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**AN ARMINGTON MODEL OF THE
U.S. DEMAND FOR SCALLOPS**

By

Fuzhi Cheng

B.A. Nanjing Audit Institute, 1997

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Resource Economics and Policy)

The Graduate School

The University of Maine

August, 2001

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AN ARMINGTON MODEL OF THE U.S. DEMAND FOR SCALLOPS

By Fuzhi Cheng

Thesis Advisor: Dr. Hsiang-Tai Cheng

An Abstract of the Thesis Presented
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The supply of scallops in the United States in recent years has remained relatively stable and the supply source has shifted noticeably from domestic production to imports, especially from China and Japan, where aquaculture production of scallops has been successful. During the past decade, the market share of imported scallops has increased drastically. The scallop fishery in the U.S. is now facing potential competitions from imports. Continuing efforts to provide information on the effect of increasing imports on the U.S. scallop market is warranted. In addition, the impacts of supply increases on domestic scallop prices, either through wild stock enhancement programs or aquaculture operations, merit further investigation.

An Armington model is developed in this study to assess the demand for scallops in the United States. Time series data for 1980-1998 are used in the estimation of the model. Results indicate that the demand for U.S. domestic scallops is less elastic in the short run than in the long run. The substitution elasticities and the cross-price elasticities

of U.S. scallops with respect to scallop imports are relatively small, indicating that they may be imperfect substitutes. U.S. domestic scallops and scallop imports from other countries may serve different market segments, and there exists little direct competition between them.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

Background

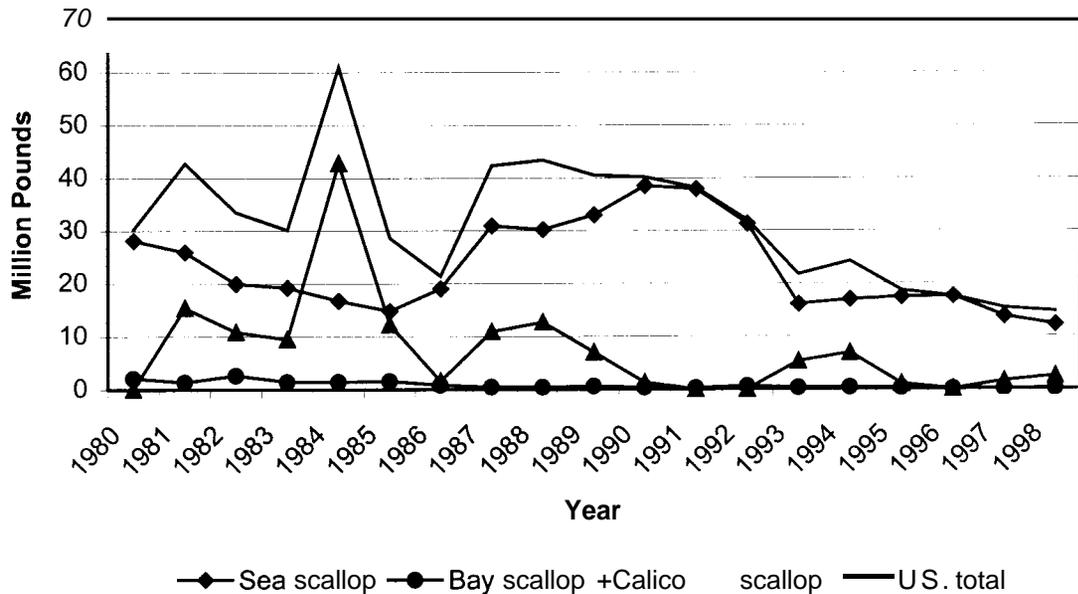
The supply of scallops in the United States in recent years has remained relatively stable, while the supply source has shifted noticeably from domestic production to imports, especially from China and Japan where aquaculture production of scallops has been successful.

Decreasing Production

Almost all of the scallops produced in the United States are from wild catch. Commercial landings of three major species, sea, bay and calico scallops, are shown in Figure 1.1. The production has declined in recent years to a total of 14.6 million pounds in 1998¹. On average, the sea scallop harvest accounted for 89% in volume and 97% in value of the total U.S. scallop production from 1990 to 1998. The calico scallops, harvested in the waters off the southeastern U.S. coast (especially Florida, which produces almost all of the calico scallops), and the bay scallops, found in shallower, inshore, coastal waters in the eastern U.S., accounted for less than 2% in value of total U.S. scallop production from 1990 to 1998. Scallop aquaculture is under development in some States, and the production is insignificant.

¹ Landings data for Alaska and Hawaii were not available at the time of the study and hence were not included in the analysis.

Figure 1. 1: U.S. Scallop Production, 1980-1998



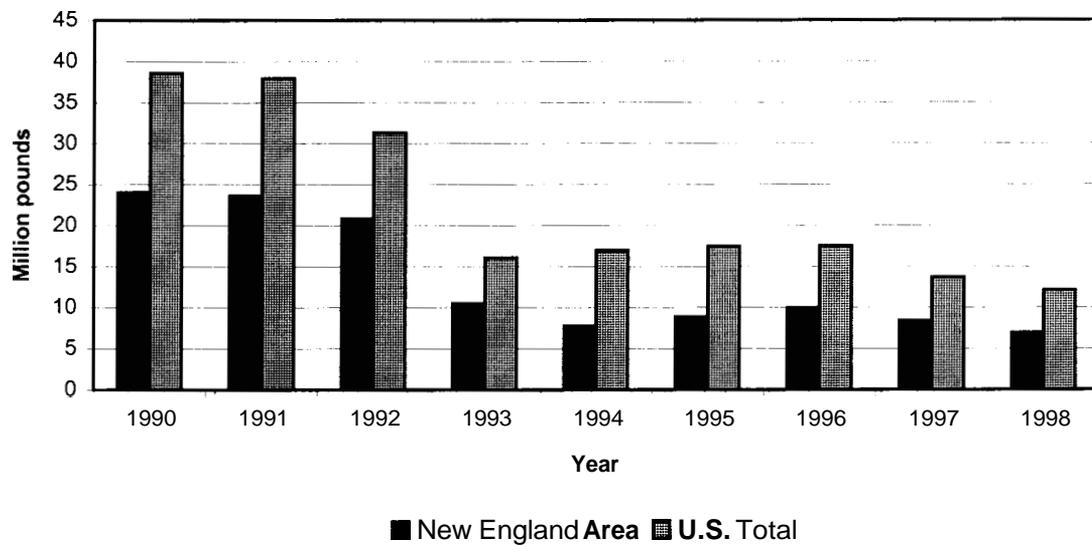
(Source: Fishery Statistics & Economics, NMFS, NOAA, U.S. Department of Commerce, Various years)

Sea scallop has been an important fishery species in the U.S., especially in the New England area, where from 1990 to 1998 approximately 14% of the value of all fish and shellfish landed was attributable to sea scallops. Sea scallops accounted for about 3% of the value of total U.S. fish and shellfish landings during the same period. Along the Atlantic coast from Maine to North Carolina, Massachusetts, New Jersey, Virginia and Maine are the leading sea scallop producing states. Sea scallop production in each of these states and the total U.S. production has decreased significantly in the past decade, and Maine’s landings have trended downward from about 1.3 million pounds in 1990 to 0.8 million pounds in 1998.

In recent years, various factors such as lowered natural abundance, partial closure of fishing grounds, increasing imports from other countries, as well as increased

operating costs of U.S. scallop vessels have resulted in a decline in the market share of the U.S. domestic sea scallops. Since December 1994, half of the U.S. portion of Georges Bank has been closed to scallop harvesting due to the implementation of area closures to protect groundfish stocks. From Figure 1.2, it was found that total New England landings of sea scallop in 1998 were 6.9 million pounds of edible meats, less than one third of the 1990 landings. Although the value of New England sea scallop landings decreased by almost 52.5 million dollars from 1990 to 1998, average ex-vessel price per pound still increased 75 percent over the period as a result of the supply drop. Total U.S. sea scallop landings in 1998, 12 million pounds of edible meats, represented only 31 percent of the record 1990 landings of 38.5 million pounds.

Figure 1. 2: Sea Scallop Landings in the New England Area and the U.S., 1990-1998 (million pounds)

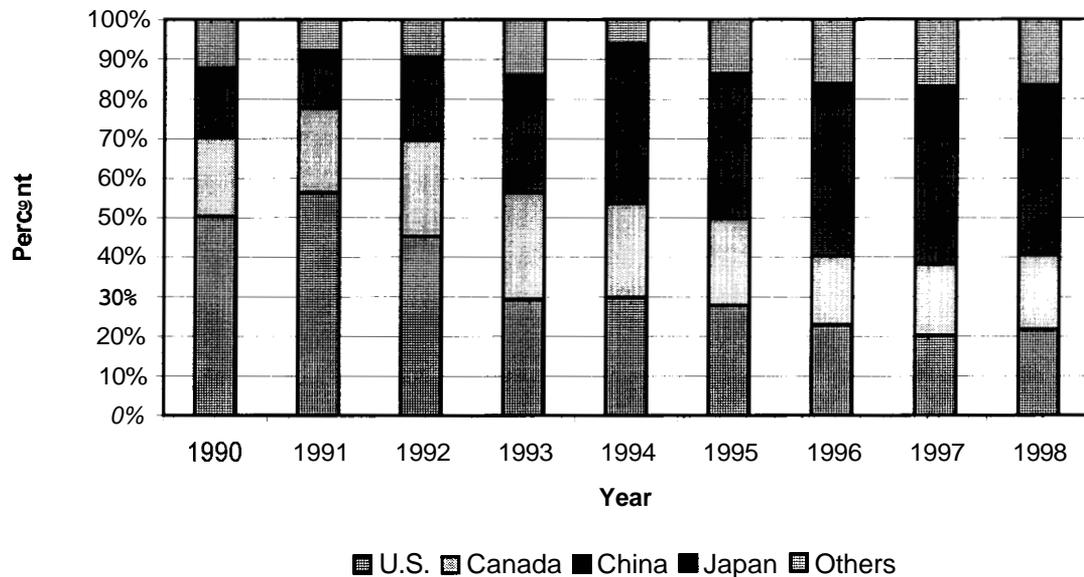


(Source: NMFS, Fisheries Statistics & Economics Division)

Increasing Imports

Scallop imports from different countries continue to increase in recent years, especially the aquacultured scallops from China and Japan. In 1998, scallop imports amounted to 52 million pounds in volume and \$221 million in value. Scallop market shares of U.S. domestic landings and imports from major exporting countries are shown in Figure 1.3. Between 1990 and 1998, the market shares of U.S. domestic landings had declined from 50% to 22%. During the same period, market shares of imports from Canada also decreased, although less drastically, to less than 20%. Both U.S. domestic landings and the imports from Canada are based almost exclusively on the wild catch of sea scallop.

Figure 1.3: U.S., Canada, China and Japan Share of the U.S. Scallop Market, 1990-1998



On the other hand, market shares of imports from China and Japan had increased significantly from 13% and 5% in 1990 to 27% and 16% in 1998, respectively. Since

1998, the Chinese bay scallop aquaculture production had experienced serious environmental and genetic problems, and imports from China had fallen sharply from a high of almost 30 million pounds in 1996 to a little over 18 million pounds in 1998. Nevertheless, imports from China still account for the largest share in the U.S. scallop market. Imports from Japan have continued to increase in recent years. Other imports are primarily from Argentina, Iceland, Peru and Russia.

Objectives

It is argued that the increasing imports of scallops may change the competitive position of the scallop industry in the U.S. The primary goal of this study is to measure the short-run and long-run substitution elasticities between domestic production and imports, as well as own-price and cross-price elasticities of U.S. scallops with respect to scallop imports.

In designing appropriate policies, a knowledge of relevant elasticities is essential. Such information will be useful in determining the substitutability of different scallops in the U.S. market and the impact of scallop imports on domestic price. It will further provide producers, entrepreneurs and policy makers with a basis for making informed decisions about investments to enhance scallop supply.

To meet the objectives, an Armington model for the U.S. scallop market is specified and estimated using the seemingly unrelated regression (SUR). The findings from this study can provide a better understanding of the major forces influencing scallop demand, prices and international trade.

Thesis Organization

Chapter 2 discusses the world and U.S. production and market of scallops. Also included in this chapter is a presentation of the history and management of the U.S. scallop fishery, different scallop species, as well as techniques of scallop aquaculture.

Chapter 3 reviews previous studies on the demand and market analysis of Atlantic sea scallop and salmon, as well as literature on the Armington model.

Chapter 4 presents the development and specification of the Armington model for this analysis. The rationale for the Armington model is also discussed.

Chapter 5 gives the source of data and basic statistics.

The estimation method and estimation results are given in Chapter 6. A summary of the major findings of the research is reported in Chapter 7. Limitations of this study are discussed and recommendations for future efforts are presented.

CHAPTER 2

AN OVERVIEW OF THE WORLD AND U.S. SCALLOP MARKET

World Scallop Production

The total world scallop production is now about 1.5 million tons (live weight) per year, including wild catch and aquaculture production. The major scallop fishing countries and their productions are shown in Table 2.1 and their shares in weight are shown in Figure 2.1.

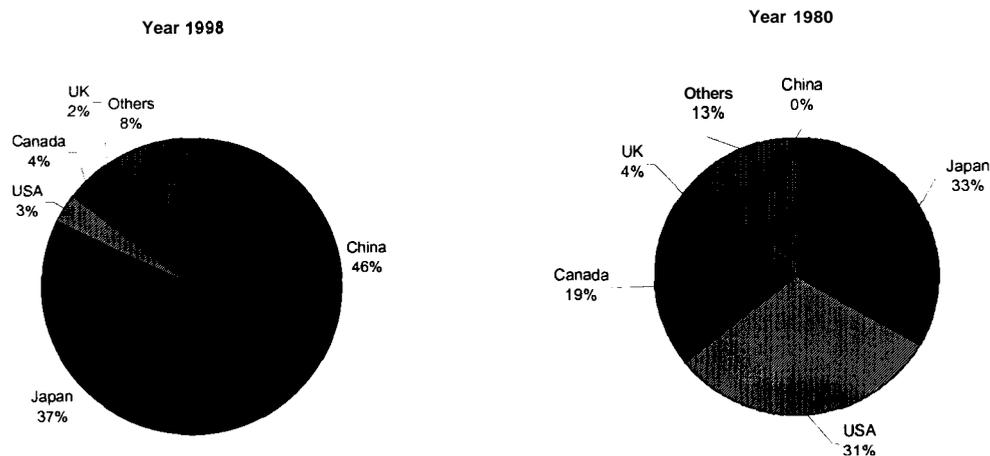
World supply of scallops had increased almost five times during the period of 1980-1997 (Table 2.1). The scallop production decreased 20 per cent from over 1.7 million metric tons in 1997 to less than **1.4** million metric tons in 1998. This is primarily due to the production drop in China, where the scallop industry is now facing serious problems. Chinese scallop farmers are battling environmental problems in northeastern China. In addition to that, there are concerns that the stocks in China may be suffering from a lack of genetic diversity.

Table 2. 1: World Scallop Production by Countries (live weight), 1980-1998 (metric tons)

Year	China	Japan	USA	Canada	UK	Others	Total
1980	207	123,533	114,639	70,473	14,864	46,434	370,150
1981	2,654	150,234	267,868	89,892	17,217	50,252	578,117
1982	1,271	176,371	198,835	65,101	14,102	69,419	525,099
1983	2,002	213,247	185,072	51,289	16,477	90,290	558,377
1984	3,815	209,187	474,386	36,479	15,256	102,223	841,346
1985	8,439	226,786	192,149	47,208	12,613	120,520	607,715
1986	23,701	249,597	97,617	56,900	12,847	96,476	537,138
1987	43,700	297,765	210,778	73,813	16,625	102,248	744,929
1988	122,157	341,618	240,862	77,537	11,810	83,221	877,205
1989	129,605	369,373	184,777	92,188	14,818	60,233	850,994
1990	147,164	421,709	150,321	83,278	14,584	85,615	902,671
1991	188,832	367,911	137,284	79,589	15,188	77,393	866,197
1992	338,080	401,525	116,086	92,078	16,640	97,035	1,061,444
1993	728,411	465,270	65,596	86,929	16,933	102,176	1,465,315
1994	825,673	470,253	140,981	89,449	17,061	99,257	1,642,674
1995	916,514	502,703	76,002	58,567	18,612	82,078	1,654,476
1996	999,649	536,677	64,154	47,628	18,886	90,948	1,757,942
1997	1,001,539	515,250	65,408	53,630	24,406	86,060	1,746,293
1998	629,373	513,936	46,948	55,454	28,368	115,806	1,389,885

(Source: FAO, United Nations, Fishery Statistics, Various years)

Figure 2. 1: World Scallop Production in Weight, 1998 vs. 1980



(Source: FAO, United Nations, Fishery Statistics, Various years)

Despite its production decrease in 1998, China is still the world's top producer of scallop. From 1980 to 1997, China has dramatically increased its production from almost nothing to nearly 60% of the world total production in 1997 and 46% in 1998. Japan was the main scallop producer until 1992 with 400,000 metric tons, but the Chinese scallop production boom in 1993 (up 390,000 metric tons from the previous year) reversed the situation. Japan is now the world's second largest producer of scallop with 37% of the world production in 1998.

The United States is also a major scallop producer in the world, producing 47,000 metric tons in 1998. This, however, was an 100,000 metric ton drop from the 1990 level. American scallop production fluctuated greatly over the period especially from 1983 to 1987, and from 1992 to 1995. Canada and the UK are the other two major scallop producers accounting for 4% and 2% of the world total scallop production. The production of scallops has been more concentrated in the above major countries as the share of "others" decreased from 13% in 1980 to only 8% in 1998 (Figure 2.1).

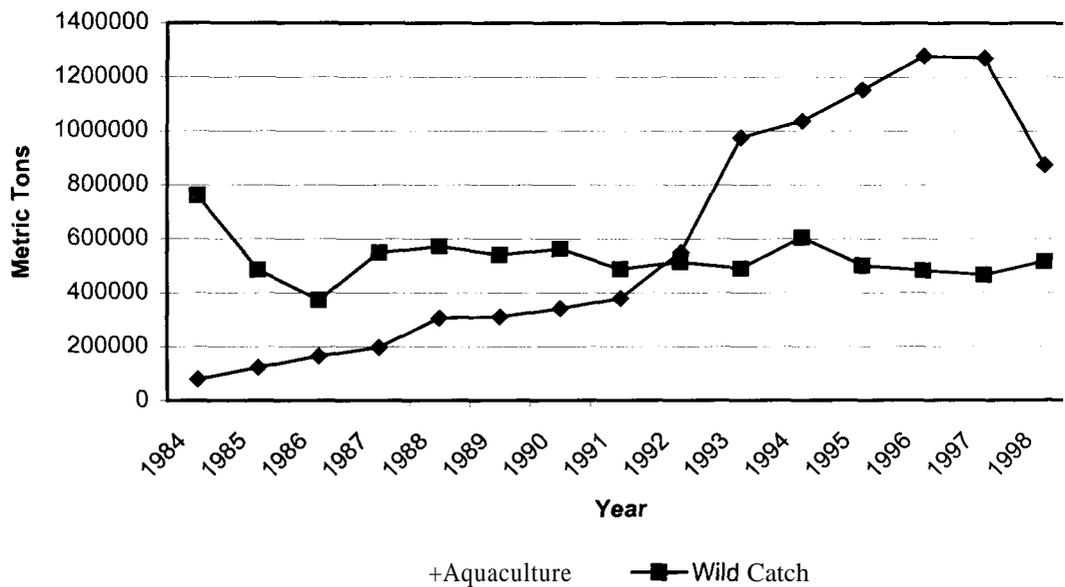
Wild Catch and Aquaculture

Production Trend

The world scallop production consists of two parts: the wild catch and the aquaculture. The wild catch production has not fluctuated very much during 1984 to 1998 (Figure 2.2). However, the aquaculture production has been trending upward during the period of 1984 to 1997, and reached its peak of 1,275,929 metric tons in 1996. There was a dramatic down turn in 1998, and the production decreased from 1,269,063

metric tons in 1997 to 874,225 metric tons in 1998, which is 31% of the total aquaculture production. This downward trend is caused primarily by China where pollution and red tides in the Gulf of Bohai have taken their toll on production since 1997. Figure 2.2 also shows that from 1992, the production from aquaculture exceeded wild catch and became the major part of the output.

Figure 2.2: Scallop Production, Aquaculture vs. Wild Catch, 1984-1998



(Source: FAO, United Nations, Fishery Statistics, Various years)

The major types of aquacultured scallops are *Patinopecten yessoensis* and *Chlamys farreri*, which are primarily produced by China and Japan. About half of the scallop production in Japan is from aquaculture, while almost all in China are from aquaculture. Table 2.2 shows the world's scallop aquaculture production, and the Chinese and Japanese production respectively. For the period from 1984 to 1998, aquacultured scallop from these two countries has stably accounted for over 90% of the

total world scallop aquaculture production. China replaced Japan and became the largest aquacultured scallop producing country in 1992. In 1993, Chinese production increased 2.2 times compared with 1992. And in 1997, the figure reached 1,001,476 metric tons, which is 78.9% of the total world scallop aquaculture production

Table 2.2: Scallop Aquaculture Production: World, China and Japan, 1984-1998 (metric tons)

Year	World Total	China	Percent	Japan	Percent
1984	78,588	3,813	4.85%	73,948	94.10%
1985	122,471	8,312	6.79%	108,509	88.60%
1986	164,274	23,686	14.42%	139,866	85.14%
1987	196,799	43,640	22.17%	152,407	77.44%
1988	305,444	121,911	39.91%	181,929	59.56%
1989	310,862	129,461	41.65%	180,255	57.99%
1990	340,698	147,003	43.15%	192,042	56.37%
1991	379,213	188,698	49.76%	188,834	49.80%
1992	548,854	338,022	61.59%	208,050	37.91%
1993	975,317	728,352	74.68%	241,426	24.75%
1994	1,037,498	825,615	79.58%	199,363	19.22%
1995	1,153,428	916,492	79.46%	227,823	19.75%
1996	1,275,929	999,573	78.34%	265,553	20.81%
1997	1,269,063	1,001,476	78.91%	254,086	20.02%
1998	874,225	629,373	71.99%	226,134	25.87%

(Source: FAO, United Nations, Fishery Statistics, Various years)

Scallop Aquaculture

Scallop aquaculture has developed in Japan over the last 30 years and is concentrated in Hokkaido and on the northern edge of Honshu. Much of the seed comes from Mutsu Bay in northern Honshu Island. The industry is based on natural seed; work on hatchery seed production is continuing, but so far the industry has been able to survive and thrive on natural production of seed.

The success in the production of aquacultured scallop in Japan has stimulated worldwide interest in scallop aquaculture. The Chinese scallop aquaculture industry is

growing very fast, and has followed a different method based on large-scale hatchery fertilization and juvenile rearing until the scallops are large enough to handle and be put into pearl nets or hanging culture. In China, the primary species aquacultured for export has been the New England bay scallop (*Chlamys farreri*), a species known for a relatively short larval phase, fast growth to market size and a two-year life span. Back in the 1980s, U.S. biologists sent a few dozen bay scallops to China and, from that humble beginning, the country now claims an aquaculture industry that produces 300,000 metric tons (meat weight) of bay scallops annually.

The Japanese use a variety of growing methods including the hanging culture, the bottom culture and the enclosed culture.

Hanging culture. As the name suggests, this is a form of culture which is carried out by suspending scallops in the water from either a line or a raft. Many new techniques are being developed to increase growth rates and reduce labor and capital costs.

Different hanging methods are used, which includes pearl nets, lantern nets, ear hanging, rope hanging, pocket nets, hog ringing, and plastic trays (Hardy, 1991). The hanging technique using nets is expensive as the scallops must be culled and thinned as they grow and the mesh which covers the nets gets clogged with algae, seaweeds, mussels, sponges and other marine organisms. Alternatively, some scallops including those thinned from the pearl or lantern nets, are grown by hanging them individually from ropes, or using special hangars placed through holes drilled in the "ear" of the shell. Sometimes, farms will have one of these suspended culture operations directly above the bottom culture farm, using all parts of the water column.

Bottom culture. Some scallops are placed directly on suitable seabed areas, where they grow and are later dredged for harvest. It is referred to as bottom culture. This category of cultivation covers methods which use the sea bed either as a support for equipment or as a growing area itself. Many large scale farmers are looking towards this type, and in Japan it is a recognized and established method of farming. As is discussed in hanging culture techniques, one of the biggest problems is the cost of buoyancy when a large proportion of it is used to support marine growth on the equipment itself. By using the bottom as a support the need for buoyancy can be eliminated.

Enclosed culture. As the seabed leases become scarcer, scallop aquaculture will move towards either floating sites in the form of barges or shore-based man made ponds. Both will need a supply of clean sea water to be pumped to the installation. Enclosed culture has the advantage of giving more protection against the weather and allowing work to be carried out year-round. Another advantage could lie in the ability to introduce artificial foods in the form of laboratory grown algae to speed up growth. Growth and mortality rates will vary with the type of culture undertaken, and although some rough comparisons can be made with scallop culture in the open sea much will depend on local conditions and general husbandry techniques.

Scallop farming has not been realized on any significant scale elsewhere in the world. The Japanese have helped setting up pilot projects in Alaska and New Zealand. Over the past five years there has been a flurry of interest in the potential for culturing bay scallops and experiments in New York have been reasonably successful. There are other activities, mainly research, in the Canadian Maritime Provinces, Maine, Vermont, Massachusetts and Virginia. Aquaculture technology and methods have also been

successfully adapted to the sea scallop in northwest Atlantic waters. Several aquaculturists in Canada and some in the U.S. are producing on a commercial basis. But there is considerable resistance to aquaculture. Opposition is based on concerns over loss of access to public waters (e.g., lobster fishermen), and also to aesthetic concerns (cottage owners). These concerns tend to be unfounded, but nonetheless persist (Maine DMR, 2001).

A small market for whole scallops exists in the U.S. Northeast. Producers in Massachusetts, Nova Scotia and Newfoundland currently supply this market. It represents a possible opportunity for prospective aquaculture producers because the demand can be met with 2-year old scallops (rather than a minimum of **3-4** years old if sold for the meat only). But the need for PSP (Paralytic Shellfish Poisoning) testing and short shelf life of the product can present significant obstacles.

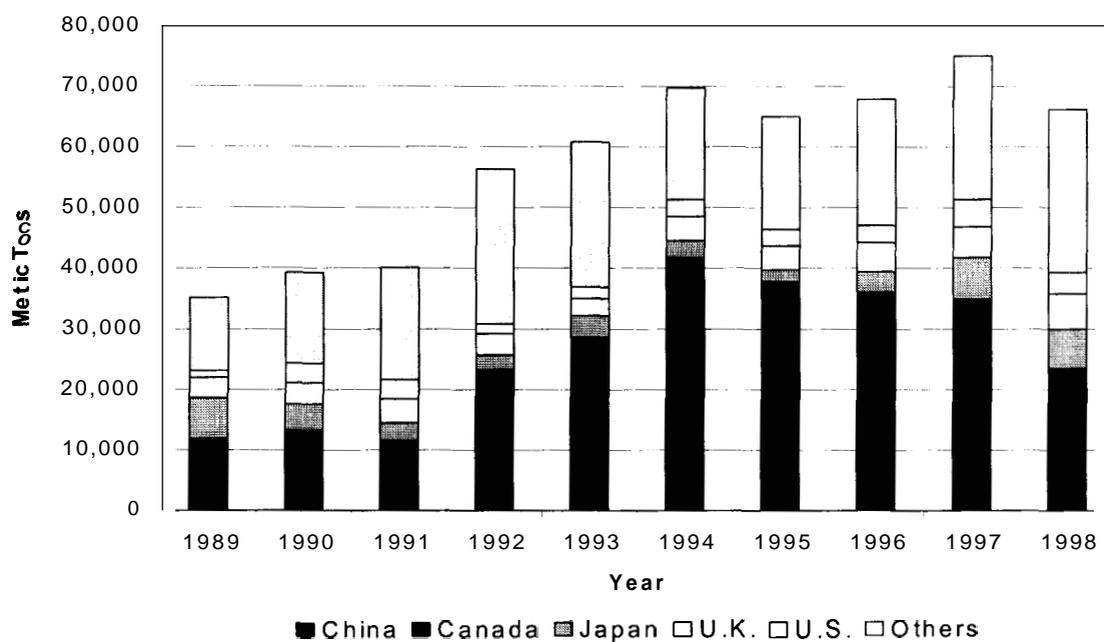
Generally, scallop farming may offer some hopes of supply security in the future, although U.S. is still a long way from having a significant and viable scallop aquaculture industry.

The World Market of Scallops

Total wild and aquacultured scallop exports almost doubled during the period included between 1989 and 1998, going from 35,000 metric tons of scallop exported worth US\$ 278 million to 66,000 metric tons worth US\$ 519 million. The trend setter is China, whose scallop exports experienced an extraordinary growth over the period. China was not a significant scallop exporter till 1989. In that year, it exported 2,160

metric tons of scallops. The figure quickly went up to its peak of nearly 32,000 metric tons in 1994. In the years that followed, the scallop exports from China were decreasing to a little over 17,000 metric tons in 1998. However, it was still the largest scallop exporter, accounting for **26%** of world total scallop exports in 1998. Canada, Japan, U.K. and U.S. are the remaining major exporters of scallops with much less export amount than China. Figure 2.3 shows the scallop exports by major exporting countries from 1989 to 1998.

Figure 2.3: Scallop Exports By Major Exporting Countries, 1989-1998 (metric tons)

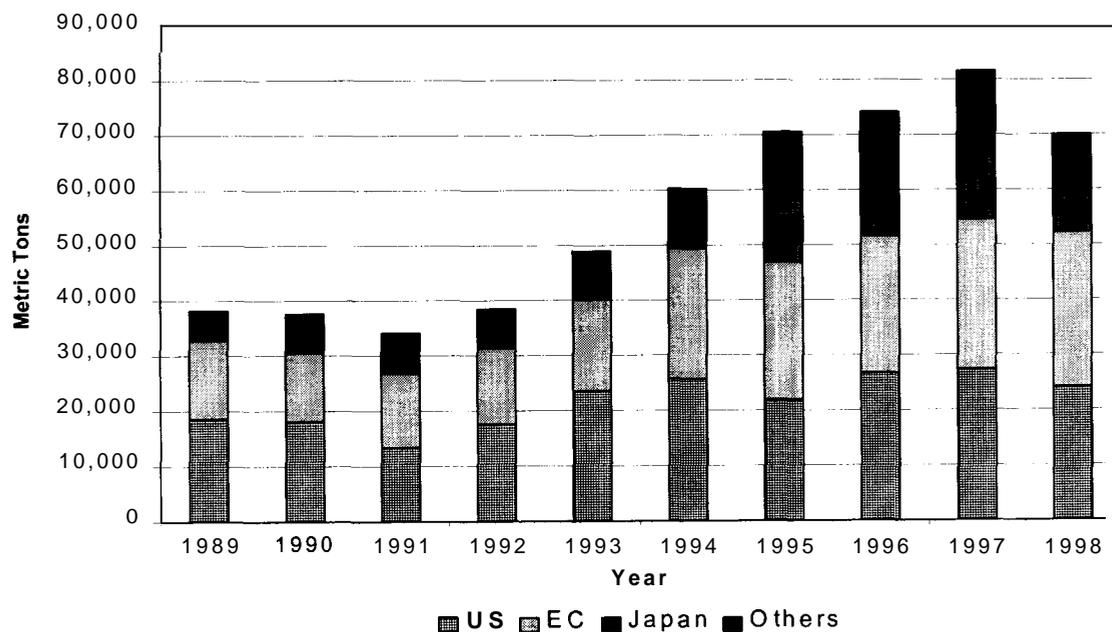


(Source: FAO, United Nations, Fishery Statistics, Various years)

Total wild and aquacultured scallop imports have expanded between 1989 and 1998. In 1989, the amount of scallop imported was 38,000 metric tons and the value 305 million dollars. A peak in scallop imports occurred in 1997 at nearly 82,000 metric tons and 620 million dollars. There are three main import markets for scallop: the European

Community (EC), the United States, and Japan. International trade in scallop focuses on these three major markets. Overall, except a down turn in 1998, all main scallop importers show a positive trend over the period contributing in different proportions to the global growth in imports of scallops both wild or aquacultured. Figure 2.4 shows the scallop imports by major importing countries from 1989 to 1998.

Figure 2. 4: Scallop Imports By Major Importing Regions, 1989-1998 (metric tons)

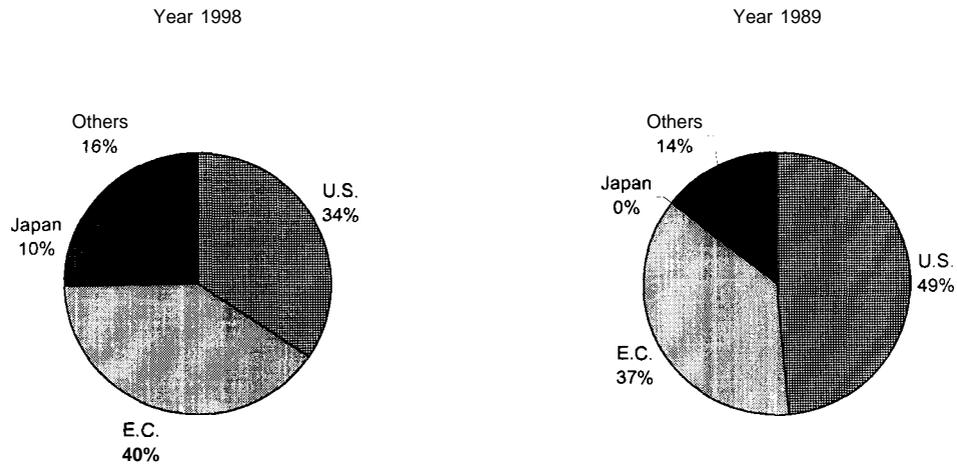


(Source: FAO, United Nations, Fishery Statistics, Various years)

The change of the world scallop import market share from 1990 to 1998 is shown in Figure 2.5. The U.S. was the largest importer as a single country but its share in the world import market had decreased from 49% in 1989 to 34% in 1998. The E.C. market accounted for 40% of the world imports in 1998. The major importing countries within the E.C. market are France, Spain and Belgium. Japan is a major producer and exporter of aquacultured scallop, and meanwhile, it is emerging in the scallop import market. Its

share of scallop imports in the world market has increased from nothing in 1980 to 10% in 1998.

Figure 2.5: World Scallop Imports Market Share by Regions, 1980 vs. 1998



(Source: FAO, United Nations, Fishery Statistics, Various years)

Among the major producers of scallops, U.S. and Japan consume most of their production in domestic market. For Chinese scallop farmers, about half of the total exports were sold to the U.S. market while the other half were sold in other foreign markets in 1998. The location advantage to the U.S. market helped Canada to sell almost 80% of their exports to the U.S. market in 1998. In the same year, 75% of the Japanese exports went to the U.S. market.

U.S. Scallop Production

History and Management

Scallops have been harvested commercially in the United States along the continental shelf from the Gulf of Maine to Cape Hatteras, North Carolina. The U.S. commercial fishing for scallops dates back to 1887, when a quarter million pounds of meats were harvested inshore in the Gulf of Maine by two-man crew sailing crafts outfitted with 3-foot wide oyster dredges (Serchuck *et al.*, 1979). The fishery expanded during the next six decades due to technological innovations in power and electronics, improved gear designs, and the discovery of large offshore beds in the Mid-Atlantic in the 1920s and on Georges Bank in the 1930s. By the 1990s, offshore sea scallop vessels were powered by large (over 800 average horsepower) diesel engines, and they were equipped with inputs that increased technical efficiency for open access fishing, including two dredges up to 15 feet wide each, up to 14 crew members who shucked catches on-board, and state-of-the-art electronics for navigation and communication (Edward, 2000). The offshore Canadian scallop fleet was developed in the 1950s and operated primarily on the scallop grounds of eastern Georges Bank.

The U.S. Fishing Conservation and Management Act (FCMA) of 1976 created an exclusive U.S. fishing zone to 200 miles off the U.S. coast. Included in this zone is all of Georges Bank (although the eastern part is a disputed area since it also falls within 200 miles of Canada), and all of the Middle Atlantic banks where scallops are harvested. A boundary dispute between U.S. and Canada flared in 1977 and was later settled by the International Court's decision in October 1984.

After the implementation of the Fishing Conservation and Management Act in 1976, open access prevailed for 16 years in the U.S. sea scallop fishery. During this period the number of full-time vessels increased eightfold and aggregate fishing effort increased 500 percent (NEFMC, 1993). Landings and dockside revenues fluctuated with sea scallop biomass levels as well as effort, ranging from nearly 15 million pounds and \$105 million in 1985 to nearly 38 million pounds and about \$180 million in 1990 and 1991. The New England Fishery Management Council's (NEFMC) Sea Scallop Fishery Management Plan (Sea Scallop Plan), which was implemented in 1982, failed to rebuild resource biomass. Consequently, the NEFMC introduced limited entry, non-transferable individual vessel effort quotas (IVEQs), and several regulations intended to control fishing inputs, including a 7-person crew limit, in 1994 and in subsequent framework adjustment actions. Amendment 4 to the Sea Scallop Plan qualified over 400 vessels for limited entry, but the net effect of disqualifications and appeals reduced the total to 357. IVEQs were scheduled for nearly a 50 percent reduction over seven years compared to recent average levels when biomass was relatively high, including to 120 days-at-sea in the year 2000 for the full-time category.

In December, 1994, an Emergency Action taken by the Secretary of Commerce and adopted by the NEFMC closed nearly 5000 square-nautical miles of the Northeast Continental Shelf to all gear capable of catching groundfish in order to rebuild depleted stocks of Atlantic cod, haddock, and yellowtail flounder (NEFMC 1996). Requests by the sea scallop fishery to regain access to Closed Areas I and II on Georges Bank and to the Nantucket Lightship Closed Area have been hindered by several groups, including trawler and gillnet fishermen concerned about groundfish bycatch, lobster fishermen who

had been limited in these areas by conflicts with mobile gear, and environmental organizations who single out dredge as well as trawl gear for damaging biogenic and geologic sediment structure.

At its meeting in December, 1997, the NEFMC rejected marketable IVEQs and permit “stacking” on fewer vessels, including companies that own more than one vessel. In addition, in April, 1998, the NEFMC adopted the Commerce Secretary’s Interim Action closure of two areas in the Mid-Atlantic, Hudson Canyon and Virginia Beach Closed Areas, to protect small scallops (NMFS 1998). Together, the three groundfish and two scallop closed areas encompassed one-third of the sea scallop resource area and, in 1998, 85 percent of the harvestable biomass (Edwards, 2000).

Major Species

Scallops are bivalve molluscs. There are over 350 species of scallops in the family *Pectinidae* worldwide. Most of the commercial harvest comes from three species: the Chinese scallop, *Chlamys farreri*, the sea scallop from the Atlantic coast of Canada and the United States, *Placopecten Magellanicus*, and the Japanese scallop, *Pecten yessoensis*. Table 2.3 presents the major scallop species landed in the United States.

Table 2.3: Major Scallop Species Landed in the U.S.

Sea scallop	<i>Placopecten magellanicus</i>
Bay scallop	<i>Argopecten irradians</i>
Calico scallop	<i>Argopecten gibbus</i>
Weathervane scallop	<i>Patinopecten caurinus</i>
Pink scallop	<i>Chlamys rubida</i>
Spiny scallop	<i>Chlamys hastate</i>

(Source: Dore, 1991 “Shellfish: A Guide to Oysters, Mussels, Scallops, Clams and Similar Products for the Commercial User”)

Scallops have a life cycle very similar to that of other filter feeding molluscs. Eggs and sperm mix in the water, and the hatched larvae metamorphose into scallops within a few weeks. Unlike oyster, most scallops do not cement themselves to a single point for life. They attach themselves when they first metamorphose using byssus threads like mussels do. However, after they have fully developed, scallops abandon their attachment and remain as free swimming creatures. Although they are able to move reasonable distances by pumping water through their siphons, scallops only seem to move when disturbed or to escape predators.

Like oysters, scallops are filter feeders, extracting the plankton and bacteria from the water which they pump through their digestive systems. Like other filter feeding molluscs, they are likely to concentrate PSP (Paralytic Shellfish Poisoning) toxins in their viscera, but not in the adductor muscles which are consumed in the U.S.

Landings of sea, bay and calico scallops in the U.S. are presented in Table 2.4, and the following is a brief description of the three scallop species respectively.

Sea scallops (placopecten magellanicus) have brownish shells with narrow ribs and symmetrical ears and grow to a maximum of eight or nine inches in diameter. The upper valve is deeply curved while the lower valve is nearly flat. It has white to creamy meat which sometimes has pinkish or brown marks. The meat can reach almost two inches across in the largest specimens and 20/30 count to the pound. The sea scallop is an important fishery product and it supports the largest scallop fishery in the U.S. (Table 2.4).

Sea scallops are found in western North Atlantic continental shelf waters from Newfoundland to North Carolina. Commercial concentrations generally exist between 40

and 100m (22 to 55 fathoms) in waters cooler than 20 °C (68 °F). Principal U.S. commercial fisheries are conducted in inshore waters of the Gulf of Maine, on Georges Bank, and in the Mid-Atlantic offshore region. Recreational fishing is insignificant, occurring primarily in Maine where shallow-water scallop beds most commonly occur.

Table 2. 4: U.S. Landings of Scallops, 1980-1998 (million pounds and million dollars)

Year	Sea Scallop		Bay Scallop		Calico Scallop		U.S. Total	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value
1980	28.16	108.60	2.13	9.65	0.0004	0.001	30.29	118.25
1981	25.95	105.87	1.42	6.24	15.42	14.58	42.79	126.69
1982	19.94	74.59	2.67	11.15	10.88	11.32	33.49	97.05
1983	19.23	108.27	1.47	8.06	9.45	11.73	30.16	128.06
1984	16.77	92.72	1.48	6.74	42.74	23.25	60.99	122.70
1985	14.79	71.27	1.57	7.72	12.28	11.45	28.64	90.44
1986	19.02	93.78	0.84	4.73	1.57	2.86	21.43	101.37
1987	30.91	128.31	0.50	3.33	10.93	11.00	42.34	142.64
1988	30.21	127.02	0.45	3.25	12.71	9.45	43.37	139.72
1989	33.01	129.98	0.58	3.31	6.95	7.91	40.54	141.20
1990	38.54	149.01	0.38	2.15	1.26	2.24	40.19	153.40
1991	37.93	153.72	0.25	1.58	N/A	N/A	38.18	155.30
1992	31.32	153.40	0.62	4.33	N/A	N/A	31.94	157.72
1993	16.08	97.12	0.32	2.05	5.31	3.66	21.71	102.83
1994	16.95	84.76	0.35	1.90	6.88	4.07	24.18	90.73
1995	17.43	90.02	0.24	0.67	0.95	0.80	18.61	91.50
1996	17.53	98.89	0.03	0.12	N/A	N/A	17.56	99.00
1997	13.68	89.79	0.07	0.28	1.55	1.49	15.30	91.56
1998	12.13	75.12	0.10	0.31	2.40	2.07	14.63	77.50

(Source: Fishery Statistics & Economics, NMFS, NOAA, U.S. Department of Commerce, Various years)

Sea scallops are harvested with dredges on gravel, sand, or sand-mud bottoms.

Some trawl fisherman harvest scallops on a part-time basis. This necessitates removing the otter trawl nets and bringing aboard the equipment needed for scallop dredging.

Scallops cannot close their shells tightly and die soon after being taken from the water.

Because of their perishability scallops are shucked aboard ship as soon as they are caught, and the meats are iced.

Bay scallops (Argopecten irradians), grow to a little less than four inches in diameter and lives for less than two years, spawning only once. This small scallop is found naturally in a range from Cape Cod, Massachusetts to North Carolina. Commercial fishing is limited, and the resource is protected by daily bag limits and closed seasons. Total catch of bay scallops seldom amounts to more than 0.5 million pounds in the recent decade (Table 2.4).

Bay scallop season generally opens in the fall and continues through the winter until the allowed catch has been taken. Like sea scallops, the natural abundance of bay scallops is decreasing due to overfishing, loss of eelgrass beds and eutrophication. Harmful algal blooms² have also taken a toll. The species has a short life cycle and spawns only once, making populations and therefore harvests fluctuate with a declining trend.

Bay scallops are usually hand picked or hand dredged and then opened on the shore. The catch is sold fresh, and commands high prices. Some distributors claim to freeze them during the season to ensure year-round availability. The bay scallops count between about 50 and 100 per pound. Most count about 70/90. The meats are creamy to pinkish in color and taste particularly sweet. They can be eaten raw or cooked lightly. Bays are generally regarded as the best tasting of all scallops (Dore, 1991).

Calico scallops, (Argopecten gibbus), are another kind of small scallops, about the same size as the bay scallops. Their range in the U.S. is from the Carolinas to

² The so-called “brown tide” (*Aureococcus anophagefferens*), which does not harm humans, inhibits feeding in shellfish and is especially noxious to bay scallops.

Florida, where they are found on both the Atlantic and Gulf of Mexico. The species is also found along the coasts of Central and South America as far south as Brazil. Calico scallops usually grow to less than three inches. The meats are rather smaller and browner than those of bay scallops. Calico meats run from about 100 to as small as 300 to the pound. The bulk of the harvest is usually 150/200 count.

The calico scallop was identified as a potential commercial species in the early 1960's, but large scale fishing off Cape Canaveral did not begin until the introduction of mechanical processing in 1980. As Table 2.4 indicates, calico scallop production levels fluctuated greatly from year to year. In December 1988, fisherman began to report finding increased numbers of dead and dying calico scallops. Mortality became evident by early January of 1989, and the population had decreased to the point that no scallops could be found by either commercial or research trawlers. Population levels became large enough for commercial fishing to resume by the beginning of 1990. But in January, 1991 mortality was again observed throughout the calico scallop population. By the end of February 1991 the calico scallop population had been reduced to minimal levels and commercial fishing was suspended till 1993.

U.S. Scallop Market

Composition of Supply³

The U.S. scallop market on the supply side consists of domestic production and many exporters. As Table 2.5 shows, the total supply of scallops in the U.S. market fluctuated between 50 to 90 million pounds with an average of 71 million pounds per

³ The U.S. scallop supply discussed in this section is new scallops excluding inventories.

year, and its composition in terms of domestic landings versus imports has changed during the period 1980-1998.

With declining stocks and area closures in the mid-1990s, domestic landings dropped to less than half their historic levels by the late 1990s. Its market share declined in the recent decade from 50.2% in 1990 to 21.8% in 1998. During the same period, imports rose to make up much of the difference, and in the late 1990s accounted for 80% of total U.S. supply. The share of Canadian imports in total supply remained around 20 percent, while the share of Chinese imports has increased dramatically from almost nothing (0%) in 1980 to a record high of 38.9% in 1996, and 27.2% in 1998. The proportion of annual imports in total supply from countries other than Canada and China increased from 11.0% in 1980 to 32.2% in 1998. These countries include Mexico, Peru, Iceland, and particularly Japan, which in 1998 supplied 10.5 million pounds of edible meats and accounted for 15.7% of total U.S. scallop supply.

Fresh and frozen scallops are imported in huge quantities from the Atlantic provinces of Canada. About 90 percent of Canadian production comes from Nova Scotia, and as much as 80 per cent of total Canadian production is sold in the U.S. Imports from Canada fluctuated between 10 and 20 million pounds annually. As a supplier to the U.S. Northeast market, Canada may be viewed more as an extension of domestic U.S. supply than an exporter. Within limits, landings and supply trend tend to parallel the U.S. experience. This is because Canada is close to and highly dependent on the U.S. market, and also because it harvests the same species (sea scallop) from adjacent fishing grounds (Georges Bank and the southern Scotian Shelf).

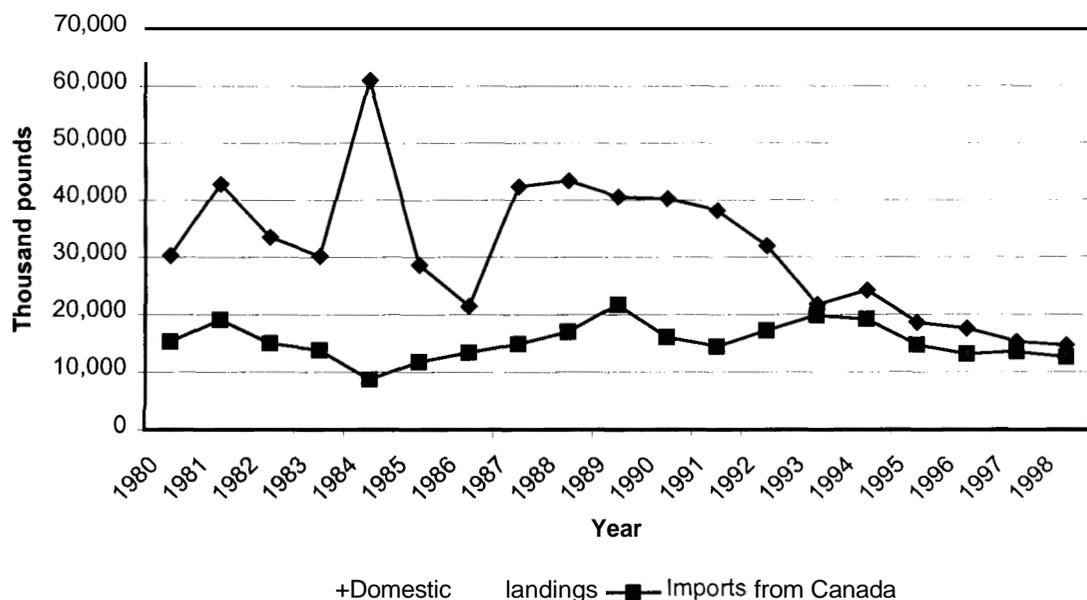
Table 2. 1: U.S. Scallop Landings, Imports and Total Supply, 1980-1998 (thousand pounds)

Year	Domestic Landings	Imports From Canada	Imports From China	Imports From Japan	Imports From Others	Total Imports	Total Supply	Domestic Landings	Percentage Shares of			
									Imports From Canada	Imports From China	Imports From China	Imports From Others
1980	30,288	15,279	1	57	5,548	20,885	51,173	59.19%	29.86%	0.00%	0.11%	10.84%
1981	42,789	19,109	1	644	6,473	26,227	69,015	62.00%	27.69%	0.00%	0.93%	9.38%
1982	33,491	14,984	3	842	5,031	20,860	54,351	61.62%	27.57%	0.01%	1.55%	9.26%
1983	30,163	13,818	52	7,427	12,983	34,280	64,443	46.81%	21.44%	0.08%	11.53%	20.15%
984	60,989	8,688	4	7,201	11,377	27,270	88,259	69.10%	9.84%	0.00%	8.16%	12.89%
985	28,637	11,807	11	10,884	19,333	42,035	70,673	40.52%	16.71%	0.02%	15.40%	27.36%
986	21,428	13,417	112	11,646	22,741	47,916	69,344	30.90%	19.35%	0.16%	16.79%	32.80%
987	42,344	14,899	963	8,417	9,655	33,934	76,278	55.51%	19.53%	1.26%	11.03%	12.66%
988	43,370	17,022	114	3,728	11,175	32,039	75,409	57.51%	22.57%	0.15%	4.94%	14.82%
989	40,538	21,683	4,227	3,734	11,230	40,874	81,413	49.79%	26.63%	5.19%	4.59%	13.79%
1990	40,186	16,053	10,247	3,884	9,655	39,839	80,025	50.22%	20.06%	12.80%	4.85%	12.06%
1991	38,177	14,480	6,944	2,727	5,377	29,528	67,705	56.39%	21.39%	10.26%	4.03%	7.94%
1992	31,938	17,222	11,260	3,552	6,648	38,682	70,619	45.23%	24.39%	15.94%	5.03%	9.41%
1993	21,709	19,824	16,030	5,865	10,254	51,973	73,682	29.46%	26.90%	21.76%	7.96%	13.92%
1994	24,175	19,159	28,883	3,695	4,939	56,676	80,852	29.90%	23.70%	35.72%	4.57%	6.11%
1995	18,609	14,705	22,325	2,116	9,185	48,331	66,940	27.80%	21.97%	33.35%	3.16%	13.72%
1996	17,558	13,147	29,679	3,563	12,297	58,686	76,244	23.03%	17.24%	38.93%	4.67%	16.13%
1997	15,296	13,497	23,967	9,873	12,809	60,146	75,442	20.28%	17.89%	31.77%	13.09%	16.98%
1998	14,628	12,572	18,248	10,548	11,077	52,445	67,073	21.81%	18.74%	27.21%	15.73%	16.51%

(Source: Fisheries of the United States, Various years.)

Imports from Canada rose in the 1980s, as Canadian landings increased. Poor year classes led to lower landings in the late 1990s, resulting in reduced scallop imports into the U.S. With the management approach taken in Canada (a combination of conservative allowable catches, meat size restrictions and individual quotas), catches and hence import levels to the U.S., can be expected to be resource-driven, and hence, imports from Canada are unlikely to change substantially from year to year. This said, in the event of particularly strong or *weak* year class, supply could change abruptly. Figure 2.6 shows the movement of domestic landings compared with Canadian imports.

Figure 2. 6: Domestic Landings vs. Canadian Imports, 1980-1998

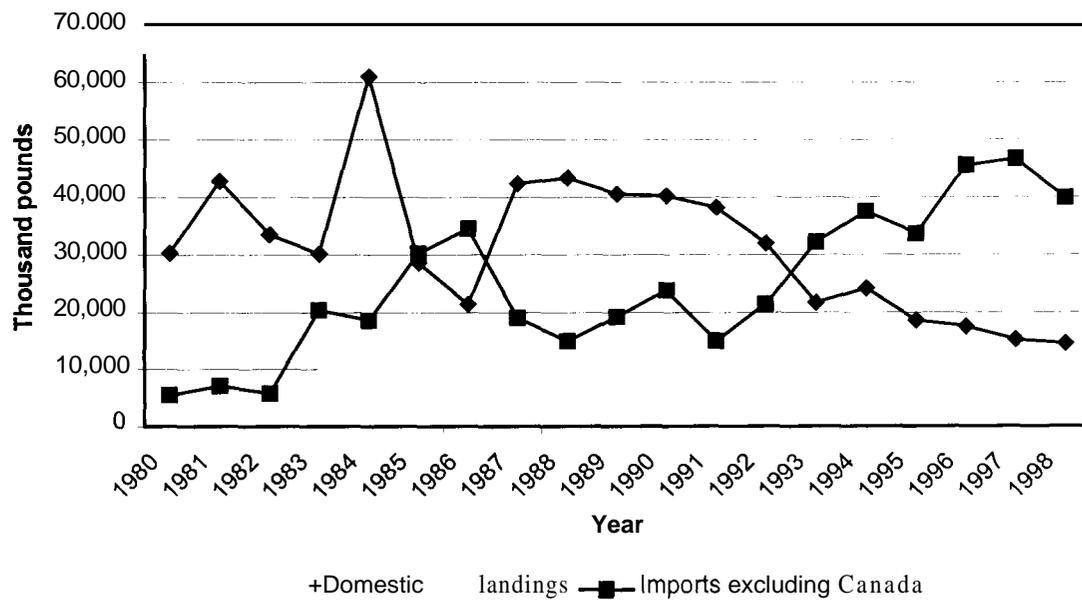


(Source: Fisheries of the United States, Various years)

Imports from countries other than Canada have increased significantly after 1991 from about 5.6 million pounds to 46.6 million pounds in 1997 and 39.9 million pounds in 1998, as is shown in Figure 2.7. In this period the domestic landings declined from 38.2 million pounds in 1991 to less than 20 million pounds in the next 4 years, and to about 15

million pounds in 1998. The reverse happened during the period 1986-1988, when the imports from these countries declined as domestic landings increased tremendously from about 21 million pounds in 1986 to 43 million pounds in 1988. Therefore, the imports from other countries clearly exhibit an inverse relation to the domestic landings as they are substituted for the domestic product during the periods when the demand could not be met with US landings and/or Canadian imports. It is worth noting that China, Japan and Argentina are the major exporters, taking over from Iceland, the major exporter in the 1980s.

Figure 2. 7: Domestic Landings vs. Imports excluding Canadian, 1980-1998



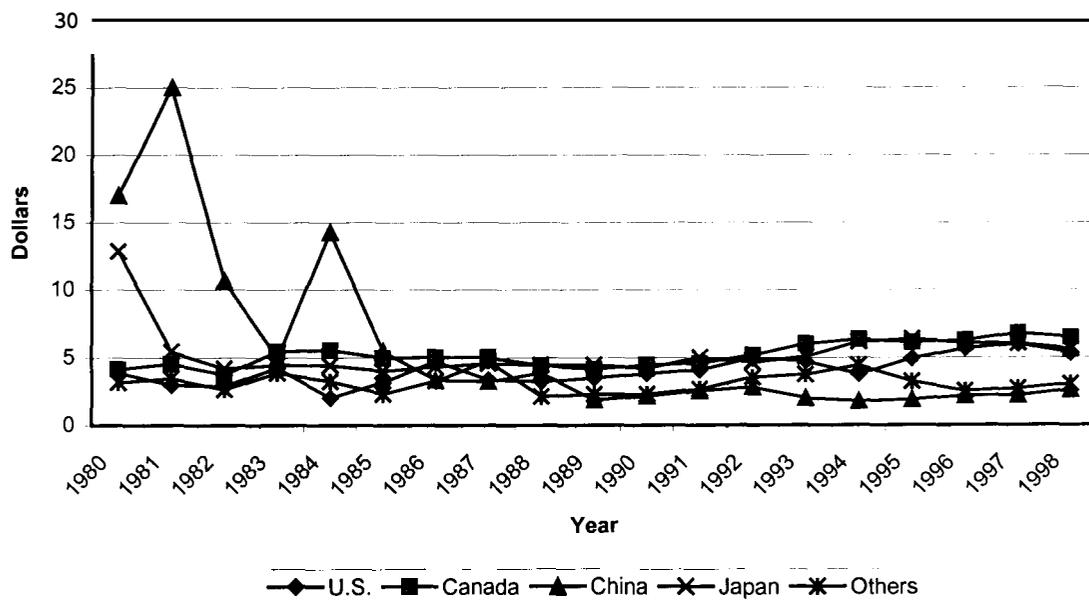
(Source: Fisheries of the United States, Various years)

Product Characteristics

Product characteristics such as size, form (i.e. fresh, frozen), and condition (dry or wet) determine market position and value of scallops from different sources. Almost all product is sold as scallop meat (the adductor muscle), though there is a growing market for whole scallops (Maine DMR, 2001).

Size is a primary determinant of value. By size, scallops in the U.S. market may be divided into two broad categories, large and small. U.S. domestic landings of sea scallops, and imports from Canada and Japan fall into the large category while imports from other countries fall into the small category. Sea scallops from U.S. and Canada, and scallops from Japan can be substitutes by virtue of size, and it is reflected by fairly close relative prices (Figure 2.8).

Figure 2. 8: Price Differentials of Scallops from Different Sources, 1980-1998



(Source: Fisheries of the United States, Various years)

Fresh scallops tend to be more highly valued than frozen. The proportion of production entering the market in fresh form varies from day to day depending on demand and supply, with the relative prices of fresh and frozen product the signal to processors to adjust product form. Since 1993, Canadian scallop processors have shipped 65%-75% of their product in fresh form. The amount peaked in 1994 at over 14 million pounds, and then dropped to the 10 million-pound range annually. Scallop imports from other countries enter the U.S. market mostly in frozen or prepared forms.

The highest quality scallops are dry, i.e., shucked and washed, but not otherwise processed or treated in any way. They command prices as much as \$2.00 per pound higher than the equivalent wet size (Maine DMR, 2001). Scallops referred to as “wet” are shucked, washed and treated with STP – sodium tripolyphosphate – ostensibly to increase shelf life. But STP also allows the scallop to retain moisture when soaked in fresh water, so it serves a second purpose – to increase weight and add value. Recent study suggests that the practice of soaking is more common with imported product. Imported frozen scallops are thawed, soaked in a solution of STP and water, and then refrozen for sale. The U.S. market discounts the value of wet scallops, as is another reason for the price differentials between domestic products and imports (Figure 2.8).

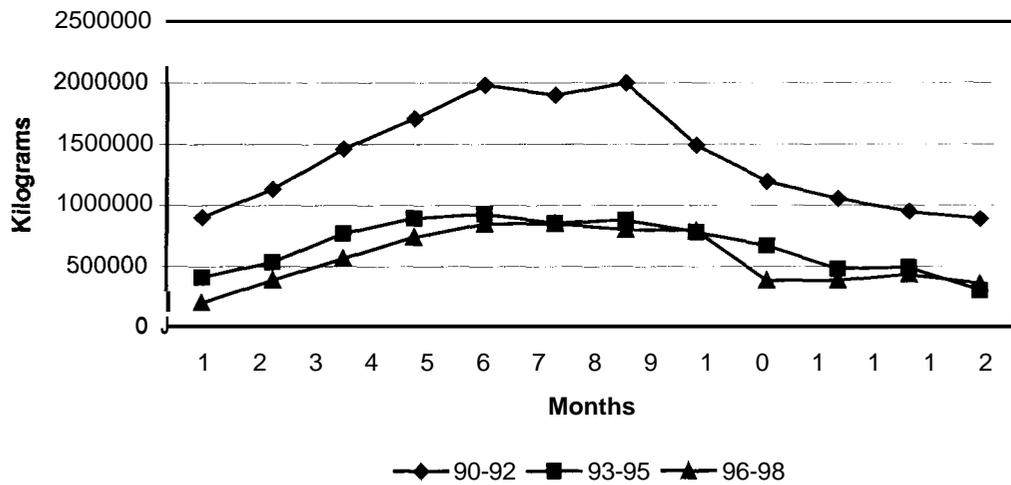
Seasonal Patterns of Supply

Figure 2.9 present the monthly movement (three-year average from 1990 through 1998) of U.S. domestic scallop landings and imports from Canada, China, and Japan. The U.S. scallop landings and imports from Canada exhibit strong seasonality in accordance with natural growth of scallops. Scallop productions of these two countries

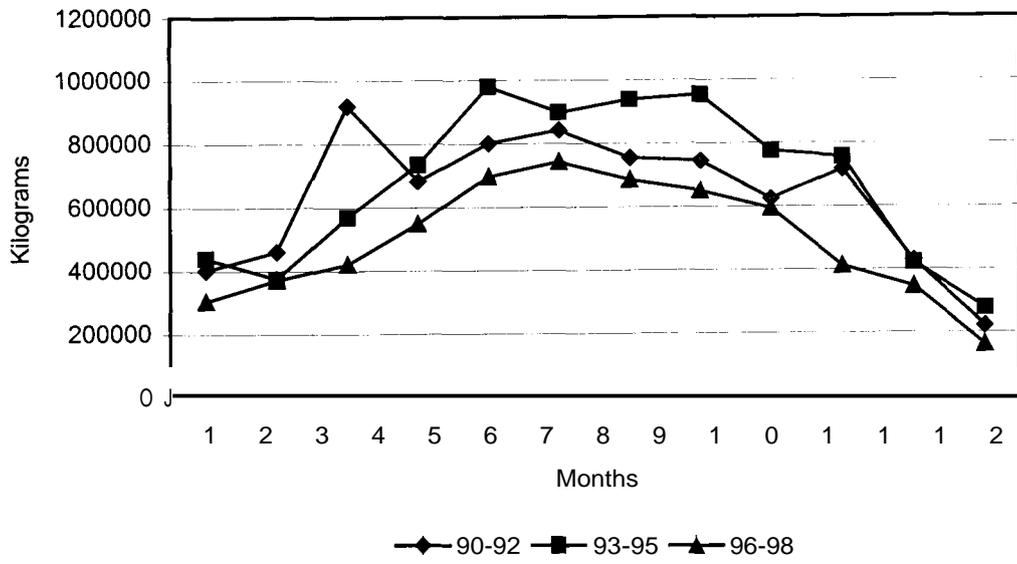
are more abundant during the summer months (normally April through August) while the wild scallops are in season. In contrast, imports of scallops from China and Japan have filled the gap created when wild scallop catches are relatively low during fall and winter months. Specifically, the Chinese imports are more in the winter months (December, January, and February), while the Japanese imports are more in the late summer and fall months (August, September and October).

Figure 2.9 also shows that over the three sub-periods 90-92, 93-95, and 96-98, U.S. domestic landings and Canadian imports have decreased, while Japanese imports have increased. Chinese imports increased from 90-92 to 93-95, but decrease in 96-98, because of its significant drop in production in the year 1998.

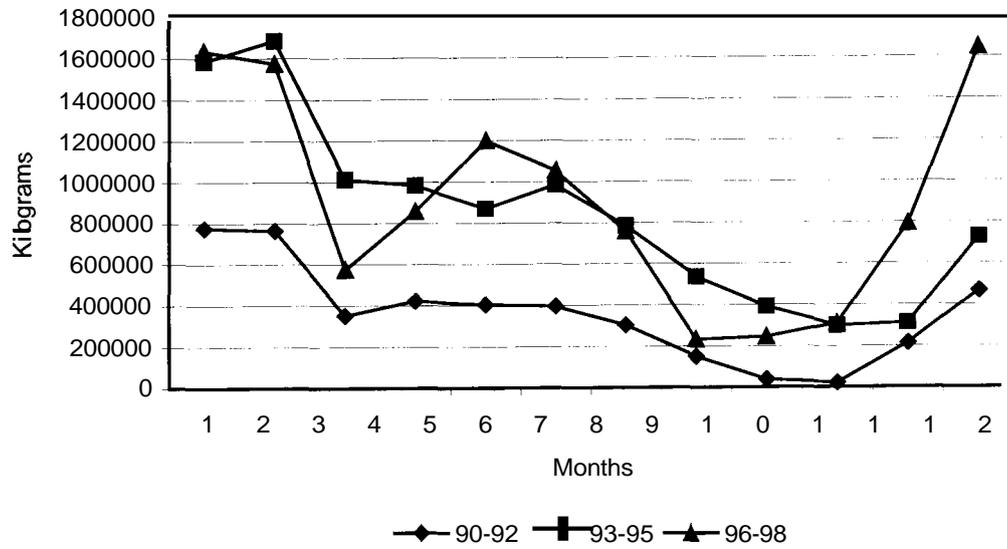
Figure 2.9: Monthly Pattern of U.S. Scallop Landings and Imports (three-year average: 1990-1998)



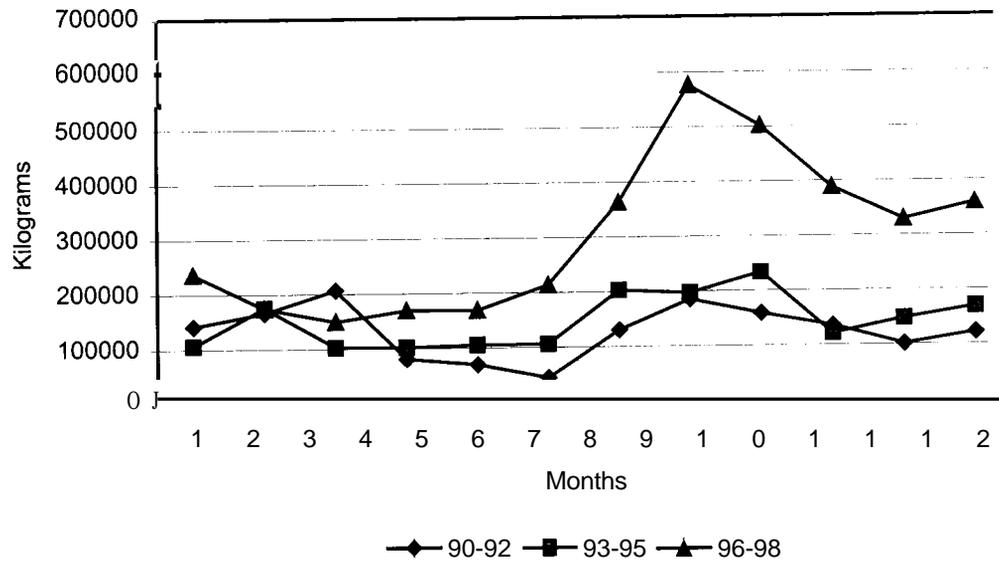
U.S. Scallop Landings



Canadian Imports



Chinese Imports



Japanese Imports

(Source: Fisheries of the United States, Various years)

CHAPTER 3

LITERATURE REVIEW

Previous Scallop Studies

To investigate the demand and supply structure of the scallop market, Altobello, Storey, and Conrad (1977) specified and estimated four sets of simultaneous equation models of the ex-vessel or landings market for sea scallops. Using the reduced form coefficients, Altobello *et al.* found the important impact of the natural abundance factor, measured by average amount of sea scallop meats landed by U.S. vessels per day fished on Georges Bank. In the four models, estimates of the coefficients associated with natural abundance, and the relative magnitudes of their corresponding standard errors indicate that the variable is a significant determinant of ex-vessel prices and landing quantities. A decline in landings price and an increase in quantities of sea scallops landed would occur if natural abundance were to increase. The relationship between disposable income, and ex-vessel prices in each of the four models is in accordance with what economic theory would claim. The positive coefficient indicates that an increase in disposable income would produce upward pressure on ex-vessel prices.

Another factor which is considered by Altobello *et al.* to have exogenous effect on ex-vessel prices as well as landings quantities is the quantity of scallops imported into the U.S. Imports were assumed exogenous to the marketing system and were included in the models either as a single variable, or as two variables representing imports from Canada and imports from rest of the world, respectively.

The price/quantity flexibility ranged from -0.46 to -0.65, indicating that scallop prices were relatively inflexible with respect to changes in landings. The price/quantity flexibility estimates relate to the effect of changes in the quantity landed on ex-vessel total revenue. When the price/quantity flexibility is less than one (in absolute value), as was the case in the study, **an** increase in the quantity landed will increase total revenue, because the percentage increase in quantity is greater than the corresponding percentage decrease in price. Furthermore, Altobello *et al.* estimated that the coefficients of price flexibility with respect to income were positive. This indicates that an increase in consumer incomes would cause **an** upward movement in prices.

Two major problems occurred in the estimation of coefficients in the structural equations. According to Altobello *et al.*, the coefficients associated with the price in the supply function are negative for all four models while, according to economic theory, they should be positive. In fact, the failure of the Altobello *et al.* models to identify supply functions consistent with economic theory (*i.e.* functions where quantity is positively related to price) may be because landings were assumed endogenous in the model when it should be considered exogenous. On the other hand, the scallop imports, which were assumed by Altobello *et al.* to be exogenous, could possibly be endogenous and affected by the prices.

In an earlier study of shrimp markets, Doll (1972) concluded "... annual fluctuations in landings reflect changes in abundance of shrimp rather in fishing effort...the biological factors causing shrimp abundance are not clearly identified and cannot be forecast; thus, domestic landings are both variable and unpredictable and are regarded as exogenous in the model." Very similar reasoning seems to apply to scallop

landings. Storey and Willis (1978) gave statistical support for this conclusion for the scallop industry as well. If landings and price were truly jointly dependent, then ordinary least squares estimation of landings price as a function of landings and several exogenous variables should for the usual reasons lead to biased estimates of the parameters. The use of an instrumental variable technique to remove this possible bias, however, resulted in nearly identical estimates of the unknown parameters from OLS estimation. Therefore, they concluded that scallop landings should be considered exogenous in the simultaneous equation model.

Since U.S. ex-vessel prices and wholesale and retail prices for scallops moved together closely, Storey and Willis (1978) used a simultaneous equation model which incorporated price changes in all three market levels. This model was based on the 1972 study of shrimp prices by Doll with minor modifications, since shrimp and scallop markets appeared to have similar characteristics (Storey and Willis, 1978). Different from Altobello *et al.* model, Storey and Willis considered scallop landings exogenous in their model. Therefore, the Storey and Willis model is a demand model specified so that predetermined domestic landings, imports and consumer income determine prices which in turn determine consumption at the retail level and end-of-year stocks held in cold storage. Scallop imports are separated into "Canadian imports" and "other imports". The estimated coefficients of the structural equations have signs which are consistent with prior theoretical beliefs except for "other imports". The expected sign for "other imports" is negative, the coefficient estimate had a positive sign. This result is similar to the Altobello *et al.* (1977) analysis. At the mean levels of prices and quantities, the retail price and income elasticities are estimated to be -0.82 and **0.43**, and landings and

wholesale price flexibilities are calculated at -0.28 and **-0.13**, respectively. Furthermore, both short-run and long-run impacts of changes in predetermined variables on the endogenous variables are analyzed. Results show that a cut in landings or imports will increase the prices at all market levels

Despite the plausible results, the Storey and Willis model is still part of a more comprehensive simultaneous equation model, since they assume the imports of scallop to be exogenous while, in fact, they should be endogenous. Therefore, their estimation results would be biased.

Wang *et al.* (1986) used a 12-equation model in the analysis of the Atlantic sea scallop fishery. In the model specification the U.S. Atlantic sea scallop fishery is divided into two components: sea scallop market and production components. In the market component, demand for sea scallops at the retail, wholesale and ex-vessel levels is specified separately. The import market is assumed parallel to and part of the domestic wholesale market. In the production component, landings are specified as functions of fishing efforts and natural abundance across three fishing areas. Their results indicate that the demand for sea scallops at all market levels is price inflexible from -0.32 at the wholesale level to **-0.64** at the retail level, which implies that an increase in supply resulting from the success of stock enhancement programs would lead to an increase in sales revenue at all market levels. Income price flexibility is positive and less than 1 for demand at all market levels. These results are consistent with the findings of Altobello *et al.*'s.

Considering the fishing effort, Wang *et al.* estimate its elasticities for each fishing area with respect to scallop abundance for that area are larger than 1. Also, reduction in

fishing effort or in meat count would accrue positive benefits to the sea scallop industries and consumers, and the greater the reduction in effort and/or in meat count, the larger the benefits under long-term equilibrium conditions.

Atlantic Salmon Market Studies

Recently, and particularly after the introduction of farmed salmon, the demand for salmon has been studied extensively. These studies cover many different markets, using data at different aggregate levels and different demand specifications. The choice of Atlantic salmon demand analysis as comparison for scallop analysis is based on the fact that both command high prices, both belong to the luxury category of consumption, and both had a similar market development in recent years. However, analysis of other fish products may be considered in future research.

Single Equation Demand Models

Single equation demand models have been used extensively in salmon market studies. With the booming of salmon farming around the world, many studies of farmed Atlantic salmon have been conducted. Riley (1986) estimated the **U.S.** demand for Norwegian fresh and frozen Atlantic salmon by regions (northeast, west, and the rest of country). A single equation model was specified under the argument that the price variable is determined by the expected supply and cost, which are approximated by previous rather than current supply and cost. Riley's model was constructed with sound economic reasoning and estimated using monthly data for the period from 1982 through

1984. However, results were rather weak as they failed to produce statistically significant prices and income coefficients.

Lin and Henmann (1988) used a single-equation model to examine the substitution relationship between Norwegian salmon and Chinook salmon in the U.S. salmon market. The quantity demanded of Norwegian Atlantic salmon was specified as a function of its own price, the price of its substitute (chinook salmon), income, lagged quantity, and a seasonal dummy variable. Using monthly data from January 1982 through August 1987, the model was estimated by OLS regression. A flexible functional form introduced by Box and Cox (1964) was also estimated and the results indicated that all the coefficients had the expected sign and relative magnitude.

Even though their results appeared to be reasonable, the model may not be free from simultaneous bias because a responsive supply to salmon price was found in the U.S. market in a separated supply equation. Therefore, simultaneous equations were then conducted later in 1988 with EC and the U.S. as segmented markets for Norwegian salmon (Herrman and Lin, 1988). This simultaneous equation model is discussed at the end of this section.

A single equation model was also used to analyze demand of farmed salmon in smaller markets such as Spain and Italy (Bjorndal et al, 1994). Because of the relatively small share of their imports in the world market, single equation quantity dependent models were used under the argument of competitive market. Hausman's test was conducted to test the hypothesis of predetermined price in these markets. Short-run substitutes between salmon and other fish products were not found in the two markets.

The results of Hausman's test suggested a predetermined price in these markets and thus OLS method was consistent and asymptotically efficient.

According to Bjorndal *et al.*, the choice of an appropriate demand model is based on the assumptions about the competitive nature of markets for salmon. If perfect competition is assumed, the price of salmon is predetermined and demand is modeled as quantity dependent relationship.

The imports of scallop in the U.S. account for 34% of total world scallop imports, and there are a number of potential suppliers to the U.S. scallop market. It is less likely that perfect competition and hence fixed price would exist. Therefore the import price of scallops to U.S. would be considered endogenous in the model, and the single-equation model would not be applicable to the current analysis.

Almost Ideal Demand System (AIDS) Models

According to Asche (1996), most previous salmon studies had used a single equation approach to specify each demand function and the degree of attention to the dynamic properties of the data varied. Cross-equation interactions between the demand functions have been ignored together with the time series properties of the data series. Alternatively, an almost ideal demand system (AIDS) model (Deaton and Muellbauer, 1980) can be used to analyze the substitution relationship among different product forms or different species of a salmon in the market. The AIDS model satisfies the adding up, homogeneity and symmetry restrictions implied by economic theory.

Asche (1996) estimated the substitution relationship among different forms of salmon in EU using an almost ideal demand system (AIDS) model. The import data of

fresh, frozen and smoked salmon during 1984-1992 were used, and fresh and smoked salmon were found to be luxury goods, while both fresh and smoked salmon were substitutes, and frozen and smoked salmon were found to be complements. The results also support Bjorndal et al (1992) in that all categories of salmon are found to be less own-price elastic than in many of the other earlier studies. By taking both product form and origin into consideration, Asche, Bjorndal and Salvanes (1998) estimated the demand for fresh Atlantic, frozen Atlantic and frozen Pacific salmon in the EU market. The demand equations were again estimated with the almost ideal demand system model.

Simultaneous Equation Models

Since the supply of farmed salmon to the U.S. and European markets was found to be responsive to import price, the results of single equation models are likely to be biased. A simultaneous equation model was established by Herrman and Lin in 1988 which includes the demand for and supply of Norwegian Atlantic salmon in the U.S., the EC demand for Norwegian Atlantic salmon, and four identity equations. This model was estimated in linear functional form.

To capture the Nerlovian partial adjustment mechanism of habit formation, Lin, Herrmann, T.Y. Lin and Mittelhammer (1989) incorporated a 12-period lagged consumption in the demand equations in the above simultaneous equation model. Herrmann, Mittelhammer and Lin further improved their 1989's simultaneous model by endogenizing the demand for Pacific salmon in Japan and EC. With quarterly statistics from 1982 through 1988, seven demand equations were estimated including imports of Norwegian salmon into the EC, Japan and North America as well as imports of North

America Pacific high- and low-valued salmon by the EC and Japan. The technique of Bayesian bootstrapping 2SLS was used.

The Armington Model Studies

Armington (1969) developed a theory of international demand for commodities. In the Armington model, products are distinguished by kind of good (lobster, scallop, shrimp, etc.) or by place of origin. Thus, U.S. scallops and Chinese scallops would be two products in the U.S. scallop market.

Conceptually, the model is based on the assumptions of two-stage budgeting and imperfect substitutability between different products. In the first stage, a country, treated as the decision-making unit, determines the total demand of a commodity needed for consumption. In the second stage, quantities to be consumed from various sources (and adding up to total demand) are determined.

Specifically, Armington's first-stage maximizes a representative country's weakly separable utility function⁴ subject to fixed total expenditure. A system of first-stage Marshallian demand equations, such as $Q_i = Q_i(E, P_1, P_2, \dots, P_n)$ $i = 1, 2, \dots, n$, results. The variable E represents total expenditure of the importing country; P_i , an aggregate price index of goods in group i ; and Q_i , an aggregate quantity index. The number of groups of goods is n . P_i and Q_i must be linearly homogeneous to satisfy the consistency requirements of two-stage budgeting. One requirement for consistency of two-stage

⁴ A utility function U is weakly separable with respect to partition of the commodity space if the marginal rate of substitution between any *two* goods i and j from within the same subset, say G_s , is independent of the quantities of the commodities consumed from other subsets. Mathematically, $\partial(U_i / U_j) / \partial q_k = 0$, for all $i, j \in G_s, k \in G_s, s = 1, \dots, S$ (Raunikaar and Huang, 1987)

optimization with single-stage optimization is that the index functions be homothetic. The further requirement that the index functions be linearly homogeneous ensures that group expenditures equal the product of the corresponding price and quantity indices (Davis and Kruse, 1993).

According to Davis and Kruse, the Armington model in its second-stage deviates from convention and the dual problem is solved. Expenditures are minimized subject to the utility index. The CES aggregator function is used for Q_i to satisfy the requirement of a linearly homogeneous utility index. The second-stage problem is:

$$\min_{q_{ij}} E_i = \sum_{j=1}^m p_{ij} q_{ij} \quad (3.1)$$

$$s.t. Q_i = \left(\sum_{j=1}^m b_{ij} q_{ij}^{-\tau_i} \right)^{-1/\tau_i} \quad i=1,2,\dots,n. \quad (3.2)$$

Variables p_{ij} and q_{ij} in equations 3.1 and 3.2 are the price and quantity, respectively, of good i from commodity source j ; E_i is the total expenditure on group i ; and $b_{ij} \in [0, 1] \forall j$, $\sum_j b_{ij} = 1$. The solution to this problem is the conditional Hicksian demand equation:

$$q_{ij} = b_{ij}^\sigma Q_i (p_{ij} / P_i)^{-\sigma} \quad j = 1,2,\dots,m. \quad (3.3)$$

The elasticity of substitution is $\sigma = (1 + \tau_i)^{-1}$, and Q_i and P_i are the CES quantity and price indices respectively. Equation 3.3 is referred to as the Armington equation, which is often written in the market share form (the Armington model can also be written in the expenditure share form and both forms yield similar results) as:

$$q_{ij} / Q_i = b_{ij}^\sigma (p_{ij} / P_i)^{-\sigma} \quad j = 1,2,\dots,m. \quad (3.4)$$

If equation 3.4 is applied to the U.S. scallop market (letting good i in the above equation represents scallops), then p_{ij} and q_{ij} are the price and quantity of scallops from country j , while P_j and Q_j are the price index of scallops and total scallop consumption in the U.S. σ is the elasticity of substitution between any two scallop products in the U.S. scallop market.

Several assumptions underlying the Armington model are made to make the framework amenable to empirical work: (a) the marginal rate of substitution between any two products (e.g., U.S. scallops and Chinese scallops) is independent of the quantity of any other products; (b) the elasticity of substitution between any two products in one market equals the elasticity of substitution between any two other scallop products in the same market; (c) the elasticity of substitution between any two products in a given market is constant.

The Armington trade model has been used by a number of researchers to compute demand elasticities for differentiated products in the import markets. Johnson *et al.* (1977) used this model to analyze the impact of devaluation and foreign trade controls on the wheat imports and U.S. domestic wheat prices. Babula (1987) estimated the export demand elasticity for U.S. cotton in a multi-regional Armington framework. Both ordinary least squares (OLS) and seemingly unrelated regression (SUR) were applied to the cotton import data. The parameter estimates and the forecast performances from OLS and SUR versions were compared.

Duffy *et al.* (1990) pointed out that the early studies (Babula; Johnson *et al.*; Grennes *et al.*) failed to give total demand response elasticity in the sense of Buse (1958) because prices of other products are assumed to remain constant in response to a change

in the price of the product from the exporting country in question. Therefore, a ‘total’ export demand elasticity for U.S. cotton is estimated in an extended Armington framework, which takes into account feedback effects of U.S. cotton price on other countries’ prices. The resulting total elasticities, according to Duffy *et al.*, are more realistic for evaluating the effects of U.S. policy changes.

Davis and Kruse (1993) argued that the theoretical and empirical problems associated with the traditional Armington model occur because the quantity aggregator function at the second-stage is misrepresented, leading to biased and inconsistent parameter estimates. The traditional Armington using a dual solution at the second-stage is a conditional Hicksian demand equation that is a function of latent utility and price indices (equation 3.3), which creates a type of approximation bias. Davis and Kruse further demonstrated an alternative way of estimating the model through a primal approach at the second-stage, resulting a conditional Marshallian demand. Japanese wheat import data were estimated to compare the primal and the traditional Armington system. Results indicate that the primal model produces consistent parameter estimates and satisfies the sufficient conditions for two-stage budgeting, while the traditional Armington specification does not (Davis and Kruse, 1993).

The Armington model is also used to explain the imperfect substitution between home and foreign goods. A number of recent studies have estimated Armington elasticities at a fairly disaggregated level. Reinert and Roland-Holst (1992) matched the Armington specification of substitution between imports and domestic goods with U.S. trade data to obtain econometric estimates of the Armington elasticities for 163 mining and manufacturing sectors. Elasticities of substitution among U.S. imports from Mexico,

Canada, the rest of the world, and competing domestic production are estimated by Shiells and Reinert (1993) for twenty-two mining and manufacturing sectors using quarterly data for 1980-1988. Blonigen and Wilson (1999) used a varying coefficients model to estimate Armington elasticities between U.S. domestic and foreign goods across over 100 industrial sectors from 1980-1988. They also examined the role of product, industry, political, and 'home bias' factors as determinants which cause the variation in the Armington elasticities.

CHAPTER 4

MODEL DEVELOPMENT AND SPECIFICATION

To estimate the impact of scallop imports on the U.S. scallop market, this chapter presents the development and specification of the Armington model. The substitution relationship among the scallop products from different origins and the own-price and cross-price elasticities of domestic scallops for both the short-run and the long-run are then measured using the Armington model estimation results.

Direct estimation of import demand elasticity has been difficult. Since price and quantity are determined by the interaction of demand and supply, whether the demand equation is free of simultaneous bias depends on the characteristics of the market, in particular, the responsiveness of quantity supplied with respect to price. If the supply to the U.S. market is responsive to the U.S. price, then the U.S. scallop price will be determined simultaneously by the demand and supply curves. In this case, a simultaneous equation model will be consistent.

More complication arises when the scallops on the supply side consist of different exporters with different factors determining the amount supplied to the U.S. market. Without a clear picture of the exact trade flow of who exports to whom, in what amount, and by what prices, it is hard to come up with a comprehensive simultaneous equation model. Failure to correctly specify the simultaneous model will result in biased estimates. This study argues against a simultaneous equation model because of the complication of the scallop market structure, and the lack of trade data. Instead, an

Arimington model is used because the market relationship for domestic landings and imports of scallop is the focus of current analysis and the Annington model is less data demanding. The market situation of scallops from different origins is discussed in the first section, which is followed by an Annington model to investigate the competition among them.

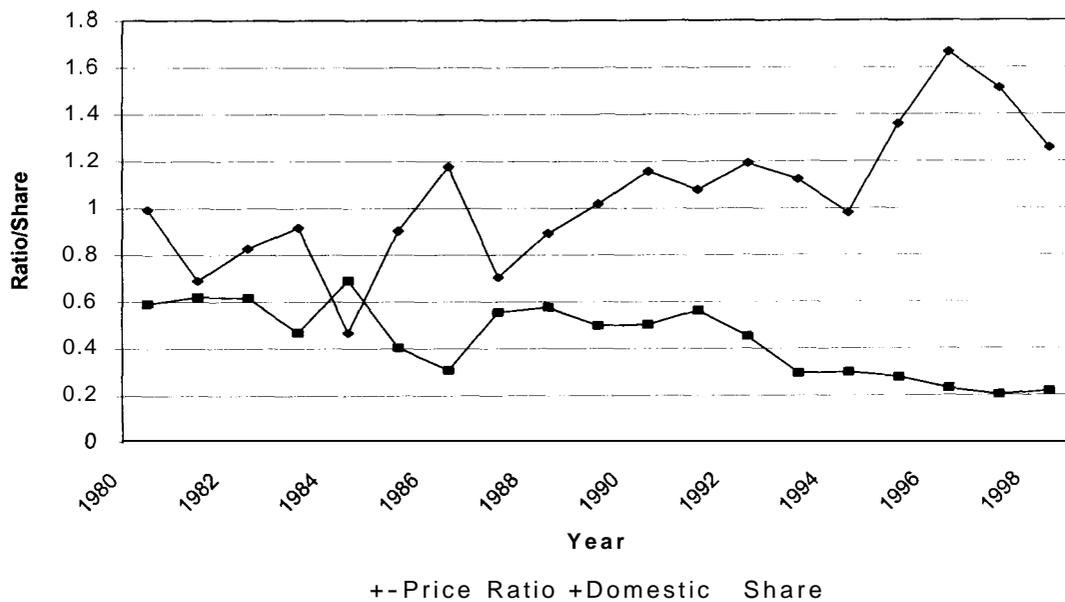
Details of the data to be used for model estimation and analysis are discussed in Chapter 5. Chapter 6 concentrates on the estimation results.

The Market Situation

Total **U.S.** imports of scallop have trended upward and increased threefold during the period considered, from 21 million pounds in 1980 to 41 million pounds in 1989 and 60 million pounds in 1997. Domestic landings in the same period grew from 30 million pounds in 1980 to 40 million pounds in 1989 but dropped drastically to less than 15 million pounds in recent years. The share of domestic scallop landings in total U.S. supply has steadily declined over the last 10 years. Domestic landings accounted for 60 percent of total scallop supply in the early 1980s. The share was around 50 percent in the late 1980s. In 1990, market share of domestic landings was 50.2%, but in 1998 it was only 21.8%. During this period, the price ratios of domestic landings to imports have changed from about 1 in the 1980s to 1.5 in 1997 and 1.3 in 1998. Figure 4.1 presents the relative price ratio of domestic landings to imports and the market share of domestic landings, and there exists a clear inverse relationship between price ratio and the market share.

Prices of domestic scallops have trended upward in recent decades. During 1980-1989, the average price of domestic scallop (sea, bay and calico weighted average) was \$3.4 per pound; it gradually increased to \$4.7 per pound in 1989-1998. During the same periods, prices of imports (all sources weighted average) dropped from \$4 to \$3.8 per pound. One may attribute the downward movement in domestic scallop share to the increase of relative price ratio of domestic landings to imports.

Figure 4. 1: Price Ratios and Market Shares of Domestic Landings (1980-1998)



(Source: Fisheries of the United States, Various years)

For the period of study, the U.S. scallop market on the supply side consisted of U.S. domestic landings, a relatively large exporter, China, and two smaller exporters, Canada and Japan. Scallops from the above sources are of different species and product forms, which give rise, with varying transportation cost and institutional factors, to price differences in the market. Table 4.1 presents average relative price ratios of U.S. domestic landings and other competitive sources in the U.S. scallop market. The sub-

period averages reflect a lessening of a disparity between U.S. and other scallops. Table 4.1 also shows the average market share for sub-periods for the U.S. as against all competitors. Relative price ratios increase for all competitors over the two sub-periods with the price ratio to Chinese imports increasing most significantly. This is primarily due to the price reduction of Chinese scallops, which is made possible by the rapid improvement of scallop aquaculture technology.

Table 4. 1: Averages of Relative Price Ratios and Market Shares for U.S. Scallops and Various Competitors in the U.S. Scallop Market

	U.S. Domestic Landings Versus			
	Canada	China	Japan	All Competitors
Price Ratios				
1980-1989	0.73	0.74	0.71	0.86
1989-1998	0.83	2.15	0.88	1.23
Market Shares (Percent)				
1980-1989				53.3
1989-1998				35.4

(Source: Fisheries of the United States, Various years)

Model Development and Specification

Substitution Between Differentiated Products

Since 1980, China has exported more aquacultured scallops to the U.S. market by taking advantage of the aquaculture technology growth and their relatively cheap labor. In 1996, almost 40 per cent of U.S. scallop supply was from China. The figure dropped significantly in recent years because of the environmental and genetic problems encountered by the scallop farmers in northeastern China. The Japanese scallop aquaculture has a longer history than that of the Chinese, and scallop imports from Japan

have been serving the U.S. scallop market for a longer period of time. In recent years, its shares in the U.S. total scallop supply have been increasing. In 1998, the figure was 15.7 per cent. The U.S. and Canadian producers market mostly wild scallops, which account for 21.8 per cent and 18.7 percent of the total supply respectively. The substitutability between different species (country origins) has become an important issue.

Two opposite views about the substitutability exist. One view is that the introduction of the aquacultured scallop has created a mass market that previously did not exist. By supplying new geographic regions and new markets, the aquacultured scallops have generated a new demand for wild domestic scallops, for which aquacultured scallops do not compete. The second view asserts that the increased demand is made possible by significantly cutting domestic prices of wild scallops instead of by the introduction of a new product to the market. They argue that the purchasing decision is driven by price instead of the difference between the species.

The substitutability between domestic scallops and imports depends on the similarity and dissimilarity of the product origin from the buyer's perspective. If the two species are similar, purchasers will respond more readily to relative price changes. The magnitude of this shift in demand is determined by the degree of substitutability among the products.

At a conceptual level, the Armington model typically specify a constant elasticity of substitution (CES) utility function over the different products with an associated consumer optimization problem. In general, the elasticity of substitution between two goods depends on the degree of product differentiation – consumers see goods as imperfect substitutes when there are obvious physical product differences. The greater

the differences, the lower is the elasticity of substitution between the products. For example, aquacultured Chinese bay scallops can be differentiated by size from the sea scallops, which are the major production from U.S. and Canada.

However, product differentiation does not depend on actual physical differences between goods alone. Physically identical goods may be differentiated by availability in time, convenience of purchase, after-sales services bundled with the good, or even consumers' perception of inherent unobservable quality. These factors not related to physical characteristics may play a particular strong role in product differentiation between U.S. domestic scallops and scallop imports from Canada, since both types of scallops are same species and come from the same fishing area.

Factors in an Armington Function

The Armington approach is particularly well suited to estimate the elasticity of import demand for a particular market because a system of market share equations for the market can be estimated (Equation 3.4). Economic theory suggests that there are many economic and non-economic factors that may alter the market share of individual products, and the market share equations permit incorporating additional variables other than prices. These include the product's quality, the extent and vigor of marketing efforts, lagged market share, changes to consumer tastes and preferences and so on. Several related studies on the cotton and the oil products have investigated the price and non-price competitiveness, and the effect of such factors on the market share of those products (Sirhan and Johnson, 1971; Houck and Ryan, 1978; Meilke and Griffith, 1981).

One of the advantages of Armington model is the reduction of the multicollinearity problem through indexing of collinear prices in both stages of the two-stage optimization. First-stage product prices are collapsed into a price index for each homogeneously separable market. The scallop market-related prices are then collapsed into the price ratio variable in the second stage relation (Equation 3.4). Specifically, the price of scallops from source j is entered as a ratio to the weighted average of 'all' scallop prices. Therefore, the analysis of price competitiveness focuses on the comparative price of scallops from source j *vis-h-vis* scallops from all sources. It is argued that if the price of scallops from source j increases in comparison with scallops from other sources, one would expect consumers of the scallops from source j to switch to scallop from other sources, resulting in a decline in the share of scallops from source j in the market. When the relative price of the scallops from source j declines, consumers tend to use more of these scallops as a substitute for other scallops. Thus any reduction in the price of scallops from source j relative to the price of other sources will improve the competitiveness of the scallops from source j and result in a increase in the market share of the those scallops.

Non-price factors, such as the product quality, industry promotion activities, changes to consumer tastes and preferences and lagged market share could also be responsible for the movement of the scallop market share. Product development of imported aquacultured scallops, for example, not only strengthens their competitiveness with U.S. domestic scallops in serving the same consumer group but also creates new demand of the population, hence results in an increased market share. For most products, the industry promotion is an effective way of changing product market share. However,

the limits on access to the data of product quality and promotion efforts prevent us from including those two variables in the equation.

Actual adjustments may not be instantaneous, and sales shipments often lag contracts. Accordingly, following Nerlove, the partial adjustment framework was used. Market share in the previous period is included as an explanatory variable, whose coefficient should fall between 0 and 1. The inclusion of lagged dependent variable is also intended to yield short-run and long-run elasticities. Details on relevant elasticities are discussed in later part of this section. Here the market share for scallops from source j depends on its market share in earlier periods. Because of the use of annual data, market share lagged by one year is specified.

Changes in consumer tastes and preferences will have an influence on the scallop market share. There are several factors that may result in such changes. For example, with more people being aware of the health benefits of aquacultured scallops, they will have greater preferences for them. In this study, a time trend variable will be used as an explanatory variable to take into account of changes in consumer tastes and preferences that affect market share, and changes in other factors such as improvement in aquaculture technology which has not been considered explicitly in the market share model but may have trend component.

The Armington Model'

Underlying the Armington market share specification of scallops is the consumers' demand in the scallop market, and changes in the market share reflect shifts in consumer demand. One can distinguish between the short-run and long-run

⁵ This section is based on Duffy *et al.* (1990)

Armington market share on grounds similar to those in demand analysis (Sirhan and Johnson, 1971). The long-run equilibrium scallop share reflects the *desired level* of purchases. Since it has been assumed that purchasers adjust their pattern of consumption gradually, only a fraction of the expected or long-run market share can be achieved within a specified period. This approach to the dynamic demand analysis utilizes the specification of a distributed lag relationship, which is often used in studying the demand for consumer durables (Harberger 1960; Stone and Rowe 1960). Once the long-run market share function and partial adjustment function are specified, the partial adjustment reduced form equation can be derived from the structural relations. Letting M_{jt} be the actual market share of scallops from source j and DM_{jt} be the desired market share at time t , equation 3.4 can be expressed in the double-log form as

$$\ln(DM_{jt}) = \sigma^* \ln(b_j) - \sigma^* \ln(p_{jt} / P_t) \quad j = 1, 2, \dots, m. \quad (4.1)$$

where p_{jt} is the price of scallops from source j at time t , P_t is the scallop price index at time t , and σ^* is the long-run elasticity of substitution. The partial adjustment model is

$$\ln(M_{jt}) - \ln(M_{j,t-1}) = \gamma [\ln(DM_{jt}) - \ln(M_{j,t-1})] \quad 0 < \gamma_j < 1 \quad (4.2)$$

According to the model, the change in the consumption of scallop is proportional to the gap between the current desired and past actual market share level. Here γ is the adjustment coefficient, indicating the speed of adjustment. Substituting equation 4.2 into equation 4.1 and rearranging terms leads to

$$\ln(M_{jt}) = \gamma \sigma^* \ln(b_j) - \gamma \sigma^* \ln(p_{jt} / P_t) + (1 - \gamma) \ln(M_{j,t-1}) \quad (4.3)$$

where $\gamma \sigma^* = \sigma$ is the short-run elasticity of substitution.

To account for possible changes over time that are unrelated to relative prices, a trend variable can also be included in the estimates. In this study, it is assumed that the intercept, b_j is a function of time (T), so that

$$b_j = A_j T^{\beta_j} \quad (4.4)$$

Substituting equation 4.4 into equation 4.3 leads to the functional form to be estimated:

$$\ln(M_{jt}) = \gamma \sigma^* \ln(A_j) - \gamma \sigma^* \ln(p_{jt} / P_t) + (1 - \gamma) \ln(M_{j,t-1}) + \gamma \sigma^* \beta_j \ln(T)$$

Letting Roman letters stand for estimates of parameters, the estimated model in the double-log form is

$$\ln(M_{jt}) = b_{j0} - b_{j1} \ln(p_{jt} / P_t) + b_{j2} \ln(M_{j,t-1}) + b_{j3} \ln T_t$$

Therefore, the short-run elasticity of substitution is b_{j1} , and the long-run elasticity is b_{j1} divided by $(1 - b_{j2})$. If the coefficient b_{j2} is between 0 and 1, the long-run elasticity of substitution is greater than the short-run.

The Armington formulation implies that the direct price elasticities (short-run) of demand of scallops from source j have the form:

$$\begin{aligned} N_{jj} &= -(1 - S_j) * \sigma + S_j * \eta \\ N_{jk} &= S_k * (\sigma + \eta), \quad k \neq j. \end{aligned} \quad (4.5)$$

where N_{jj} is the own price elasticity of demand for scallops from source j , N_{jk} is the elasticity of demand for scallops from source j with respect to the price of scallops from source k ; S_j and S_k are the expenditure shares of scallops from countries j and k ; and η is the overall elasticity of demand for scallop in the U.S. The short-run substitution elasticity in equations 4.5 could be replaced by its long-run counter-part σ^* to get the long-run price elasticities.

CHAPTER 5

DATA DESCRIPTION

Data Information and Source

The data period covered in this study is from January 1990 to December 1998. Table 5.1 presents the variables used in this study and their source of data.

The import prices and the U.S. domestic ex-vessel prices were calculated from value and quantity data. The scallop import data came from the National Marine Fishery Service (NMFS), but were purchased from the Foreign Trade Division of the Bureau of the Census. As the original data source for scallop import quantity and value, Foreign Trade Statistics of U.S. Census Bureau normally releases the international trade data to the public 45 days after the close of every statistical month. Imports for "consumption" which are the data maintained in their data base are a combination of entries into the U.S. for immediate consumption and withdrawals from Customs bonded warehouses. These data reflect the actual entry into U.S. consumption channels of commodities that originated outside the United States.

The import value used by Foreign Trade Statistics is the custom value. This is generally defined as the price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance and other charges incurred in bringing the merchandise to the United States (This value approximates F.O.B. value).

Data	Original Data Source
Annual scallop import quantity and value by country of origin	Foreign Trade Statistics, Foreign Trade Division, the Bureau of the Census, U.S. Department of Commerce
Annual U.S. scallop landings quantity and value by species	Fishery Statistics and Economics Division, National Marine Fishery Service, NOAA, U.S. Department of Commerce (Online)

The Fishery Statistics and Economics Division of the National Marine Fisheries Service (NMFS) maintains a data set for the U.S. commercial landings (<http://www.st.nmfs.gov/st1/commercial/index.html>). NMFS has automated data summary programs, from which U.S. commercial fisheries landings for this study were summarized. However, these summary programs are currently applicable to fisheries conducted in Atlantic and Gulf of Mexico waters and in the Pacific off of the states of Washington, Oregon and California. Landings for Alaska and Hawaii were not available at the time of this study. The ex-vessel price of scallops is the unit value of sea scallop because of its overwhelming dominance in scallop landings.

Statistics

Table 5.2 presents basic statistics for the data used in the Armington model.

Table 5. 2: Summary Statistics of Variables (annual average)

Variable	Mean	Std. Dev.	Minimum	Maximum
U.S. landings				
Quantity (million pound)	31.38	12.09	14.63	60.99
Value (\$million)	117.25	25.69	77.50	157.72
Price (\$/pound)	4.06	1.04	2.01	5.99
Canadian Imports				
Quantity (million pound)	15.34	3.13	8.69	21.68
Value (\$million)	79.31	18.94	48.32	121.21
Price (\$/pound)	5.22	0.90	3.75	6.77
Chinese Imports				
Quantity (million pound)	9.11	10.80	0.001	29.68
Value (\$million)	19.61	22.45	0.017	63.99
Price (\$/pound)	5.77	6.40	1.77	25.00
Japanese Imports				
Quantity (million pound)	5.28	3.64	0.06	11.65
Value (\$million)	25.81	17.83	0.73	59.40
Price (\$/pound)	5.38	1.96	4.01	12.86

Note: The import and ex-vessel prices were calculated from the data. The maximum Chinese import price \$25.00/pound occurred in 1981, when 1 million pounds and 25 million dollars of scallops were imported from China.

CHAPTER 6

ARMINGTON MODEL ESTIMATION AND RESULTS

The Armington model is estimated in this chapter in order to get the short-run and long-run substitution (market share) elasticities, as well as the own price and cross price elasticities of U.S. domestic scallops.

Model Estimation

The data period of the Armington model estimation is from 1980 to 1998. The statistical model in the double-log form is as follows:

$$\ln(M_{jt}) = b_{j0} - b_{j1} \ln(p_{jt} / P_t) + b_{j2} \ln(M_{jt-1}) + b_{j3} \ln T_t \quad j = 1, 2, 3, 4, 5. \quad (6.1)$$

The annual multi-source Armington model of U.S. scallop demand is specified in equation 6.1, where all variables have been defined earlier. Total scallop market is delineated into demand for U.S. domestic scallops, Canadian scallops, Chinese scallops, Japanese scallops, and a residual rest of the world scallops, represented by subscript j from 1 through 5, respectively.

Armington's approach first determines the total scallop market demand, which subsequently serves as a predetermined second-stage argument. For a single product, the ordinary least squares (OLS) would be the appropriate econometric techniques for the parameter estimation. In a multi-product framework, however, problems with contemporaneous correlation may arise; OLS would be unbiased but inefficient. The

demand for scallops from different sources may be contemporaneously correlated through the error term. In this case, seeming unrelated regression (SUR) estimates would be unbiased, asymptotically consistent, and efficient (Griffiths *et al.*). The substitution elasticity σ (\mathbf{d})s held constant across equations by putting certain parameter restrictions in the SUR estimation. The constraints would assure that the assumption of equal elasticity of substitution between product pairs would not be violated. For this study, the parameters associated with the price ratios and the lagged market shares are held constant across equations in the estimation process.

Table 6. 1: Parameter Estimates for the Armington Model via Seemingly Unrelated Regression (SUR) Method

Models	Dependent Variables	Coefficients of Independent Variables				R^2
		Intercept	$\ln(p_{jt} / P_t)$	$\ln(M_{jt-1})$	$\ln T_t$	
U.S. scallops ($j = 1$)	$\ln(M_{1t})$	-0.45* (0.14) (-3.20)	-1.32* (0.12) (-11.37)	0.33* (0.05) (6.81)	-0.05 (0.06) (-0.79)	0.80
Canadian imports ($j = 2$)	$\ln(M_{2t})$	-0.77* (0.14) (-5.50)	-1.32* (0.12) (-11.37)	0.33* (0.05) (6.81)	0.06 (0.06) (1.06)	0.62
Chinese imports ($j = 3$)	$\ln(M_{3t})$	-6.97* (0.94) (-7.39)	-1.32* (0.12) (-11.37)	0.33* (0.05) (6.81)	1.86* (0.35) (5.42)	0.97
Japanese imports ($j = 4$)	$\ln(M_{4t})$	-1.70* (0.45) (-3.77)	-1.32* (0.12) (-11.37)	0.33* (0.05) (6.81)	0.11 (0.17) (0.66)	0.68
Other imports ($j = 5$)	$\ln(M_{5t})$	-1.19* (0.30) (-4.01)	-1.32* (0.12) (-11.37)	0.33* (0.05) (6.81)	0.20 (0.12) (-1.60)	0.32

Note: Fitting Period: 1980 - 1998, degree of freedom: 19.

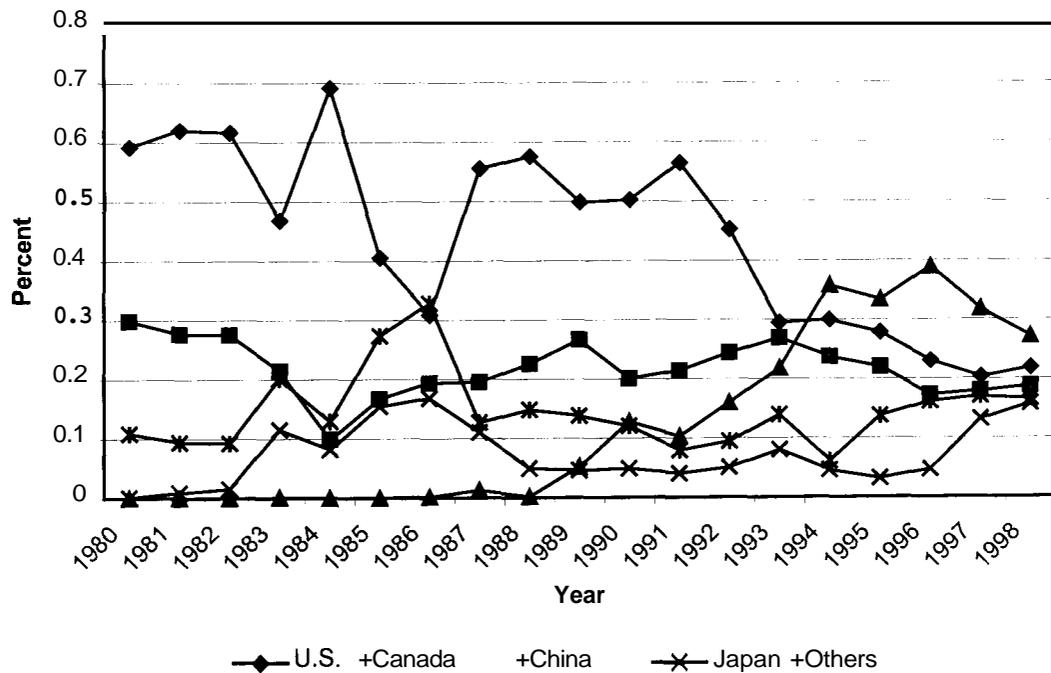
Standard error and t-value are given in parentheses below each parameter.

* specifies the significant coefficient with 5% significant level.

Estimation Results

It can be seen from Table 6.1 that all coefficients of the price variable (b_{j1}) and the lagged market share (b_{j2}) of the four equations are significantly different from zero at 5 percent probability level. The estimation results suggest that changes in the price ratio of scallop of one source over the others and the lagged market share have significant influence on the current market share. The coefficients of the time trend are not significantly different from zero for most of the scallops, except Chinese imports, suggesting that Chinese imports may be significantly gaining market power over the estimation period,

Figure 6.1: Annual Average Scallop Market Shares: 1990-1998



(Source: Fisheries of the United States, Various years)

Figure 6.1 shows that the Chinese scallop market share exhibited a significant upward trend within the period 1990 to 1996, but decreased at the end of the estimation period. Canadian and Japanese scallop market shares remained relatively constant, while U.S. domestic landings and imports from other sources tend to move opposite to each other with many fluctuations.

Although the Chinese product enters U.S. markets for a fraction of the domestic wholesale cost (as cheap as \$3.5 a pound or less), it is sometimes judged inferior because of smaller meat size and frozen product form. After 1997, the Chinese scallop industry has been experiencing serious environmental problems and to make up for some of the shortfall, more Chinese farmers have started soaking their scallops in fresh water on the beach before selling them to exporters. More and more of the Chinese scallops came in at 82 percent moisture or higher⁶, and have been rejected by the U.S. scallop processors. On the other hand, although the Japanese Yen strengthened against the U.S. dollar in recent years, causing a sudden jump in prices for Japanese product, Japanese scallop imports still increased significantly because of their better quality compared with scallop imports from China.

It is also found that the price ratios have negative (-1.32) impacts on the market shares, while lagged market shares have positive (0.33) impacts on current market shares.

The short-run and long-run substitution elasticities (also referred to as the market share elasticities) of U.S. scallop market were computed on the basis of the coefficients obtained. Table 6.2 presents the substitution elasticities as well as the coefficients of

⁶ According to FDA (1992) anything with more than 79 percent moisture had to be labeled a water-added scallop product (depending upon the time of year, a scallop's natural moisture will typically range between 76 and 80 percent), and anything with more than 84 percent water could not be sold.

adjustment. It can be seen that the long-run elasticity, as expected, are greater than that of the short-run. Results also indicate that the U.S. scallop market shares are elastic with respect to prices both in the short-run and in the long-run. According to values presented in Table 6.2, a 1 percent increase in the relative price ratios of U.S. scallops to that of competitors will lead to a decrease in their market shares by 1.32 percent in the short run and by 1.97 percent in the long run.

Table 6.2: Estimates of Short-run and Long-run Substitution (Market Share) Elasticities of the U.S. Scallop Market

Short-run elasticity (α)	Long-run elasticity (σ^*)	Rate of adjustment (γ)
1.32	1.97	0.67

The results also indicate that substitution possibilities between scallops from different sources are indeed limited indicating that they are imperfect substitutes.

Given the estimated substitution elasticities, the own price and cross price elasticities can be further calculated. As indicated in Chapter 5, the price elasticities in the Armington framework are given by

$$N_{xx} = -(1 - S_j) * \sigma + S_j * \eta$$

$$N_{jk} = S_k * (\alpha + \eta), \quad k \neq j.$$

where all the variables are defined earlier.

In Table 6.3, elasticity estimates are presented for three assumptions about the overall elasticity of demand for scallops (η). Specifically, an upper bound of 0 (perfectly inelastic) and a lower bound of -1 (unitary elasticity) were assumed. Cheng (1985) reported the total scallop demand elasticity at -0.8109 using household data. The price elasticity of demand for scallops was estimated to be -0.82 by Storey and Willis (1978).

In this study, it was assumed the first-stage demand to be inelastic, and 0 and -1 were chosen as probable bounds on the total elasticity. Two estimates of the elasticity of demand for U.S. domestic scallops were calculated by setting total demand elasticities equal to these boundary values. Finally, a third estimate was calculated using Cheng and Storey and Willis estimates of -0.8 as the total demand elasticity.

Table 6. 3: Estimates of Short-run and Long-run Price Elasticities for U.S. Domestic Scallops

Elasticities	Short-run ($\alpha=1.32$)			Long-run ($\sigma^* = 1.97$)		
	$\eta = 0$	$\eta = -0.8$	$\eta = -1$	$\eta = 0$	$\eta = -0.8$	$\eta = -1$
Own-Price	-0.74	-1.09	-1.18	-1.10	-1.46	-1.54
Cross Price						
Canada	0.38	0.15	0.09	0.57	0.34	0.28
China	0.09	0.04	0.02	0.13	0.08	0.07
Japan	0.12	0.05	0.03	0.18	0.11	0.09
Others	0.15	0.06	0.04	0.22	0.13	0.11

The estimated short-run own price elasticities are less than one, or a little over one. That is to say, an increase in the price of the U.S. domestic scallops will reduce the quantity demanded by approximately the same percentage. However, in the long run, the price elasticities of demand are over one, and one percent increase in price will decrease the quantity demanded by more than one percent. This further implies that the long-run marginal revenue will be negative if the U.S. scallop price increases, *ceteris paribus*. This result supports the argument that the U.S. scallop industry has been materially injured by its increasing price.

On the other hand, increasing U.S. scallop supply either by successful stock enhancement programs or by mass aquaculture may have greater effects on domestic

scallop prices in the short-run. However, in the long-run, such effects on prices may be smaller. According to a recent report, the U.S. domestic scallop price flexibility is estimated to be 0.4 (Maine DMR, 2001). This further suggests that it would be beneficial to the scallop industry in the long-run to increase scallop supply since the prices are relatively inflexible. Scallop aquaculture could be a viable component of the U.S. scallop industry.

The cross price elasticities of U.S. scallops with respect to different import price changes range from 0.02 to 0.38 in the short-run and 0.07 to 0.57 in the long-run. As is clear from the table, the U.S. scallop demand is more responsive to Canadian scallop prices, and less responsive to Chinese scallop prices. This result is plausible, since U.S. and Canadian scallops are closest substitutes, while Chinese scallops differ most from the domestic ones. The relatively low cross-price elasticities, combined with the low substitution elasticities presented earlier, may suggest imperfect substitutability between U.S. scallops and scallop imports from other countries. This also implies there exist different market niches for different scallops and the competition between the niches is insignificant. Developing niche markets for U.S. domestic scallops would be an effective strategy to compete with various imports in market place.

CHAPTER 7

SUMMARY AND DISCUSSIONS

Summary of Major Findings

The Armington model is suggested as a method of overcoming the estimation problems which have plagued the efforts to estimate the demand for scallops using structural equations. In general, the parameter estimates and the implied substitution, direct, and cross price elasticities seem reasonable, based on a *priori* knowledge.

Due to the decreasing natural abundance, and increasing price, the U.S. scallop industry has been losing market shares to rapidly expanding imports of products from China and Japan, as is shown in Figure 6.1. The impact of imports of scallops on the U.S. industry, especially imports from China as it is likely the lowest-cost producer in the world, has received considerable attention. Price competition with imports is likely to intensify if the U.S. scallop industry's market share continues to decline. The objective of this thesis is to estimate the relationship between scallops from different sources, and assess the impact of a successful stock enhancement program or aquaculture operations on the U.S. industry.

To meet the above objectives, an Armington framework was developed and estimated. The major findings from the estimation results are that the short-run own price elasticities were approximately or less than one, and long-run own price elasticities were greater than one. This means that a one percent increase in the scallop price would result in less than one percent decrease in the quantity demanded in the short-run and

more than one percent decrease in the quantity demanded in the long-run. In other words, increasing price would have little effect on total revenue in the short-run but will result in a loss in total revenue in the long-run. The long-run situation for the U.S. scallop industry has worsen in recent years since its price has been increasing over the period. However, in the meanwhile, the fact that the U.S. scallops are relatively price inflexible in the long-run would motivate the natural stock enhancement programs or scallop aquaculture production in the U.S. to increase the market supply.

The substitution relationship between U.S. domestic landings and imports from Canada, China, Japan and other countries was also assessed using the model. The short-run and long-run substitution for scallops from different sources are small, indicating the existence of imperfect substitutability between those products. The small cross price elasticities also support the argument that U.S. domestic scallops and imports from other countries are imperfect substitutes with relatively weak competition. Although the Chinese or Japanese scallop import prices may continue to decrease, originating from aquaculture technology development, they may not have significant impacts on the demand and hence price of domestic scallops.

One of the most important facts for the U.S. scallop industry is that it is able to differentiate its product from the imported scallops, especially the aquacultured Chinese and Japanese scallops. The majority of U.S. domestic landings are sea scallops, which are generally considered more desirable in taste and texture. **Also**, sea scallops tend to be larger than other kinds. Domestic landings generally run between 20 to 40 count per pound, while scallop imports from China and other countries run from 50 to 60 count per

pound'. For U.S. scallop industry, it may be necessary to develop its own market niche where people have a preference for the freshness and high quality of wild-caught scallops. It is argued that some people would want to pay more for the freshness of wild scallops, and the motivation for paying more on a special characteristic of a product may be achieved by stronger marketing effort on this characteristic. This is especially important for scallopers who have difficulty increasing production through access to more fishable sites.

In the New England, the scallop fishery has been so threatened by overfishing, that 6,000 square miles of the most productive bottom is now closed, and pressure on inshore areas may lead to more closures. However, the demand for scallops continues to increase. Based on the results of this study, there may exist feasibility of carrying out scallop aquaculture within the U.S., since different scallops have certain substitutability without exhibiting keen competition, and adding one product would not significantly impair the current fishery industry. The evolution of domestic scallop aquaculture could possibly develop a viable component of this fishery industry.

Suggestion for Future Improvement

In this study, highly aggregated data were used, treating the U.S. scallop market as a whole. However, the different regions such as the East Coast, West Coast, and the Midwest of U.S. might have very different preference over scallops. Future research on the demand in each region might greatly improve the research results. Only the second-

⁵ Japanese scallops are as large as sea scallops, and sometimes larger, reaching 10-20 count per pound.

stage Armington model was specified in this analysis. The own-price and cross-price elasticities were derived based on several assumptions of total elasticities. Given a clear trade flow of scallops and sufficient data, a comprehensive simultaneous model can be used, which may yield more accurate coefficients and information.

Marketing effort is a variable that may positively affect market shares in the Armington model by shifting the demand curves outward. However, it is not included in this study because of the unavailability of marketing budget of different scallops. It is also suspected that with an increasing marketing budget on a special characteristic of certain scallop, a market niche might be created with relatively more stable price and market share within the market niche as well as the whole market.

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