttormsen, et al. (1999). "Environmental Problems, Productivity and Innovations in Norwegian Salmon Aquaculture." Aquaculture Economics and Management **3**(1): 19-29.Asche, F. and R. Tveteras (1999). "Modeling Production Risk with a Two-Step Procedure." Journal of Agricultural and Resource Economics **24**(2): 424-39.Bjorndal, T. (2002). "The Competitiveness of the Chilean Salmon Aquaculture Industry." Aquaculture Economics and Management **6**(1-2): 97-116.Bjorndal, T. and K. G. Salvanes (1995). "Gains from Deregulation? An Empirical Test for Efficiency Gains in the Norwegian Fish Farming Industry." Journal of Agricultural Economics **46**(1): 113-26.Bjørndal, T. and K. G. Salvanes (1991). Production technology and regional productivity differences in the Norwegian fish farming industry. Bergen.Guttormsen, A. G. (2002). "Input Factor Substitutability in Salmon Aquaculture." Marine Resource Economics **17**(2): 91-102.Kumbhakar, S. C. (2001). "Estimation of Profit Functions When Profit Is Not Maximum." American Journal of Agricultural Economics **83**(1): 1-19.Kumbhakar, S. C. (2002). "Risk Preferences and Technology: A Joint Analysis." Marine Resource Economics **17**(2): 77-89.Kumbhakar, S. C. and R. Tveteras (2003). "Risk Preferences, Production Risk and Firm Heterogeneity." Scandinavian Journal of Economics **105**(2): 275-93.Ostbye, S. (1999). "A Technical Note on Input Price Proxies Used in Salmon Farming Industry Studies." Marine Resource Economics **14**(3): 215-23.Salvanes, K. G. (1985). Fiskeoppdrett og offentlig regulering: ein empirisk analyse av kostnadstilhøve i norsk matfiskoppdrett. Bergen, K. G. Salvanes**:** vi, 149 bl.Salvanes, K. G. (1988). Salmon aquaculture in Norway: an empirical analysis of cost and production properties. Bergen, Institute of Fisheries Economics, Norwegian School of Economics and Business Administration**:** vii, 142 bl.Salvanes, K. G. (1989). "The Structure of the Norwegian Fish Farming Industry: An Empirical Analysis of Economies of Scale and Substitution Possibilities." Marine Resource Economics **6**(4): 349-373.Salvanes, K. G. (1993). "Public regulation and Production Factor Misallocation: A Restricted Cost Function for the Norwegian Aquaculture Industry." Marine Resource Economics **8**: S. 50-64.Toft, A., T. Bjørndal, et al. (1994). Kostnadsstruktur og kostnadsutvikling i matfiskoppdrett - ei drøfting av empiriske resultat. SNF-rapport. S. f. s.-o. næringslivsforskning.Tveteras, R. (1999). "Production Risk and Productivity Growth: Some Findings for Norwegian Salmon Aquaculture." Journal of Productivity Analysis **12**(2): 161-79.Tveteras, R. (2000). "Flexible Panel Data Models for Risky Production Technologies with an Application to Salmon Aquaculture." Econometric Reviews **19**(3): 367-89.Tveteras, R. (2002). "Industrial Agglomeration and Production Costs in Norwegian Salmon Aquaculture." Marine Resource Economics **17**(1): 1-22.Tveteras, R. and G. E. Battese (2006). "Agglomeration Externalities, Productivity, and Technical Inefficiency." Journal of Regional Science **46**(4): 605-25.Tveteras, R. and O. Kvaløy (2004). Vertical Coordination in the Salmon Supply Chain. SNF Working Paper No 07, Stiftelsen for samfunns- og næringslivsforskning.Tveteras, S. (2002). "Norwegian Salmon Aquaculture and Sustainability: The Relationship between Environmental Quality and Industrial Growth." Marine Resource Economics **17**(2): 121-32.Tveterås, R. (1993). Økonomisk rente i norsk matfiskoppdrett: med vekt på biofysiske faktorers betydning for lønnsomheten. Bergen,

Pluss many more

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Challenge for modeling supply: Limited access to data from Chile !!

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THE BIOLOGY OF SALMON

- Production of broodstock and roe
- Production of fry (hatcheries)
- Production of smolts
- Production of farmed fish

- One measure of the high degree of intensity in salmon production is that while steps 1 and 2 tend to take place at the same plant, 3 is normally at a separate plant and 4 is always at another separate plant
- Most research have been concerned about the growout phase. However modeling supply might also involve the other stages.
- Today we have very little knowledge about stage 1-3 but knows a lot about stage 4.

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PRODUCTION PROCESS

- The production process for all aquaculture species mimics the steps in nature
- Control allows innovation
- Confinement system influence the degree of control and living conditions for the species and also the possibility for further innovation with respect to living conditions
- Control is the main reason for productivity improvement

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KNOWLEDGE OF BIOLOGY ALLOWS ONE TO:

- Close the production cycle
  - Often the most difficult part for new species
  - Necessary for breeding
  - Allows reduction of susceptibility to disease
- Develop feed
  - Most fish has particular dietary needs
  - Even herbivore species growth can be improved with the right feed
- Improve living conditions
  - Light, stream, oxygen
  - Depends on technology and species
  - Pharmacy
- Develop support equipment
  - Feeding systems, control systems
- And some knowledge often leads to more as it is gathered and systemized

MODELS OF BEHAVIOR

- As knowledge develops, one can develop models to predict fish behavior and needs

- A common feeding methodology in extensive pond farming is supply of household leftovers, and to augment feed production in the pond by adding fertilizer to the water

- For species like salmon, shrimp, turbot one has quite accurate growth functions
- For salmon the simplest is W=A*w*days*degrees where W is weight A is a site specific constant and w is starting weight
  - Assume feeding to saturation
  - I.e. salmon growth in controlled conditions is largely a function of day-degrees given sufficient feeding

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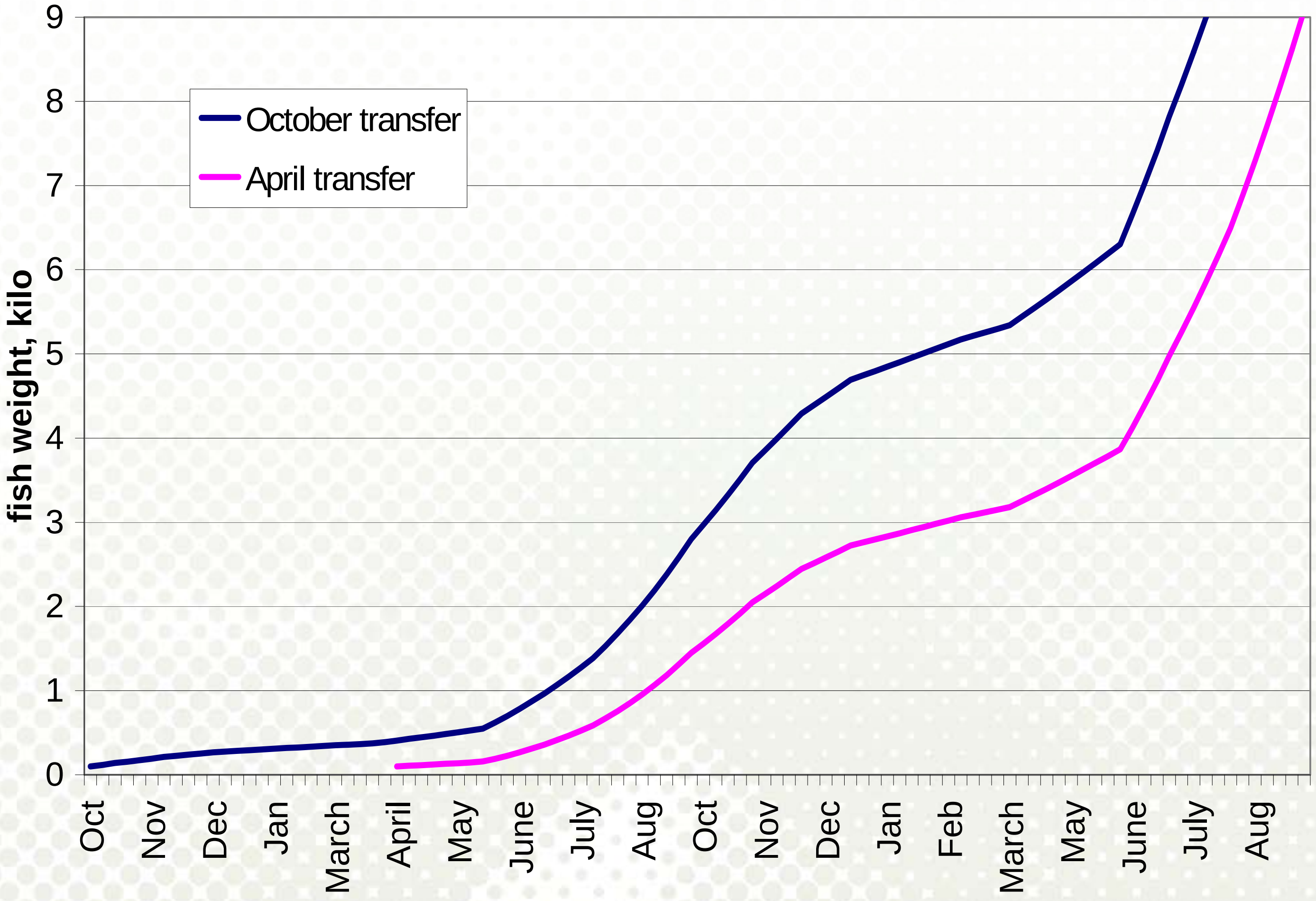
GROWTH CURVES FOR SALMON (individual fish)



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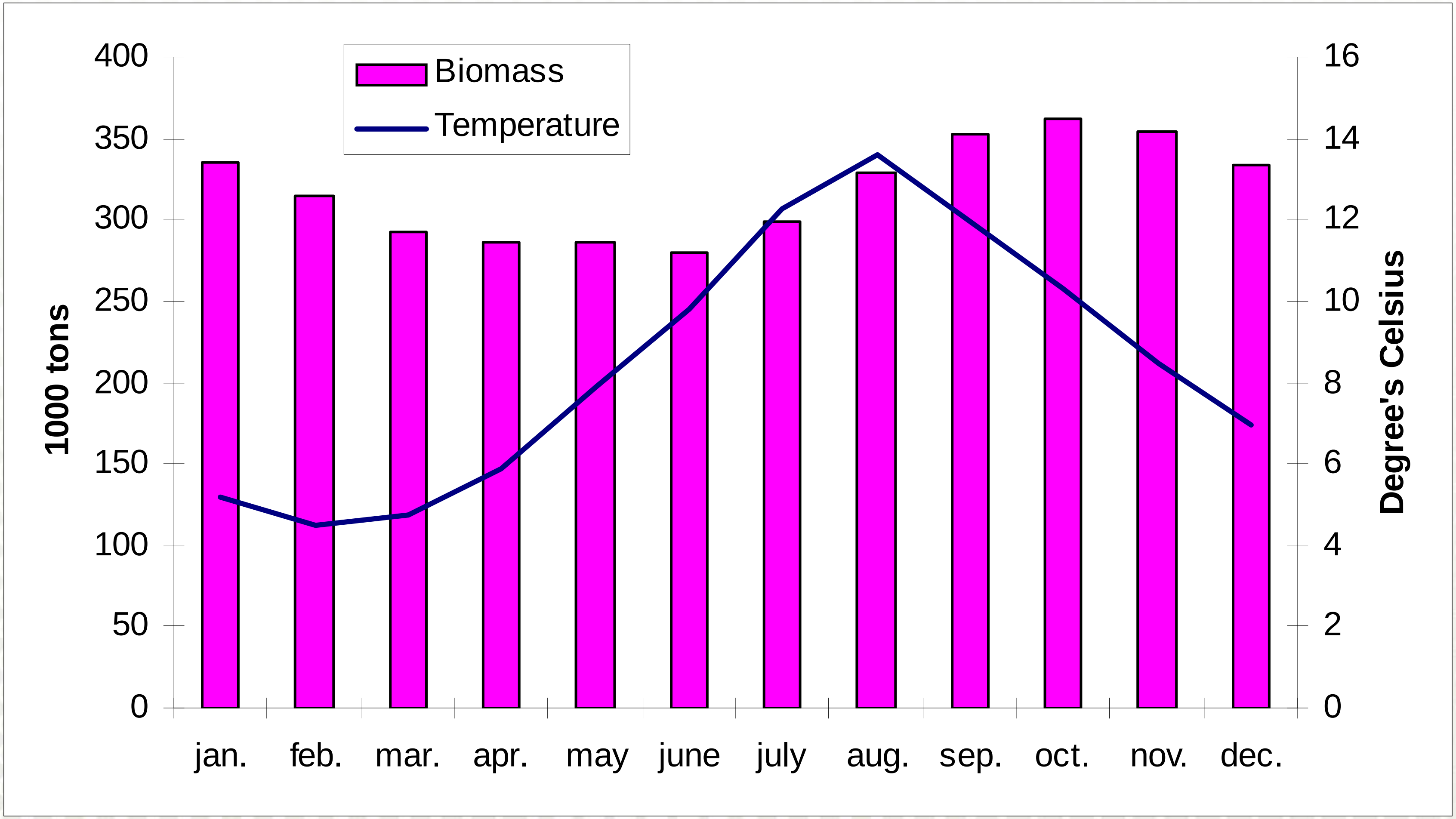
NORWEGIAN SALMON BIOMASS IN 2004



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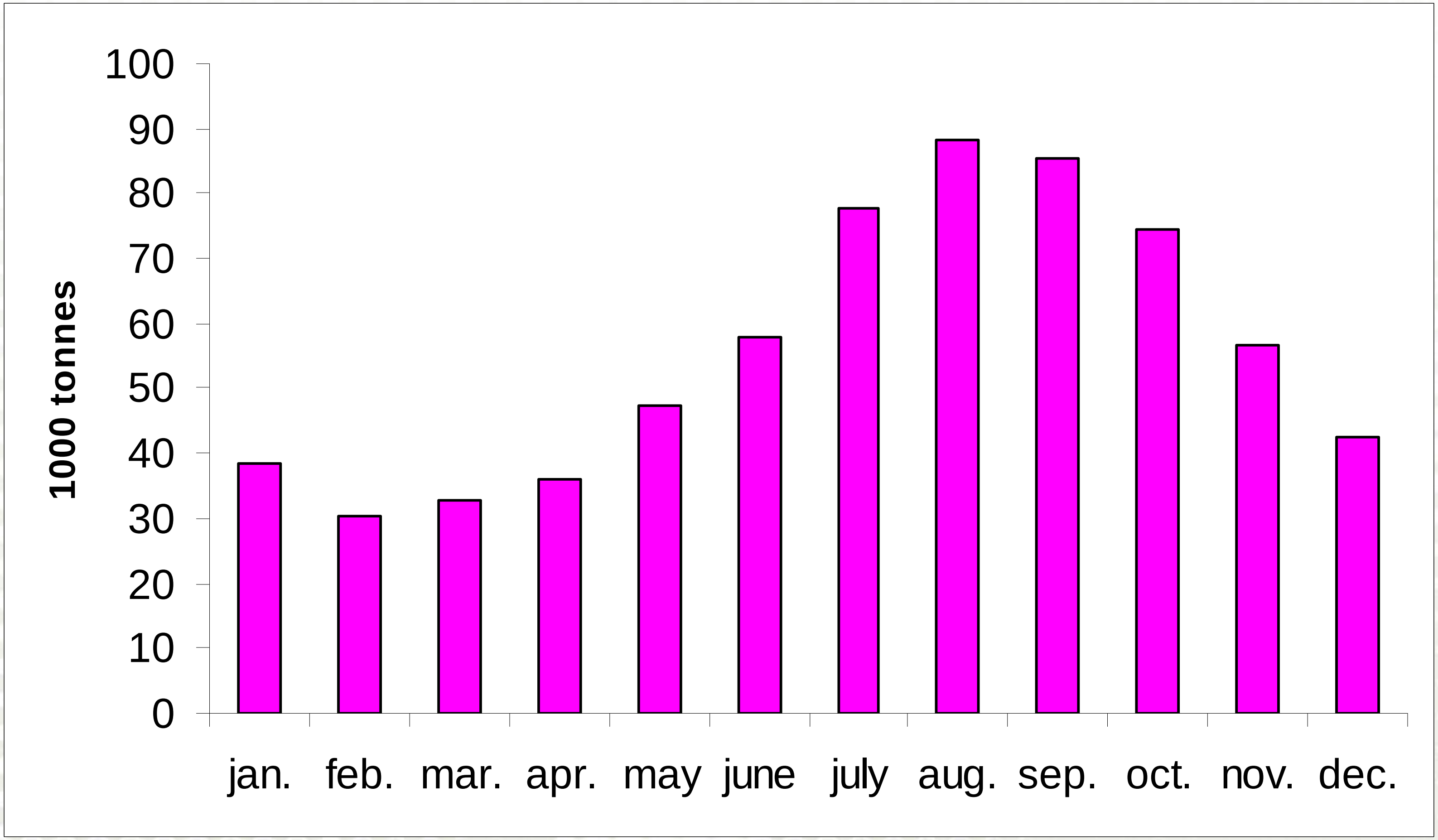
NORWEGIAN FEED DELIVERIES IN 2004



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TEMPERATURE AND SUPPLY

- Temperature influences on harvesting plans and hence on supply.
- Last year a warm winter together with a ”cold” summer gave optimal conditions for salmon growth. Hence the fish was ready for market long before planned.
- Gave pressure on the price for large fish

→ Challenge for modeling

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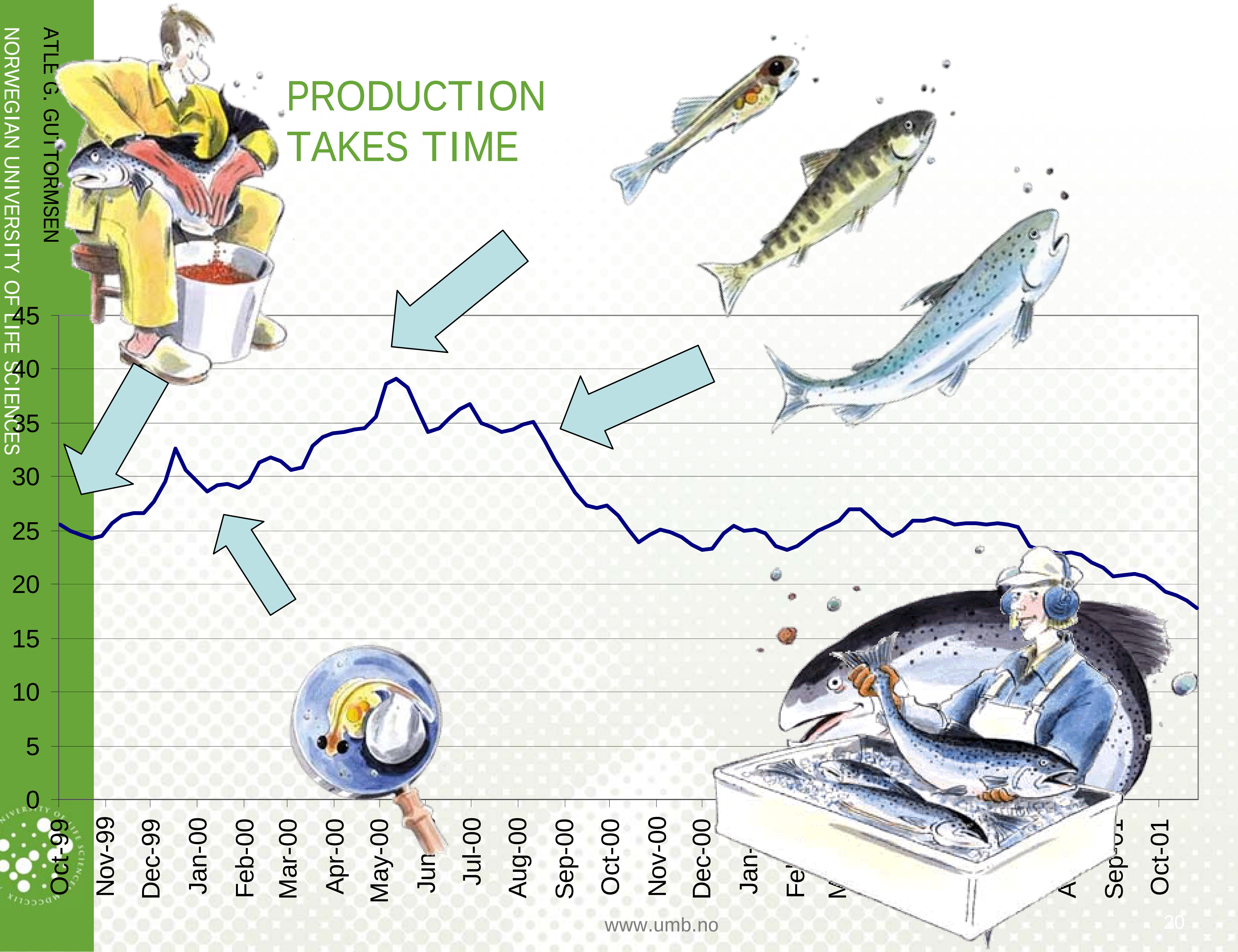
PRODUCTION TAKES TIME



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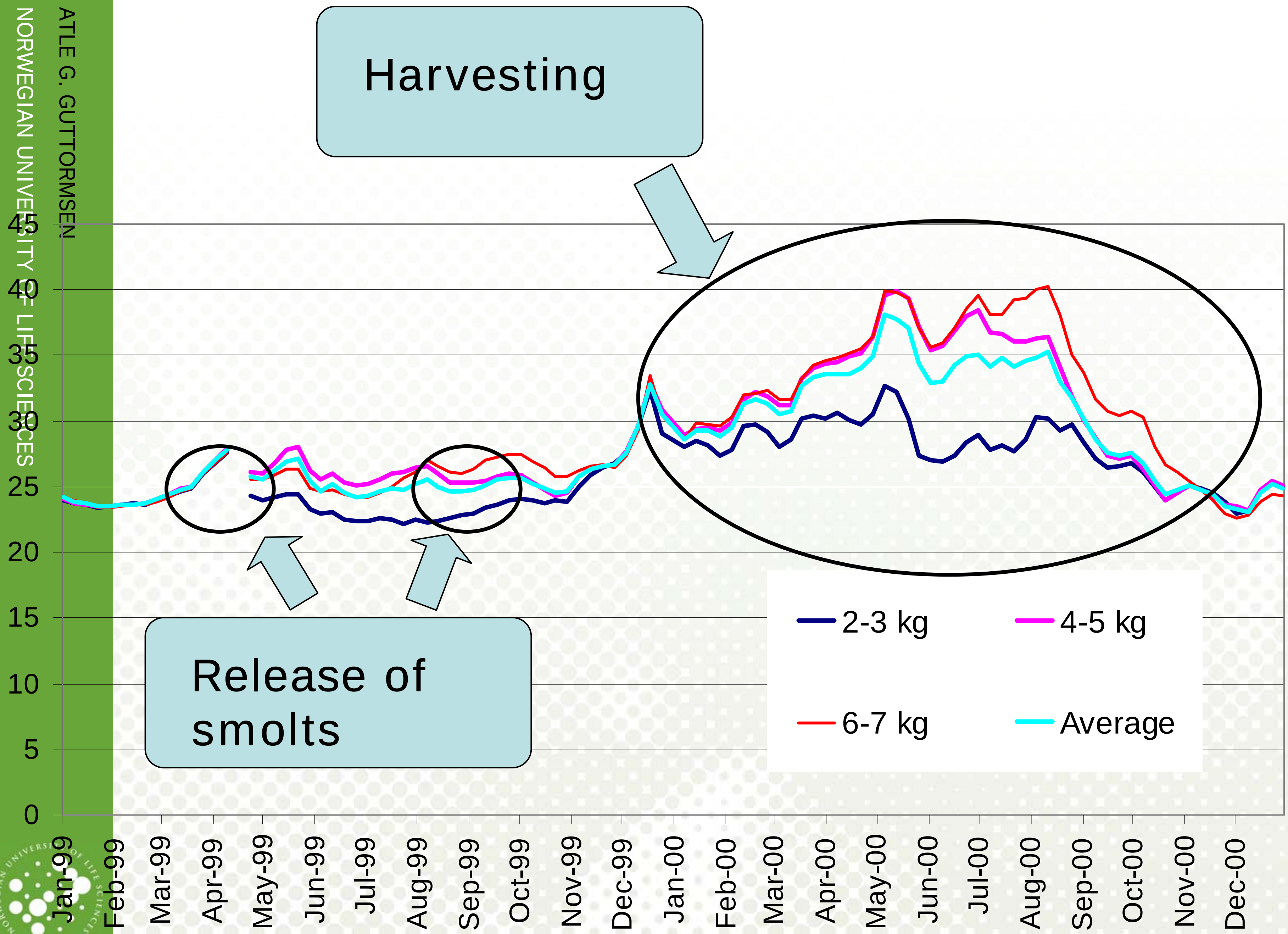

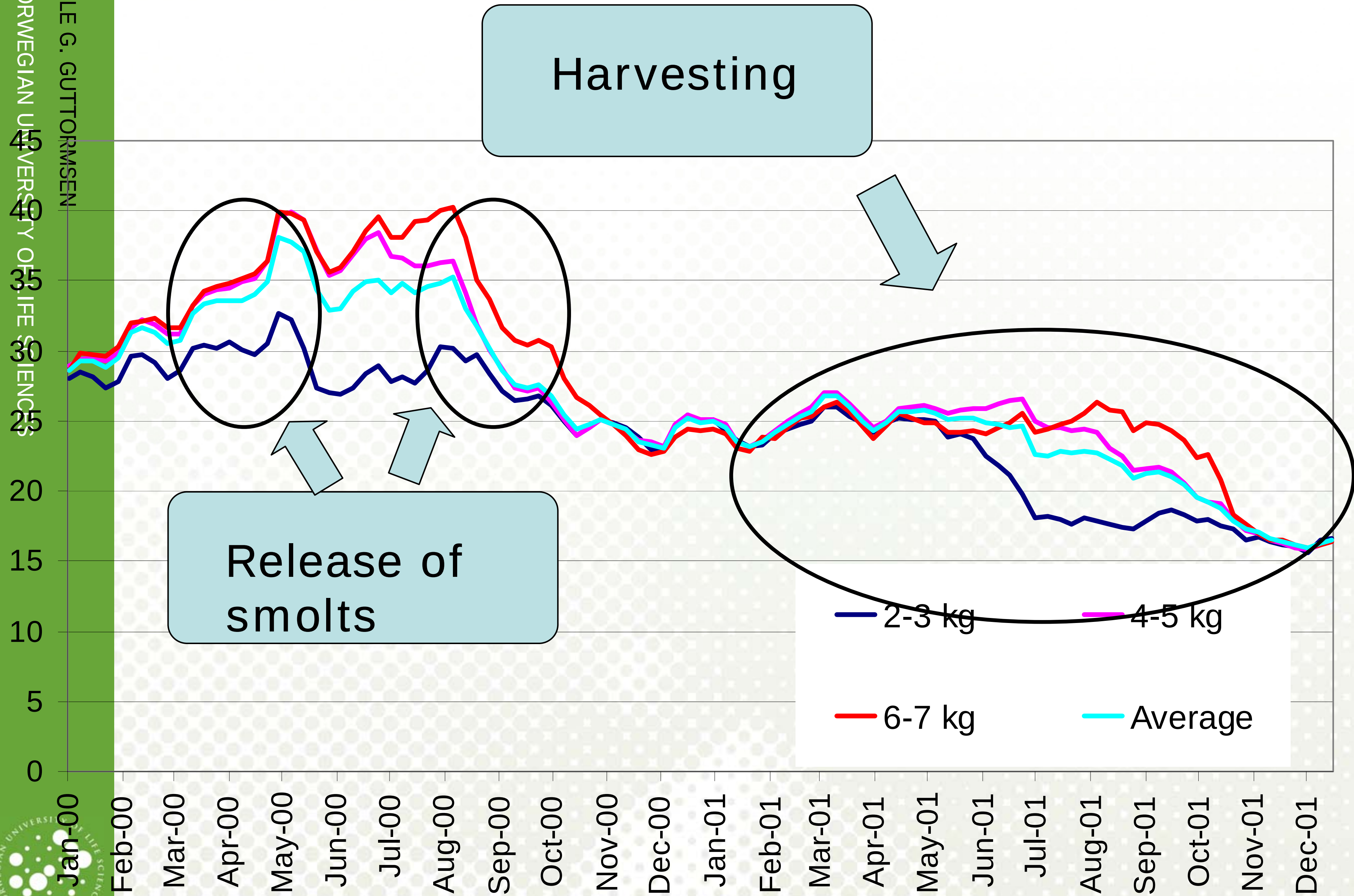
Harvesting
Release of smolts
45
40
35
30
25
20
15
10
5
0
Jan-00
Feb-00
Mar-00
Apr-00
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
2-3 kg
4-5 kg
6-7 kg
Average

CYCLES

- The industry is dependent on a biological production process, and it takes more than one year from when one decides to produce a salmon until it is ready for the market

- If profitability is good, one would like to increase production
- If it is poor, one would like to limit production

- When everybody is doing the same, it is easy for the industry to miss the target

→ Challenge for modeling

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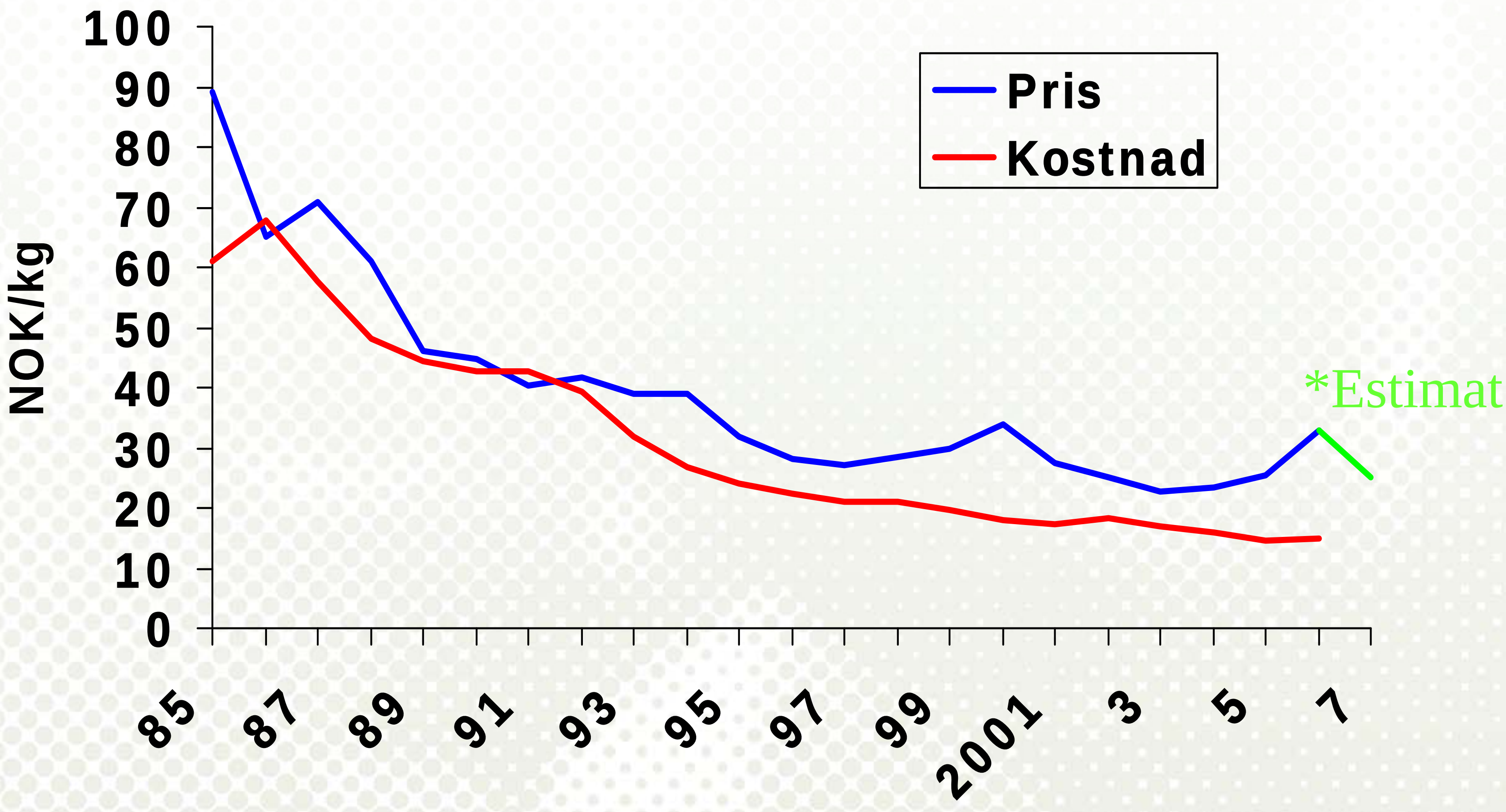
EXPORTPRICE AND PRODUCTION COST 1985-2007 (2006=1)



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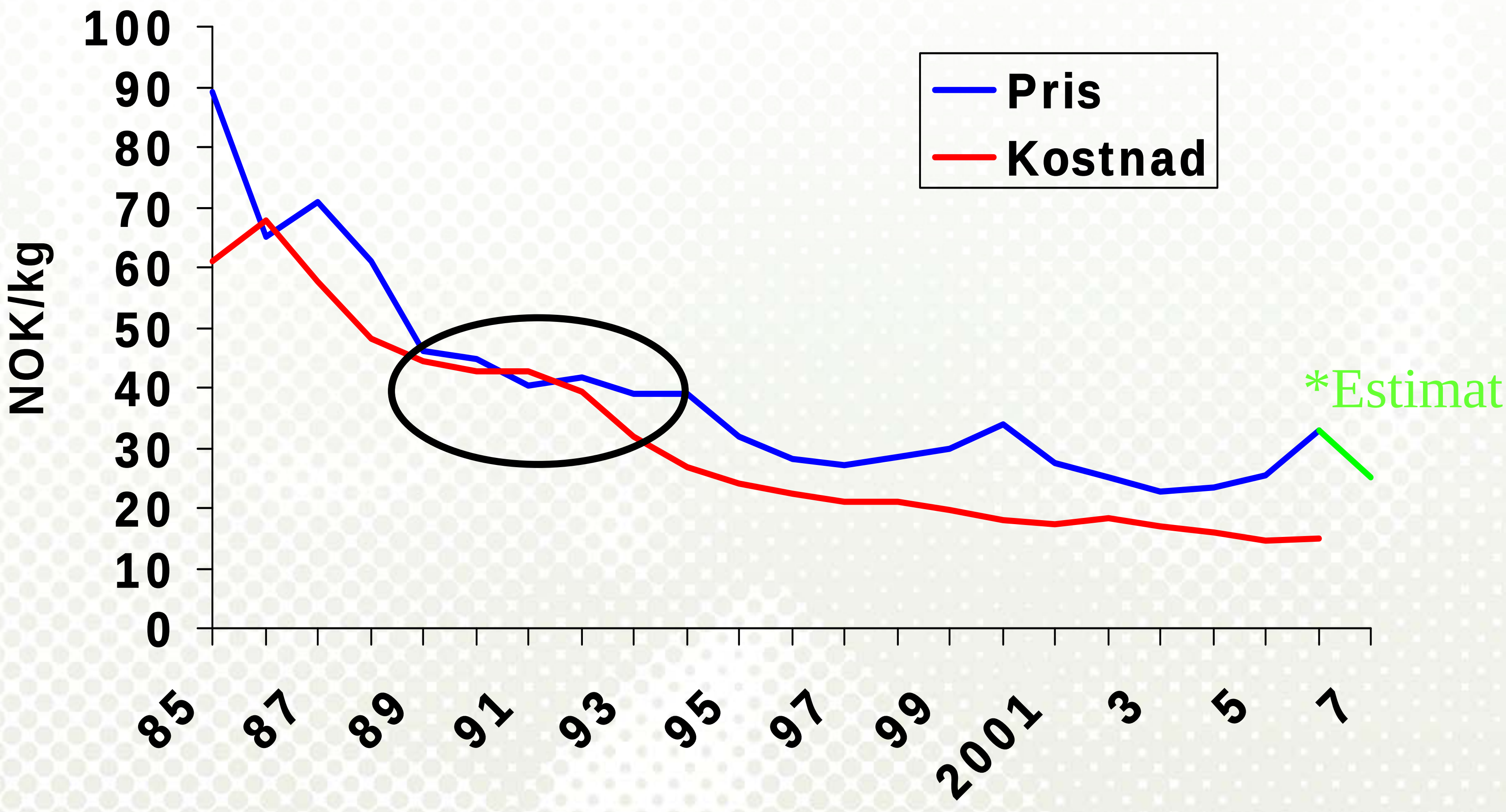
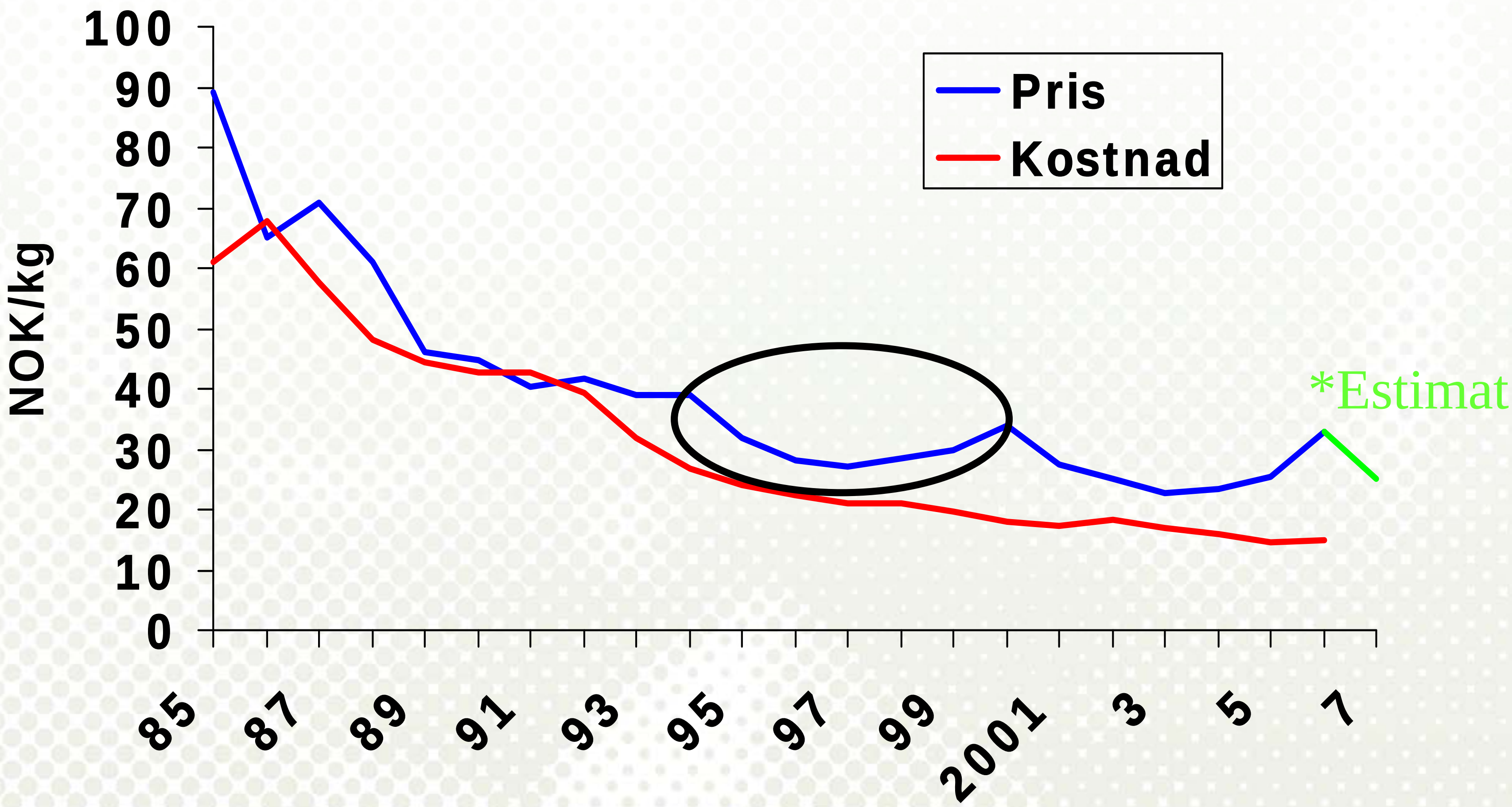
EXPORTPRICE AND PRODUCTION COST 1985-2007 (2006=1)



EXPORTPRICE AND PRODUCTION COST 1985-2007 (2006=1)



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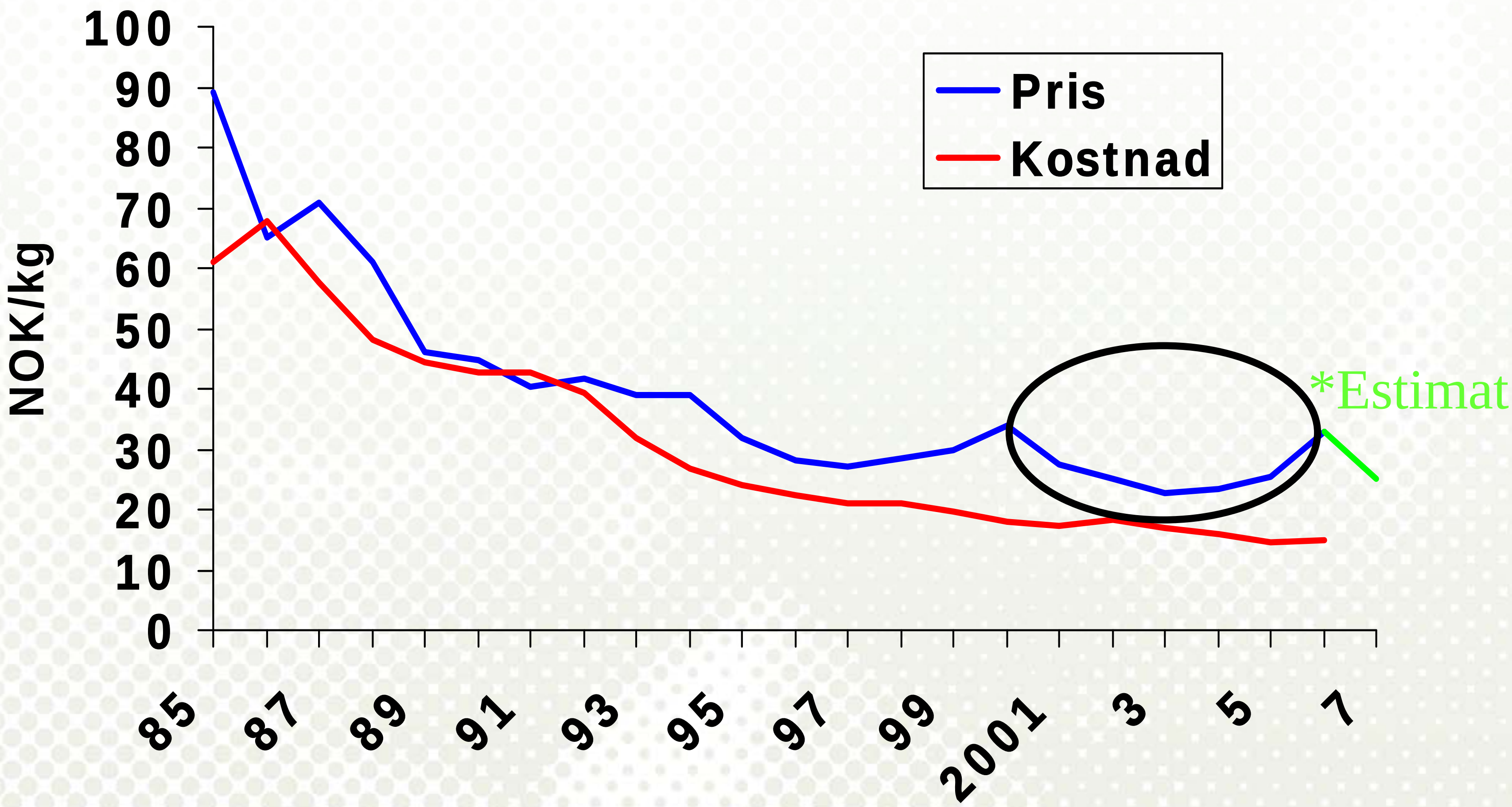
EXPORTPRICE AND PRODUCTION COST 1985-2007 (2006=1)



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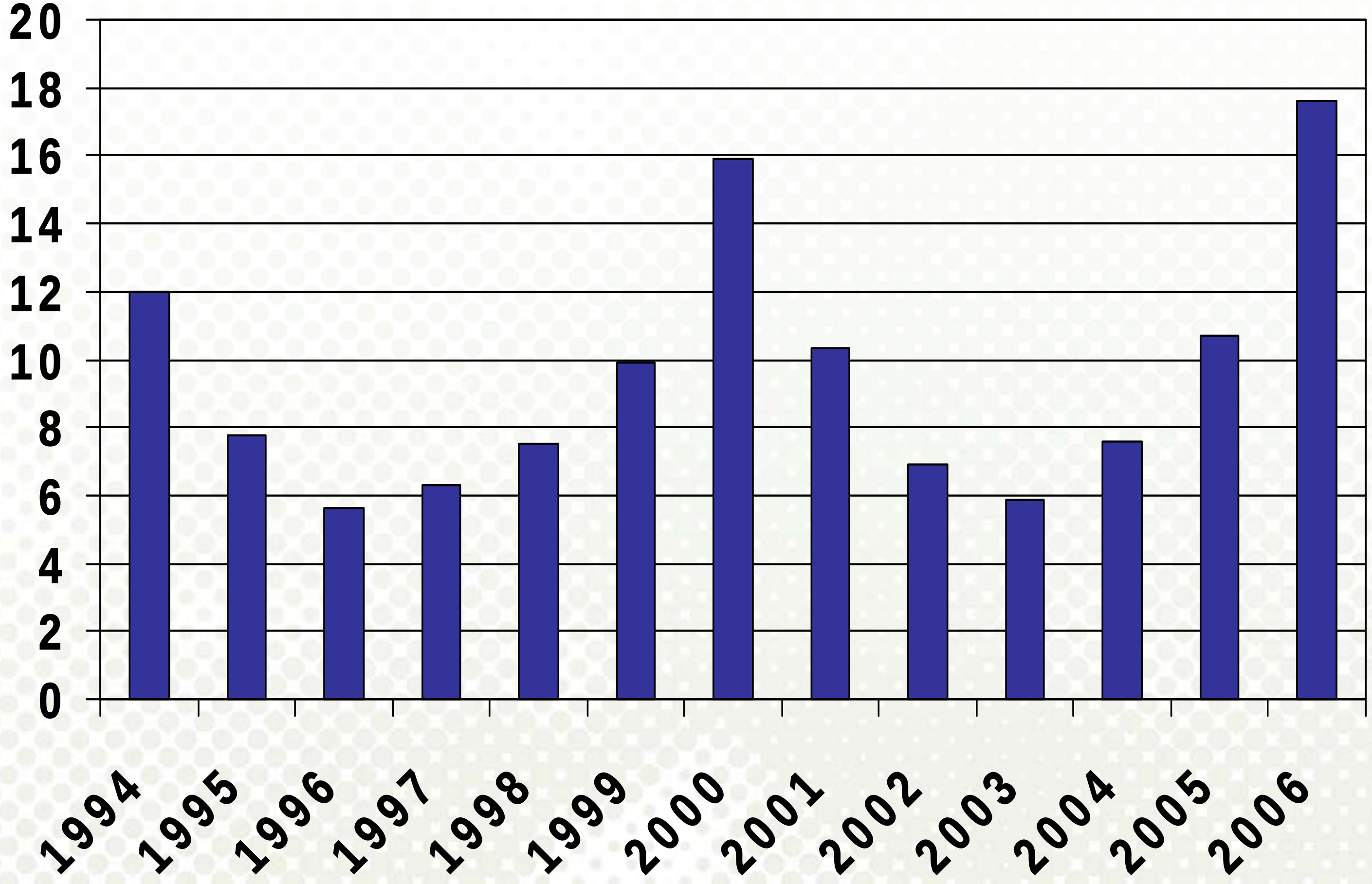
EXPORTPRICE - PRODUCTION COST 1985-2007 (2006=1)



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PRODUCTIVITY GROWTH

- The main reason for the increased production in aquaculture is the productivity growth that reduce production costs, and makes it profitable to sell the product at lower prices
  - Market growth and product development has further contributed to the industry growth

- The prodctivity growth is possible because the control of the production process
- Productivity growth leads to lower production cost because one can produce more output with less use of input factors

- Will often be technically nonneutral so that the input composition changes

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- Productivity can be decomposed into input factor effects and improved technical efficiency
- For salmon about two tirds of productivity growth is improved input factors, while about one third is better farming practices (Tveterås and Heshmati)

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SCALE

- Often improved technologies requires a larger scale
- This is often due to indivisibilities of inputs
- As one learn from each other, technology will become more similar over time – catching up
- In salmon aquaculture, the scale of the operations has changed. A single plastic pen in the early 1980s were 5 meters in diameter and about 4 meters deep. A standard modern pen is about 40 meters in diameter and are also 50 meters deep

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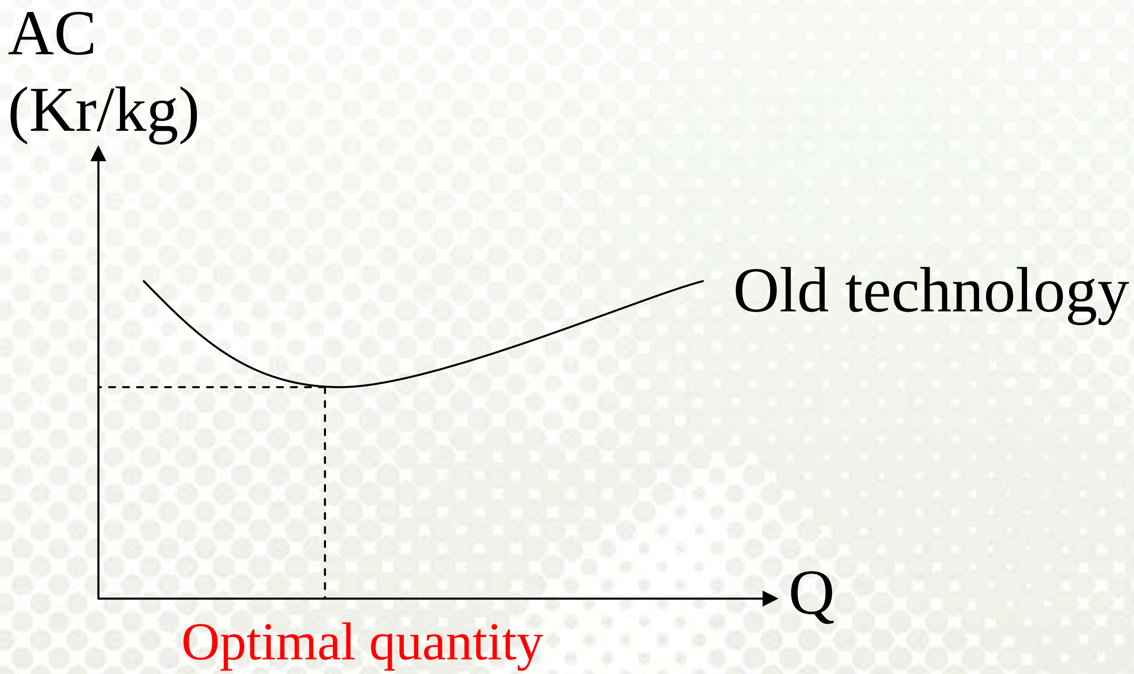
THE TECHNOLGY CHANGES...



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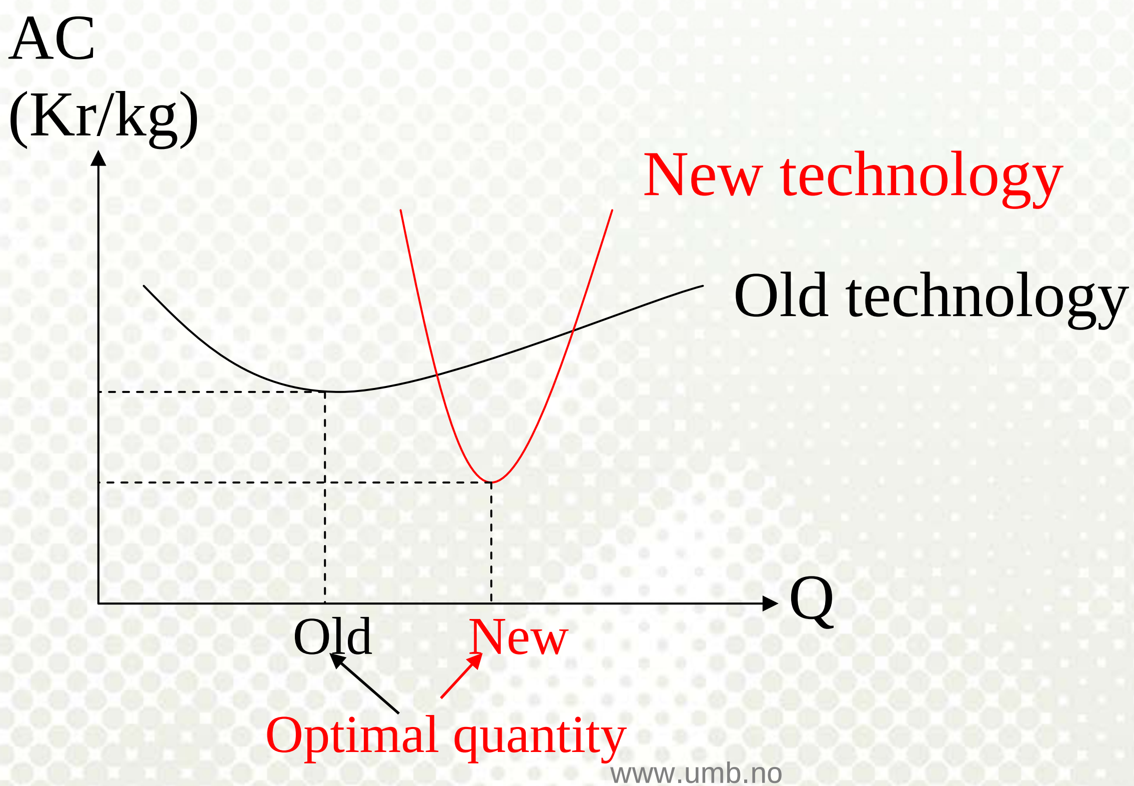
...SO THAT OPTIMAL SCALE HAS INCREASED



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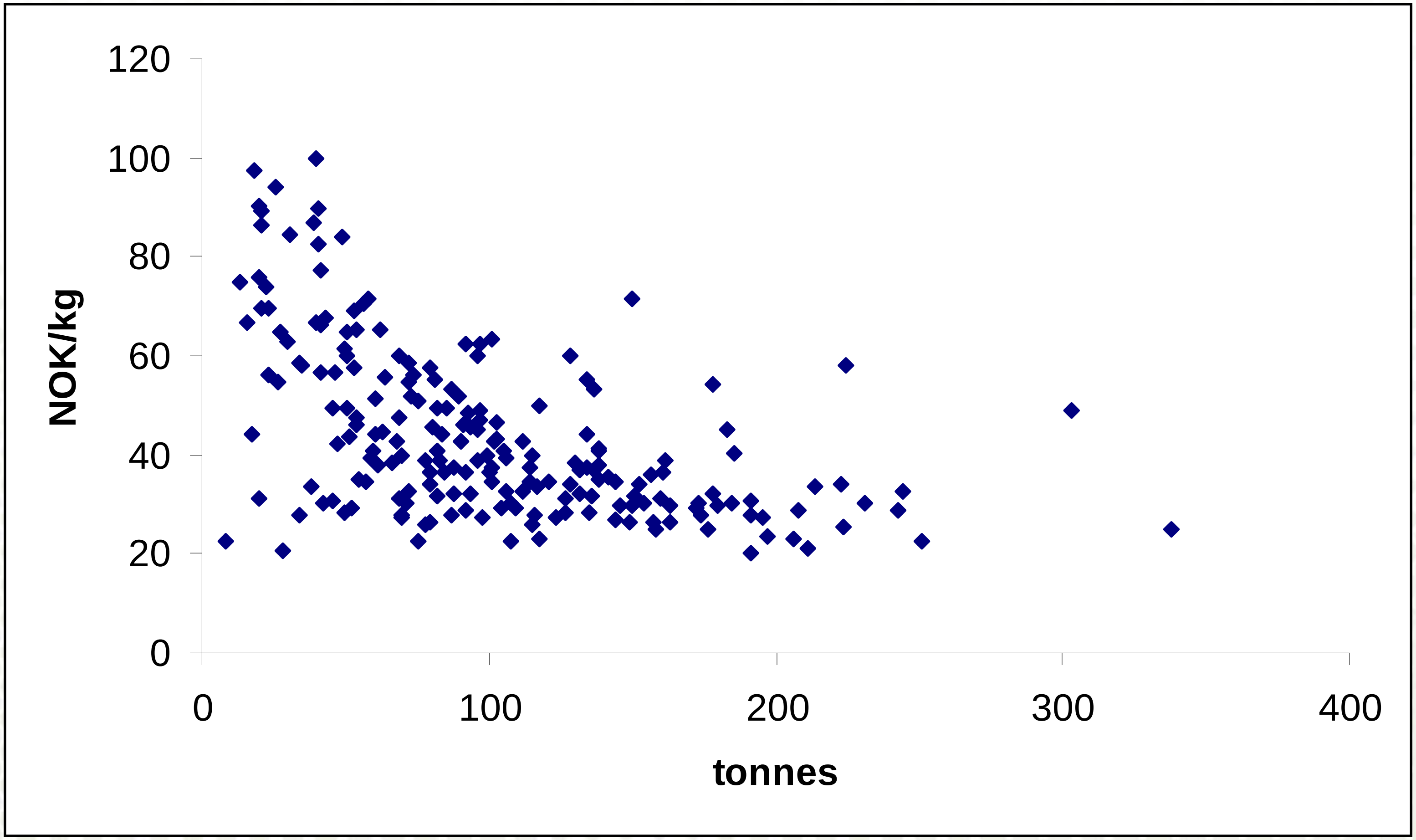
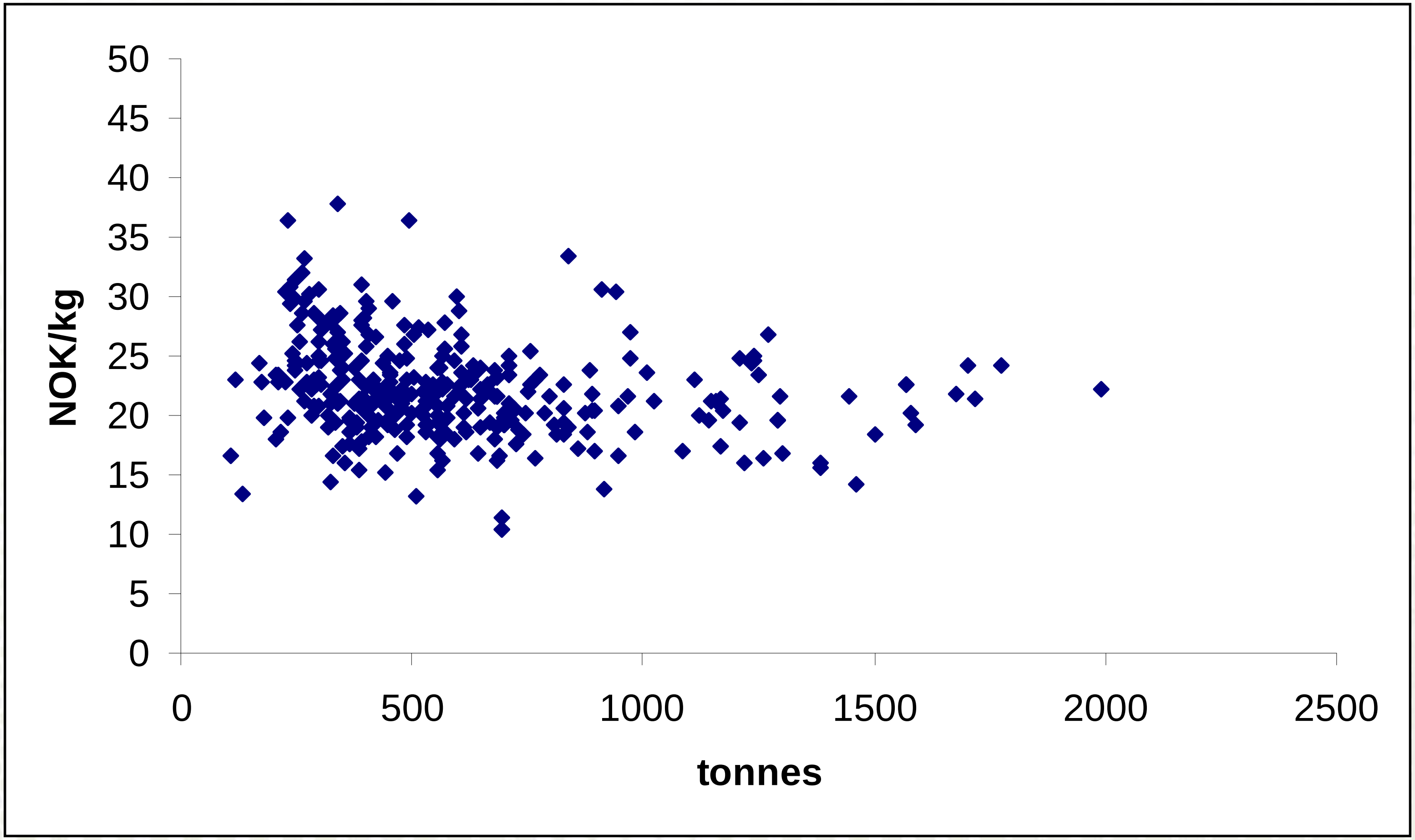
COST/PRODUCTION PER UNIT IN 1986



COST/PRODUCTION PER UNIT IN 1995



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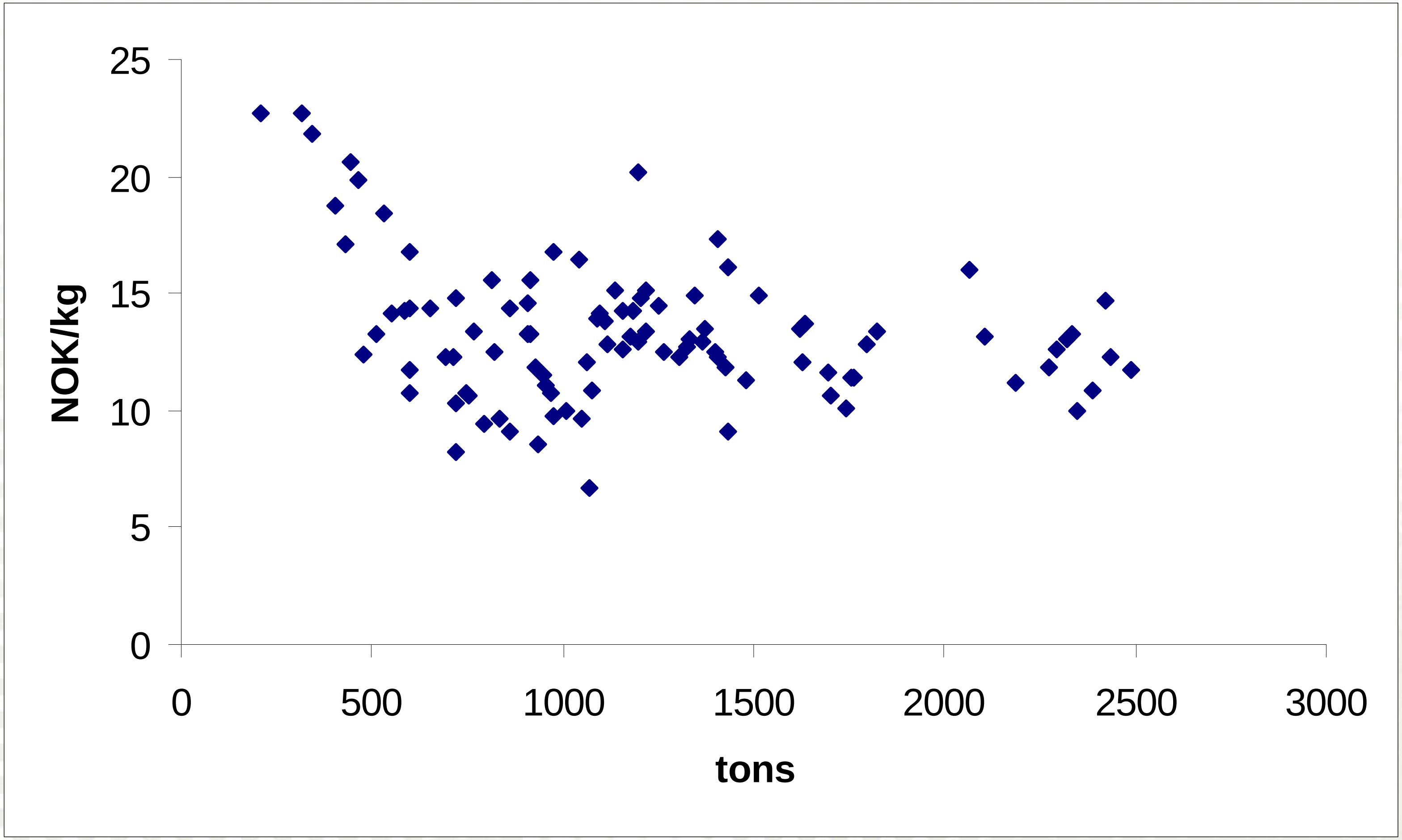
COST/PRODUCTION PER UNIT IN 2004



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PLASTIC PENS

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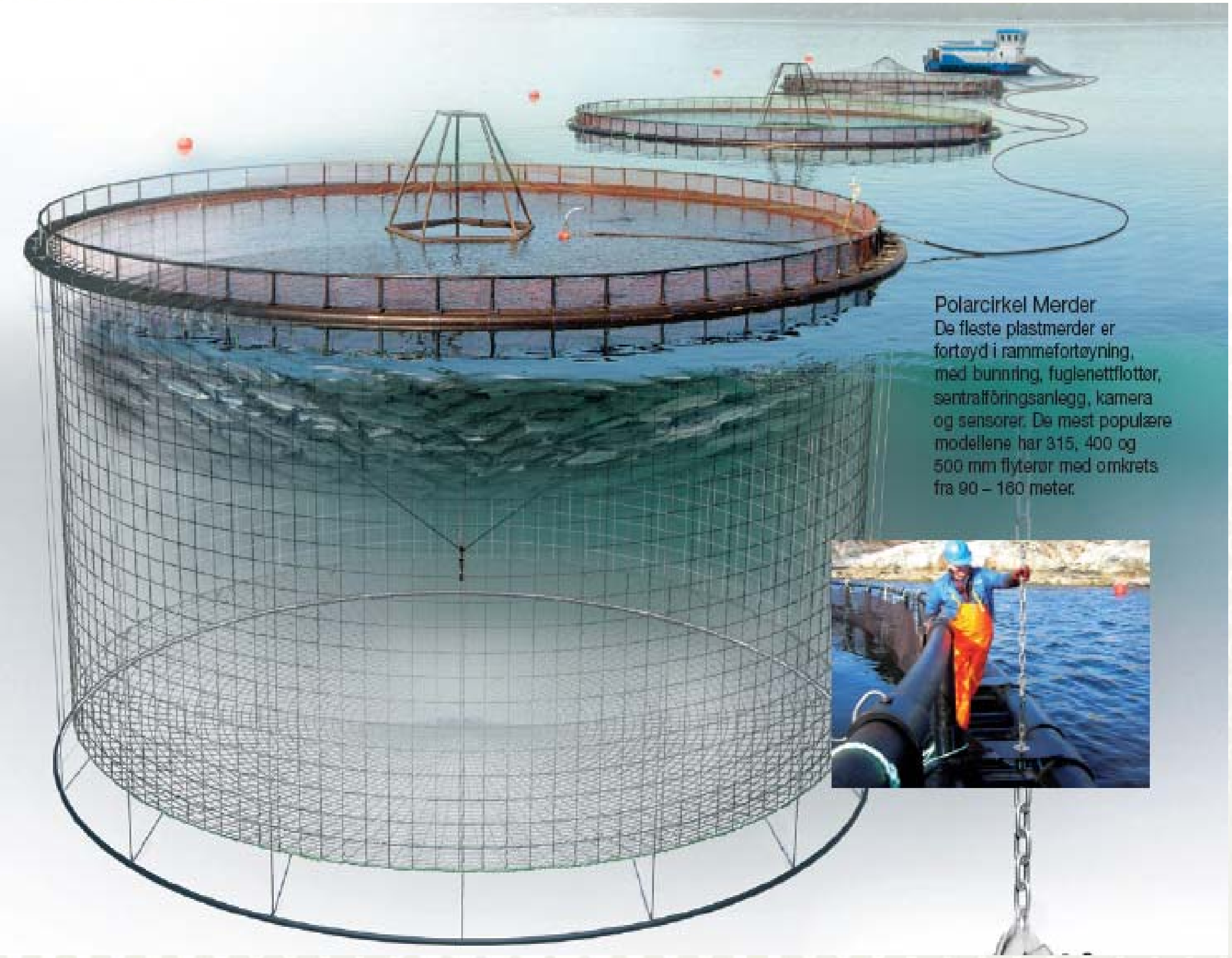
PART OF SALMON FARM



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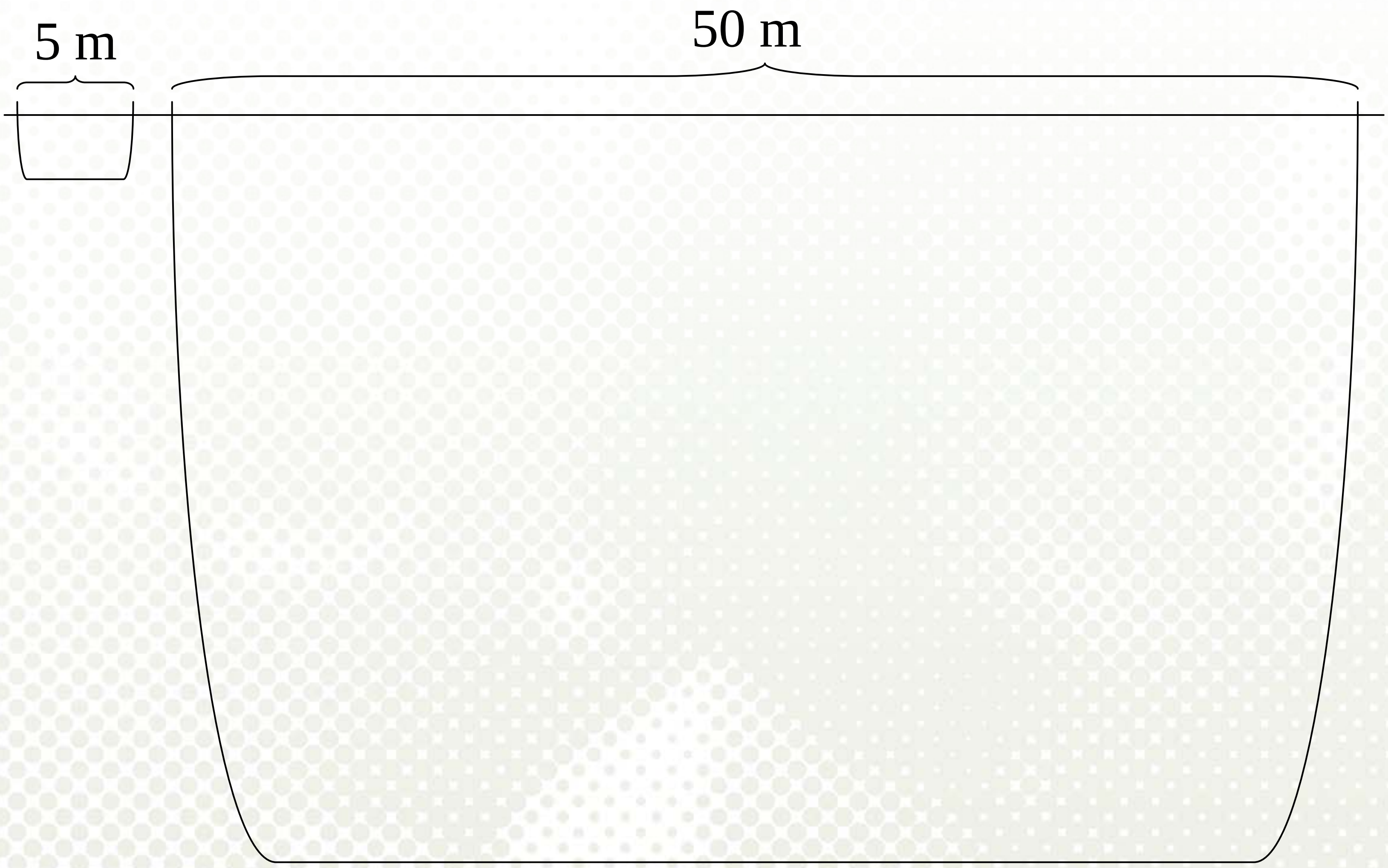
A PEN FROM 1980 AND ONE FROM 2007



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NOMINAL SALMON PRODUCTION COST BY MAIN CATEGORY

	1985	1990	1995	2000	2005	2006
Smolt cost	7.96	5.03	3.74	2.40	1.85	1.58
	(0.25)	(0.17)	(0.19)	(0.15)	(0.13)	(0.11)
Feed cost	11.00	12.92	9.15	7.80	7.46	8.36
	(0.34)	(0.43)	(0.48)	(0.48)	(0.54)	(0.57)
Insurance	1.14	1.11	0.40	0.26	0.22	0.16
	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.01)
Wages	4.79	3.39	1.86	1.54	1.38	1.43
	(0.15)	(0.11)	(0.1)	(0.1)	(0.10)	(0.10)
Depreciation	1.14	1.24	0.51	0.74	0.83	0.74
	(0.04)	(0.04)	(0.03)	(0.05)	(0.06)	(0.05)
Other operating cost	3.55	3.30	2.59	2.89	1.52	2.23
	(0.11)	(0.11)	(0.13)	(0.18)	(0.11)	(0.15)
Financial cost	2.43	3.31	0.96	0.50	0.55	0.23
	(0.08)	(0.11)	(0.05)	(0.03)	(0.04)	(0.02)
Production cost	**32.01**	**30.30**	**19.21**	**16.13**	**13.80**	**14.74**

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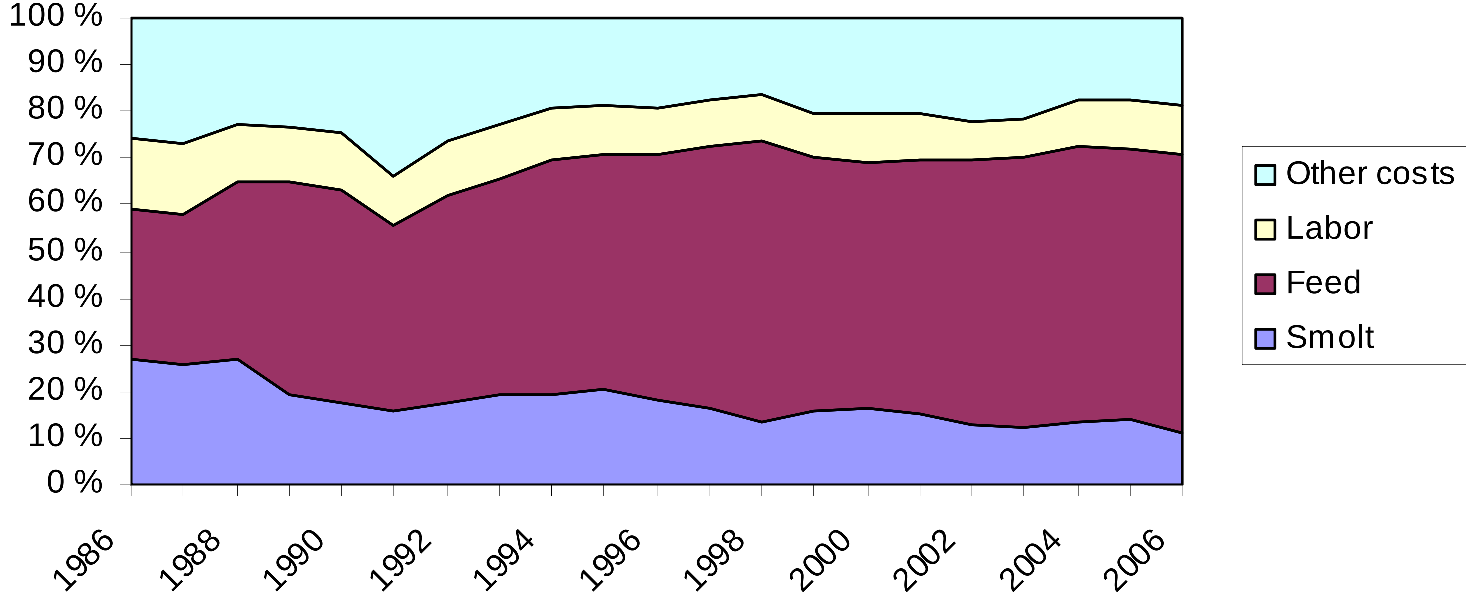
PRODUCTIVITY GROWTH

- COST SHARES IN NORWEGIAN AQUACULTURE INDUSTRY



Source: The Norwegian Directorate of Fisheries

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NOMINAL SMOLT COST BY MAIN CATEGORY

	Cost per smolt	Cost share
Roe and fry	0.92	(0.16)
Feeding	0.75	(0.13)
Insurance	0.16	(0.03)
Vaccination	0.71	(0.12)
Wages	1.11	(0.19)
Depreciation	0.53	(0.09)
Other operating costs	1.41	(0.24)
Net financial expenses	0.22	(0.04)
Total cost	5.81	1.00

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FEED BARGE

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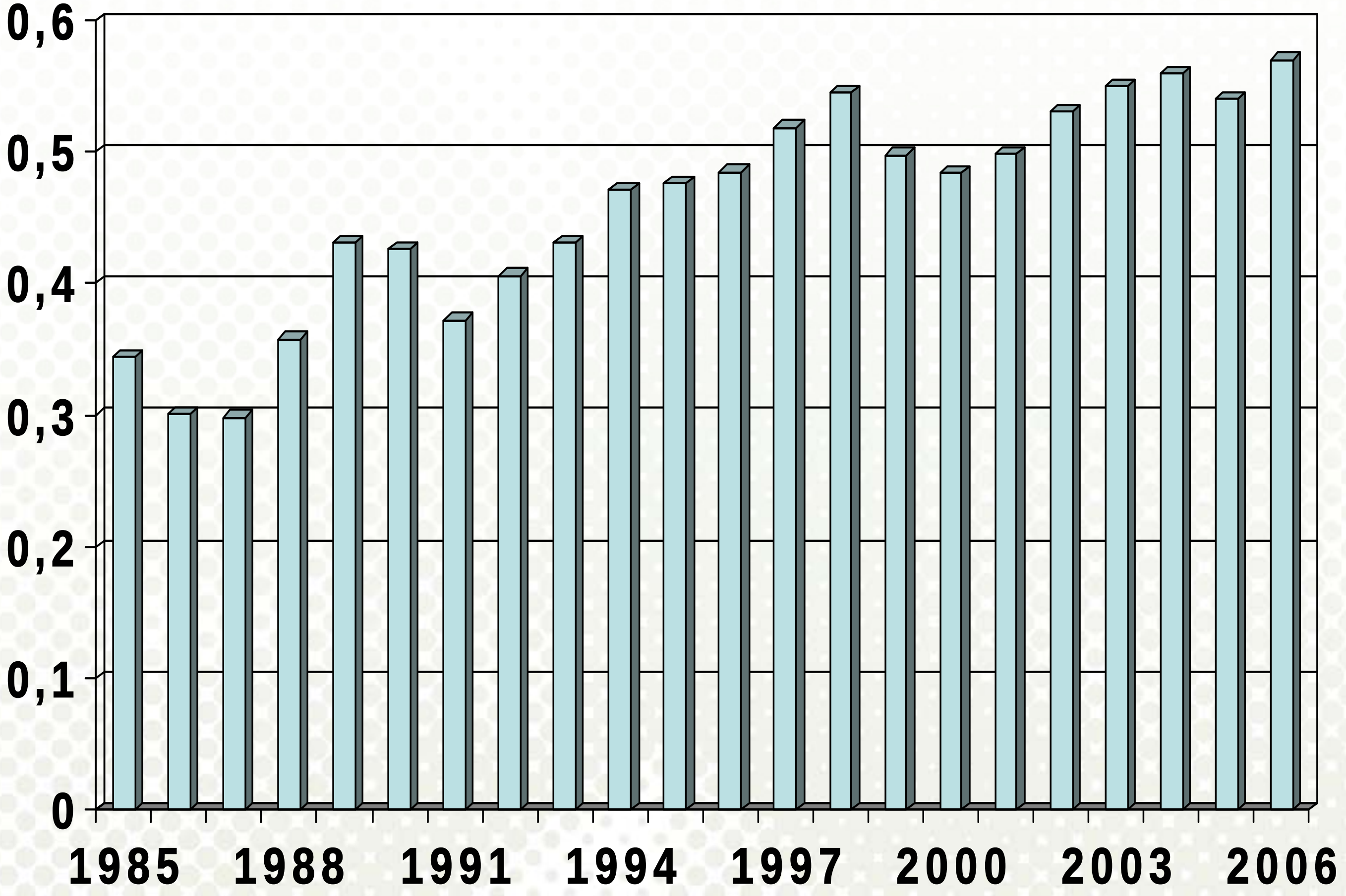
FEED COST SHARE



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PRODUCTIVITY GROWTH

- The development of the input factors has been tremendous, with better feed, automatic feeding systems etc
  - And there is a substantial catching up potential for most species

- Twenty years ago feed made up 25% of salmon farmers cost, and smolt about 20%. Currently feed is 55% and smolt is still 20%

- Increased growth rates, earlier smolt release
  - For efficient chicken farmers, feed is more then 80% of the production cost

- Efficient species are basically converters of cheap low quality inputs to more desirable outputs

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CONTROL WITH THE PRODUCTION PROCESS AND INDUSTRY SIZE ALSO LEAD TO SPECIALICED SUPPLIERS

- Specialized suppliers focus on a specific issue, and tend to be more competent on this issue
  - Important part of industry clusters (Porter)
- Feed industry
  - Better pellets
  - Less fish meal
  - Increased variation in possible inputs reduce the influence of any price increase
  - Slowly sinking pellets
  - Allows the development of automatic feeders etc.
  - The feed formula currently used in Norway contain about 35% fish meal and about 26% fish oil, requiring respectively about 2 kg and 2.6 kg landings of wild fish
  - Lower Feed Conversion Ratio (FCR)
- Pharmaceuticals
- Other equipment providers
- Financial services

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FISH HEALTH AND DISEASES

- Diseases is a phenomenon that occurs naturally
  - With high density of fish as in a cage, diseases transfer more easily
- Salmon diseases
  - Furunkolosis (Hitra), Infectious Salmon Anameia (ISA), Pancreatic Neurosis (PN)
- Antibiotics
- Vaccines
  - Prevent illnesses
  - Reduce growth

Outbreaks of diseases occurs regularly and have huge impact on global supply !!!

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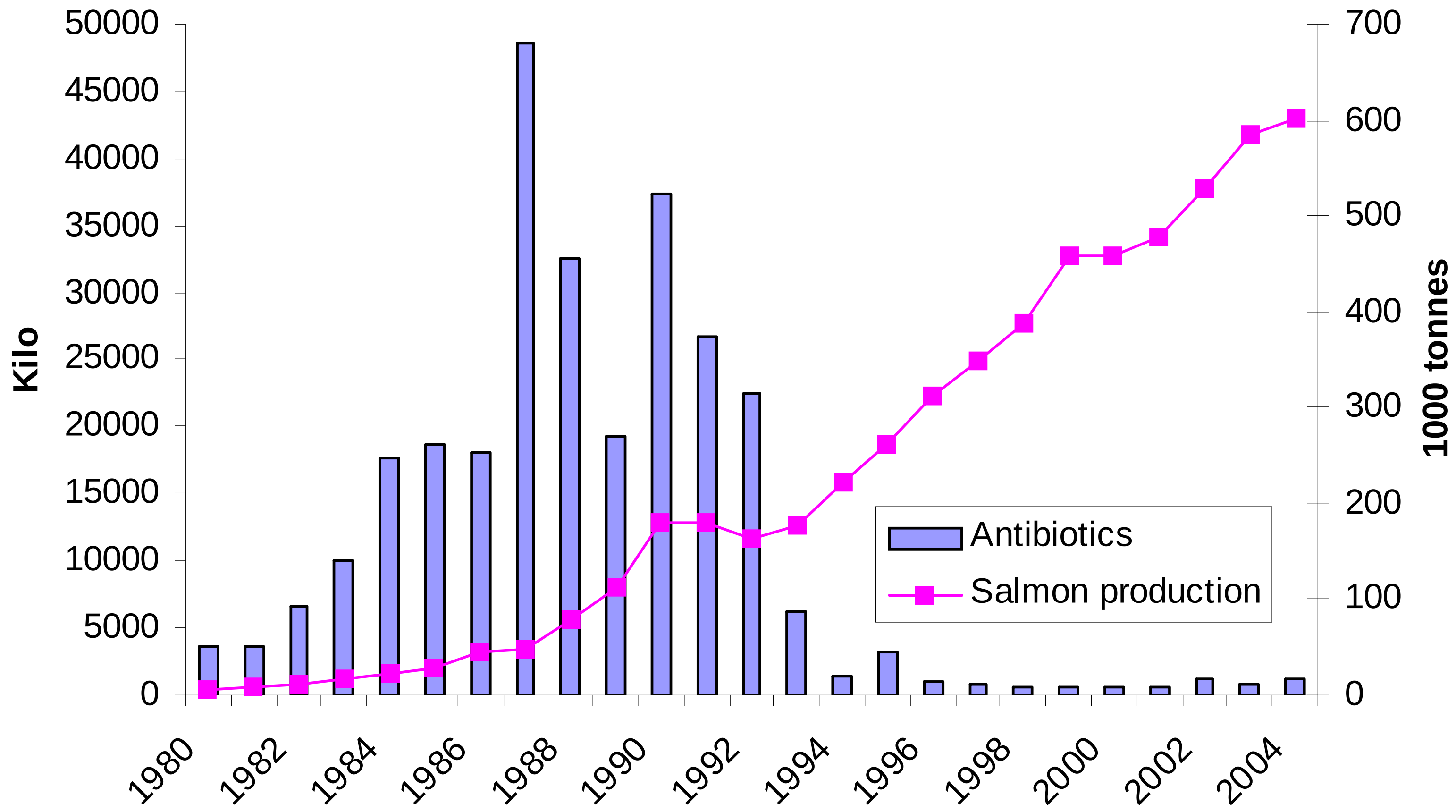
USE OF ANTIBIOTICS IN THE NORWEGIAN SALMON FARMING INDUSTRY



Chile still have a problem with antibiotics !!

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BREEDING
(the single most important factor for productivity growth)

- Breeding focus on several traits
  - Growth, Reduced early sexual maturity, Condition factor (weight/length) correlated for gender, Filet fat percent correlated for gender, Filet color, Filet thickness, (thickest and thinnest point), Loss from smolt to 3 kg, Skin color , Skin color, back, Resistance against Furunculosis, Resistance against ISA, Resistance against IPN, Stress tolerance, Skeletal deformities, Heart weight/body weight

- More and more tailormade products:
  - I.e. products from Salmobreed

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REGULATIONS

- Licence
- Environmental
  - Assessments
  - Fallow sites
- Size
  - In Scotland size is in practice restricted by pollution permits

Changes in regulations are a challenge for modeling !

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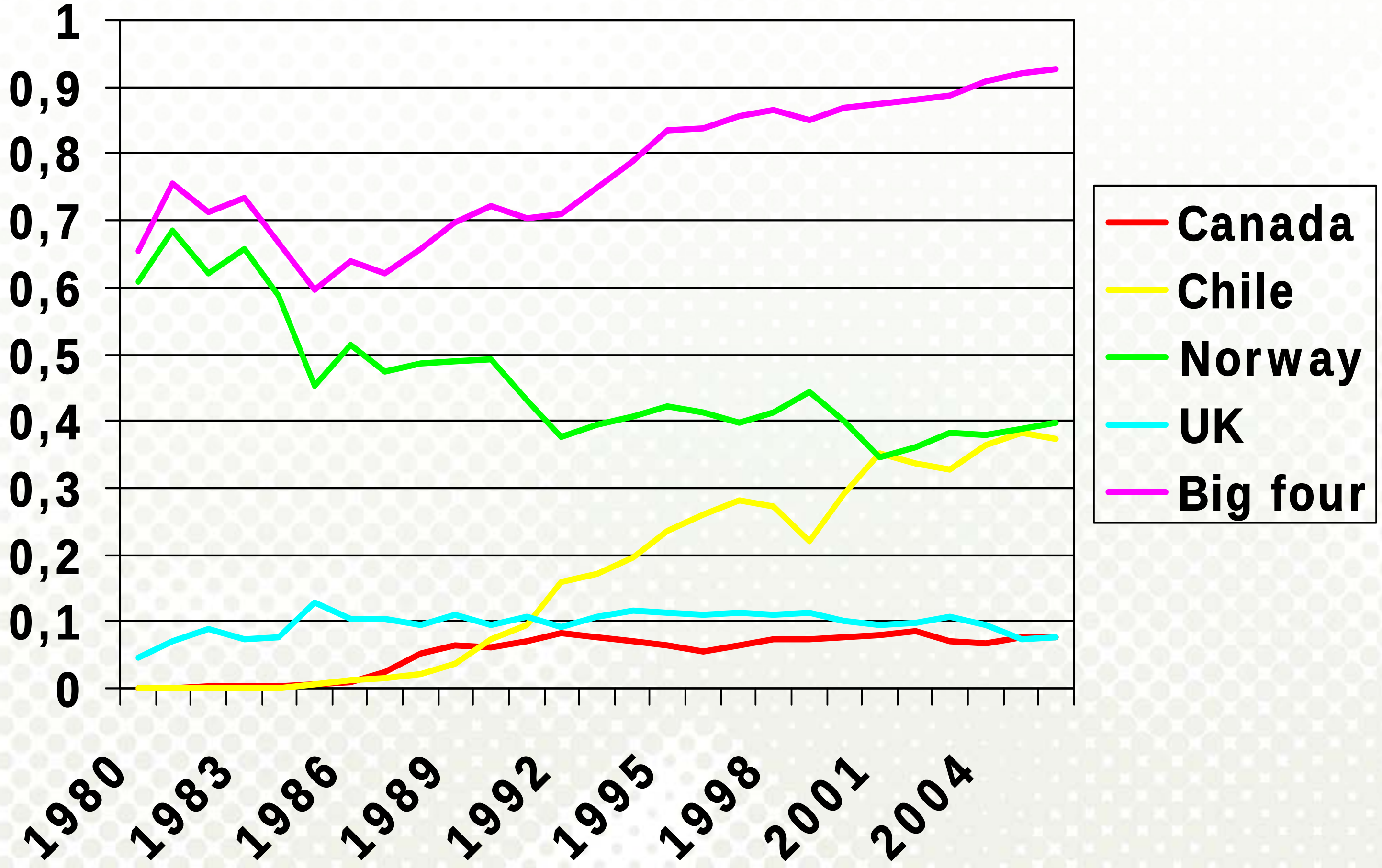
PRODUCTION SHARES, ALL SALMON



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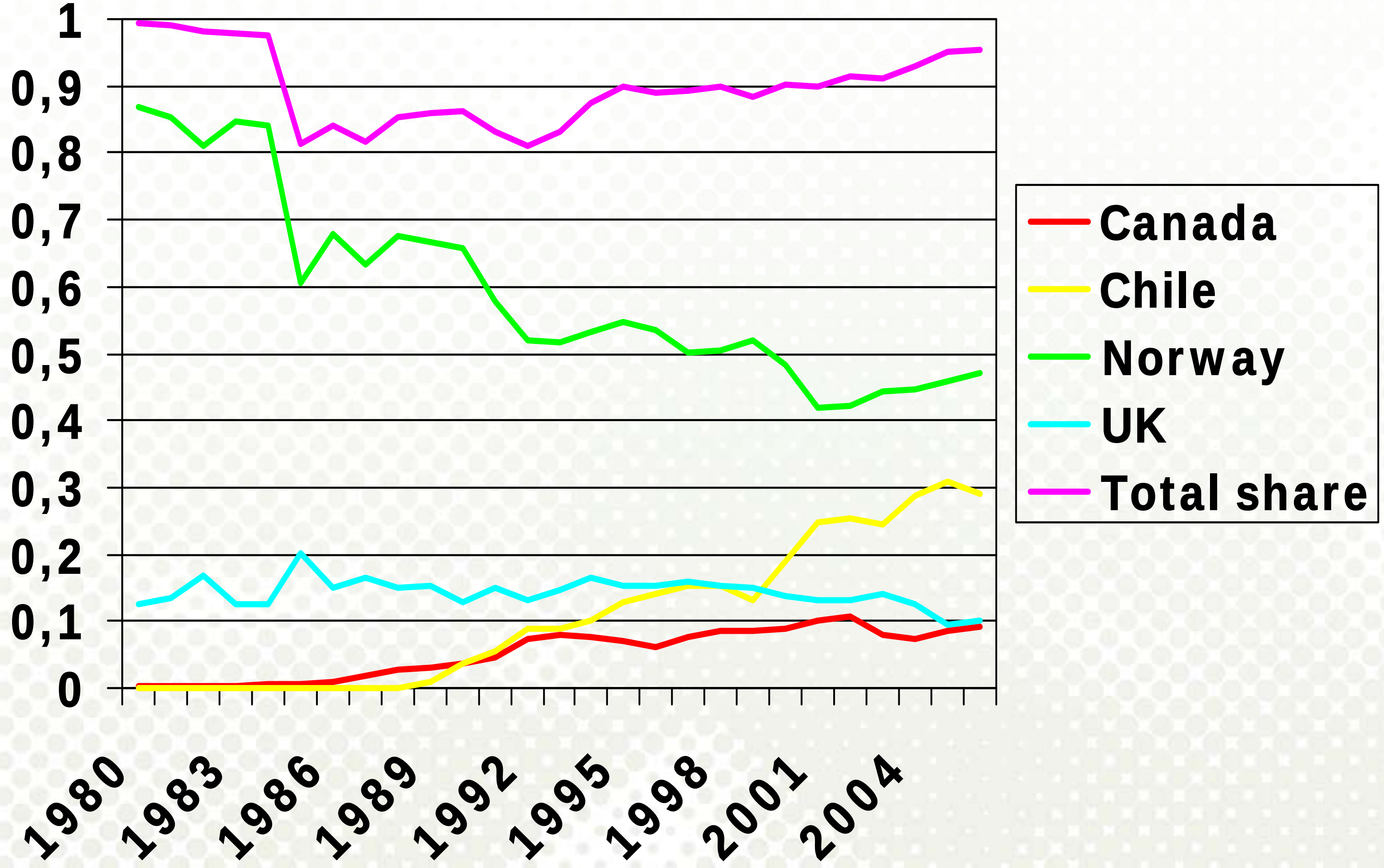
PRODUCTION SHARES, ATLANTIC SALMON



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PRICES FOR DIFFERENT WEIGHT CLASSES

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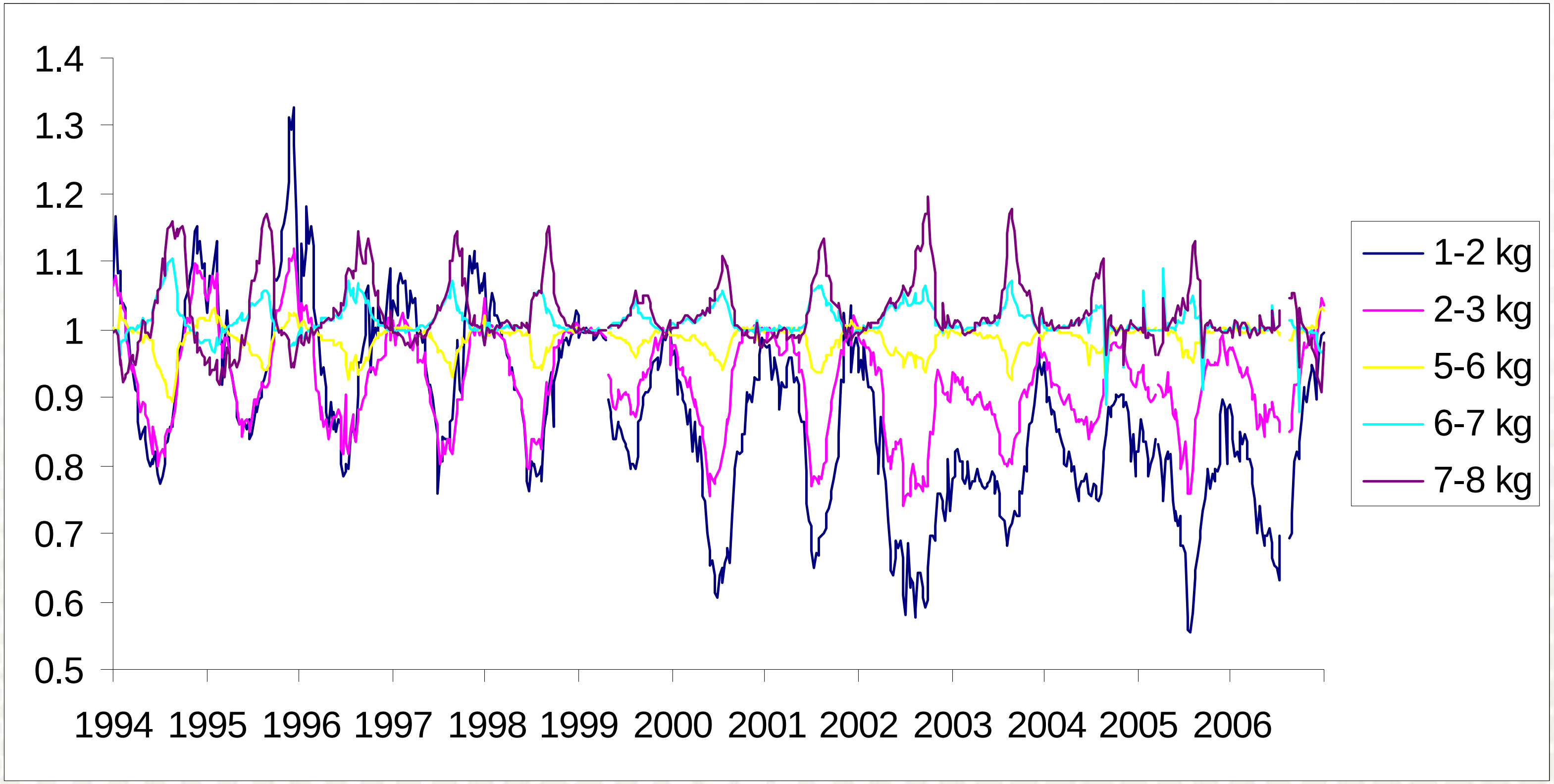
PRICES RELATIVE TO 3-5 KG



Overview of Equilibrium Displacement Models with Application to Salmon

Henry W. Kinnucan
Svalbard Workshop
25-26 September 2008

Overview of Equilibrium Displacement Models with Applications to Salmon

- Definition
- Literature Sketch
- Applications to Salmon
- Concluding Comments

Definition
(adapted from R. Piggott, *Aust. J. Agr. Econ*, 1992)

- Equilibrium Displacement Modeling is a procedure involving three steps:
  - A particular market situation is characterized by a set of supply and demand (and perhaps other) functions that are general in the sense that no particular functional forms are assumed
  - The market is disturbed by a change in the value of some exogenous variable
  - The impacts of the disturbance are approximated by functions that are linear in elasticities

- EDM in essence is comparative static analysis. The main difference is that changes in variables are expressed in percentage (rather than absolute) terms, and parameters are expressed as elasticites rather than as derivatives.

- Sometimes called "Muth modeling" in recognition of Richard F. Muth's seminal contribution "The Derived Demand Curve for a Productive Factor and the Industry Supply Curve" published in 1964.

Literature Sketch

- Hicks (1932)

  Uses a log differential model to assess the effects of technical change on labor's share of the cost of production. Generally considered the first application of the EDM approach.

- Muth (1964)

  Extends Hicks framework to include supply schedules and equilibrium in input markets. Derives "general equilibrium" output supply and input demand curves for a competitive industry that uses two inputs to produce a single output under constant returns to scale.

- Floyd (1965)

  Applies Muth's model to determine the effects of farm price supports on the return to land and labor in agriculture.

- Gardner (1975)

  Applies Muth's model to determine the effects of shifts in farm supply, marketing services supply, and retail demand on the farm-retail price spread.

- Alston and Mullen (1992)

  Develops a dual version of Muth's model to evaluate costs and benefits associated with industry R&D for a traded good (open-economy model).

- R. Piggott (1992)

  Discusses strengths and weaknesses of EDM for policy analysis.   One of the first papers to define "equilibrium displacement modeling" and promote its use.

- Alston, Norton and Pardey (1995)

  A 585 page book entitled *Science Under Scarcity* that elucidates the application of Muth-type models for evaluating the returns to agricultural research. The "Bible" for EDM practitioners.

- Perrin (1997)

  Extends Muth's framework to the *n*-input case and generalizes the specification of technical change. Technology-induced shifts in farm supply are shown to equal the rate of technical change plus the share-weighted induced change in input prices.

- Holloway (1991), Azzam (1998), Kinnucan (2003)

  Extend the Muth/Gardner model to include oligopoly power in the output market and oligopsony power in the farm market.

- McCorriston, Morgan, and Rayner (1998, 2001), Weldegebriel (2004)

  Extend the imperfect competition models to include non-constant returns to scale.

- Davis and Espinoza. (1998), Zhao, Griffiths, Griffith, and Mullen (2000), Piggott (2003)

  Develop methods to incorporate parameter uncertainty into EDMs. Bayesian procedures and Monte Carlo integration are used to calculate confidence intervals to indicate the precision of simulated effects, and to test whether welfare effects implied by the EDM are significant in a statistical sense.

- Harrington and Dubman (2008)

  Extend equilibrium-displacement methods to include mathematical programming. An aggregate model of the US farm sector is developed to illustrate procedures, and to indicate sectoral adjustments to exogenous shocks under alternative markets structures (perfect competition, monopoly/monopsony, and mixed competition).

Applications to Salmon

- Kinnucan and Myrland, *ERAE*, 2000
  - Uses an EDM to determine the optimal advertising intensity for a competitive industry that produces large tradable surpluses and raises funds for promotion through a per-unit assessment on farm output or, alternatively, on exports.
  - Results suggest that, owing to the ability to shift part of the advertising cost onto foreign consumers, an export levy in general is more profitable from the domestic producer perspective than a levy on farm output. In addition, domestic consumers prefer an export levy because, holding constant the advertising effect, it lowers (rather than raises) domestic price.
  - Applying the model to the 1997 Norway-EU Salmon Agreement, results suggest the Agreement was welfare increasing from the domestic (Norwegian) producer perspective in that for plausible advertising responses the optimal export levy of between 3.5% and 5.8% was well above the pre-agreement levy of 0.75%.

- Kinnucan and Myrland, *MRE*, 2002
  - Uses an EDM to determine the optimal seasonal allocation of a fixed promotion budget when substitution effects are important and prices are determined under competitive conditions.
  - Allocation rules depend on elasticities of supply and demand, advertising elasticities, and consumer expenditure shares, all of which can vary seasonally.
  - Applying the rules to Norwegian salmon promotion in France, results suggest a smooth expenditure pattern is more profitable than pulsing. Specifically, the actual quarterly allocation of 4%, 52%, 17%, and 27% was inefficient in that

- Kinnucan and Myrland, *JAE*, 2002
  - Uses an EDM for the Norwegian salmon sector to test Houck's assertion that "exchange rate movements can easily swamp or obscure the desired price, trade, or production effects of any specific agricultural commodity policy."
  - Results were affirmative in that the three most important variables to affect the Norwegian farm price are:
    the euro/kroner exchange rate ($p^*/Z_E^* = -0.76$)
    Feed quota ($p^*/F^* = -0.38$)
    the US$/kroner exchange rate ($p^*/Z_R^* = -0.17$).
  - By way of comparison, the largest advertising effect was $p^*/A_E^* = 0.017$ and the largest levy effect was $p^*/T_E^* = -0.008$, which means that kroner strengthening or feed quota relaxation could easily neutralize the effect of the levy *cum* advertising on farm price.
  - The largest transportation cost effect was $p^*/C_E^* = -0.04$, larger than the advertising effect, but substantially smaller than exchange rate effects.

- Kinnucan and Myrland, *Agribus.*, 2003
  - An EDM is used to determine the free rider effects of salmon promotion sponsored by the Norwegian Seafood Export Council.
  - Results suggest promotion intensification funded by an increase in the levy on Norwegian salmon sold in the EU would have a positive effect on producer surplus worldwide. However, the distribution of gains is uneven, with most of the benefit (47%) accruing to producers in the United Kingdom. Norway, with a 47% market share, receives only 23% of the incremental gain.
  - The reason UK producers capture most of the benefit is tax shifting. Specifically, the increased export tax used to fund the promotion increment raises the price UK producers receive for salmon sold in the EU, which augments the gain they receive from the demand shift. The same tax lowers the price Norwegian producers receive for their EU sales, which attenuates their gain from the demand shift.

- Kinnucan and Myrland, *App. Econ.*, 2005
  - Uses an EDM to determine the effects of income growth and tariffs on the world salmon market.
  - Results suggest the total or general equilibrium income elasticity for salmon in world trade is about one. This means salmon imports worldwide will grow at about the same pace as world income.
  - However, owing in part to policies that restrict supply response, not all exporters will share evenly in this growth, with UK producers benefiting the most and Norwegian producers the least.
  - US tariffs on imports from Norway and Chile are counterproductive in that they reduce world salmon imports with little effect on the US price. The reason is that US import demand for salmon from Norway and Chile is more elastic than export supply, which means most of the tariff's incidence falls on the named exporters.
  - Norway's feed quota (biomass limit) reduces the efficacy of US tariffs, makes imports less responsive to income, and increases price volatility. Hence, quota elimination may yield producer benefits in excess of producer losses associated with a lower world price.

- Kinnucan and Myrland, *JIATD*, 2006
  - Uses an EDM to determine the effects of increased supplies of farmed salmon from Chile on world salmon prices, trade flows, and welfare.
  - Results indicate that the 71% increase in exports from Chile between 2000 and 2002 generated a surplus gain worldwide of $1.3 billion. Most the gain ($1.03 billion) accrues to Chilean producers, as might be expected since the implied cost reduction (58%) far exceeds the associated price decline (11%). With the lower prices consumers gain $771 million, and Chile's international competitors lose $525 million. Most of this loss ($381 million) is absorbed by Norwegian producers, thanks in part to the feed quota that makes Norwegian supply less elastic.
  - Removal of the feed quota leaves the total welfare gain from Chile's supply expansion unchanged at $1.30 billion, but shifts the incidence in favor or producers. Specifically, removal of the feed quota causes the producer incidence of the welfare gain to rise from 41% to 54%. The producer gain rises because quota removal makes Norwegian supply more elastic, which attenuates the price decline associated with Chile's supply expansion.
  - Overall, results indicate the general equilibrium demand curve for salmon in world trade is price elastic at -1.2. This suggests feed quotas, tariffs, or other trade restrictions are not an effective instrument for assisting salmon producers.

- Kinnucan, and Myrland, *JAE*, 2006
  - Uses an EDM to determine the price effects of safeguard tariffs contemplated by the European Commission on salmon imports from Norway, Chile, and Faroe Islands
  - Results suggest the tariffs lack efficacy in that most of the tariffs' incidence falls on producers in the named exporting countries with little benefit for producers in the importing country (EU). For example, a 6% tariff on imports from Norway reduces the Norwegian price 5.5% and raises the EU/UK price a mere 0.5%. The combined effect of 6%, 30%, and 22% tariffs imposed, respectively, on imports from Norway, Chile, and Faroe Islands raises the UK price a mere 6.6%.
  - The reason the tariffs are ineffective is that export supply is less elastic than import demand on a bilateral basis, which means most of the tariff is borne by targeted producers rather than EU consumers. The incidence problem is exacerbated by feed quota (biomass limit) that Norway uses to limit its production.
  - A marketing fee that expands demand is shown to be less distortionary than its tariff equivalent, and thus may be preferred from a second-best perspective.

Concluding Comments

- Equilibrium Displacement modeling has a rich intellectual history and has proved useful in applied policy analysis

- Limitations of the approach include:

    - Displacements are restricted to the neighborhood of the initial equilibrium.

    - Paths of adjustment are ignored. (This weakness can be overcome to some extent by repeated applications of the procedures for different lengths of run.)

    - Structural parameters (elasticities) are assumed to be fixed. (The Lucas critique.)

    - Technology is assumed to be known and fixed.

    - Responses are assumed symmetric. That is, a one percent increase in an exogenous variable has the same proportionate effect on endogenous variables as a one percent decrease

Cost Functions in Analysis of Tariff and Technology Changes

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Prepared for the research conference on Salmon Market Analysis Modules, Longyearbyen, Norway, Sept 25-26, 2008

The objective here:

- A cost-function based model of impacts on salmon of:
  - Income change
  - tariff change
  - technological change with input biases
- Calculate impact elasticities on:
  - input and output prices and quantities
  - welfare of affected consumers and producers

A cost function applicable to the Norwegian salmon industry

(1)
$C(\mathbf{w}, y, \tau) \equiv \min_x \{\mathbf{wx} \mid (\mathbf{x}, y) \in S_\tau\}$, where

$\mathbf{x}$ is an nx1 vector of inputs,

$\mathbf{w}$ is a 1xn vector of input prices,

y is salmon production,

τ is an index of technical change

S_τ is the technology set τ, such that $dS / d\tau$ represents some discrete change in technology

Cost function derivations and notation

(2)

$\mathbf{H} \equiv (\tilde{x})^{-1} C_{ww}(w, y, \tau)\tilde{w}$, nxn output-constant input demand elasticity matrix, where subscripts indicate derivatives and $\tilde{\mathbf{x}}$ designates a matrix with $\mathbf{x}$ on the diagonal;

$\mathbf{s} \equiv C_{\mathbf{w}}(w, y, \tau)(\tilde{\mathbf{x}})^{-1}$, a $1xn$ vector of input shares;

$\delta \equiv -C^{-1}\partial C / \partial\tau = -d \ln C / d\tau$, the rate of technical change;

$\mathbf{B} \equiv (\tilde{\mathbf{x}})^{-1} C_{\mathbf{w}\tau} + \mathbf{i}\delta$, $nx1$ bias vector of technical change, measuring the percentage change in shares at constant prices, where $\mathbf{i}$ is a $nx1$ unit vector.

Equilibrium conditions

(3)

a. net export demand: $y = f(p^w, Y)$

b. foreign ad valorem tariff: $p^w = p(1+t)$

c. zero industry profit: $py = C(\mathbf{w}, y, \tau)$

d. optimal $\mathbf{x}$: $\mathbf{x} = C_{\mathbf{w}}(\mathbf{w}, y, \tau)$

e. supply of $\mathbf{x}$: $\mathbf{x} = S(\mathbf{w})$

Log differentiation

notation:

(4)

$\eta = d\ln y / d\ln p,$ price elasticity of world demand;

$\varepsilon = d\ln y / d\ln Y,$ income elasticity of world demand;

$\mathbf{S} =$ nxn input supply elasticity matrix;

log differentials:

(5)

a. $d\ln y = \eta d\ln p^w + \varepsilon d\ln Y$

b. $d\ln p^w = d\ln p + dt$

c. $d\ln p = \mathbf{s}d\ln \mathbf{w} - \delta d\tau$

d. $d\ln \mathbf{x} = \mathbf{H}d\ln \mathbf{w} + \mathbf{i}d\ln y + (\mathbf{B} - \mathbf{i}\delta)d\ln \tau$

e. $d\ln \mathbf{x} = \mathbf{S}d\ln \mathbf{w}$

Log differential equations in matrix notation

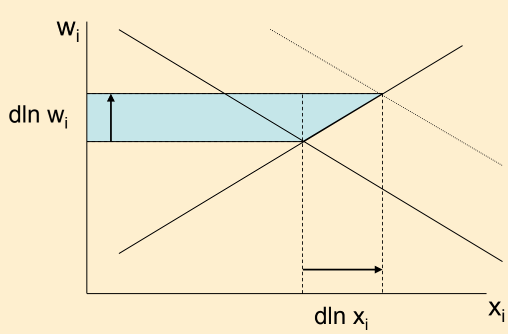
$$(6)\quad \begin{bmatrix} -\eta & 1 & 0 & \mathbf{0} & \mathbf{0} \\ 1 & 0 & -1 & \mathbf{0} & \mathbf{0} \\ 0 & 0 & 1 & -\mathbf{s} & \mathbf{0} \\ \mathbf{0} & -\mathbf{i} & \mathbf{0} & -\mathbf{H} & \mathbf{I} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & -\mathbf{S} & \mathbf{I} \end{bmatrix} \begin{bmatrix} d\ln p^w \\ d\ln y \\ d\ln p \\ d\ln \mathbf{w} \\ d\ln \mathbf{x} \end{bmatrix} = \begin{bmatrix} \varepsilon \\ 0 \\ 0 \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix} d\ln Y + \begin{bmatrix} 0 \\ 1 \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix} dt + \begin{bmatrix} 0 \\ 0 \\ -\delta \\ \mathbf{B} - \mathbf{i}\delta \\ \mathbf{0} \end{bmatrix} d\tau$$

Welfare implications

(7)

$$d\ln CS \equiv dCS / p^w y = d\ln p^w (1 + 0.5 d\ln y), \text{ and}$$

$$d\ln PS_i \equiv dPS_i / w_i x_i = d\ln w_i (1 + 0.5 d\ln x_i), \text{ for } i = 1,\ldots n.$$



Numerical implementation

$$(8)\quad \begin{matrix} a. \\ b. \\ c. \\ d1. \\ d2. \\ d3. \\ e1. \\ e2. \\ e3. \end{matrix} \begin{bmatrix} 1.3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & -.3 & -.3 & -.4 & 0 & 0 & 0 \\ 0 & -1 & 0 & -.10 & .02 & .08 & 1 & 0 & 0 \\ 0 & -1 & 0 & .02 & -.10 & .08 & 0 & 1 & 0 \\ 0 & -1 & 0 & .06 & .06 & -.12 & 0 & 0 & 1 \\ 0 & 0 & 0 & -1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & -.25 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} d\ln p^w \\ d\ln y \\ d\ln p \\ d\ln w1 \\ d\ln w2 \\ d\ln w3 \\ d\ln x1 \\ d\ln x2 \\ d\ln x3 \end{bmatrix} = \begin{bmatrix} 1.2 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} dY + \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} dt + \begin{bmatrix} 0 \\ 0 \\ -.1 \\ 0 \\ -.2 \\ -.1 \\ 0 \\ 0 \\ 0 \end{bmatrix} d\tau$$

Spreadsheet solution

$$(9)\quad \begin{bmatrix} d\ln p^w \\ d\ln y \\ d\ln p \\ d\ln w1 \\ d\ln w2 \\ d\ln w3 \\ d\ln x1 \\ d\ln x2 \\ d\ln x3 \end{bmatrix} = \begin{bmatrix} 0.74 \\ 0.23 \\ 0.74 \\ 0.11 \\ 0.11 \\ 1.70 \\ 0.11 \\ 0.11 \\ 0.49 \end{bmatrix} d\ln Y + \begin{bmatrix} 0.19 \\ -0.25 \\ -0.81 \\ -0.12 \\ -0.12 \\ -1.84 \\ -0.12 \\ -0.12 \\ -0.46 \end{bmatrix} dt + \begin{bmatrix} -0.08 \\ 0.11 \\ -0.08 \\ 0.12 \\ -0.11 \\ 0.04 \\ 0.12 \\ -0.11 \\ 0.01 \end{bmatrix} d\tau$$

Table 1. Welfare impact elasticities, measured as percent change in the ratio of economic surplus to market value

Agent	Measured as	Exogenous variable		
		dln Y	*dt*	*dτ*
Consumer	$\Delta CS^{y}/ y^{0}p^{w,0}$	-	-0.17	0.09
Tariff value	$tax/ y^{0}p^{w,0}$	-	0.75	-
Producers of x_1	$\Delta PS^{1}/ x_1^{0}w_1^{0}$	0.11	-0.11	0.12
Producers of x_2	$\Delta PS^{2}/ x_2^{0}w_2^{0}$	0.11	-0.11	-0.10
Producers of x_3	$\Delta PS^{3}/ x_3^{0}w_3^{0}$	2.06	-1.42	0.04

Fig 1. The spreadsheet layout

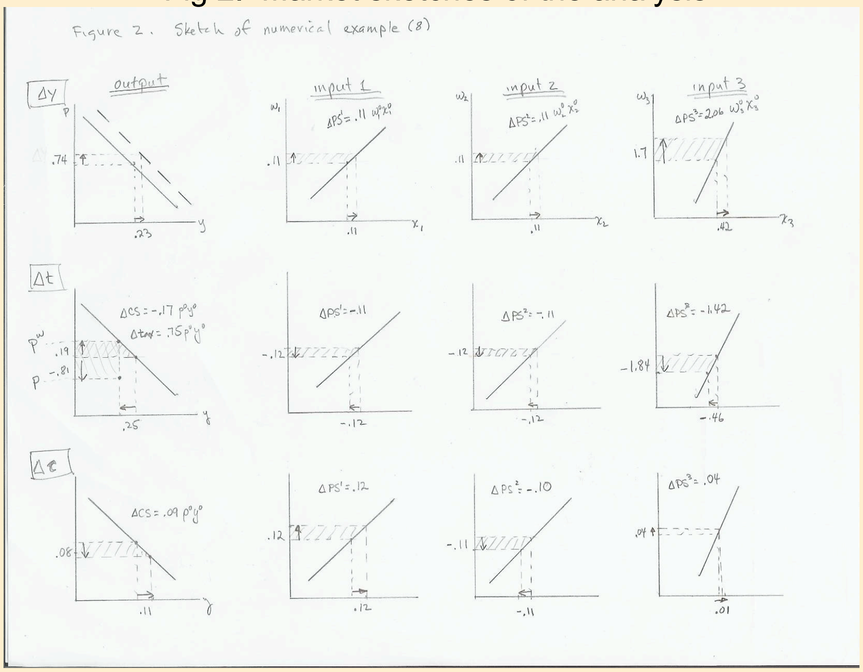
	dln p^w	dln y	dln p	dln w^1	dln w^2	dln w^3	dln x^1	dln x^2	dln x^3										
a.	1.3	1	0	0	0	0	0	0	0	dln p^w		1.2		0		0			
b.	1	0	-1	0	0	0	0	0	0	dln y		0		1		0			
c.	0	0	1	-0.3	-0.3	-0.4	0	0	0	dln p		0		0		-0.1		0.1	delta
d1.	0	-1	0	-0.100	0.020	0.080	1	0	0	dln w^1		0		0		0		0.1	=b1
d2.	0	-1	0	0.020	-0.100	0.080	0	1	0	dln w^2	=	0	dln Y +	0	dln t +	-0.2	dln τ	-0.1	=b2
d3.	0	-1	0	0.060	0.060	-0.120	0	0	1	dln w^3		0		0		-0.1		0	=b3, fixe
e1.	0	0	0	-1	0	0	1	0	0	dln x^1		0		0		0			
e2.	0	0	0	0	-1	0	0	1	0	dln x^2		0		0		0			
e3.	0	0	0	0	0	-0.25	0	0	1	dln x^3		0		0		0			

0.619	0.195	0.195	0.026549	0.0265	0.56637	-0.03	-0.03	-0.57	dln p^w		0.74		0.19		-0.08	
0.195	-0.25	-0.25	-0.03451	-0.0345	-0.7363	0.035	0.035	0.74	dln y		0.23		-0.25		0.11	
0.619	-0.81	0.195	0.026549	0.0265	0.56637	-0.03	-0.03	-0.57	dln p		0.74		-0.81		-0.08	
0.088	-0.12	-0.12	1.143403	0.007	-1.0619	-1.14	-0.01	1.06	dln w^1		0.11		-0.12		0.12	
0.088	-0.12	-0.12	0.007059	1.1434	-1.0819	-0.01	-1.14	1.08	dln w^2	=	0.11	dln Y +	-0.12	dln t +	-0.11	dln τ
1.416	-1.84	-1.84	-0.79646	-0.7965	3.00885	0.796	0.796	-3.01	dln w^3		1.70		-1.84		0.04	
0.088	-0.12	-0.12	1.143403	0.007	-1.0619	-0.14	-0.01	1.06	dln x^1		0.11		-0.12		0.12	
0.088	-0.12	-0.12	0.007059	1.1434	-1.0819	-0.01	-0.14	1.08	dln x^2		0.11		-0.12		-0.11	
0.354	-0.46	-0.46	-0.19912	-0.1991	0.75221	0.199	0.199	0.25	dln x^3		0.42		-0.46		0.01	

Welfare impact elasticities:

ΔCS/ $y^0p^{w,0}$	-	-0.17	0.09
tax/ $y^0p^{w,0}$	-	0.75	-
ΔPS/ $x^{1,0}w^{1,0}$	0.11	-0.11	0.12
ΔPS/ $x2^0w2^0$	0.11	-0.11	-0.10
ΔPS/ $x3^0w3^0$	2.06	-1.42	0.04

Fig 2. Market sketches of the analysis



Comments

- This is a *linear* approach
  - recursive application might help
- Cost function vs production function:
  - technology parameters are also behavioral parameters
  - often more feasible to estimate from market data
- Technical change parameters may be simple to evaluate
- Many extensions have been developed

More questions or comments ?