The Economics of Aquaculture with respect to Fisheries

95th EAAE Seminar
Civitavecchia (Rome), 9-11 December 2005

Edited by
Kenneth J. Thomson and Lorenzo Venzi

MODELLING RISKS IN THE SALMON INDUSTRY AND MARKETS

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Abstract

The paper proposes developing a trade model for salmon to assist in discussions and negotiations of current international salmon trade issues and major risk problems facing the salmon industry. Two modeling approaches are discussed: 1) developing a traditional equilibrium trade programming model designed to maximize total welfare across all model regions by solving for a medium-term price that balances the amount of salmon supplied by the world region to the amount processed and consumed by this region; and 2) developing an econometric stochastic simulation model based on linear or non-linear equations. Some disadvantages and weaknesses of the programming model are discussed, whereas the econometric model needs further exploration and consideration. The main use of the models will be to study the effects of problems related to market interventions, transportation, and competition in different exporting, processing or consuming regions.

Key words: risks, salmon, programming model, econometric model, international trade

JEL classification: C60; C50.

Introduction

Since its birth in the late 1960s, European salmon aquaculture has grown to become an important industry. Much is due to the development of the Norwegian production, which amounted to more than 500 thousand tonnes in 2003, compared to less than 100 tonnes in 1971. However, production has also increased in Scotland, Ireland and the Faeroe Islands. Also, there has been strong growth of production in other parts of the world, especially in Chile which is now the most important supplier outside Norway. World aquaculture

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production of salmon has now surpassed natural catches. Both fresh (chilled in ice) and processed salmon are widely traded on world markets, sometimes involving transport over long distances to markets overseas. In the years 2000-2001, about two-thirds of the Norwegian production (in value terms) was exported to the EU, around 5% to the USA and 13% to Japan. The remaining 14% was exported to several other markets (Statistics Norway, 2001). Some of the Norwegian exports to the EU have been processed in Denmark or France, whereas in more recent years processing in Poland has increased.

As growth continues, production- and trade-related problems affecting the salmon industry have emerged. Due to its importance, trade problems for Norwegian salmon are most likely to arise in connection with the EU market. After a short period with provisional safeguard measures, Norwegian salmon exporters and the European Commission agreed in June 2005 on a provisional regime with a minimum price for fresh salmon sold in the EU, thus removing the immediate threat of a penalty duty. However, in early November 2005, new threats of implementing such duties were raised. Furthermore, a trade conflict with the US in the early 1990s resulted in an anti dumping duty on fresh Norwegian salmon entering the US market. This penalty tariff is currently being re-evaluated in the US. Frozen or processed (i.e. smoked or canned) salmon may still be sold on the US market under regular trade conditions, i.e. the WTO-MFN (Most Favoured Nations) duties apply. Chile also exports a substantial part of its aquaculture production to markets overseas, whereas salmon aquaculture production in most other countries is mainly for domestic or regional markets. Competition from Chile is of concern to the Norwegian salmon farmers on all markets. The development of new markets (e.g. India) gets little attention, at least in the news. In view of the large expansion of markets in the US, the EU and Japan, potential should also exist outside these regions.

In this paper, we develop a proposal for a salmon trade model and discuss different modeling approaches to account for risks associated with production, international trade and consumption. The paper is organized as follows: in Section 2 there is a brief overview of the world production and export of salmon followed by a general description of some of the problems facing the salmon industry and motivation for development of a model, and some general model requirements in Section 3. Section 4 contains a brief description of a deterministic trade model for agricultural commodities which may serve as a basis for developing and applying a similar trade model for salmon. A programming approach for solving such a model is described, together with the data requirements for a programming model and a way of incorporating risks. The use of such a model related to the industry problems, and some disadvantages of the programming model approach, are also discussed. In order to incorporate risks in a programming model, it would be necessary to write and compute the full equations for estimating production and consumption and to calculate the residuals. Due to this need, one idea would be to simulate the econometric equations. The econometric approach which would omit optimization but otherwise involve stochastic simulation and validation is described in Section 5. In the final section, we discuss some problems to be solved before a final model decision can be made.

World Production and Export of Salmon

Salmon from natural catches constitutes several salmon species but only a few of these are farmed. The aquaculture production in Europe consists of Atlantic salmon only, while in South and North America Pacific (primarily Coho) salmon varieties are also reared. In Asia, only the Pacific salmon is reared, while in Oceania it is Atlantic (mostly) and Pacific salmon. Table 1 shows the world production of farm-raised salmon. The table shows a dominant position for Norwegian (about 40 per cent in 2003) and a total European production of 58 per cent. There has also been a strongly growing production in Chile (30 per cent in 2003) and in North America (10 per cent). Salmon aquaculture production in Asia and Oceania is small by comparison (2 per cent) and seems to be consumed in the region.

Table 1: World supply of farm-raised salmon, 1999-2003, tonnes

Area	1999	2000	2001	2002	2003
Total America, North	90 532	104 990	126 375	139 055	123 565
Total Chile	179 774	262 840	394 527	370 711	377 272
Total America, South	179 774	262 840	394 527	370 711	377 272
Asia	11 148	13 107	11 616	8 023	9 208
Norway	425 154	440 816	436 103	462 495	507 412
Total Europe	611 671	621 765	649 763	674 360	730 323
Total Oceania	14 895	17 047	21 248	21 345	18 772
Grand Total	908 020	1 019 749	1 203 529	1 213 494	1 259 140

Source: FAO/Fisheries Global Information System (FIGIS)

According to the FAO (2002), total salmon production constituted 1 730 600 tonnes in 1999 whereas aquaculture salmon production was 908 020 tonnes in that year (Table 1). Overall production from natural catches was in decline in the latter 1990s. According to Bjørndal et al. (2003), farmed quantities have been higher than the wild catch since 1997. The trade statistics (Table 2) do not distinguish between farm-raised and natural-caught salmon, and the three main exporting countries Norway, the USA and Chile exported roughly one third of total world salmon production in 1999. Broadly speaking, Norway's exports of fresh salmon are mainly to the nearby EU market or to other European countries. The rest is exported as frozen salmon to the USA or as frozen or fresh to Japan and to some other Far East countries.

Table 2. Exports of salmon from Norway, Chile and the US, 1999 and 2000, tonnes

	From Norway		From Chile		From the USA	
Destination	1999	2000	1999	2000	1999	2000
USA	11 500	10 200	44 530	63 490	0	0
Japan	41 400	38 200	91 822	113 800	47 600	37 800
EU	228 600	237 900	7 053	9 570	14 400	19 900
Other	56 500	55 600	10 687	19 394	31 700	39 300
Total	338 000	341 900	154 092	206 254	93 700	97 000

Source: FAO, 2002.

The salmon export from Chile is also mainly as frozen to Japan or the EU, frozen or fresh to the US and to some nearby South American countries. The US is a main exporter of frozen salmon, distributed to Japan, Canada and to the EU. In addition to the numbers in Table 2, the US exports canned salmon, amounting to 36 300 tonnes in the year 2000. The natural salmon catches by Japan and Russia are mainly for local consumption.

Salmon Aquaculture Problems and Model Requirements

Problems facing the Salmon Industry

The challenges facing salmon aquaculture producers can broadly be divided into three categories: 1) market problems, caused by different government market interventions; 2) competition problems, due to producers in other countries being able to supply salmon at a lower price; and 3) transportation problems, due to the long distances from the production site to some of the markets. Similar problems are well known in agriculture and have motivated the development of agricultural trade models. Trade models for studying such issues can either be rather general, covering a range of agricultural products, or specific to a single commodity, e.g. wheat or rice. Single-commodity models can be used in trade negotiations and discussions, facilitating a more balanced approach to the issues than without the model. For many agricultural commodities traded on international markets (e.g. rice),only a small proportion of production is exported. For both Norway and Chile, a dominant share of the salmon aquaculture production is exported.

Some General Model Requirements

Which world regions to model, as well as how much detail to model, will be determined by the system of production and trade to be represented. A model should involve both Atlantic and Pacific salmon. There has to be at least four producing regions: North and South America, Norway and the EU, the latter comprising Scottish and Irish production. Scotland and Ireland are important players on the EU market, and their aggregate supply is needed if problems related to the EU market are to be analyzed. It may also be necessary to consider the supply of naturally caught salmon in the US/Canada, and in Asia, in particular in Russia and Japan. Production in other parts of the world is currently too small to justify separate supply regions. The cost of transportation from the producing to the processing and final market regions should also be considered in the model.

The model should have a domestic market in each of the producing regions and international markets in: 1) Eastern Europe outside the EU (Bulgaria, Romania, Belarus, Russia, Ukraine, Turkey, etc.); and 2) South and East Asia (Japan, South Korea, China, Taiwan, Singapore, India, etc.). Markets in the Middle East and Africa can be excluded due to low and unstable income growth and uneven income distribution. Many of these countries also lack the needed infrastructure to handle chilled or frozen salmon, so that canned salmon would be the main possibility. However, some can be important fish markets, for instance Norway has traditionally exported dried cod to Nigeria. These regions should be treated as a Rest of the World (ROW) region, which can be later subdivided into more specific sub-regions.

The model should allow for a minimum of three different forms of the product: fresh, frozen or processed (i.e. canned or smoked) salmon. Separate demand functions for salmon have to be estimated for each market region or retrieved from literature, depending on the modeling approach. Atlantic or Pacific salmon may also be subject to different tastes and preferences in different markets or be better suited to some processing. This characteristic may have to be reflected in different demand functions.

Since the model may be used in connection with salmon dumping allegations against Norway, the situation on the Norwegian market might be of particular interest in spite of its small size. Dumping allegations may be based on several grounds: a) the price charged in the export market is lower than the price charged in the domestic market; b) the price charged in one export market is lower than the price charged in another export market; and/or c) the price charged in the export market is lower than the cost of production, taking into consideration a reasonable amount of extra administrative costs. In case a) the countries considering imposing penalty tariffs or other import restrictions would need to take into account the situation on the domestic market of the supplier. Furthermore, allegations of subsidies and subsequent threats of implementing countervailing duties may be based on a determination of "illegal" governmental support to salmon producing or exporting firms. Regarding safeguard measures, i.e. provisional measures to protect the domestic salmon industry, these have to be directed towards all foreign producers, and may comprise additional duties or quotas.

Finally, the model should be able to capture the different trade regimes prevailing in different world regions. Relevant existing trade restrictions, free trade agreements for exporting countries, tariffs and export duties should be incorporated into the model. A model should demonstrate how different tariffs for fresh and processed salmon would be likely to affect trade and development of the processing industry in different parts of the world. Since the US penalty tariff was introduced, Norway has not been able to compete with its fresh salmon on the US market. Processed salmon is still favourably treated on the US market, but processed Norwegian salmon has been subject to higher tariffs than fresh salmon under EU import rules. There have been problems related to Norway developing its own processing industry. Instead, salmon has been exported fresh, and the processing has taken place in for instance Denmark or France. As for the markets in Japan and South Korea, fresh as well as processed salmon might be sold and compete with frozen or canned salmon from Chile and the USA.

Developing a Trade Model for Salmon

The Programming Approach

One option for developing a trade model for salmon would be to construct a partial equilibrium model, similar to the market model for trade of agricultural commodities. The agricultural trade model was developed by Takayama and Judge (1971), and is described by McCarl and Spreen (2004). The problem is an extension of the least-cost transportation problem. In a solution, if the regional prices differ by more than the interregional costs of transporting goods, then trade occurs and the price difference is driven down to the transportation costs. Modeling this situation addresses the question of who produces and consumes what quantities of salmon and what level of transportation occurs. In the remainder of this section, a proposed programming technique for running a deterministic partial equilibrium model for salmon will be described, together with a procedure for adding risks to such a model.

A partial equilibrium model relies on own-price and cross-price elasticities of demand (or demand per capita) in each market, and on supply elasticities estimated for each producing region. Unless the elasticities can be retrieved from literature, they have to be estimated. The estimation procedure would involve solving demand and supply functions (f) for each market or production region (i) as function of time (t)

$$Demand_i = f(\text{Price Fresh Salmon } t, \text{Price Processed Salmon } t, \text{Price Other Fish } t, \text{Price Meat } t, \text{Income } t, \text{Population } t, \text{Other Demand Shifters } t) \quad (1)$$

$$Supply_i = f(\text{Salmon Price } t\text{-}1, \text{Price Fuel } t\text{-}1, \text{Price Feed } t\text{-}1, \text{Price Other Products } t\text{-}1, \text{Interest Rates } t, \text{Exchange Rates } t, \text{Technology } t, \text{Other Production Variables } t\text{-}1) \quad (2)$$

Knowing the supply and demand functions, a "quasi-welfare function" for each region can be defined as the area between the supply and demand curves (to the left of where they cross) in each region, i.e. the sum of the consumer and producer surpluses. From this, we can further derive a total welfare function (NW), defined across all regions, which is the sum of the welfare function in each region minus the total transportation costs. The total welfare function is then maximized subject to transportation constraints. To maximize total welfare across all modeled world regions, a program solver is applied to Equation 3,

$$Max \sum_i \left(\int_0^{Q_{di}} P_{di} dQ_{di} - \int_0^{Q_{si}} P_{si} dQ_{si} \right) - \sum_i \sum_j c_{ij} T_{ij} \quad (3)$$

such that $Q_{di} - \sum_j T_{ij} \leq 0$ *for all i*, $-Q_{si} + \sum_j T_{ij} \leq 0$ *for all i, and* $Q_{di}, Q_{si}, T_{ij} \geq 0$

for all i and j

which has an equilibrium solution as long as the demand curves slope downwards and the supply curves slope upwards. The optimal solution must satisfy the Kuhn-Tucker conditions, and the equilibrium price in a region must be less than the supply price in all other regions plus the transportation costs.

Equations (1) and (2) indicate that estimation of the functions can be made quite sophisticated, with extensive data requirements. However, somewhat simpler equations can be used at the cost of accuracy, i.e. not dealing with all possible sources of variation in demand and supply. Table 3 shows a preliminary overview of the elasticities needed. Much of the required data can be obtained from the FAO Globefish databank which covers both aquaculture and fish catches. To estimate the equations and associated elasticities, a coupling with other data sources would be needed. The time period for the available data is annual and thus the model has to be annual. Both the supply elasticities covering different producing regions, and demand and cross price elasticities in different markets needed in a programming model, may be retrieved from literature.

For a programming model the costs of processing also have to be quantified, i.e. the costs of ice, freezing, canning, or smoking. Spatial market programming models may include several processed products (Bouamara-Mechemache et al., 2002). A problem in such multi-commodity models is to get good estimates of cross-price elasticities for demand. It is necessary to estimate all these elasticities for a model. Access to a global databank such as Globefish would be advantageous to avoid extensive collection of local data. However, some local data collection seems unavoidable. The relevant historical exchange rates have to be coupled with trade data. All the computations should be conducted in US dollars due to the dominant position of that currency in world salmon trading.

Table 3: Elasticities of supply and demand assumed to be needed in a world salmon trade model

	Norway	Chile	N. America	Southeast Asia	EU	ROW
Supply of fresh salmon	s	s	s	-	s	x
Demand for						
- fresh/frozen salmon	d	d	d	d	d	d
- processed salmon	-	-	d	d	d	x
- salmon and other fish	-	-	cp	cp	cp	-
- salmon and meat	-	-	cp	cp	cp	-

s) Data to compute supply elasticities required.

d) Data to compute demand elasticities for fresh salmon required.

cp) Data to estimate cross price elasticities required.

x) Data may be needed.

Data is also needed to estimate the cost (per kg) of transporting fresh or processed salmon to different regions. It can be assumed that transportation of fresh salmon (on ice) from Norway to the EU and other European markets is by truck, needed to carry salmon to harbours or airports. Frozen salmon is sent overseas (to the US and Asia) by ship. Fresh Norwegian salmon may go by airplane to Japan, but sometimes first by truck to a European airport. Transportation costs for fresh salmon to overseas markets are of the order of 1.5 US $ per kg while frozen salmon can be transported for as little as 0.15-0.30 US $ per kg.

The cost of transportation can be modeled as linear functions of quantity transported to one or two (in the case of capacity limits) destinations in each market region. Whenever relevant, restrictions on transportation have to be taken into consideration, such as size of outgoing shipment not exceeding incoming shipment. In a programming model the effects of changes in transportation cost on world price and prices in each country are similar to those of a change in an import duty. For sale of chilled salmon to the Far East markets, a main industry concern is the high cost of transportation, partly due to energy costs, and soa particular need may be to assess the influence of these costs on salmon prices. Energy prices are subject to large variations and a possible upward trend.

A trade model would simulate the equilibrium price across the world and in each of the markets or regions. Additionally, it would indicate how trade distortion in a region would affect the world equilibrium price, by removing the trade restriction and observing the new equilibrium price. Data on production of farm-raised salmon in different world regions, in particular Norway, the EU and Chile, would be needed to calibrate a programming model to a base year or a three-year average. Historical data on exports to and imports from the different regions and for different processed products would be needed to calibrate the model output with actual data in a base year.

Dealing with Risk in a Programming Model

Adding risks to a programming model would give a range of outcomes for the decision variables and might provide better insights into how the system works , thus facilitating better decisions than a deterministic model. The approach considered would involve model-solving in GAMS combined with stochastic simulation in Simetar©, an Excel add-in (Richardson, 2003). The Simetar simulation tools have been used to combine simulation with optimization (using the Excel solver) for a small dairy farm model (Asheim, Richardson, Schumann, and Feldman, 2005). In the proposed model, GAMS will optimize the supply and demand model using stochastic values generated by Simetar, and reading stochastic values directly from Excel files. The intended procedure combining GAMS and Simetar© should work via the following steps:

(1) Simetar generates stochastic values affecting either the supply or demand functions, and simulates one realization (iteration) of the random values for the stochastic variables

(2) Excel calculates all equations dependent upon the random values, and exports the values into the GAMS programming model

(3) GAMS optimizes the programming model and writes the resulting prices to an Excel file where Simetar records values for key output variables (KOVs)

(4) Simetar proceeds with the next iteration and returns to Step 1.

Stochastic variables in the model can include energy prices, exchange rates, production and income in each region. Stochastic shocks for production will incorporate historical deviations from trend due to weather and other uncontrollable forces. Stochastic shocks to income from historical trends will allow the model to account for fluctuations in demand due to economic conditions in individual countries. The stochastic nature of energy prices will be modeled as probability distributions derived from history. As for exchange rates, a deviation from an average or the most recent value seems most appropriate, as any long-run trends seems unlikely to be identified. Currently (2005), one US dollar trades for around 6.5 Norwegian kroner, somewhat less than in the 1960s when it was stable at 7.16. In the meantime, it has been down to 4.5 in the late 1970s and well above 9 in the 1990s. The Yen has also varied considerably, whereas the Euro has not been in use for a very long time and therefore not much data on its exchange rate risks are available.

After the last iteration, KOV statistics will be calculated, empirical distributions summarized, nd confidence intervals computed. Simetar includes a scenario function which enables programming models to be run with alternative decision variables while varying the stochastic variables during a simulation. The scenario function can be utilized to simulate different policy scenarios, such as alternative energy pricing regimes, alternative trade restrictions, alternative assumptions regarding growth of farm-raised salmon production in Chile or the US or Norway, or alternative assumptions about US-Norway trade agreements on fresh salmon.

Use of a Programming Trade Model

A programming model should have some applications regarding the three general problem areas, of markets, competition and transportation. One area of application would be to assist in discussions and negotiations of current salmon trade issues of interest between the national producer governments and the EU or the US or Japan. In considering some competition or transportation problems, for instance related to efforts to develop new markets, fish farmers and fish exporters might also be interested in making use of a model. Some examples for each of these are cited below, together with our view of how the model may assist in gaining insight in such situations.

Government market interventions can be exemplified by the agreement in the late 1990s between Norway and the EU to implement a minimum price on imports of Norwegian salmon to the EU market, or by the decision in the early 1990s by the US to tariff imported salmon from Norway, due to dumping allegations. The minimum price (and abolished provisional penalty tariff) for Norwegian salmon on the EU market in 2005 also falls in this category. The various market interventions may be made to please some lobby groups, such as local salmon producers who benefit from import control. But the principle of comparative advantage implies that most countries suffer from such restrictions. The interests of domestic meat producers, the salmon processing industry and consumers in a country may actually be quite the opposite. Both consumers and the processing industry in a region prefer cheaper salmon imports. Providing subsidies or introducing safeguard measures or penalty duties to satisfy producer interest groups in a region may bring about problems to other groups in the same region. Salmon might be produced in one country, processed in another, and exported to a third. Interventions to limit imports of unprocessed salmon might pit groups against each other, for instance in the EU the processing industries in Denmark and France are opposed to producer groups in Scotland or Ireland. While consumers face more expensive salmon and might substitute meat for salmon, the processing industry might face lack of cheap raw material and loss of markets.
A programming salmon model should solve for fresh salmon supplied to Japan by Norway and frozen salmon by Chile, in terms of what solution maximizes total welfare. However, welfare losses in exporting and importing countries due to import restrictions may be important bargaining tools in trade negotiations. Similar solutions should be obtained for processed salmon. As such, the model should be well suited to compare effects of different trade distorting measures such as which is worst: a minimum price (in Euro) or a penalty tariff on the EU market assuming stochastic exchange rates? The utility of a programming model can be demonstrated by running the model with and without the actual measures and comparing the outcomes of the different runs.

If we want to use the model to examine the costs and effects of such trade barriers, we should consider model solutions a) with the US limit on salmon imports, b) with the EU penalty tax, c) with both the US and the EU measures, and d) without the US and EU measures. Other combinations of measures are also possible, and an alternative without trade might also be run. Modeling the different alternatives involves the removal or addition of the relevant constraints to the model. Without trade, a model should show higher prices and lower consumption in Japan, EU and the US, and cheaper inland prices and higher consumption in Norway and Chile. Additionally, the model will show the size of the processing industry in different areas, and thus powerful arguments regarding the introduction of measures affecting them might be put forward and quantified. Measures might be modified, for instance different penalty rates might be tested and the prospect for reaching an agreement made easier. Different governmental bodies, such as ministries of fisheries or trade, or private exporters and organizations, should be the main users of the model in this respect.

Regarding **competition**, one main challenge or threat to Norwegian as well as EU salmon farmers is increased competition from Chile supplying frozen salmon to the EU, the US (also fresh) and Japan. Chile has experienced strong growth of salmon production in recent years, quite similar to the development of production in Europe, and is likely to remain the most important competitor in the coming years. The country has negotiated several free trade agreements allowing them a preference tariff on certain markets. Currently the frozen salmon supplied by Chile has different applications compared to fresh, but if this should change the model can assess consequences to Norwegian production on the three different markets.

However, to assess this competitiveness, one would need a comprehensive study of the costs of production in different countries for sale on different markets. Successful competition in the salmon markets is due to several factors such as cheaper labour or fish feed, better farm structure or efficiency, abundant fisheries, research and development, food safety standards, exchange rates, etc. Competition from the US, Canada and the UK is less likely as production in these countries is hampered by biophysical conditions, environmental regulations and competition for other uses of coastal areas. Japan, Russia and Alaska can supply wild Pacific salmon from salmon fisheries. However, these supplies aremore variable depending on fish stocks, fisheries management and naturally occurring biophysical shocks, among other factors. Developing local processing in Norway has also been hampered by high costs of labour, although labour quality (education, productivity etc.) and food safety standards are quite high.

Transportation costs in particular affect the markets in the Far East (South Korea and Japan), where air transportation is needed to supply fresh salmon.

An important advantage for Norway is the short distance to its main market in the EU, making truck transport of fresh salmon possible. On the other hand, its distance from important markets is an important disadvantage for Chile. This makes the salmon industry vulnerable to increased transportation costs likely to be caused by higher energy prices. Cheaper transportation of Norwegian salmon by railway through (or by ship north of) Siberia is being investigated. Air freight costs may be lowered by refueling planes in Siberia. Much of the cost of truck and air transport is due to the ice needed to keep the salmon cool, and improved cooling technology might lower the cost of these transportation methods. Some of these changes could be investigated in a model to see if the amount demanded would justify them. A model would also take into account larger sales due to cheaper supplies to a market.

Since this model will be developed and used in Norway, the need of the Norwegian salmon producers will be decisive regarding what to model and how to construct the model. This effort may increase the likelihood that the model will provide the users with a strategic advantage, compared to non-users. However, although motivated by the problems of Norwegian salmon on international markets, the model will not become a strictly "Norwegian salmon" model, and may be applied in salmon trade negotiations in different parts of the world.

Disadvantages of a Programming Model

A major weakness of the programming approach is that it assumes that all the decision makers in the system have some foreknowledge of what the realization of the stochastic variables is going to be. The method is based on the assumption that production decisions, in particular, are made knowing what demand, exchange rates, etc. will be. However, how fast the supply of farmed salmon can change will depend on the length of the production cycle. In the short term, supply of salmon is assumed to be almost perfectly inelastic. A programming model would, however, assume a medium-term perspective, i.e. around 3-5 years. In this period, the farmers would be able to change production due to a shift in demand within their capacity constraints. However, in such a short time, farmers would not be able to undertake investments in new plant or research, or to apply for the quotas, discharge permits, etc. needed to increase production capacity. Assuming a longer horizon, optimization under perfect foreknowledge would be less realistic.

In a programming model one would need to find own-price and cross-price elasticities in the literature, or by estimation using different time periods and different methods. The model developer would need to check each elasticity because some have probably been reported incorrectly or were estimated for an old period (1960s or 1970s), or used an inappropriate model form or methodology. The supply of farmed salmon has been subject to considerable stochastic changes on the individual farms due to, for instance, disease in the fish stock or the occurrence of toxic algae in the sea. On the aggregate country level, there has been a more steady growth, as not all farms are affected simultaneously, but the variation due to stochastic events is still important. Due to these problems and the need to include the residuals in order to have a stochastic component in a model, it seems necessary to estimate one's own equations in a programming model project.

Probably the biggest problem with this type of demand and supply elasticity model is that it does not give a history of deviations from a forecast. Series of residuals would allow estimation of standard deviations and percentage deviations from a trend for use in a multivariate empirical (MVE) simulation model. This is important because, in addition to making some key exogenous variables stochastic (fuel price, feed price, exchange rate, and disposable income, etc.), each equation in the model needs to be made stochastic using its residuals. Thus the supply and demand equations cannot be stochastic in this type of model. Both supply and demand are significant stochastic variables that need to be separately incorporated into a model. Demand is not constant, but is subject to stochastic forces which embrace the response of consumers in addition to reactions/responses to changes in exchange rate, price, and income. However, the residuals to demand and supply may be unrealistically restricted to be un-correlated with exchange rates and fuel prices

An Econometric Approach

Since it is probably difficult to collect relevant and reliable elasticities from the literature, it may be better to estimate econometric equations for all endogenous variables in the models. The estimation of the elasticities thus has to be a part of a project, and data will be needed for several years. The most likely choice of function form is first-order flexible (e.g. linear and Cobb-Douglas) or second-order flexible (e.g. quadratic and translog) forms for demand as well as supply. A comprehensive search of the literature (e.g. Asche, 1996; Asche and Wessels, 1997; Asche, Bremnes and Wessels (1999) is warranted in order to see which variables to include in the model and to compare historical and new elasticities.

When elasticities have been estimated, one could go on using the resulting econometric equations to simulate a final econometric model. A main advantage of an econometric approach over programming models is that there is a time path as the model is annual whereas the former have a base year (or three-year average) that has to be changed when the model is updated. A simulation for 10 years ahead of the last year with data would show how the system adjusted, not just a new equilibrium. This ability can be important to policy analysis by illustrating adjustments over time to policy changes.

In this type of model, constraints to trade such as import quotas and tariffs are easily dealt with. Also, non-linear constraints can be used. In an econometric simulation model, one can use "if" statements and linear and non-linear equations to implement restrictions similar to what has been used for years in US farm policy studies. The supply functions in an econometric model would have to account for processing and transportation costs whereas this is added in a programming model depending on product and market.

Another advantage of an econometric model is the possibility to actually simulate the completed model in Excel or SAS, and to use the observed residuals as the stochastic components, with appropriate correlation to exchange rates, fuel prices, etc. To simulate the model, the optimal control features in Excel and SimSolver in Simetar can be used (or the Newton solver in SAS can be integrated into Excel, as GAMS would be used in a programming model). Examples of these types of models are found in the dissertations by Brown (1994) and Adams (1994), and are used in the FAPRI policy analysis models that are widely known and used for simulation of US agricultural policy. Another model, using optimal control type techniques, is described in Ray and Richardson (1978), Richardson and Ray (1979), Richardson, Ray and Trapp (1979), and in Richardson and Ray (1982).

Timing is often of importance in a policy model. Different markets have developed over time, and although the EU is currently the most significant to Norwegian salmon, the development of this market in recent times has been hampered by threats of dumping allegations or slow income growth. Different stochastic events such as the mad cow disease or the more recent bird flu may affect demand for salmon in different directions. From time to time, there is a problem in one market, for instance the EU, the US or Russia might impose import regulations. In an econometric model, a strategy for dealing with such risks may be tested because the equations are set up as a function of time such as $Production_t = f(Price_{t-1}, \text{feed price}_{t-1}, \text{other variables in t or t-1})$. If one of the markets is very important, this may limit options as to how to deal with such risks, i.e. a ban on an important market can be very difficult to absorb in other less important markets.

Discussion

Programming models have been used for a long time in analyzing trade in agricultural commodities. The above review of the programming approach for developing a trade model for salmon has revealed some possible ways of doing things, and some advantages of developing such a model. But it has also revealed some shortcomings of this modeling approach, related to dealing with risks, or adjustment over time. It may assist decision makers in dealing some of the industry problems, but it will not always be of much help.

Thus the idea of an econometric model has emerged. This proposal has to be developed further before a model-building decision can be taken and research money devoted to developing it. A middle option would be to build a very simple two-country elasticity displacement model (Norway and the rest of the world) as a prototype to demonstrate the method. This would also be useful because one will have to identify most or all of the elasticities for the model, and thus force one to find these values. In the process, one would find out if there are enough elasticities to use a programming approach or an econometric approach, and if there are enough data and elasticities to support the development of a multiple-country elasticity model.

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