Spatial Interaction of Domestic Fishing Fleet and Import Competition

Water Policy Working Paper #2004-007

Prepared by:

Ujjayant Chakravorty
Emory University

Donna Fisher
Georgia Southern University

Paulo Röwer
Georgia Southern University

May 2004

The authors gratefully acknowledge financial support for this work provided by the Georgia Soil and Water Conservation Commission (480-04-GSU1001) and the U.S. Department of Agriculture (2003-38869-02007).
Spatial Interaction of Domestic Fishing Fleet and Import Competition

by

Ujjayant Chakravorty, Donna K. Fisher and Paulo Röwer

Abstract

Globalization of the fisheries sector in most developed nations has led to a flooding of the market with imports to the U.S. from abroad. At the same time, the domestic fleet has polarized into a traditional sector that uses environmentally benign technologies such as castnetting, and a more mechanized fleet with adverse environmental effects such as trawling. How do imports affect multiple fishing fleets? Which sector will be affected the most? This paper addresses these issues through a simple spatial model of a coastal fishery. An empirical model of a typical Southeastern US shrimp fishery is developed as an illustration. We show that the effect of imports on the domestic fleet may depend upon technological constraints of the fleet and the spatial distribution of the cost of fishing.

Key Words: multiple fleets, imperfect competition, Cournot models, trade, regulation

JEL Codes: Q22, Q28, L51

Draft for Circulation

Last Revised: May 25, 2004

---

1 Chakravorty: Department of Economics, Emory University, email unc@emory.edu; Fisher and Röwer: School of Economic Development, Georgia Southern University, email: dkfisher@georgiasouthern.edu and paulorower@coastalrivers.org.
1. Introduction

A substantial literature exists 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. However, very little attention has been paid to the issue of multiple fleets and in particular, how the cost and demand characteristics of the fishery as well as import competition affect the regional specialization of fleets in different locations in the ocean. This is especially important for species such as shrimp and other bottom fish, which have several unique characteristics: (i) they migrate in limited but predictable ways, by spawning in estuarine areas and migrating away from the coast. Their size often increases as they move further offshore; (ii) there is an element of heterogeneity in the fishing fleet, with traditional techniques such as castnetting (catching fish through dropping nets in the water) and more mechanized methods such as trawling (with potentially negative environmental effects) coexisting side by side, often not very peacefully; (iii) cheap foreign imports of fish, especially shrimp, have taken an increasing share of the domestic market in countries such as the United States.

The policy questions that we want to address are: given a resource that is mobile over space and possibly growing in size, what is the optimal allocation of the heterogenous fishing fleet in the ocean? That is, which fleet should fish where and how much? If the modern fleet is more efficient but is also damaging to the environment, then how would the fishing effort be allocated? What is the effect of regulatory policies that aim to protect small fishermen or reduce

---

2 For a recent and comprehensive survey, see Wachsman (2002) and Sumaila (1999).
environmental damage? Finally, we look at how imports may affect the equilibrium allocation of effort by the two fleets?

We first develop a simple spatial model of the coastal fishery with a traditional and a modern fleet. Economically efficient fishing behavior of the two fleets is derived under a range of parameter values and regulatory policies. The model is then extended to include imports. Finally we discuss the main characteristics of the US Southeastern Coastal fishery and run simulations to show the magnitude of welfare effects under alternative policy instruments.

We show that spatial considerations are important in the allocation of fishing effort. The price premium from fish size or other characteristics that vary with distance may determine the spatial distribution of the two fleets. On the other hand, technological constraints may affect the decision to fish in a particular location. An increase in the slope of the variable cost curve will imply that the effort is located closer to the coast. Imports reduce domestic production and profits but their effect on each of the two fleets depends upon the cost of fishing and also on technological constraints. For example, if castnetting is confined to inshore areas, imports may wipe out the entire industry. On the other hand, if the cost of trawler fishing is sensitive to distance, then castnetters may still be economically viable under import competition.

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 his study 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, and uses it 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 their sensitivity to regulatory policies.

Section 2 presents a simple competitive model with two domestic fleets – traditional and modern. In section 3, we extend this model to include imports in which the domestic and foreign industries operate in an imperfectly competitive market. Section 4 details an empirical simulation of the model using the Georgia shrimp industry as an example. Section 5 concludes the paper.

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 constant \( p \). Later when we consider imports, we will examine price-setting by incorporating a demand function for fish. For now, a fixed price of fish is adequate for our purpose. The model is mainly relevant for bottom fish such as shrimp, which breed in estuaries where the salt water interfaces with fresh water and then swim away from shore. Other pelagic (migratory) fish, such as tuna could be modeled using this framework provided we know the general direction of their movements.\(^3\) As the population of shrimp moves away from the coastline, they grow bigger in size. This is reflected in a higher price for fish caught further

\(^3\) Recent advances in fish tracking technology using satellites and other global positioning devices is making this increasingly feasible.
offshore. We model this issue by letting the distance from the coast be measured by the variable $x$ and 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, as the fish achieve maturity, the price premium may fall with a decline in quality from age, so that $s''(x)<0$. This premium may be interpreted simply as the gain (finally, loss) in weight of the fish as it travels away from the breeding grounds.\footnote{Increased fish mortality from aging may also be captured by this declining trend in price.}

The cost of fishing by each fleet is given by $c_c$ and $c_t$, respectively. Since our main purpose is to examine the allocation of effort over space, we focus on the costs of fishing that are sensitive to distance and not those (e.g., wages to crew, fishing devices etc..) which we consider to be the same across the two fishing technologies. 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., $v'(x)>0$. For simplicity we assume that the cost of the traditional fleet is not sensitive to distance. This may be an oversimplification. It is straightforward to include a distance sensitive cost specification for the traditional fleet, but to the extent that the unit cost of fishing by the traditional fleet is lower than that of trawling - a reasonable assumption given that the modern fleet is more sensitive to fuel costs - our analysis holds.

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. This may be due to the fact that only a limited number
of vessels of a given type may be able to operate at any given spot in the ocean and the
harvesting capacity of each boat is limited by factors such as technology and boat size. These
constraints are given by \( \bar{h}_i, i = c, t \), respectively. In the short-run, there may also be constraints
not only on harvesting capacity at any location but also aggregate fleet capacity, i.e., the number
of vessels and crew in any given fleet. Let \( \bar{H}_i, i = c, t \), be the aggregate harvesting capacity of the
two fleets respectively. Then we have
\[
\int_0^\infty h_i(x) \, dx \leq \bar{H}_i, i = c, t
\]
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 that is invariant with respect to population 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:
\[
\int_0^\infty \left[ h_c(x) + h_t(x) \right] \, dx \leq n(0)
\]  
which generates the differential equation

\[
n'(x) = -h_c(x) - h_t(x).
\]
The social planner maximizes aggregate net benefits from the fishery by solving the following problem:

\[
\begin{align*}
\text{Max} \quad & \int_0^X \left[ \frac{ps(x)h_c(x) - c_c h_c(x)}{\lambda_n(x)} + \frac{ps(x)h_t(x) - (c_t + v(x))h_t(x)}{\lambda_c(x)} \right] dx \\
& \lambda_n(x)(h_c(x) + h_t(x)) - \lambda_c(x)h_c(x) - \lambda_t(x)h_t(x) \\
& + \theta_c(\bar{h}_c - h_c(x)) + \theta_t(\bar{h}_t - h_t(x)) \\
\end{align*}
\]

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 \( \theta_c \) and \( \theta_t \) are Lagrange multipliers attached to the two harvest constraints. The Hamiltonian is written as:

\[
H = ps(x)h_c(x) - c_c h_c(x) + ps(x)h_t(x) - (c_t + v(x))h_t(x) \\
- \lambda_n(x)(h_c(x) + h_t(x)) - \lambda_c(x)h_c(x) - \lambda_t(x)h_t(x)
\]

so that the necessary conditions are:

\[
\begin{align*}
ps(x) & \leq (\geq) c_c + \lambda_n(x) + \lambda_c(x) + \theta_c (= \forall 0 < h_c < \bar{h}_c; \leq \forall h_c = 0; \geq \forall h_c = \bar{h}_c); \\
ps(x) & \leq (\geq) c_t + v(x) + \lambda_n(x) + \lambda_t(x) + \theta_t (= \forall 0 < h_t < \bar{h}_t; \leq \forall h_t = 0; \geq \forall h_t = \bar{h}_t); \\
\lambda'_i(x) & = 0, i = n, c, t,
\end{align*}
\]
the complementary slackness conditions are given by

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

(7)

and the terminal condition

$$H(X) = 0.$$  

(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 $\lambda_n$ is constant over space, as well as the two shadow prices of the aggregate fleet capacity constraints, $\lambda_c$ and $\lambda_t$. Let us now examine the solution for some plausible cases.

\[a. \text{Trawling is more efficient:}\]

This situation may be modeled by assuming that the unit cost of traditional fishing methods is 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, castnetting 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 from the coast. 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 any location $x$ to location $x+\varepsilon$ (for sufficiently small $\varepsilon > 0$) since the price increases with distance.

Figure 1. Trawling more efficient than traditional fishing
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 effort from trawling to the traditional fleet. The latter becomes economical and takes place in the region $A_c$. Fishing activity stops at location $X$, the boundary of the system at which the marginal benefit falls below the marginal cost of fishing. Beyond this location, there may be positive quantities of fish but the price they fetch does not cover the marginal cost for either fleet.

It will be useful to speculate what happens if, for example, the traditional fishing 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, $\lambda_c$, 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 $\lambda_n$ 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. The cumulative harvest will decline and more fish will remain uncaught beyond the boundary.

b. **Trawling is less efficient than traditional fishing**

While trawling may be more efficient than other more traditional methods, it may impose social costs such as scraping of the ocean surface and damaging bycatch species such as turtles. There is considerable documentary evidence of the negative environmental effects of trawling on the coastal ecology. These social costs are not likely to be included in the unregulated market.
behavior of the industry. We now consider the case when the unit cost of trawling is higher than that of the traditional fleet, possibly for social reasons, \( c_t > c_c \). Suppose fish are abundant so that the constraint in (1) is satisfied strictly. Then \( \lambda_n = 0 \). If trawling is relatively 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 the boundary. Apart from a higher social cost of trawling, nonfuel input costs such as the fixed cost of technology or mechanized vessels or higher wage rates may lead to the same outcome. This outcome may be preferred by environmentalists who care about the negative effects of fishing activity close to the coast line.

Figure 2. Trawling is more costly than traditional fishing

\[
\begin{align*}
\text{c. A regulatory constraint on trawling}
\end{align*}
\]
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 in which fishing areas are often informally demarcated so that traditional boats stay close to shore while trawlers go further away. Regulators may want to protect traditional fisheries, by designating areas close to the coastline 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 $\bar{X}_t$, such that $h_t(x) \equiv 0 \forall x \in [0, \bar{X}_t]$. 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 the traditional technology becomes 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
3. The Effect of Fish Imports under Imperfect Competition

Imports could affect the domestic market for fish in several ways. The best way to model it 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. We can thus modify the model presented in the previous section to the case of imperfect competition between the domestic and foreign fleets. We continue to assume no strategic behavior within the domestic industry, i.e., between the modern and traditional fleets. That is, the domestic industry operates strategically in the world market, while there is optimal allocation of effort between the modern and the traditional fleets in the coast. This may happen if for example, the domestic fishing industry competes in a Cournot game with the foreign sector, and then allocates its quota optimally among the two domestic fleets.

Let the quantities of fish supplied by the domestic and foreign industries be given by \( Y_d \) and \( Y_f \) respectively. Let the aggregate demand function be given by \( D^{-1}(Y_d + Y_f) \). Define the aggregate cost function of the domestic fleet \( C(Y_d) \). For simplicity we abstract from modeling the foreign fleet in detail and assume that the unit cost of fishing from the foreign fleet is a constant \( c_f \). Then the domestic fleet maximizes profits by choosing its harvest and assuming the foreign harvest as given:

\[
\max_{Y_d} D^{-1}(Y_d + Y_f)Y_d - C(Y_d)
\]

which assuming an interior solution yields

\[
D^{-1}(Y_d + Y_f)Y_d + D^{-1}(Y_d + Y_f) - C'(Y_d) = 0.
\]
Similarly the foreign fleet solves

\[
\begin{align*}
\max_{Y_f} & \quad D^{-1}(Y_d + Y_f)Y_f - c_f Y_f \\
\text{which yields} & \quad D^{-1}(Y_d + Y_f)Y_f + D^{-1}(Y_d + Y_f) - c_f = 0.
\end{align*}
\]

The solution of these two necessary conditions yields the Cournot equilibrium \(Y_d^c\) and \(Y_f^c\). It is clear that the aggregate harvest from the domestic fishery will decrease with trade. The cheaper the cost of imported fish \(c_f\), the lower the market share of domestic fish \(Y_d^c\). This in turn would impact the spatial allocation of fishing in the coastal fishery.

The effect of imports on the harvest of the two fishing fleets depends on which fleet has lower cost. For example, consider an unregulated fishery in which trawling is cheaper than castnetting. Then the lower aggregate harvest needs to be optimally allocated between the two fleets. It is straightforward to check that decline in harvest from foreign competition will be borne by the more expensive traditional fishery. Similarly, if the cost of trawling is higher (say due to environmental damages) or if the fishery is regulated such that trawling is not allowed in inshore areas, then the effect of competition will be on the trawling fleet. These cases are shown in Fig. 4. In fact, Cournot competition with cheap foreign fish may altogether eliminate the higher cost domestic industry. Thus if the social costs of trawling are high enough, then imports may totally wipe out the trawling fleet. In fact, in the case that the social costs of harvesting by mechanized vessels is high and taxing or regulating the domestic fleet is politically costly, imports may achieve the same objective.
4. The Empirical Model

In this section, we begin with a discussion of the major stylized facts associated with the southeast US shrimp fishery and then illustrate the theory with a simulation model for the Georgia fishery.

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

Source: NMFS 2002

The omnibus bill H.J.RES.2, passed February 2003, included $35 million in government
support to help the deteriorating US 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, makes up nearly 80% of the shrimp production in the

---

5 Value of landings is reported as Ex-Vessel nominal price. In order to convert to real values the GDP 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.
United States.\textsuperscript{6} However, as figure 6 illustrates, imports have nearly doubled over the past decade. During the 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

![Graph showing US Shrimp Supply 1990-2001](image)

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, and

\textsuperscript{6} The Gulf remains the largest domestic production area (70%).
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.

Data for Simulation

A demand function for shrimp in the state of Georgia is calibrated from shrimp supply and demand data during the period 1989-2001 as follows:

\[ Y = 24,153,381 \times p^{-2} \]

where $Y$ is quantity demanded and $p$ is the price of shrimp. This demand function has an elasticity of -2 and passes through a point with equilibrium quantity of 4,614,800 lbs and price of $2.29 per lb of shrimp (Fisher et al, 2002). The value of the constant is given by 24,153,381 units.
The spatial distribution of fish landings can be aggregated into five size cohorts which roughly correspond to five different fishing zones. The mean weights for each cohort are estimated on a liner growth distribution of shrimps where the smaller size (60 shrimps per pound) are closer to shore, and the bigger (1 shrimp per pound) are further from shore. The weights are as follows:\(^7\)

Zone 1 = 0.262295
Zone 2 = 0.290909
Zone 3 = 0.40
Zone 4 = 0.695652
Zone 5 = 1.067

The above data by zone was used to compute the price of shrimp in any given zone, \(p(x)\). The price premium \(s(x)\) was computed as

\[s(x) = -0.084 + 0.392x - 0.049x^2\]

where \(x\) in this empirical model represents the distance of the zone from the shore. In keeping with empirical evidence, this model assumes that the price of shrimp peaks in zone 4. The quality of shrimp declines beyond the peak due to aging and eventual mortality, reducing the premium paid for the shrimp. Thus, the price per pound of shrimp by distance is then given by:

\[p(x) = p(1 + s(x)).\]

\(^7\) Georgia landings for the year 2000 were largest in Zone 4.
Define the cost of fishing per pound of fish by the trawler fleet as $c_t(x)$. These costs are expected to increase with distance $x$, as follows:

$$c_t(x) = 0.69 + 0.1725x$$

where the constant term represents the fixed costs of shrimping. Let the corresponding cost of fishing by the castnetting fleet be $c_c$. These costs are assumed to be a constant $1.00 per pound.

The average capacity of each trawling (castnetting) vessel is given by $h_t(x)$ ($h_c(x)$), which is obtained by dividing the total trawling (castnetting) catch in the state of Georgia in year 2001 by the number of licensed vessels in the same year.

**The Baseline Scenario**

The baseline or base case scenario assumes only a domestic industry. If the growth rate of shrimp is a uni-modal distribution, and trawlers face a cost function that has a positive slope then as we see in Fig.8 and Table 1 that the optimal allocation of effort according to maximum profit implies that castnetters fish in zone 4 and trawlers in zone 3. However, in reality castnetters are unable to travel that far, a case we will deal with subsequently. Notice that industry profits equal are approximately $12 million. Because of capacity constraints on the castnetting fleet, the bulk of the profits go to the trawlers.

Figure 8. Base Case Scenario
Table 1. Base Case: Allocation of Fishing Effort in the Base Case

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(x)</td>
<td>0.26</td>
<td>0.50</td>
<td>0.65</td>
<td>0.70</td>
<td>0.65</td>
</tr>
<tr>
<td>p(x)</td>
<td>2.83</td>
<td>3.38</td>
<td>3.71</td>
<td>3.83</td>
<td>3.71</td>
</tr>
<tr>
<td>c_t</td>
<td>0.86</td>
<td>1.04</td>
<td>1.21</td>
<td>1.38</td>
<td>1.55</td>
</tr>
<tr>
<td>c_c</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Marginal profit t ($)</td>
<td>1.97</td>
<td>2.35</td>
<td>2.51</td>
<td>2.45</td>
<td>2.16</td>
</tr>
<tr>
<td>Marginal profit c ($)</td>
<td>1.83</td>
<td>2.38</td>
<td>2.71</td>
<td>2.83</td>
<td>2.71</td>
</tr>
<tr>
<td>Total Profit t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11,909,438</td>
</tr>
<tr>
<td>Total Profit c</td>
<td>75,315</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Y_t$ (Lbs)</td>
<td>4,750,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Y_c$ (Lbs)</td>
<td>26,660</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The Price Premium is Positively Sloped*

When there is a positively sloped price premium, i.e., the price of shrimp keeps rising with distance, then the castnetters fish in zone 5 and trawlers in zone 4. This case, illustrated in Fig. 9 and Table 2, can be interpreted as representing a situation in which there is no decline in the price premium. Or that the migratory distance of shrimp is relatively large. In this case, growth peaks not in zone 4 as in the previous case, but in zone 6, which is not shown here. The price premium equation is given by:

\[ s(x) = 0.0664 + 0.2112x - 0.0176x^2. \]

Figure 9. A Positively Sloped Price Premium
Table 2. Fishing Effort when the price premium is positively sloped

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(x)</td>
<td>0.13</td>
<td>0.29</td>
<td>0.41</td>
<td>0.50</td>
<td>0.55</td>
</tr>
<tr>
<td>p(x)</td>
<td>2.54</td>
<td>2.89</td>
<td>3.17</td>
<td>3.37</td>
<td>3.49</td>
</tr>
<tr>
<td>ct</td>
<td>0.86</td>
<td>1.04</td>
<td>1.21</td>
<td>1.38</td>
<td>1.55</td>
</tr>
<tr>
<td>cc</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Marginal profit t</td>
<td>1.67</td>
<td>1.86</td>
<td>1.96</td>
<td>1.99</td>
<td>1.93</td>
</tr>
<tr>
<td>Marginal profit c</td>
<td>1.54</td>
<td>1.89</td>
<td>2.17</td>
<td>2.37</td>
<td>2.49</td>
</tr>
</tbody>
</table>
Technological Constraints on Castnetting

In this case, we introduce constraints on castnetting technology and assume that they are unable to fish beyond zone 1. In other words they can only fish within a mile of the coast. Fig. 10 and Table 3 indicate that this restriction does not affect the trawler fleet output and profits but reduces the profit of the castnetters by about 35%. Industry profits, however, decline only by 0.2%, to nearly $12 million.

Figure 10. Castnetting Limited to Inshore Areas
Table 4. Castnetting Limited to Inshore Areas

<table>
<thead>
<tr>
<th>Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(x)</td>
<td>0.26</td>
<td>0.50</td>
<td>0.65</td>
<td>0.70</td>
<td>0.65</td>
</tr>
<tr>
<td>p(x)</td>
<td>2.83</td>
<td>3.38</td>
<td>3.71</td>
<td>3.83</td>
<td>3.71</td>
</tr>
<tr>
<td>c_t</td>
<td>0.86</td>
<td>1.04</td>
<td>1.21</td>
<td>1.38</td>
<td>1.55</td>
</tr>
</tbody>
</table>
\[ \begin{array}{c|ccccc} \hline c_c & 1.00 & 1.00 & 1.00 & 1.00 & 1.00 \\
Marginal profit t & 1.97 & 2.35 & 2.51 & 2.45 & 2.16 \\
Marginal profit c & 1.83 & 2.38 & 2.71 & 2.83 & 2.71 \\
Total Profit t & 11,909,438 & \\
Total Profit c & 48,861 & \\
Y_t (Lbs) & 4,750,000 & \\
Y_c (Lbs) & 26,660 & \\
\hline \end{array} \]

*Imports from Abroad*

Now the domestic and foreign sectors play a Cournot game. We compute the reaction functions of each player by taking the other player’s output as given. This is shown in Fig. 11. Notice that when imports are included in the model, then the equilibrium quantity supplied by the domestic sector shrinks. This in turn means that these cuts in harvest must be borne by the two domestic fleets. However, in our spatial setting, suppose the castnetters have a technological constraint in fishing beyond zone 1. Then as seen in Fig. 11, the profits from zone 1 are lower than the profits from zone 2. Thus the smaller quantity is fished entirely by the trawling fleet. So the effect of imports is that the castnetting fleet is wiped out and there is a 92.5% reduction in trawling profits.
Figure 11. Reaction Functions for the Domestic and Import Sectors

Figure 12. Effect of Imports on Domestic Production with Technological Constraints on Castnetting
### Table 5. Allocation under Imports

<table>
<thead>
<tr>
<th>Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(x)</td>
<td>0.26</td>
<td>0.50</td>
<td>0.65</td>
<td>0.70</td>
<td>0.65</td>
</tr>
<tr>
<td>p(x)</td>
<td>1.24</td>
<td>1.48</td>
<td>1.62</td>
<td>1.67</td>
<td>1.62</td>
</tr>
<tr>
<td>c_t</td>
<td>0.86</td>
<td>1.04</td>
<td>1.21</td>
<td>1.38</td>
<td>1.55</td>
</tr>
<tr>
<td>c_c</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Marginal profit t</td>
<td>0.37</td>
<td>0.44</td>
<td>0.42</td>
<td>0.29</td>
<td>0.07</td>
</tr>
<tr>
<td>Marginal profit c</td>
<td>0.24</td>
<td>0.48</td>
<td>0.62</td>
<td>0.67</td>
<td>0.62</td>
</tr>
<tr>
<td>-------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Total Profit t</td>
<td>886,629</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Profit c</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Y_t$ (lbs)</td>
<td>2,000,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Y_c$ (Lbs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Imports under High Fuel Costs

Now we examine the effect of imports with high fuel costs. As shown in Fig. 13, high fuel costs reduce the profit of the trawling fleet which in turn makes castnetting viable. The castnetters come back in this scenario along with trawlers who now fish in zone 2 because fishing away from the coast is more expensive. One could also interpret this as an example of an environmental tax that is a function of distance.

Figure 13. Effect of Imports with Castnetting Technology Constraints and High Fuel Cost
Table 6. Effect of Imports with Castnetting Technology Constraints and High Fuel Cost

<table>
<thead>
<tr>
<th>Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>s(x)</td>
<td>0.26</td>
<td>0.50</td>
<td>0.65</td>
<td>0.70</td>
<td>0.65</td>
</tr>
<tr>
<td>( p(x) )</td>
<td>1.24</td>
<td>1.48</td>
<td>1.62</td>
<td>1.67</td>
<td>1.62</td>
</tr>
<tr>
<td>( c_t )</td>
<td>1.21</td>
<td>1.39</td>
<td>1.56</td>
<td>1.73</td>
<td>1.90</td>
</tr>
<tr>
<td>( c_c )</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
5. Concluding Remarks

This paper is a first attempt at developing an economic framework that explicitly models location choice of multiple fishing fleets and then examines their behavior when they compete with foreign fleets in the domestic market. The framework allows us to understand the factors that determine locational choice of fishing fleets in a typical coastal fishery in which the price premium increases in a possibly non-monotonic fashion. This is in contrast to previous studies which do not recognize the heterogeneity of the coastal fishery. This framework could be used by policy makers to estimate the benefits and costs of alternative regulatory measures such as reducing gear conflict, and to prevent the allocation of effort in environmentally sensitive areas. For example, the effect of temporary area closures on specific fishing regions can be estimated by using the model to determine the spatial distribution of vessels when certain areas are no longer accessible. The model also allows us to determine the effect of imports on specific fishing fleets, as opposed to aggregate effects on the industry as a whole.
It is clear if the first-best profit maximization were the only objective, in many instances, the traditional fishery may be wiped out, and replaced by more efficient modern fleets. However, if the policy maker chooses to devise regulation that ensures that the subsistence fishery survive, then several policy instruments such as taxes and area closures are available. Our framework can be used to examine how these instruments will affect spatial location decisions in the coastal fishery. The empirical model shows how foreign imports will affect catches and profits in both domestic fishing fleets.

There are several restrictions in the model that could be removed in future work. For example, the price premium is independent of harvest decisions. That is, the premium facing a fleet at a given location is not affected by harvests upstream. In future work this assumption could be removed. In that case, the location of say the traditional fleet closer to the coast may affect the profit per unit fish further away from the coast. We also do not consider strategic behavior by the fleets. Future work could focus on strategic locational or harvest decisions by each fleet. This is particularly important because it is possible that the traditional fleet may be able to impose a negative externality on the trawling fleet by maximizing their catch, because the price premium increases with distance. From a industry point of view, the profit per unit may be higher if a given fish is caught when its price premium net of harvesting cost is maximum. Experimental techniques could be used to determine conditions under which the fleet may come closer to the Pareto optimal solution.
References


