Industrial Evolution in Response to Changes in the Demand for Traceability and Assurance: A Case Study of Chilean Salmon Aquaculture

Tyler K. Olson  
Utah State University

Keith Criddle  
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/eri

Recommended Citation
https://digitalcommons.usu.edu/eri/309

This Article is brought to you for free and open access by the Economics and Finance at DigitalCommons@USU. It has been accepted for inclusion in Economic Research Institute Study Papers by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.
Industrial Evolution in Response to Changes in the Demand for Traceability and Assurance: A Case Study of Chilean Salmon Aquaculture

TYLER K. OLSON
Department of Economics
Utah State University
3530 Old Main Hill
Logan, UT 84322-3530
Email: tko.olson@gmail.com

KEITH CRIDDLE
Department of Economics
Utah State University
3530 Old Main Hill
Logan, UT 84322-3530
Email: kriddle@econ.usu.edu

August 2005
Industrial Evolution in Response to Changes in the Demand for Traceability and Assurance: A Case Study of Chilean Salmon Aquaculture

TYLER K. OLSON
Department of Economics
Utah State University
3530 Old Main Hill
Logan, UT 84322-3530
Email: tko.olson@gmail.com

KEITH CRIDDLE
Department of Economics
Utah State University
3530 Old Main Hill
Logan, UT 84322-3530
Email: kcriddle@econ.usu.edu

The analyses and views reported in this paper are those of the author(s). They are not necessarily endorsed by the Department of Economics or by Utah State University.

Utah State University is committed to the policy that all persons shall have equal access to its programs and employment without regard to race, color, creed, religion, national origin, sex, age, marital status, disability, public assistance status, veteran status, or sexual orientation.

Information on other titles in this series may be obtained from: Department of Economics, Utah State University, 3530 Old Main Hill, Logan, UT 84322-3530.

Copyright © 2006 by Tyler K. Olson, Keith Criddle. All rights reserved. Readers may make verbatim copies of this document for noncommercial purpose by any means, provided that this copyright notice appears on all such copies.
Industrial Evolution in Response to Changes in the Demand for Traceability and Assurance: A Case Study of Chilean Salmon Aquaculture

Tyler K. Olson
Keith R. Criddle

ABSTRACT

The structure and organization of industries evolves over time in response to changes in the price and availability of inputs, changes in the demand for outputs and output attributes, and changes in technology. The growing demand for traceability and assurance is a change in the demand for credence attributes. Firms that are able to organize to provide traceability and assurance at low cost will, ceteris paribus, have an advantage. In recent years, many segments of the food and agribusiness industry have become more concentrated through horizontal or vertical integration within firms or within associations of firms (cooperatives). This paper explores changes to the relative competitiveness of vertically integrated firms and horizontally and vertically aligned cooperative associations in response to demand for traceability and assurance with respect to food safety, product quality, and credence attributes. The Chilean salmon aquaculture industry is used as a contextual example.
INDUSTRIAL EVOLUTION IN RESPONSE TO CHANGES IN THE DEMAND FOR TRACEABILITY AND ASSURANCE: A CASE STUDY OF CHILEAN SALMON AQUACULTURE

Tyler K. Olson  
Utah State University,  
Department of Economics, Logan UT 84322; Email: tko.olson@gmail.com

Keith R. Criddle  
Utah State University,  
Department of Economics, Logan UT 84322; Email: kcriddle@econ.usu.edu

ABSTRACT

The structure and organization of industries evolves over time in response to changes in the price and availability of inputs, changes in the demand for outputs and output attributes, and changes in technology. The growing demand for traceability and assurance is a change in the demand for credence attributes. Firms that are able to organize to provide traceability and assurance at low cost will, ceteris paribus, have an advantage. In recent years, many segments of the food and agribusiness industry have become more concentrated through horizontal or vertical integration within firms or within associations of firms (cooperatives). This paper explores changes to the relative competitiveness of vertically integrated firms and horizontally and vertically aligned cooperative associations in response to demand for traceability and assurance with respect to food safety, product quality, and credence attributes. The Chilean salmon aquaculture industry is used as a contextual example.

INTRODUCTION

Increased demand for traceability and assurance will affect the relative competitiveness of firms in markets such as the U.S., Japan, and E.U., which are evermore conscious of food safety, quality, and credence attributes related to labor, capital, and resource inputs to production, and the impact of production processes on the physical, biological, and human environment. Given the nature of tracing products or product attributes through the food chain, transaction costs will differ depending on industry and company structures and the nature of the information being transmitted. Thus, the effect of traceability on the relative competitiveness of firms will depend on their ability to efficiently organize and transfer information through the supply chain. Large vertically integrated firms that transfer information internally may or may not have a cost advantage over smaller non-integrated firms that bundle information and goods in market transactions.

As recently as 1995, the salmon aquaculture industry was, to a large degree, composed of many small independent firms: small farms, small feed suppliers, and small processors (Anderson 1995). Since then, salmon aquaculture has increasingly become the domain of horizontally and vertically integrated firms. This paper explores how this transition has affected the ability of firms to provide traceability and assurance.

---


2 Support for this project was provided, in part, by the Utah Agricultural Experiment Station.
INDUSTRIAL EVOLUTION IN RESPONSE TO CHANGES IN THE DEMAND FOR TRACEABILITY AND ASSURANCE: A CASE STUDY OF CHILEAN SALMON AQUACULTURE

Tyler K. Olson
Utah State University,
Department of Economics, Logan UT 84322; Email: tko.olson@gmail.com

Keith R. Criddle
Utah State University,
Department of Economics, Logan UT 84322; Email: kcriddle@econ.usu.edu

ABSTRACT

The structure and organization of industries evolves over time in response to changes in the price and availability of inputs, changes in the demand for outputs and output attributes, and changes in technology. The growing demand for traceability and assurance is a change in the demand for credence attributes. Firms that are able to organize to provide traceability and assurance at low cost will, ceteris paribus, have an advantage. In recent years, many segments of the food and agribusiness industry have become more concentrated through horizontal or vertical integration within firms or within associations of firms (cooperatives). This paper explores changes to the relative competitiveness of vertically integrated firms and horizontally and vertically aligned cooperative associations in response to demand for traceability and assurance with respect to food safety, product quality, and credence attributes. The Chilean salmon aquaculture industry is used as a contextual example.

INTRODUCTION

Increased demand for traceability and assurance will affect the relative competitiveness of firms in markets such as the U.S., Japan, and E.U., which are evermore conscious of food safety, quality, and credence attributes related to labor, capital, and resource inputs to production, and the impact of production processes on the physical, biological, and human environment. Given the nature of tracing products or product attributes through the food chain, transaction costs will differ depending on industry and company structures and the nature of the information being transmitted. Thus, the effect of traceability on the relative competitiveness of firms will depend on their ability to efficiently organize and transfer information through the supply chain. Large vertically integrated firms that transfer information internally may or may not have a cost advantage over smaller non-integrated firms that bundle information and goods in market transactions.

As recently as 1995, the salmon aquaculture industry was, to a large degree, composed of many small independent firms: small farms, small feed suppliers, and small processors (Anderson 1995). Since then, salmon aquaculture has increasingly become the domain of horizontally and

---


2 Support for this project was provided, in part, by the Utah Agricultural Experiment Station.
vertically integrated multinational firms (Tveterås 2004). Consolidation has been driven by increasing returns to scale in feed production, hatchery operations, grow-out facilities, processing, and distribution. In addition, total output has increased both in response to cost-savings associated with efficiencies of scale, cost savings associated with technology advances (Asche 1997), and cost savings associated with efficiencies of scope. In Chile, increased scope has come about through ownership, cooperation, and contracts. Positive agglomeration externalities often arise in regions where production is localized in the form of a cluster of interdependent firms (Tveterås 2002). For the past decade, the Chilean salmon industry has actively encouraged the development of just such a cluster.

**Chilean Salmon Aquaculture Industry**

It is only in the last decade that Chile has emerged as a major supplier of farmed salmon and trout (Bjørndal and Aarland 1999). The Chilean salmon industry is concentrated in southern Chile, with hatchery operations in and around Lake Llanquihue, feed production in and around the cities of Osorno and Puerto Montt, grow-out operations around Chiloé Island, and processing facilities around the city of Puerto Montt and on Chiloé Island. Recently, grow-out and processing operations have extended increasingly into regions that are more southerly. The long coastal strip—approximately 1,700 kilometers—running from Region X through Region XII provides several natural advantages for hatcheries and salmon farms: abundant clean freshwater, cool clean seawater, low salinity, moderate currents, and fjords and inlets that shelter net-pens and associated farm structures from storm surges. Production by region for 2003 was 83% for Region X, 16% in Region XI, and 1% in Region XII (Sernapesca 2005).

The four salmonids farmed in Chile are Atlantic salmon, coho salmon, chinook salmon, and rainbow trout. Production of Atlantic salmon represents over 57% of harvest, nearly 50% of export volume, and near 60% of export value (Table 1).

<table>
<thead>
<tr>
<th>Year</th>
<th>Atlantic salmon</th>
<th>Coho salmon</th>
<th>Chinook salmon</th>
<th>Rainbow trout</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>29,182</td>
<td>25,177</td>
<td>859</td>
<td>22,257</td>
<td>77,475</td>
</tr>
<tr>
<td>1994</td>
<td>34,175</td>
<td>34,538</td>
<td>379</td>
<td>32,866</td>
<td>101,958</td>
</tr>
<tr>
<td>1995</td>
<td>54,250</td>
<td>44,037</td>
<td>371</td>
<td>42,719</td>
<td>141,377</td>
</tr>
<tr>
<td>1996</td>
<td>77,327</td>
<td>66,988</td>
<td>341</td>
<td>54,429</td>
<td>199,085</td>
</tr>
<tr>
<td>1997</td>
<td>96,675</td>
<td>73,408</td>
<td>738</td>
<td>77,110</td>
<td>247,931</td>
</tr>
<tr>
<td>1998</td>
<td>107,066</td>
<td>76,954</td>
<td>108</td>
<td>75,108</td>
<td>259,236</td>
</tr>
<tr>
<td>1999</td>
<td>103,242</td>
<td>76,324</td>
<td>208</td>
<td>50,414</td>
<td>230,188</td>
</tr>
<tr>
<td>2000</td>
<td>166,897</td>
<td>93,419</td>
<td>2,524</td>
<td>79,566</td>
<td>342,406</td>
</tr>
<tr>
<td>2001</td>
<td>253,850</td>
<td>136,870</td>
<td>3,807</td>
<td>109,895</td>
<td>504,422</td>
</tr>
<tr>
<td>2002</td>
<td>248,407</td>
<td>94,927</td>
<td>2,248</td>
<td>105,410</td>
<td>450,992</td>
</tr>
<tr>
<td>2003</td>
<td>280,301</td>
<td>91,797</td>
<td>1,526</td>
<td>114,607</td>
<td>488,231</td>
</tr>
</tbody>
</table>

Source: Sernapesca (2005).

Although initially comprised of small independent firms with heavy reliance on foreign technology and production inputs, the Chilean salmon aquaculture industry has evolved into a complex cluster of interdependent suppliers, producers, processors, distributors, and supporting entities. Clusters are regional concentrations of companies and institutions that compete but also cooperate (Porter 1990, 1998). The Chilean salmon cluster presents multiple levels of competition and cooperation. The cluster consists of a mix of small, medium, and large firms; some integrated vertically, horizontally, or in cooperatives; all interacting under the auspices of one encompassing association, SalmonChile.

Over half of all firms who participate in the nucleus of the value chain, from hatchery to processing, are forward or backward integrated. Feed inputs are the only source of supply that is integrated mainly within the largest salmon producers. Consolidation in feed production has
resulted in a decline from 23 factories in 1992 to seven in 2003. Of those seven, two—Salmones Antártica S.A. and Cultivos Marinos Chiloé Ltda—are wholly vertically integrated with coordinated management (SalmonChile 2004). While Skretting Chile S.A., Ewos Chile S.A., and Salmofood S.A share ownership interests with particular farm operators, they, along with Biomar Chile and Alitec, also produce and sell feed to independent farm operators.

Over the past few years, consolidation has left 39.5% of export value concentrated among the top three producers and 70.3% of export value concentrated among the top nine producers (Table 2). These trends indicate increasing returns to scale; being big seems to offer advantages with respect to production, logistics, and marketing in the global salmon market.

<table>
<thead>
<tr>
<th>Company</th>
<th>Export Value (2004) $ million</th>
<th>Structure and Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Harvest Chile S.A. / Stolt Sea</td>
<td>216</td>
<td>Vertically integrated, Dutch owned (Nutreco)</td>
</tr>
<tr>
<td>Farm Chile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AquaChile / Aguas Claras S.A.</td>
<td>190</td>
<td>Vertically integrated, Chilean owned</td>
</tr>
<tr>
<td>Salmones Mainstream S.A. / Fjord</td>
<td>164</td>
<td>Vertically integrated, Norwegian owned (Cermaq and Fjord Seafood, merger pending)</td>
</tr>
<tr>
<td>Seafood Chile S.A.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesquera Camanchaca S.A.</td>
<td>100</td>
<td>Vertically integrated, Chilean owned</td>
</tr>
<tr>
<td>Salmones Multiexport Ltda.</td>
<td>95</td>
<td>Vertically integrated, Chilean owned</td>
</tr>
<tr>
<td>Cultivos Marinos Chiloé S.A.</td>
<td>75</td>
<td>Vertically integrated with coordinated management, Chilean owned</td>
</tr>
<tr>
<td>Pesquera Los Fiordos Ltda.</td>
<td>66</td>
<td>Vertically integrated, Chilean owned (Agrosuper)</td>
</tr>
<tr>
<td>Salmones Antártica S.A.</td>
<td>64</td>
<td>Vertically integrated with coordinated management, Japanese owned (Nippon Suisan)</td>
</tr>
<tr>
<td>Pesca Chile S.A.</td>
<td>44</td>
<td>Vertically integrated, Spanish owned (Pescanova)</td>
</tr>
<tr>
<td>Other Exporters</td>
<td>427</td>
<td>29.7%</td>
</tr>
</tbody>
</table>

Sources: Revista Aqua (2005); Montero (2004); Aqua al Día (2005).

Information Transfer through the Production Chain

The amount, accuracy, and verifiability of information recorded are choices for producers trying to satisfy demands of food safety and traceability; more information allows for more detailed traceability, but can be costly to maintain and could be an asset or liability in the event of legal action against the firm. Information costs increase when it becomes necessary to maintain a verifiable trail of information about the genetic characteristic of broodstock or the use of organic feeds. These types of attributes are difficult to detect through sampling the fish and must instead be verified by auditable records that document that batches with differing attributes are not co-mingled or provided inappropriate feeds or pharmaceuticals at anytime from egg-production through grow-out.

The credibility of a traceability system could depend on whether assurance is provided by the firm, by a government agency, or by an independent for-profit firm or nonprofit association. Compromising the integrity of a traceability system for credence attributes could be as simple as the inadvertent mixing of fish from different cages, inaccuracies in information transferred from the hatchery, or mislabeling of feeds or human error in the application of feeds and pharmaceuticals. Implementing traceability systems means solving a variety of complex problems that differ depending on company structure (vertically integrated, etc.), market requirements, and resources available. Any credible traceability system must address the transfer of information through the three stages of production (hatchery/nursery, grow-out, and processing) and the transfer of information regarding feed and other inputs used in each of the production stages. In
the next sections, we will discuss the three stages of fish production and feed production to illustrate the type of information that would need to be transferred and potential vulnerabilities that could compromise the integrity of a traceability system.

**Hatchery/Nursery Operations**

The first stage of production—spawning, egg fertilization, incubation, and development and growth from egg to smolt is carried out in hatchery facilities located in or adjacent to a source of high-quality fresh water. Two production systems and three modes of operation are currently used for hatchery/nursery operations in Chile. The two production systems are lake-based tank and pen systems, and stream-based tank systems. The three operation modes are smolt production from hatchery-provided eggs for farms owned by the same company; smolt production from hatchery-provided eggs for farms owned by unrelated companies; and, smolt production for farms owned by unrelated companies, using eggs provided by those farms.

Piscicultura Río de la Plata, located near Tegualda, about 30 miles northwest of Puerto Montt, Chile is a typical of stream-based tank system hatchery. The hatchery is designed for batch production in independent tanks. Because each tank is independent, it is relatively simple to isolate disease and to produce multiple verifiably distinct genetic strains or feed regimes. Piscicultura Río de la Plata produces about 600 million smolts per year. Of these, 93% are produced for farms owned by its parent, the Camanchaca Fishing Company. The remaining smolts are produced for sale to farms owned by other companies. While most of the smolts sold to other farms are grown from eggs produced by the Camanchaca Fishing Company, some smolts are produced using eggs provided from broodstock maintained by contracting farms. In November 2004, about 10% of the smolts in production at Piscicultura Río de la Plata were being maintained on certified organic feeds. In March 2005, Camanchaca Inc. introduced "Pier 33 Organic Salmon," certified by Naturland, a leading organic certifier (The Wave 2005a).

Phase I begins with broodstock whose eggs and roe are stripped and mixed together for fertilization. Eyed eggs (245-510 degree days for Atlantic salmon and 175-370 degree days for rainbow trout) are very resistant to handling stress and can be shipped great distances. Consequently, although Chilean-spawned eggs were available as early as 1980, Chilean hatcheries remained largely dependent on fertilized eggs from Norwegian broodstock through the 1990s. Since 2000, Chilean egg production has increased dramatically; as of September 2004, over 90% of all eggs used in Chilean hatcheries were produced from local broodstock (Aqua al Día 2004). The increase in local egg production has resulted from improved understanding of the role of light (photoperiod) and temperature (thermal) in the timing and rate of egg development and growth rates in fry. This knowledge has permitted greater control over growth rates and allows smolts to be produced in any month (Mundo Acuícola 2004). The Atlantic salmon eggs hatch after about 510 degree days (approximately 64 days at 8°C) as alevins or sac-fry. After 290 degree days (approximately 36 days at 8°C), the sac-fry begin feeding and are referred to as fry or parr (Edwards 1978). Rainbow trout eggs hatch after about 370 degree days (approximately 46 days at 8°C) months and begin feeding after 150 degree days (approximately 19 days at 8°C) after which they are referred to as fry or fingerlings (Edwards 1978). Once Atlantic salmon parr reach 30-60 grams, they undergo physiological changes, smoltification, that prepares them for entering seawater. Rainbow trout fingerlings can be transferred to saltwater at about 50g.

The principle environmental concern with hatchery facilities is nutrient enrichment of effluent water. While water re-circulation systems are increasingly common in developed nations, they are not yet common in Chile. Indeed, effluents are often discharged without treatment in lake-based tank and pen systems and in some stream-based systems. The Piscicultura Río de la Plata facility represents one of the newer hatcheries that are being held to effluent discharge quality standards. The standards require that tailwaters not exceed the level of BOD (biological oxygen demand) of the source water and that dissolved oxygen levels in the tailwaters match or exceed levels in the source water. At the Piscicultura Río de la Plata facility, these effluent standards are met with a combination of physical screens, biofiltration, and paddlewheel aeration.
Information that may be important for traceability and assurance regarding this stage of production includes information about broodstock genetics, information about feed and prophylactic regimens applied to broodstock, eggs, sac-fry, fry, parr, and fingerlings. Information about the quality of water inflow and effluent discharges, the status of native aquatic fauna in source and receiving waters may be needed to demonstrate environmental sustainability and information about employee work-conditions, compensation and demographics may be needed to demonstrate social responsibility.

**Grow-out**

In the second stage of production, smolts are transferred to marine cultivation centers for grow-out. The grow-out phase takes 8 to 18 months depending on species and water temperature. Water temperatures vary by season, with cooler winter (June, July, and August) temperatures slowing the rate of growth. The time required for grow-out is also dependent on feeding rates and target slaughter size. The Chilean government regulates the size and placement of fish farm sites and requires concession owners to report monthly stock and harvest volumes. Long-term leases for farm sites are allocated on a first-come first-serve basis.

The cultivation phase accounts for 51.6% of the total cost of bringing salmon to the market, with feed costs, alone, accounting for 60% and 70% of farm level costs (SalmonChile 2004). High feed cost are due to dependence on high cost inputs (medications, vitamins, pigments, fishmeal and other proteins, fish oil and fats, etc.). Recent cost savings have arisen from the substitution of vegetable fats and proteins for higher-cost fish-based fats and proteins. Feed is delivered to each pen using hopper-blower systems, similar to systems used in the installation of loose cellulose insulation. Some farms use a portable hopper-blower system and carry the bags of feed to the hopper. Other farms have a system of valved plastic pipes that distribute feed from a central hopper/blower in the feed shed. In either case, feed delivery to individual pens is varied according to the number and average size of fish, season, and water temperature. Feeding is monitored using underwater cameras to ensure that feed is only delivered if the fish are actively feeding and that feed delivery is continued until active feeding has ceased.

Farmed salmon are subject to viral, fungal, and bacterial diseases. Until recently, most of these diseases were treated with antibiotics. However, some of the most effective antibiotics for fish diseases are not approved for human consumption. Nevertheless, many of these antibiotics continue to be used in Chile and elsewhere. In recent years, importing nations have become more rigorous in testing for the presence of prohibited antibiotics and rejecting shipments found to exceed established limits. Fish farmers have developed better understanding of the rate at which traces of antibiotics are cleared from fish and labs have proliferated in salmon-producing regions to test the level of antibiotics in samples before harvesting and shipment. While these measures have reduced the number of shipments found to exceed established limits, there remain concerns about the heavy use of antibiotics in finfish aquaculture in general and salmon/trout culture in particular. These concerns have spurred interest in the development of vaccines. For example, in 2003, the majority of on-farm mortality resulted from rickettsia, a bacterial liver disease that makes the fish lethargic and slows growth. A vaccine for rickettsia was developed in late 2003 and became widely available in 2004. Fish are siphoned from the pen, defective fish are culled, and the remaining fish are segregated by size, anesthetized, and vaccinated.

To reduce the incidence of disease and to ensure that penned fish receive sufficient oxygen, farm managers must maintain good environmental conditions. Excessive feeding or stock rates that exceed site capacity could lead to a concentration of organic wastes and localized eutrophication that could reduce the concentration of dissolved oxygen and increase the density of undesirable microorganisms. Even with careful feed management, net pens must be cleaned of algae and fouling organisms about once every ten days to avoid reductions in water exchange that increase the risk of oxygen deprivation.
Another suite of issues arise in organic production. Without pharmaceuticals and feed supplements, it is necessary to reduce stocking densities and increase monitoring and handling of fish, thus the cost of organic production is higher than the cost of traditional production. The premium consumers are willing to pay for organic salmon would have to be substantial to offset the cost of higher mortality, more expensive feed, and increased labor (Sutherland 2001). Although Chern et al. (2002) find that consumers in the United States, Norway, Japan, and Taiwan are willing to pay premiums of up to 50% for non-GM salmon, their estimate should be viewed with caution because it does not reflect differences in the relationship between marginal willingness-to-pay and the volume of certified non-GM salmon made available to the market. It should be noted that organic producers may pose adverse externalities for other producers by increasing the reservoir of un-immunized fish that may increase the likelihood of disease throughout a region.

In addition to carrying forward information from hatchery/nursery operations (broodstock genetics, feed and prophylactic regimens applied to broodstock, eggs, sac-fry, fry, parr, and fingerlings, etc.), traceability and assurance systems must document feed and prophylactic regimens applied during the grow-out phase, demonstration that there is no mixing of fish undergoing different regimens or mixing of feeds, medications, or colorants delivered fish being grown under different regimens. Information about the quality of water inflow and effluent discharges, the status of native aquatic fauna in source and receiving waters may be needed to demonstrate environmental sustainability and information about employee work-conditions, compensation and demographics may be needed to demonstrate social responsibility.

**Processing and Distribution**

When the salmon or trout reach market size—usually 1 kilo for pan size trout, 2.8-3 kilo for whole trout or coho salmon, and 4 to 5 kilos for salmon and trout to be cut into steaks or filleted—they are readyed for processing. Although growth rates can be influenced by feeding rates and feed composition, and harvest size is a choice variable, in practice, the harvest window is dictated by broodstock genetics and the date that smolts are stocked in the net-pens. While a continuous product flow from hatchery to cultivation center and on to processing and distribution would be ideal, the vagaries of supply and demand can upset this delicate balance, sometimes leaving seawater pens empty or filled with aged and oversized fish. In Chile, the production of Atlantic salmon and rainbow trout has been stabilized to yield near constant output throughout the year. In contrast, production of coho and chinook salmon remains highly seasonal with peak output in November through January, a season in which there is very little wild production to compete against.

Chile's distance from North American, European, and Asian markets and the perishable character of salmon and trout are disadvantageous. However, Chile's productive capacity and low production costs offset this disadvantage and have allowed Chile to position itself as the foremost producer of value-added salmon and trout products. In 2003, Chilean salmon and trout exports exceeded one billion dollars, 67% of those exports were value-added products (SalmonChile 2004). One of the limits to profitability and market development lies in the difficulty of pairing airfreight imports with airfreight exports. Because most Chilean farmed salmon is transported to market by air, there is relatively high payload for outbound freight. Chile has a relative advantage in foreign markets that produce high volume exports for airfreight into Chilean markets. In foreign markets that do not produce goods that are in high demand in Chile, the transportation costs for salmon include the cost of deadhead return flights.

Several channels are used in the distribution of Chilean salmon: sales to wholesale distributors; sales to institutional buyers, retailers and food service establishments; and direct sales to end consumers. Each of these channels may require unique traceability and assurance information. Barcodes and tracking numbers provide for rapid and transparent access to information for food safety recalls or for accessing production information. The principle challenges for traceability and assurance at the processing and distribution stages have to do with conservation of
information from the hatchery and grow-out stages. There must be a verifiable flow of information with the fish as it is processed for consumption and distributed to end markets. In addition, there may be demand for information about the environmental impacts of processing operations and waste discharges and about employee work-conditions, compensation and demographics.

**Feed Industry**

Because feed is the largest component of farm level production costs for salmon and trout, many producers coordinate with corporate owned yet separately managed feed companies, or are part of a fully integrated feed manufacturing—fish farming operation. Variable supplies of key inputs, fishmeal and fish oil also create incentive for further upstream coordination. Feed production is highly concentrated, both vertically and horizontally. Consolidation in feed production has resulted in a decline from 23 factories in 1992 to seven in 2003. Of those seven, two—Salmones Antártica S.A. and Cultivos Marinos Chiloé Ltda—are wholly vertically integrated with coordinated management (SalmonChile 2004). While Skretting Chile S.A., Ewos Chile S.A., and Salmofood S.A share ownership interests with particular farm operators, they, along with Biomar Chile and Alitec also produce and sell feed to independent farm operators.

The seven factories produce different sizes of pelletized feeds formulated to meet the dietary requirements of trout and salmon fry, smolts, and maturing fish, medicated feeds, organic feeds, feeds with and without colorants. Because nutrients and vitamins included in the feeds are not stable for extended periods at ambient temperatures, most feed is produced near the fish farms where it will be used and very little feed is shipped over long distances. The high cost of feed results from dependence on high cost inputs (medications, vitamins, pigments, fishmeal and other proteins, fish oil and fats, etc.).

Fishmeal prices are highly volatile and futures markets are not well established, so it is difficult for feed producers to secure long-term contracts for fishmeal. The volatility of fishmeal prices is largely due to fluctuations in fishmeal supply that arise from natural variation in the abundance of wild stocks of the fish species harvested as inputs into fishmeal. The primary sources of fishmeal are the capture-fisheries for herrings, sardines, and anchovies. The largest of these fisheries is the Peruvian-Ecuadorian-Chilean fishery for anchovetta (*Engraulis ringens*). While this fishery is often the world's largest in capture fishery with landings in excess of 10 million metric tons, population fluctuations driven by changes in nutrient availability associated with El Niño-Southern Oscillation can lead to order-of-magnitude swings in abundance and landings. Thus, even though Chilean feed producers have an advantage of being close to a key source of fishmeal, volatility in the availability and price of fishmeal has provided strong incentive to develop feed formulations that are less dependent on fishmeal. However, diversifying towards vegetable proteins would mean increased difficulty and complexity of providing traceability and assurance. The more inputs used in feed production, the more breadth and depth of information will be required. Extending traceability to include feed inputs (fishmeal, fish oil, nutritional supplements, medications, grains, or vegetable proteins) will increase the complexity and cost of ensuring traceable product and quality assurance. Based on this, firms may choose to organize production (e.g., integrate upstream into vegetable production) in different ways to achieve a desired level of traceability and assurance.

**Markets for Salmon**

Chilean salmon and trout exports for 2004 have increased in volume and value when compared to exports for the same period in 2003 (Table 3). In terms of value, the largest markets for Chilean salmon are the U.S. and Japan. Other important markets include Germany, Brazil, France and Thailand. Improved trade relations with developing markets have helped increase the share of Chilean salmon sold in China, Israel, Russia, South Korea, Singapore and other nations.
Table 3. Main markets, export quantity and value (2003 and 2004)

<table>
<thead>
<tr>
<th>Market</th>
<th>Quantity (net tons)</th>
<th>Value (millions $U.S. FOB)</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2003</td>
<td>2004</td>
<td>2003</td>
</tr>
<tr>
<td>United States</td>
<td>117,142</td>
<td>124,052</td>
<td>543,690</td>
</tr>
<tr>
<td>Japan</td>
<td>119,075</td>
<td>154,283</td>
<td>427,066</td>
</tr>
<tr>
<td>European Union</td>
<td>15,340</td>
<td>24,084</td>
<td>60,574</td>
</tr>
<tr>
<td>Latin America</td>
<td>16,840</td>
<td>22,957</td>
<td>55,926</td>
</tr>
<tr>
<td>Other</td>
<td>17,449</td>
<td>29,360</td>
<td>60,172</td>
</tr>
<tr>
<td>Total</td>
<td>285,846</td>
<td>354,736</td>
<td>1,147,428</td>
</tr>
</tbody>
</table>


Asche, Bjørndal, and Young (2001) note that increases in production volume have depressed prices in most markets. While technological has allowed production cost savings to keep pace with declining product prices, Guttormsen (2002) reports that salmon farms, especially in Norway, have reached a point where there is limited potential for additional substitution among inputs. Because exchange rates fluctuate through time and because inputs are purchased in local markets while products are sold in foreign markets, FOB prices in U.S. dollars do not accurately reflect the actual value of revenues received by Chilean producers. It becomes evident that when prices are expressed in Chilean pesos, Chilean producers have benefited from an average 3.4% depreciation over the past 15 years. To understand changes in the value of revenues over time, it is important to adjust for inflation. Over the past 15 years, annual wholesale price inflation has averaged 10.5% in Chile. From 1990 through 2004, the average real price of Chilean Atlantic salmon has declined by an average of 4% per year; the average real price of Chilean rainbow trout has declined by an average of 4.8% per year; and, the average real price of Chilean coho salmon has declined by average of 7.9% per year. Average real FOB prices for Chilean salmon and trout (pesos/kg) are represented in Figure 1.

Figure 1. Average real FOB prices for Chilean salmon and trout (pesos/kg), 2004 base year.

---

3 The 95% confidence interval for the estimated average rate of depreciation is 3.4%±0.55%.
4 The 95% confidence interval for the estimated average rate of wholesale price inflation is 10.5%±2.1%.
5 The 95% confidence interval for the estimated decline in the average real price is 4.0%±1.6% for Chilean Atlantic salmon, 4.8%±4.5% for Chilean rainbow trout, and 7.9%±4.4% for Chilean coho salmon.
The interplay between markets for farmed and wild salmon has been thoroughly explored, by Anderson (1985a, 1985b), Bird (1986), Herrmann and Lin (1988), Lin, Herrmann, and Mittelhammer (1989), Lin et al. (1989), Herrmann, Lin, and Mittelhammer (1991), Herrmann, Mittelhammer, and Lin (1992, 1993a,b), DeVoretz and Salvanes (1993), Herrmann (1993), Herrmann and Greenberg (1994), Wessells and Wilen (1993a, 1993b), Wessells and Holland (1998), Asche, Bjørndal, and Salvanes (1998), Asche, Bremnes, and Wessells (1999), Clayton and Gordon (1999), and Jaffry et al. 2000. The basic finding is that farmed Atlantic and coho salmon are close substitutes in fresh and frozen markets in the United States, E.U., and Japan. As world prices for salmon have declined with the expansion of farmed production, the capture fisheries have been thrown into financial disarray that has led to bankruptcy and cessation of fishing by those least able to restructure to reduce their harvesting costs.

**Production Costs**

Salmon producers have generally separated their activities into fresh water or smolt production, sea farming operations, processing, and sales. The most recent estimates of the cost share of each of these production stages are reported in table 4.

<table>
<thead>
<tr>
<th>Table 4. Cost Components for Chilean Salmon Production (2003)</th>
<th>% of Total Cost</th>
<th>% of Cost by Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hatchery/Nursery Operations</td>
<td>3.0%</td>
<td></td>
</tr>
<tr>
<td>Farming Operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed</td>
<td>30.0%</td>
<td>58.1%</td>
</tr>
<tr>
<td>Pigments</td>
<td>6.0%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Manual labor</td>
<td>6.0%</td>
<td>11.6%</td>
</tr>
<tr>
<td>External services</td>
<td>4.8%</td>
<td>9.3%</td>
</tr>
<tr>
<td>Other costs</td>
<td>4.6%</td>
<td>8.9%</td>
</tr>
<tr>
<td>Other costs of grow-out</td>
<td>0.2%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Subtotal of Farming Operations</td>
<td>51.6%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Processing Plant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual labor</td>
<td>12.0%</td>
<td>63.5%</td>
</tr>
<tr>
<td>Packaging materials</td>
<td>4.0%</td>
<td>21.2%</td>
</tr>
<tr>
<td>Energy</td>
<td>0.9%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Maintenance and other costs</td>
<td>2.0%</td>
<td>10.6%</td>
</tr>
<tr>
<td>Subtotal of Processing Cost</td>
<td>18.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Transport and Sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground freight</td>
<td>1.5%</td>
<td>8.1%</td>
</tr>
<tr>
<td>International airfreight</td>
<td>13.0%</td>
<td>70.3%</td>
</tr>
<tr>
<td>International ocean freight</td>
<td>3.0%</td>
<td>16.2%</td>
</tr>
<tr>
<td>Cool and frozen storage</td>
<td>0.5%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Sales costs</td>
<td>0.5%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Subtotal of Transport and Sales Costs</td>
<td>18.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Administrative and Financing Costs</td>
<td>8.0%</td>
<td></td>
</tr>
<tr>
<td>Total Production Cost</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

Activities generating the most significant costs for farming operations are feed and feed pigments (69.7%) and labor to administer feed (11.6%). The most costly activities for processing operations are labor (63.5%) and packaging (21.2%). Processing labor costs are high primarily because pin bones are too fine for machine removal. It is surprising that marketing (sales costs) are such a small share (0.5%) of total production and distribution costs. In contrast, the U.S. broiler industry (e.g., Tyson Foods, Pilgrims Pride, Perdue, Foster, Gold Kist, etc.), which like integrated salmon
aquaculture operations in Chile, controls the entire value-chain from feed input through end-consumer brands, spends substantially more.\(^6\)

Increased consolidation among vertically integrated salmon producers could increase the resources available for as well as potential benefits of investment in own-brand development and marketing to end-consumers. Implementation of traceability and assurance systems capable of documenting assertions about measurable characteristics of end products and credence attributes regarding production inputs and processes will create the opportunity for marketing to consumers who are willing to pay a premium for particular quality characteristics and credence attributes. One advantage for larger producers with multiple farms is that natural variations in their output caused by lags in the production process can be smoothed by staggering production across multiple farms. For large producers, fluctuations in output can be a small percentage of their total output and it is relatively easy to maintain brand awareness. For small producers, the production cycle results in intervals when product is available and intervals when it is not; maintaining brand awareness becomes difficult in such an environment (Tveterås and Asche 2004). As a whole, the industry should benefit from increased emphasis on understanding the end-consumer and establishing an international presence through foreign sales offices (Hernández 2004). However, part of the problem with advertising expenditures for salmon is that advertising benefits all producers whether they do or do not help pay the cost (Kinnucan and Myrland 2001, 2002, 2003; Myrland and Kinnucan 2001; Myrland et al. 2004).

**INDUSTRIAL EVOLUTION AND INDUSTRY STRUCTURE**

The structure and organization of industries changes over time in response to changes in input and output markets and changes in technology. Firms can thrive or founder as circumstances change, either because they had the good fortune to be pre-adapted to the new circumstances or because they have chosen to position themselves strategically in anticipation of the new circumstances. That is, firms and industries may evolve through time under the influence of “Darwinian” natural selection—survival of the fittest, or “Lamarkian” transferal of acquired characteristics. When consumer preferences change, when new physical or organizational technologies emerge, when the cost of inputs change, firms and industries will thrive or fail because of the suitability of pre-existent inherent characteristics or because of their adaptive capabilities. In other words, a firm or industry may evolve consciously or randomly.

The rise of consumer and political demand for traceability and assurance with respect to food safety, product quality, and credence attributes represents a new competitive pressure on firms and industries. Some firms and organizational structures, by happenstance or foresight, are pre-adapted to satisfy the demand for traceability and assurance. Firms that are not pre-adapted must either acquire infrastructure and organization to support traceability and assurance or surrender real and potential market share in markets that demand traceability and assurance. Out of rational self-interest, firm owners can be expected to maximize some objective: maximizing profits, manager-utility, market share, growth rate, shareholder value, etc. Other goals of the firm may include minimizing transaction costs (Coase 1937), or the cost of principal-agent incentives (Alchian and Demsetz, 1972). Firms or organizations that are successful further the collective interest of their members—benefiting from the synergies created.

**Recent Evolution in the Meat Industries**

In recent years, many segments of the food and agribusiness industry have become more concentrated through horizontal or vertical integration within firms or through the formation of cooperatives or other associations. The vertical and horizontal consolidation taking place in the salmon aquaculture industry resembles changes that have already taken place in the poultry and

\(^6\) In August 2004, Tyson Foods launched a $75 million campaign for poultry, beef, and pork (Tyson Foods 2004). Although the largest private label poultry producer, Gold Kist, does little consumer advertising, their total marketing budget is over $2 million (Moore 2005).
pork industries, and to a lesser degree in beef. Tvetenås and Kvaløy (2004) assert that potential incentives for increased consolidation in the salmon aquaculture industry are in part due to food safety, food quality, and environmental effects. Consequently, an examination of the evolution of poultry, pork, and beef industries and their experience in adapting to heightened concerns about food safety, and demands for traceability and assurance may provide insight into the types of organizational structures that are likely to be successful for the salmon aquaculture industry.

The U.S. pork industry has recently undergone a transformation in its structural organization from 11% of production under contract or vertical integration in 1993 to 64% in 1999 (Preckel et al. 2004). Preckel et al. (2004) suggest that a primary reason for the emergence of vertical integration in the pork industry is that vertical integration provides improved communication to suppliers about animal characteristics valued by the market. The demand for traceability and assurance can be motivated as a demand for information about latent product attributes; information that some, but not necessarily all, consumers want. Implementing traceability systems may provide a mechanism for improved signaling of these product attributes. Reimer (2004) suggests that with increased demand for traceability and assurance, packers are more likely to integrate upstream if producers exhibit low investment productivity. Producers with low investment productivity are less able to access capital needed to invest in new technologies or traceability software and assurance systems. In addition, given their proximity to and need to communicate with consumers and retailers, packers are on the front line with respect to liability for food safety, environmental, and animal welfare concerns. Exercising direct control of upstream production is one of managing risk associated with liability for food safety, environmental, and animal welfare concerns. In addition, if packers consolidate horizontally, producers will lose market power and have even less ability to access capital needed to invest in traceability software and assurance systems.

The recent evolution of the pork industry suggests some possible changes in the Chilean salmon industry. For example, it can be expected that independent salmon farmers are at a relative disadvantage in negotiations with processors because processors are relatively few in number and control some production capacity through ownership or contract. Similarly, it can be expected that independent salmon farmers are at a relative disadvantage in negotiations with feed-suppliers because feed-suppliers are relatively few in number and control some production capacity through ownership or contract. Moreover, because many of the processors and feed-suppliers are controlled by the same parent firms, and because those parent firms also control production facilities, it can be expected that independent farmers have relatively little power. The perishable nature of feed inputs and farm output also shift market power to feed-suppliers who have many customers and away from independent farmers who cannot stockpile feeds, and to processors who can rely on their own farms and many other independent farmers for process-ready fish and away from farmers who have a perishable product and a limited ability to transport their product to any but the closest processors.

Producers would be likely to integrate upstream when hatcheries show low investment productivity and if liability is high. In the case of producers, it is expected that horizontal integration will be used as a risk management strategy because it is unlikely that multiple geographically distributed production facilities would suffer simultaneous “crop” failures. Indeed, the strategy of horizontal consolidation and geographical diversification is evidenced by recent mergers and acquisitions. Under Nutreco’s ownership, Marine Harvest and Stolt Sea Farms produce upwards of 20% of global farmed salmon with facilities in Norway, Chile, Canada, the Faroe Islands and other locations. As supply relationships increasingly bypass the middleman, it becomes evermore costly to fail to deliver product at an expected time; processors can increase the likelihood of satisfying contractual obligations to wholesalers and retailers by taking steps to ensure that supply from producers is not interrupted. Although processors could ensure the scheduling of deliveries through ownership or contract, the advantage of ownership is that it reduces the possibility that a producer might renege on the contract.
Like the pork industry, most poultry slaughter firms (e.g., Tyson Foods or Perdue) have integrated ownership throughout the chain and detailed contracts with growers. Ollinger, MacDonald, and Madison (2005) analyzed structural change in poultry industries and found that from 1967-1992 the mean plant size increased six fold for turkey processors and nearly tripled for chicken processors. However, they suggest that the presence of negative cost externalities places limits on further expansion of processing scale economies. As processing capacity has increased, processors have faced increased transportation costs because of limitations placed on the scale and density of poultry production facilities due to concerns about manure disposal and animal and human health. Food safety is also an issue, if authorities purposefully limit plant size for accurate inspections, or in one case, insufficient water supply for washing carcass restrained plant size (Ollinger, McDonald, and Madison 2005).

These types of constraints also apply to processors and producers of Chilean salmon. For instance, environmental regulations limit the size and concentration of farm sites. It is important to locate processing facilities near concentrated producer areas to exploit economies of scale and scope. Processors can increase the number of products, increase further processing, expand product mix to include other fish or seafood, and expand the number of international markets into which they sell. With greater consolidation, the ability to control food safety would likely increase, but increasing plant size and product mix might increase the cost of traceability and assurance due to differing product requirements and the number distant/ distinct suppliers.

In a recent review of the effects the United State's National Animal Identification (NAIS) will have on the cattle market structure, Mark (2004) suggests that competitive effects will depend on a firm’s size and position in the marketing chain; smaller cow-calf producers, stockers, and feed yards will likely be exposed to the greatest structural changes as economies of size, price discounts/premiums relayed from downstream feed yards and packers, liability protection, and possible gains with increased management information influence adaptive capability. Productivity or marketing gains could come from improved genetic tracking where consumers demand characteristics verifiable through genetics.

In the case of salmon, if traits such as “not genetically modified” (non-GM) are valued by retailers, or consumers, traceability and assurance systems which trace and verify breeding and genetics could be important for maintaining market share. With increased costs of transferring this additional information, it is advantageous to reduce the number of transactions between input sources, producers, processors, and customers. Producers and processors who can minimize the number of intermediate transactions will have lower costs for animal identification and traceback.

The NAIS system has received considerable debate over whether it should be voluntary or mandatory. Imposing a traceability system through political processes rather than allowing it to emerge in response to consumer demand expressed through the market, imposes costs on those who do not value traceability and subsidizes those who do. While debate over whether implementation of traceability and assurance programs could or should be left to the market or mandated by government may be interesting, it is, in large measure, moot; requirements for traceability and assurance are being implemented by governments in Chile's principal export markets. Tothova and Oehmke (2004) note that cross-country differences in consumer preferences and regulatory approaches have polarized markets into clubs (e.g., those such as the United States, that accept GM foods and those such as the E.U. that do not). The polarization of markets increases the challenges that firms and industries face. Should they specialize in serving the consumer preferences and regulations of a single trade partner or generalize to meet the divergent consumer preferences and regulations of multiple partners? In order to participate in multiple markets, producers may need to implement parallel production and traceability systems—to be used for example in simultaneously servicing separate GM and GM-free markets.

**Cooperation vs. Competition**

The Chilean salmon industry exhibits diverse patterns of governance and ownership. Ownership within the Chilean salmon industry includes large multinational firms, a large number of
medium- to large-sized domestic firms, and a few smaller firms. The initial success of the Chilean salmon industry came from small producers emerging in response to international demand. As the scale of production increased, firms increased their size and began to integrate. Under the umbrella of SalmonChile, these fragmented producers began to share information, input sources, and output markets, consciously evolving into an industrial cluster. The current pattern of inter-business relations is quasi-hierarchical, with cooperative efforts in research and development, foodstuffs, vaccines, etc., and hierarchic relations between large firms and the small and medium sized suppliers. As vertical and horizontal consolidation takes place, the benefits of cooperation may decline.

Bontems and Fulton (2004) note that "privately held information is valuable to those that possess it, while it imposes a cost on those that do not." This, they suggest, can provide cooperatives with an organizational cost advantage over for-profit firms when privately held information is important to the success of the organization. If a Chilean cooperative held private information—related to traceability and assurance—that was important to the objectives of its members, it could have an organizational and cost advantage over the independent firms operating outside that cooperative. For instance, a cooperative in the Chilean salmon industry could share the cost of knowledge intensive software requisite to ensuring traceable product. One positive externality might be the development of consumer trust towards the firm or cooperative able to meet requirements of either regulation or consumer preferences for credence attributes.

Weaver and Chin (2004) suggest that collective bargaining can increase producer profits when they face individual processors that might exercise monopsony power. Collective bargaining through producer cooperatives enables farmers to capture margins that otherwise would go to processors and can maximize total surplus. If market power is held by one intermediate stage, e.g. processing, coordination through supply contracts may be better than coordination through open markets (Asirvatham and Bhuyan 2004). Tveteras (2004) suggests that long-term contracts could be a viable alternative to vertical integration for salmon farmers and processors. Similarly, it may be advantageous for independent farm operators to organize as an input-buying cooperative to offset the market power associated with the high degree of concentration in feed production. To date, feed manufacturers have exercised considerable power over smaller salmon producers, who often enter loan contracts to be repaid after harvest, and by so doing, give feed suppliers partial influence over production and marketing. Because implementation of a traceability system requires transmission of information from each stage of production to the next, and because the development and transmission of information is costly, it can be anticipated that the burden of the cost of traceability systems will be distributed between stages of production according to their relative market power.

With respect to food safety, or product recalls, the collective industry image is at stake; therefore, a cooperative effort would be expected largely focused on painting a picture of transparency and quality assurance to buyers and consumers. This effort is evident with SalmonChile's new Integrated Management System (SIGES) created in response to emerging international requirements for safety, security, social responsibility, and sustainable production. Fourteen companies, including several of the largest multinationals, have enrolled so far. In order to obtain the SalmonChile-SIGES certification, companies must commit to adhere to otherwise voluntary protocols (e.g., information system software, ISO, OSHA, HACCP, best practice guidelines, etc.). A software package from Chilessoft S.A. is available for tracking records and product, but is not required for SIGES certification; companies can employ other electronic record systems. Although feed inputs have not yet been included in SIGES, efforts are underway to expand SIGES to include feed inputs. One problem, which has been identified in other production processes (e.g. pork, beef, etc.), is maintaining traceability to the farm level (Bailey, Jones, and Dickinson 2002). It appears that the depth of traceability required by SIGES addresses this problem.

These collective efforts are not limited to one industry; a workshop organized by SOTA brought representatives from the Chilean and Canadian salmon industries and from the U.S. Food Marketing Institute (FMI) to discuss harmonization of standards. The plan is to integrate the
Chilean (SIGES) and Canadian systems with the Safe Quality Food (SQF) program from FMI. Interestingly, this system would not include Norwegian, U.K., and Faroe Island producers. This materializes into using the attributes certified by SQF (including quality, environment, safety, and sustainability) to benefit SOTA member producers. By using common standards and certification schemes, SOTA members (Chile, United States, and Canada) should be able to benefit by promoting a clean, dependable, and sustainable industry while also intensifying advertising for additional certified attributes.

If some firms wish to convey additional information about quality or credence attributes beyond the basic information conveyed through SIGES it may be advantageous to develop a stand-alone alternative rather than support SIGES and a parallel system for these other attributes. For example, a retailer in the United States selling organic salmon from Chile could not rely on SIGES to verify that inputs and processes complied with organic production standards. Since SalmonChile does not certify organic, a separate or combination traceability chain would need to be used to ensure that certified organic product is not mingled with uncertified product between being shipped from the producer and arriving at the retailer. Thus, a producer seeking to differentiate a product based on credence attributes would likely incur costs greater than costs incurred by participants in SIGES. If several producers desired to market the same attribute, they might be able to cooperatively arrange and share the cost of certification, inspections, etc. Unless premiums are sufficiently high, producers might be discouraged from creating differentiated products and investing in separate traceability systems. The size and type of firm could also influence this decision. Where vertically integrated firms are responsible for several stages of recordkeeping and information transfer, single stage firms are less so and could have lower transaction costs. Furthermore, the largest integrated and single stage firms should have larger capital resources for investment and specialization of traceability and assurance systems from which information management can exploit gains to productivity and marketing.

**TRACEABILITY AND ASSURANCE**

While traceability in the E.U. and United States is driven by consumer demand and food safety concerns, traceability in Chile is driven by a desire to maintain access to the E.U. and North American markets. While the idea of traceability is rather simple, execution and implementation is complex. The seafood industry—including the salmon aquaculture industry—has not yet achieved the level of traceability and assurance that is characteristic of beef, poultry, pork, and other protein industries. However, with recent advancements in the seafood and salmon industries, the disparity is shrinking. Improvements in traceability are originating from stricter governmental oversight, industry association involvement with supply and production-chain traceability systems, and individual producer investments in software for tracking and database integration.

**Definitions**

There are many definitions and terms used to describe traceability: trace, traceback or tracing, traceforward or tracking, product tracing, or simply recordkeeping. Although we use traceability as a catchall term, it is important to acknowledge that specific terms and specific definitions have specific meaning in law and regulation. ISO 9000:2000 (ISO 2004) guidelines define traceability as: the ability to trace the history, application or location of that which is under consideration. E.U. (2002, 2004) define traceability within the food chain as: the ability to trace and follow a food, feed, food-producing animal or substance intended to be or expected to be incorporated into a food or feed, through all stages of production, processing and distribution. Codex (2004) defines traceability as: the ability to follow the movement of a food through specified stage(s) of production, processing and distribution. Farm Foundation (2004) defines traceability as: the efficient and rapid tracking of physical product and traits from and to critical points of origin or destination in the food chain necessary to achieve specific food safety and, or, assurance goals. SalmonChile specifies traceability or tracking systems as a: method of exact and opportune identification of products, in any part of the supply chain, by means of a bar code with an incorporated database of information leading to its origin. It may also be helpful to define
traceability by what it does not do—it does not assure food quality or safety, rather it provides useful information for decision-making. As it implies, traceability tracks the product, its inputs, attributes or other processes. Traceability is an information system, which provides information about the extent to which quality assurance systems such as HACCP, ISO, SQF, etc., are functioning.

Differences in traceability systems may lead to inefficiencies and confusion (Dickinson and Bailey 2005). Resolving these differences has been one of the aims of several international (e.g., CIES7, EAN.UCC, Codex, OIE), national (e.g., British Retail Consortium, Farm Foundation), and aquaculture specific organizations (e.g., Tracefish/SeaFoodPlus8, Global Aquaculture Alliance9). These, along with other government, associations, and private sector organizations have endeavored to accurately define traceability and make the sharing of traceability information more flexible and useful. The objectives of traceability systems differ; therefore, each should be defined by those characteristics that drive the system. Golan et al. (2004) and Souza-Monteiro and Caswell (2004) classify traceability systems according to: breadth—the amount of information recorded; depth—how far backwards or forwards the system tracks information; and, precision—the degree of assurance to which the system can pinpoint or isolate a product's movement or characteristics. The breath, depth, and precision of a traceability system will depend on the product and the incentives for adopting a traceability system.

**What is Driving Traceability?**

Interest in implementing traceability in the food chain was initially set in motion by high profile food safety scares—bovine spongiform encephalopathy (BSE), foot and mouth disease, and dioxin and PCB contaminants. For example, in January 1999, dioxins and PCBs contaminated animal feed in Belgium, affecting an array of agricultural products, disrupting trade, and costing the country millions of euros. Without proper records to identify and trace contaminated feed, blanket recalls were issued, imposing a cost on products which in hindsight may have been perfectly safe (Buzby 2003). In 2001, an outbreak of foot and mouth disease in the United Kingdom cost the U.K. cattle industry about $13 billion. Similarly, the 2003 discovery of BSE in a small number of Canadian cattle cost the Canadian industry billions of dollars and led the Canadian government to outlay over $400 million in aid to affected ranchers. The discovery of a BSE infected dairy cow in eastern Washington, in 2003, effectively halted U.S. beef exports to Asian and other markets, costing U.S. producers over $180 per head in reduced sales value; a loss of over $6 billion for the U.S. cattle industry as a whole (FoodOrigins 2004).

FAO (2004) suggests that traceability systems could be useful as an effective protocol for administering food safety, quality assurance, and biosecurity, while also enhancing management of production, distribution, and marketing. The motives and objectives for traceability and assurance systems are diverse and specifically tailored to meet the needs of consumers and food chain participants from retail to production. Golan et al. (2004) suggest that firms will benefit from implementing and maintaining traceability systems when used as a tool for supply management. Firms may also use traceability systems to limit liability in case of recall and to complement HACCP, good management practices (GMP), and other assurance systems for ensuring food safety and quality assurance. Additional benefits may arise from using traceability systems as a means of verifying authenticity of differentiated products with credence attributes10.

---

7 CIES—The Food Business Forum includes over two thirds of the world's largest retailers and suppliers.
8 TraceFish is a European Commission initiative to establish a common position for recording traceability information in the farmed and captured fish supply chains (EAN 2002). SeaFoodPlus is an implementation of Tracefish.
9 Global Aquaculture Alliance (GAA) is a nongovernmental organization that has established best aquaculture practices and standards. GAA runs a nonprofit certifying body (Aquaculture Certification Council) that verifies adherence to mandatory requirements for food safety and traceability.
10 Credence attributes may be either content or process attributes. Content attributes are related to the physical properties of a product and in some cases may be hard for consumers to detect. For example, the level of healthy
In addition, using traceability as a business management tool to maintain contractual quality, develop commercial partnerships, optimize production, distribution, and marketing, and to facilitate horizontal and vertical integration (FAO 2004). Beyond the firm, governments also have incentive to use traceability as a security device for protecting the food supply from terrorist actions (e.g., contamination of food or feedstuffs with pathogens or toxins).

The standards and requirement for traceability are in large part driven by domestic and foreign government regulation and the downstream power of large retailers. The most relevant and significant legislation on traceability has come from the E.U., United States, and Japan. The E.U. has passed comprehensive regulations covering several foods including beef, fish, and GM products (E.U. 2002, 2004). Effective January 1, 2005, the E.U. began requiring mandatory traceability for the entire food chain; under E.U. regulations, this means that firms must be able to track all suppliers and buyers of food or feed and store the information for inspection. The E.U. regulations also require country of origin identification. In the U.S., the National Animal Identification System (NAIS) and the Public Health Security Bioterrorism Preparedness and Response Act of 2002 are in the initial stages of implementation with final requirements still in development. The goal of these regulations is to protect food supply from tampering and fully trace food products to their source of origin in the event of a safety related incident. The USDA's National Organic Standards Board (NOSB) will also present standards for handling and labeling organic seafood products in the fall of 2005 (The Wave 2005b). Japan's Ministry of Agriculture, Forestry, and Fisheries has implemented mandatory traceability requirements for beef and is updating requirements for other products in the food chain.

While governments have taken a prominent role in mandating traceability, firms have also taken a key role. For example, in 2004, Wal-Mart and Sam's Club in cooperation with several manufacturers (The Gillette Company, HP, Johnson & Johnson, Kimberly-Clark, Kraft Foods, Nestle-Purina PetCare Company, Procter & Gamble, and Unilever) started tracking cases and pallets using electronic product codes (EPC) and radio frequency identification (RFID) technology. Wal-Mart's top 100 suppliers were expected to have RFID tags by January 2005. Similarly, McDonald's had a goal of tracking 10% of its beef before the end of 2004 (Gjerde et al. 2004). Wal-Mart and McDonald's are asking suppliers to go beyond government regulation and use traceability systems to add value and reduce liability.

In evaluating the desirability of implementing traceability and assurance systems, it is important to consider the trade-offs between mandatory and voluntary systems and between public and private implementation. Because traceability and assurance have characteristics of public and private goods, it is difficult to decide who should administer, enforce, or certify such systems—governments or firms. Goldsmith (2004) indicates that for public food safety problems, such as disease outbreaks or bioterrorism, it may be more effective to incentivize public-private partnerships rather than wholly devolve responsibility to private firms. However, in open markets, private industry innovation and investment will usually precede government involvement. For proprietary or private goods, such as, differentiated credence attributes or management information firms have opportunity to secure competitive advantages with market position and/or product price, and thus have private incentive to develop traceability and assurance systems (Farm Foundation 2004). Even so, in certifying traceability and assurance systems or resultant product attributes, information asymmetries or dishonesty could diminish consumer trust in government, third party, or producer certifications (Christensen et al. 2003; Ward, Hunnicutt, and Keith 2004). Certification preferences for safety, quality, organic, sustainability and social responsibility attributes, etc., vary across products, industries, and nations. In lieu of these tradeoffs, it is evident that “one size does not fit all”; flexibility and customization should be considered depending on the traceability capabilities and goals of specific industries (Farm Foundation 2004).

omega-3 fatty acids in salmon cannot be discerned by tasting it. Process attributes refer to the characteristics of the production process. These include country-of-origin, free-range, shade-grown, dolphin-safe, fair trade, earth-friendly, and organic (Golan et al. 2004).
One consequence of mandatory or voluntary traceability is the potential for increased accountability and liability. Indeed, increased liability is a primary concern of many who oppose the implementation of mandatory traceability programs. With movement towards full chain traceability in the E.U. and stricter tracing of products in the U.S., increased depth of traceability will place greater liability on producers (Liddell and Bailey 2001). With this pressure, producers face a dilemma of whether to falsify information or improve production and processing methods. Given the choice, producers may reduce risk and preserve reputation and consumer trust by responsibly providing transparent information (Souza-Monteiro and Caswell 2004).

It can be anticipated that the costs and benefits of traceability and assurance will vary according to size and market or chain position of businesses, and on consumer's willingness-to-pay (WTP) or demand for particular product attributes. Two examples cited by Gjerde et al. (2004) indicate a general willingness to pay for quality attributes and origin. In the first example, Gjerde et al. (2004) report that research by two U.S. retailers, suggested that consumers are willing to pay 12-15% more for source-verified products with identifiable positive attributes. In the second example, Gjerde et al. (2004) report that a recent E.U. survey suggests that 52% of European consumers would be willing to pay more for their meats and vegetables if they were provided with information about the country of origin and assured of a 5-10% increase in product quality. Results from willingness-to-pay experiments conducted for red meats (beef and pork) in the United States, Canada, United Kingdom, and Japan indicate that nontrivial premiums exist for traceability with even higher WTP for specific attributes such as safety and animal treatment (Dickinson and Bailey 2005). However, a significant portion of consumers in these countries also indicated that they would not pay for traceability attributes. A broader observation highlighted by Dickinson and Bailey (2005) is that irrespective of product, results indicate that consumers are willing to pay for environmental and food safety related attributes. Indeed, there is a growing interest, among some consumers, for goods associated with attributes related to the choice of inputs, source of inputs, origin, or production processes employed in manufacturing the good—attributes such as “organic,” “fair labor,” “GMO-free,” “sustainable,” “Made in the U.K.,” etc. Huffman et al. (2003) estimate consumers are willing to pay a 14% premium for food perceived as non-GM.

In the case of salmon, Chern et al. (2002) find that consumers in the United States, Norway, Japan, and Taiwan are willing to pay premiums of up to 50% for non-GM salmon. Nevertheless, their estimate should be viewed with caution because it does not reflect differences in the relationship between marginal willingness-to-pay and the volume of certified non-GM salmon made available to the market. Kaneko and Chern (2003) also found that some U.S. consumers were willing to pay 40.9% and 52.5% above base price to avoid farmed GM-fed salmon and GM salmon. In a survey of U.S. consumers, Wessells and Holland (1998) and Holland and Wessells (1998) suggest that for retail purchases of salmon, consumers prefer farmed to wild, and federally inspected as the means of seafood safety inspection.

The issue of GM-fed and GM salmon draws into focus the concern over sustainability. Some NGOs have decried the use of fish meal derived from capture fisheries and the use of GM-soy in fish feeds. One response has been to promote sustainable fisheries with ecolabels (e.g., MSC). Gudmundsson and Wessells (2000) use bioeconomic modeling to discuss the effectiveness of ecolabels on sustainable fisheries management. They report that ecolabels could increase sustainable fisheries management if there is a price premium for ecolabels and if the label is trusted and unique from other labels. An ecolabeling survey conducted by Wessells, Johnston, and Donath (1999) found that consumers with larger weekly seafood budgets where more likely to choose certified seafood. However, a difference is reported between those with larger budgets and those purchasing a particular species more often. Those purchasing salmon at least once a month, were less likely to choose certified salmon compared to those purchasing salmon less frequently, and those involved with environmental groups were more likely to choose ecolabels. Wessells

11 Salmon fed with genetically modified inputs (e.g., GM soybeans) would be characterized as GM-fed salmon. Gene modification of the fish itself would be characterized as GM salmon.