Environmental Regulation and Globalization in the Coastal Fishery

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Abstract

Most coastal fisheries in the U.S. and other developed economies are going through a major transition. On the one hand, new technologies such as electronic enhancement to assist trawling have led to a decline in the unit cost of fishing, making it more economically efficient. On the other hand, this improved efficiency has possibly led to increased environmental damage. This has led to conflicts between fishermen and conservation groups.

In the past, the main policy issue confronting fishery managers was the task of ensuring that stocks were managed at levels that sustained employment and profits in the fishing industry. However, in recent years, the dynamics of the coastal fishery has changed dramatically. More and more affluent people have settled into coastal areas. Recreational demand has increased faster than demand for commercial fish. Environmental concerns have often become more important than the matter of providing fish at reasonable prices to the urban consumer. This trend has been exacerbated by the globalization of the world fish industry, so that cheaper imports from overseas can now compete with higher cost domestic fish.

The paper addresses this problem by developing a simple spatial model of the coastal fishery with two fleets, a traditional higher cost fleet which is environmentally less damaging (e.g., castnetting), and a modern lower cost fleet (trawling) which may have negative environmental effects. As fish move away from inshore breeding grounds to areas offshore, they grow bigger in size, attracting a price premium. The model tries to answer the question: which fleet should fish in what location? This depends on various cost and demand parameters. The optimal spatial allocation of fishing effort is derived when fleets have harvest and capacity constraints. The effect of regulation, for example to preserve inshore fishing grounds for the traditional fleet or imposing environmental taxes on the modern fleet are examined. The effect of imports on effort allocation is discussed. The paper concludes with a case study discussion of the southeastern U.S. shrimp fishery.

Key Words: fishery regulation, competition, Cournot models, environmental regulation

JEL Codes: Q22, Q28, L51

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1. Introduction

There is a substantial literature in fishery economics that deals with transboundary issues as well as strategic behavior by different agents fishing in common waters or in two different jurisdictions sharing a common straddling stock. For a survey, see Wachsman (2002), Sumalia (1999). Very little attention has been paid to the issue of multiple fleets and in particular, how the cost and demand characteristics of the fishery affect the regional specialization of fleets in different locations in the ocean. This is especially important for those species that migrate in limited but predictable ways, such as shrimp and other bottom fish that spawn in estuarine areas and migrate away from the coast. The questions that arise are: which fleet should fish in what location? How does the stock as well as cost and demand parameters affect this behavior? Given that there have been many cases of conflict between alternative fleets fishing in the same locations, how can a regulatory agency choose policies that minimize this conflict in the most efficient way?

In this paper we propose a spatial model of fishing with multiple fleets, one traditional and another modern. Economically efficient fishing behavior is derived. The effect of regulatory policies is examined. The model is then used to study the effect of fishing imports. A case study of the southeastern US shrimp fishery is provided to motivate the theory. The model closest in spirit to ours is Sumaila (1997). He examines the shared cod fishing grounds in the Barents Sea, where the Russian fleet mainly uses trawling vessels that target young fish, while the Norwegians use trawlers and coastal vessels to target mature cod. The goal of the paper is to find out the distribution of the harvest across the two fleets based on cooperative and non-cooperative behavior. It does not explicitly model location as done in our paper. Sampson (1992) develops a spatial model in which the density of fish increases with distance from the coast, to derive the optimal location for fishing as a function of the price of fish. Our model may be considered to be an extension to a multiple fleet framework in which we examine the specialization of fleets over space as a function of demand and cost parameters and regulatory policies.

2. The Model

We assume a competitive model of a fishery with two fleets: a traditional fishing methods fleet and a modern trawling fleet, denoted by the subscripts *c* and *t* respectively. The price of fish is assumed to be *p*. Later we will examine the effect of imports by incorporating a demand function for fish. Especially for shrimp, we assume that they breed in estuaries where the salt water interfaces with fresh water. As the population of shrimp move away from the coastline, they grow bigger in size. The distance from the coast is given by the variable *x*. This is reflected in a higher price for fish caught further offshore. We model this issue by assuming a price premium given by $s(x)$, where $s'(x)>0$, $s''(x)<0$. That is, the price premium increases with fish caught further away from the coast, at a decreasing rate. Finally, however, as the fish achieve maturity, the price premium may fall with a decline in quality from age. In that case, $s'(x)<0$. This premium may be interpreted simply as the gain (finally, loss) in weight of the fish as it travels away from the breeding grounds.

The cost of fishing by each fleet is given by c_c and c_t respectively. Traditional methods involve fishing through laying nets in the water, and thus do not involve significant fuel costs. However, trawling is a fuel intensive operation, and its fishing costs are sensitive to distance. Let $v(x)$ be the unit fuel cost of fishing, i.e., it is the per unit transportation cost of fish from trawling. It is expected to increase with distance, possibly in a non-linear fashion, i.e., $v'(x)>0$.

Denote the harvest at any given location x by the traditional fishing and trawling fleets as $h_c(x)$ and $h_t(x)$, respectively. These harvests are non-negative but are bounded above by their capacity, which is expected to be fixed in the short-run. That is, the maximum harvest by any fleet at any given location may be limited. They are given by $\bar{h}_i, i = c,t$, respectively. In the short-run, there may also be constrains not only on harvesting capacity but also fleet capacity, i.e., the number of vessels and crew. Let $\bar{H}_i, i = c,t$, be the aggregate harvesting capacity of the two fleets respectively. Then we have

$$\int_0^\infty h_i(x)dx \le \bar{H}_i, i = c,t$$

which can be represented by the reduced form

$$H_i'(x) = -h_i(x), i = c,t \, .$$

Let $n(x)$ be the population of fish at any given distance x. We abstain from fish mortality and migration. A constant mortality rate will, as we note later, not make a major difference to the analysis. We assume that migration in directions normal to x may be small. Then n(0) is the stock of fish given exogenously and the aggregate quantity of harvest must not exceed the initial stock:

$$\int_0^\infty [h_c(x) + h_t(x)]dx \le n(0) \tag{1}$$

which generates the differential equation

$$n'(x) = -h_c(x) - h_t(x)\,. \tag{2}$$

The social planner maximizes aggregate net benefits from the fishery by solving the following problem:

$$\begin{aligned}\underset{h_c(x),h_t(x),X}{Max} \int_0^X & [\,ps(x)h_c(x) - c_c h_c(x)] + [\,ps(x)h_t(x) - (c_t + v(x))h_t(x)]\,dx \\ & -\lambda_n(x)(h_c(x) + h_t(x)) - \lambda_c(x)h_c(x) - \lambda_t(x)h_t(x) \\ & \quad + \theta_c(\overline{h}_c - h_c(x)) + \theta_t(\overline{h}_t - h_t(x))\end{aligned} \tag{3}$$

where X is the boundary of the system, endogenously determined; $\lambda_n(x)$ is the shadow price of the stock of fish, $\lambda_c(x)$and $\lambda_t(x)$ are the shadow prices attached to the aggregate fleet capacity constraints, and θ_c and θ_t are Lagrange multipliers attached to the two capacity constraints. The Hamiltonian is written as:

$$\begin{aligned}H = {} & ps(x)h_c(x) - c_c h_c(x) + ps(x)h_t(x) - (c_t + v(x))h_t(x) \\ & -\lambda_n(x)(h_c(x) + h_t(x)) - \lambda_c(x)h_c(x) - \lambda_t(x)h_t(x)\end{aligned}$$

so that the necessary conditions are as follows:

$$ps(x) \le (\ge) c_c + \lambda_n(x) + \lambda_c(x) + \theta_c (= \forall 0 < h_c < \overline{h}_c; \le \forall h_c = 0; \ge \forall h_c = \overline{h}_c; \tag{4}$$

$$ps(x) \le (\ge) c_t + v(x) + \lambda_n(x) + \lambda_t(x) + \theta_t (= \forall 0 < h_t < \overline{h}_t; \le \forall h_t = 0; \ge \forall h_t = \overline{h}_t; \tag{5}$$

$$\lambda_i'(x) = 0, i = n, c, t, \tag{6}$$

the complementary slackness conditions

$$\theta_i(\overline{h}_i - h_i(x)) = 0, \theta_i \geq 0, i = c, t \tag{7}$$

and the terminal condition

$$H(X) = 0. \tag{8}$$

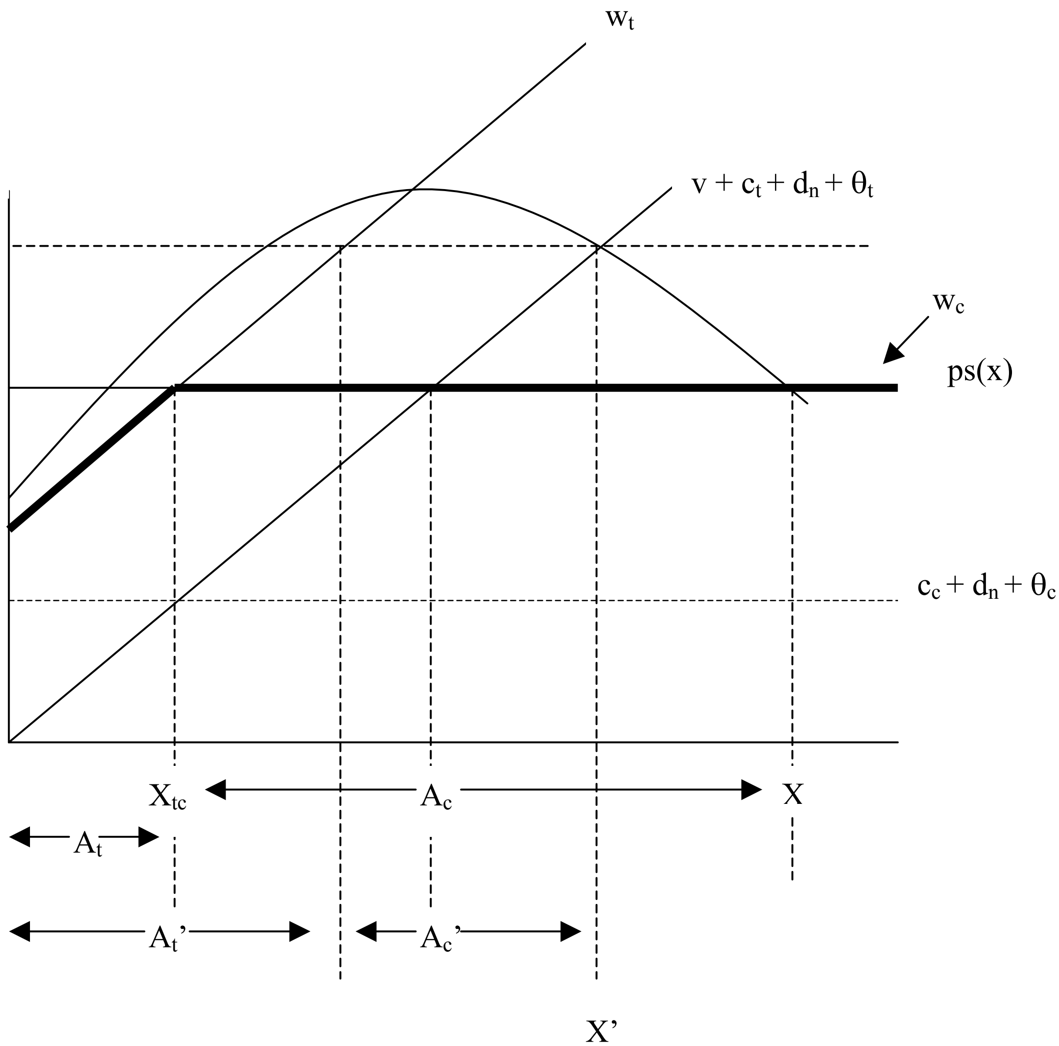
Conditions (4) and (5) yield the typical marginal conditions for harvests by the traditional fishing and trawler fleets, respectively. Condition (6) suggests that the shadow price of stock λ_n is constant over space, as well as the two shadow prices of the aggregate fleet capacity constraints, λ_c and λ_t. Let us now examine the solution for some plausible cases.

a. Trawling more efficient than traditional fishing methods with high fuel costs:

This situation may be modeled by assuming that the unit cost of traditional fishing methods is significantly higher than the unit cost of trawling, i.e., $c_c > c_t$. See Fig.1. Note that the marginal benefit curve over distance is given by $ps(x)$. Denote the total marginal cost of the two fleets given by (4) and (5), as $w_c = c_c + \lambda_n + \lambda_c + \theta_c$ and $w_t = c_t + \lambda_n + \lambda_t + \theta_t + v(x)$. Since the fuel cost $v(x)$ of trawling increases with distance, its marginal cost curve is upward sloping. However, trawling costs are constant over distance. More efficient trawling implies that trawling is likely to be economical closer to the coast and more expensive, due to fuel costs, than traditional fishing further away. Since the marginal benefit increases with distance because of the price premium on bigger fish, it is always more profitable to catch fish further away from the coast. Because of this, note that an interior solution, in which harvests occur at levels below maximum capacity $\overline{h}_c$ or $\overline{h}_t$, will never happen, since it is always profit-enhancing to transfer the marginal harvest from say any location x to location $x+\epsilon$, for sufficiently small $\epsilon>0$. As shown by the bold lines in the figure, trawling is economical inshore in the region denoted by area A_t where the total marginal cost of trawling is lower than that of traditional fishing methods, $w_t<w_c$. Fuel costs increase with distance so that at X_{tc}, there is a switch in fleet from trawling to other methods. The latter becomes economical and takes place in the region A_c. Fishing activity stops at location X, the boundary of the system.

It will be useful to speculate what happens if, for example, the traditional fishing methods fleet is relatively small in aggregate capacity than trawling, as is empirically observed in many coastal fisheries. This will increase the value of the shadow price of aggregate capacity for the traditional fleet, λ_c, which in turn will shift up the aggregate marginal cost curve for traditional fishing, w_c. Since less fish will be caught by the two fleets together, the shadow price of the stock constraint λ_n will decline. The costs of fishing by trawlers will decline and more fishing will now be done by the trawling fleet. Their area of operation will be given by the new region A_t' while the area under traditional fishing shrinks to A_c'. The switch point X_{tc} shifts to the new X_{tc}' and the boundary of the system moves closer than earlier at X', as shown in Fig.1.

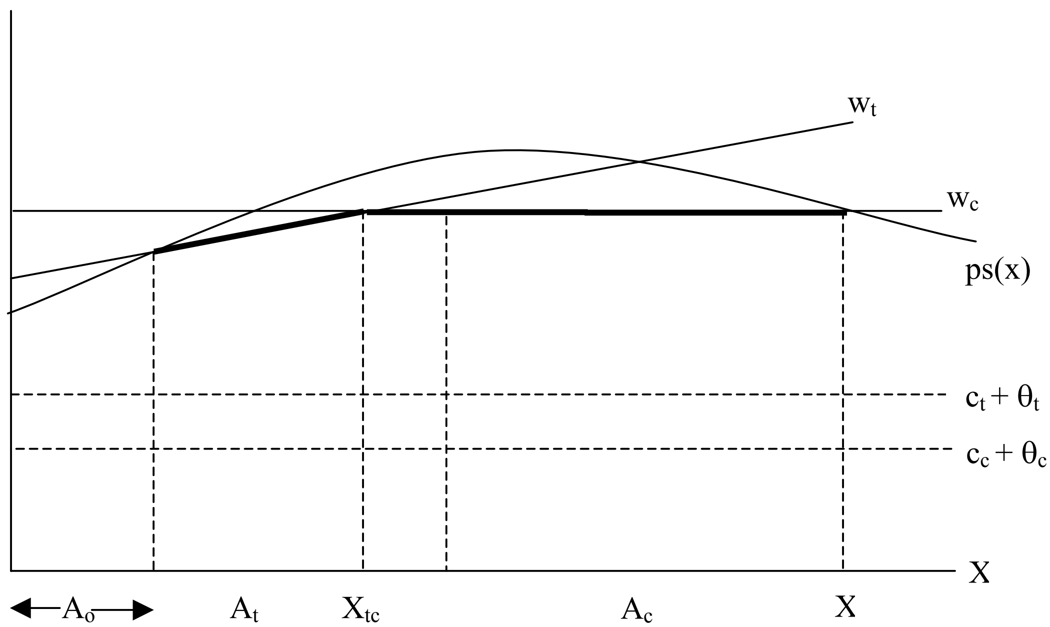
Figure 1. Trawling more efficient than traditional fishing methods with high fuel costs



b. *Trawling is more costly than traditional fishing methods*

While trawling may be more efficient than other more traditional methods, it may be impose social costs such as scraping of the ocean surface and damaging other animal species such as turtles. We then consider the case when the unit cost of trawling is higher than that of traditional methods, possibly for social reasons, $c_t>c_c$. Suppose fish is abundant so that the constraint in (1) is satisfied strictly. Then $\lambda_n=0$. If trawling is sufficiently expensive, there may be no fishing close to the shore, in the region demarcated as A_0 in Fig.2. In this region the marginal costs of both fleets are greater than the marginal benefit. Trawling becomes economical in the region A_t followed by traditional fishing. In this situation, the fish stock is not depleted at X.

Figure 2. Trawling is more costly than traditional fishing methods

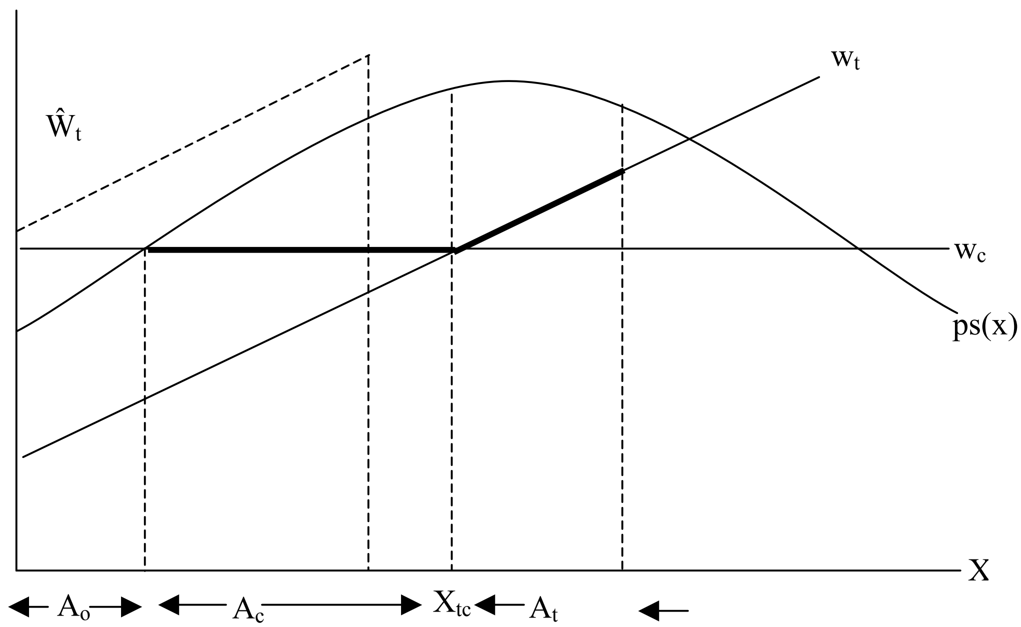


c. *A regulatory constraint on trawling*

In many fisheries, it is not likely that those using traditional methods can fish in distant offshore areas. As we saw in the solutions above, if left to the market, trawlers may be the ones who fish close to shore, and that has been the source of conflicts in many fisheries. Regulators may want to protect traditional fisheries, by designating areas as off-limits to trawling. These area closures can be modeled by imposing constraints on trawling harvests in the above optimization problem. Let us now impose an area closure that protects inshore areas from trawling. This can be exogenously imposed by specifying $\overline{X}_t$ such that $h_t(x) \equiv 0 \forall x \in [0, \overline{X}_t]$.

This constraint imposes an additional shadow cost to the cost of trawling in the inshore areas. Fig. 3 shows the effect of this regulation. There is no fishing immediately close to the coastline since traditional methods are expensive and trawling is forbidden. However, under regulation, the cost of trawling goes up and traditional methods become economical in the area A_t. Trawling activity is relegated to beyond the area closure designated by A_c.

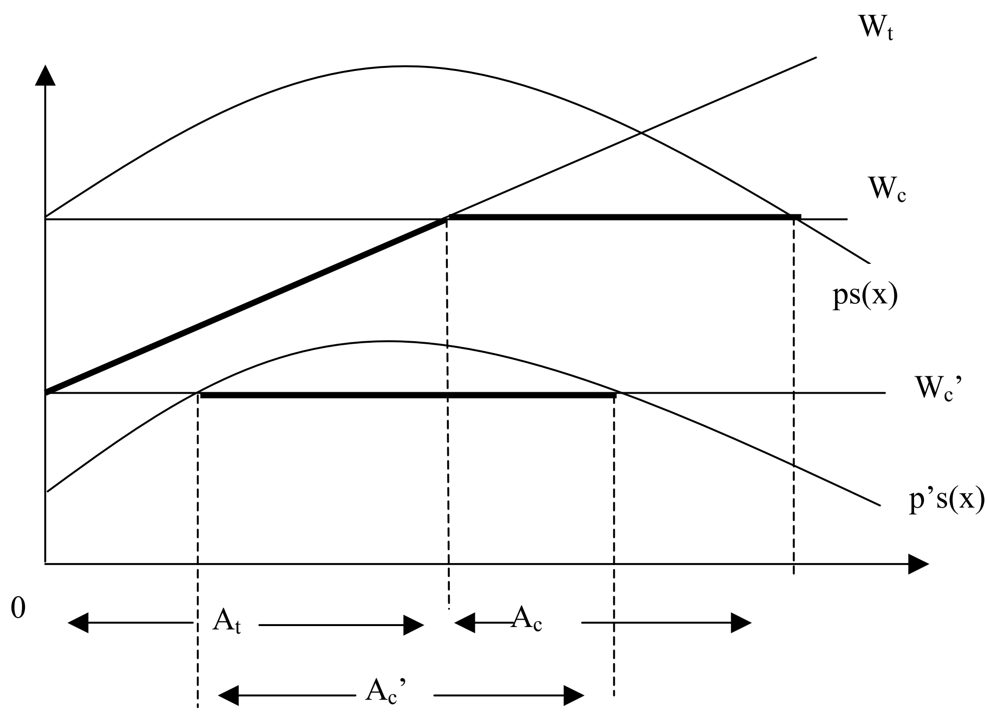
Figure 3. A regulatory constraint on trawling



d. Effect of foreign imports on fleet specialization

Imports could affect the domestic market for fish in several ways. The best way to model this may be in an imperfect competition framework where the two fleets play a quantity or price game under alternative assumptions about the cost of imports. However, that analysis gets complicated in this explicitly spatial framework. In another paper, we examine imports in a simplified non-spatial framework. Here we assume the most likely case: that imports result in a decline in the price of fish. This in turn would lead to a downward shift in the marginal benefit curve, *ps(x).* In general, a lower marginal benefit curve will imply a reduction in harvests by both fleets, as shown in Fig.4. This is not terribly surprising. However, a more interesting result may arise if we assume that the unit cost of trawling (including environmental damages) is higher than the unit cost of traditional fishing. Then as we see in Fig.4, imports may altogether eliminate the higher cost domestic industry, i.e., trawling. That is imports hurt the higher cost industry more than it does the lower cost industry.

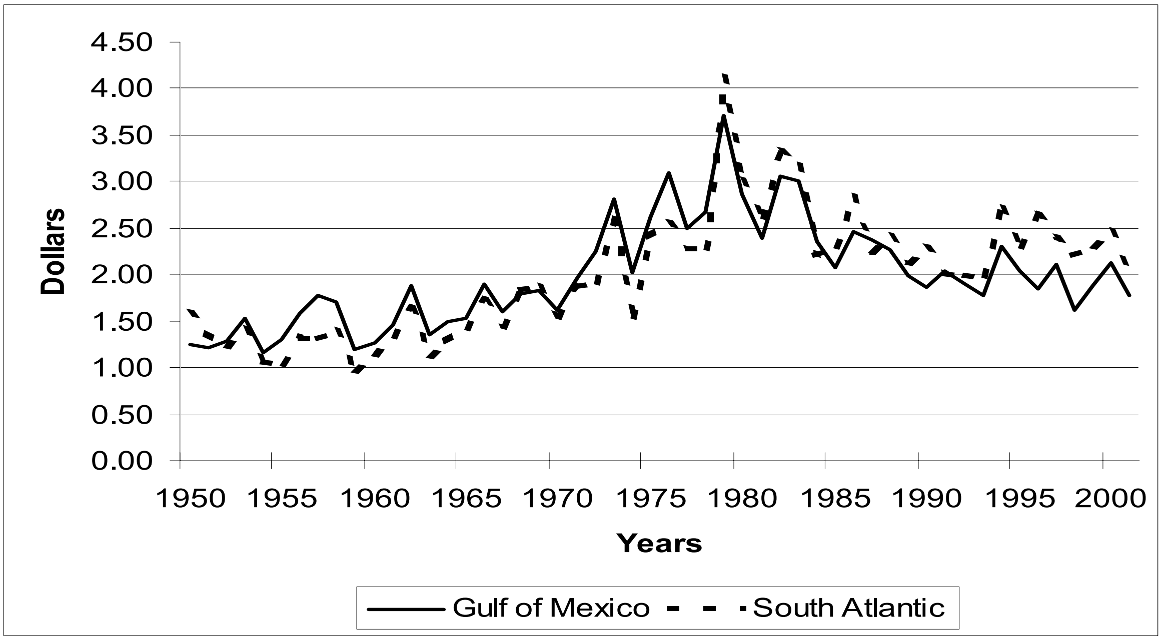
Figure 4. Effect of foreign imports on fleet specialization



3. Empirical Observations

Low-priced imports have rendered the US shrimp industry unprofitable over the last several years (Keithy, *et al*, 1990; Diop, *et al*, 1999; Diop, *et al*, 2000). Real ex-vessel shrimp prices have been on the decline since the early 80s (Fig. 5). Domestic shrimpers blame this on *free* trade. The bulk of the imports comes from Thailand, Vietnam, Mexico, India, Ecuador, China, and Indonesia (NMFS 2003). These countries maintain low production and harvest costs because of non-compliance to global fisheries environmental regulations (Bisony, 2000). More over, anecdotal evidence indicates that health standards in these countries result in inferior, albeit dangerous product entering the US market (Schmidt, 2003).

Figure 5. Gulf and South Atlantic Shrimp Ex-Vessel Prices 1950 to 2001[1]



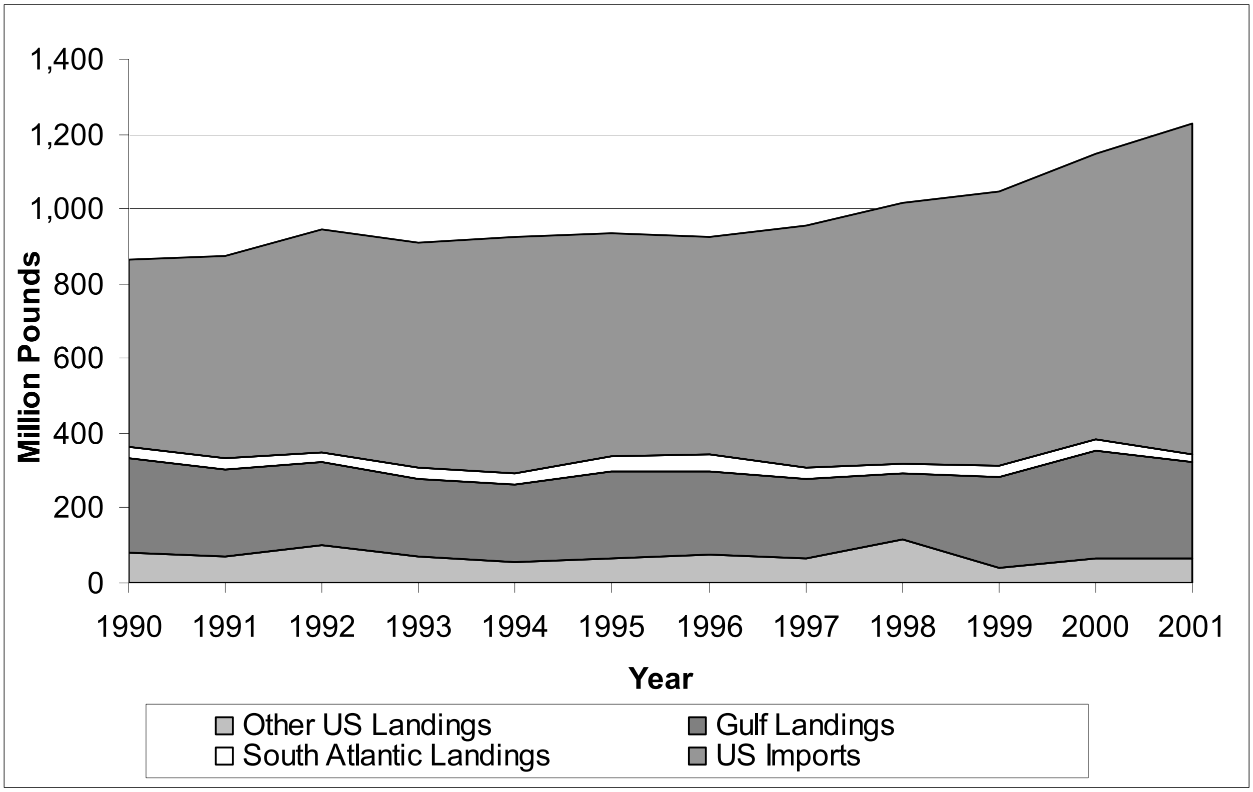
Source: NMFS 2002

The omnibus bill H.J.RES.2, passed February 2003, included $35 million in government support to help deteriorating shrimp industry. This money was obtained primarily through the lobbying efforts by the Southern Shrimp Alliance. The Alliance, comprised of shrimpers and processors from the Gulf of Mexico (Texas, Alabama, Louisiana, and Florida's west coast) and the South Atlantic (Florida's east coast, Florida's inland lakes, Georgia, South Carolina, and North Carolina) region, make up nearly 80% of the shrimp production in the United States.[2] However, as figure 6 illustrates, imports have nearly doubled over the past decade. During the

[1] Value of landings is reported as Ex-Vessel nominal price. In order to convert to real values the GDP[1] deflator was used having 1996 as base year, provided by the Bureau of Economic Analysis (BEA) at http://www.bea.gov/bea/dn/nipaweb/TableViewFixed.asp#Mid.
[2] The Gulf remains the largest domestic production area (70%).

same time period, the quantity of US production has remained relatively constant. Consequently, the US producers' market share of the US shrimp market has declined.

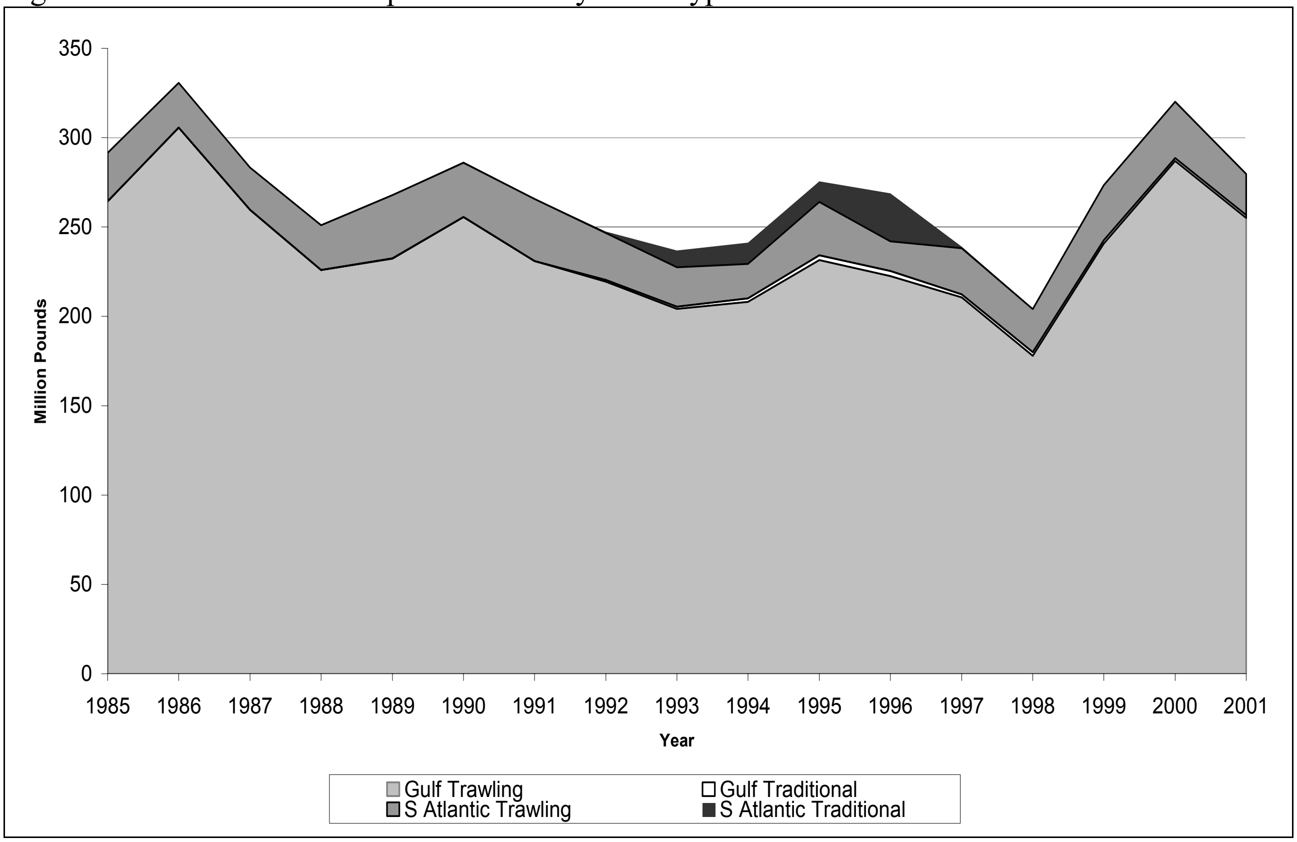
Figure 6. US Shrimp Supply 1990- 2001



Source: NMFS 2002

Shrimp harvesting practices vary across the world from traditional techniques of catching by hand and with a cast net to more technologically sophisticated methods of trawling. Trawling allows for a more efficient use labor as large quantities of shrimp are caught in nets drug across the ocean floor. Yet, the social cost of habitat degradation and bi-catch of endangered species can render this an unpopular choice. For our purposes, we distinguish between trawling and traditional methods based on efficiency (cost per unity), environmental sustainability, distance/physical limitation. Trawling has a high efficiency level, and is not limited by distance, but environmental sustainability is problematic in many areas. On the other hand, the traditional fisheries are lower in efficiency, and generally unable to fish beyond certain distances or ocean depths. Still, they are environmentally sustainable. Fig. 7 illustrates the shrimp landings by gear type for the southeastern Atlantic region, most of which are attributed to trawling in the Gulf.

Figure 7. Southeastern Shrimp Production by Gear Type



Source: NMFS 2002

Within the US shrimp fishing industry, trawlers and traditional fishermen experience considerable tension. Trawlers believe cast netters and others deplete the shrimp stock, especially of the small, immature shrimp that tend towards the shoreline. Regulations, particularly in Georgia, limit the number of cast netting licenses and the daily landings volume in attempt to alleviate this tension (Georgia Law O.C.G.A. Title 27).

This model completes the first phase of a multi-stage effort to evaluate the relationship between trawling and traditional methods of shrimp in the southeastern Atlantic, and to explore the effects imports have on that relationship. Future work will utilize the model defined in this document to develop a simulation of the coastal fishery. The affects of various policy alternatives will be explored through sensitivity analysis on initial stocks, fuel costs, fishing costs, growth functions *s(x)*, price (imports), and regulations (zones, demarcation, environment, volume constraint, number of licenses. Theoretical extensions could include strategic "rent-shifting" behavior between the two fleets (Ruseski, 1998) although the fact that there are spatial externalities between the two fleets makes the problem somewhat more complicated.

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