Fisheries management is a particularly vexing problem in public policy. On the one hand, many coastal communities depend on their fisheries for their economic survival, and fishing is often deeply ingrained as an integral, even core, part of local culture and community. On the other hand, many fish stocks simply cannot sustain the demands that modern fisheries place upon them. The recent collapse of much of the New England fishery underscores this dilemma—attempts to limit fisheries to sustainable catch levels often run into fierce opposition in maritime communities in the short term, but the failure to limit fisheries to sustainable catch levels can completely undermine the way of life in those communities in the long term. The solutions to the problem of fisheries management are equally controversial. The first approach to mitigating overfishing has generally been to control supply, either by directly limiting the ability or the right of fishers to catch fish. Quotas and permits are classic examples of supply management. These types of policies, when properly implemented, can be effective in limiting catches. Because they involve the government dictating the behavior of fishers, however, they can also generate considerable local political opposition.

More recent is the attempt to decrease the number of fish caught by decreasing the market demand for those fish. This strategy, of demand management, is designed to affect the behavior of fishers indirectly, through the mechanism of market pricing, rather than through direct government regulation. As such, it is less prone to generating strong local political opposition. In addition, nongovernmental groups, which cannot control the behavior of fishers directly but can on occasion affect consumer behavior, can also attempt strategies that lower the demand for particular depleted fish species. These political advantages suggest a role for demand-based policies in the management of fish stocks. But this management approach can backfire. It can have the perverse effect of leading fishers to try to catch more, rather than less, of the species that the management effort is trying to protect.

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Demand Management of Fisheries

Demand management is used broadly as a form of environmental regulation, particularly by those who favor market mechanisms over government as instruments of public policy. The idea underlying demand management is that lowering the demand curve for a good should, according to conventional economic theory, lower both the market equilibrium price and the market equilibrium quantity supplied of the good. In other words, if demand for the good is lower, consumers will not be willing to pay as much for a given quantity of a good. As a result, producers receive less remuneration for the good, and thus are less willing to produce as much of it. A classic example of demand management of an environmental good is a gasoline (or carbon) tax, which should make people want to use less gasoline. Such a tax is explicitly designed to decrease demand for gasoline, and as a result decrease the amount consumed.¹

There are no direct equivalents to a gasoline tax in fishery management—there are no proposals out there for a “fish tax” for threatened species. But there are other measures that have the equivalent effect of decreasing consumer demand for specific fish stocks. These include the creation of alternative sources of supply for the species in question, which decreases demand for fish caught at sea, and convincing consumers that they should not be eating the fish in question.

The primary way of arranging for alternative sources of supply of a particular species is through aquaculture, also known as fish farming. The environmental argument in its favor is that, by increasing the number of fish available, aquaculture makes conservation of stocks in the wild easier. It also allows for harvesting of the fish under controlled circumstances that do less damage to ecosystems than do some fishing practices, such as bottom-trawling, purse-siennetting, or gillnetting.² Public policy can affect the development of aquaculture in a number of ways. Governments can promote fish farming through the use of subsidies or regulatory concessions. They can also affect the cost-effectiveness of aquaculture through the stringency of the environmental regulations and controls that affect the industry.

The effects of aquaculture on the demand for fish are important because it is a big business. With some species, farming is the predominant source of supply. For example, all commercially-available Atlantic salmon are farmed, an industry that brings in more than $100 million in the United States alone.³ And the introduction of widespread farming of salmon, both in the Atlantic and the Pacific, did have the predicted effect of lowering the demand for, and hence the market price of, salmon caught in the wild.⁴

1. On which see, for example, OECD 1994.
2. There are also environmental arguments against aquaculture, relating to such issues as marine pollution and biodiversity. For a review of this issue, see Naylor et al 2000.
4. This impact began to be felt by the Pacific salmon fishery in the period from the late 1980s to the mid-1990s. Of the three largest fisheries by value, for example, between 1988 and 1995 the
Another method of demand management in the fishing industry is consumer boycotts. Instead of lobbying governments to regulate the behavior of consumers or producers, environmental organizations lobby consumers directly, completely circumventing government. To the extent that efforts to convince consumers succeed, this method lowers demand by lowering the number of consumers willing to buy the species in question. If there are fewer consumers willing to buy the species, the price should fall, and fewer producers (in this case fishers) should be willing to supply it. To date, this second method of demand management has had less effect on the industry than aquaculture. But two recent campaigns, one focused on Atlantic swordfish and the other on Chilean seabass, have changed consumer behavior. These successes may well encourage similar campaigns in the future, as environmental NGOs realize that there is a significant proportion of the public that is willing to change its seafood-eating habits to support species preservation.

Demand-management policies aimed at the management of specific fish stocks are predicated on the assumption that fish have standard demand and supply curves. This may well be true for the demand curve for fish generally. But significant parts of the fishing industry do not correspond to the pattern of supply that the standard economic model predicts. In particular, parts of the industry display what can be called backward-bending supply curves. In these instances, attempts at demand management can backfire, and actually lead to greater rather than lower pressure on the specific fish stock in question.

Fisheries and Backward-Bending Supply

The basic diagram of market equilibrium that one sees in any economics textbook, shown in figure 1, has an upward sloping supply curve (S) and a downward sloping demand curve (D). When demand decreases (to \( D^* \) in figure 1), then, both the price and the quantity supplied at market equilibrium decrease as well. But fisheries, we argue, can have backward-bending, or S-shaped, supply curves. This is illustrated in figure 2. At extremely high or low prices, the supply curve behaves normally. But in the middle, in the region in which the supply curve is bent backwards, as the demand curve goes down, though the equilibrium price does indeed go down, the quantity supplied goes up. This means that, in this section of the supply curve, a decrease in demand will force prices
down, but this decrease in prices will cause fishers to catch more, rather than fewer, of the species that the policy is designed to protect.8

Why would a supply curve bend backwards? Economists have found this phenomenon elsewhere, for example in the market for labor.9 Laborers have basic minimum needs that have to be met. As the point on the supply curve at which the laborer’s ability to meet these needs is threatened, the laborer will have to compensate for lower wages by working more hours, thus causing the supply curve to bend backwards. The supply curve for fishers can bend back-

8. A more formal economic model of this phenomenon can be found in Mansori and Barkin 2001.
9. For a review of this literature, see Penceval 1986.
wards because lower returns from fishing threaten their ability to continue to fish. Because of the cost of buying and equipping boats, fishing is a fairly capital-intensive industry. The boats are generally bought on borrowed money; therefore, interest payments must be made regularly. When repossession becomes a real threat, the supply curve can be expected to bend backwards. Beyond this point, a lower price for fish means that fishers have to catch more in order to make their payments.

The effects of high levels of indebtedness are exacerbated by barriers to exit from and to re-entry into the industry. The barriers are both economic and social. If one loses one's boat, one invariably also loses a fair amount of capital, both financial and human, invested in the boat. The social barrier to exit, particu-
ularly in traditional fishing communities, is that fishing can define a way of life that has often been practiced in a family for generations, and once that way of life disappears, it might not be possible to recreate it.\textsuperscript{10} Barriers to re-entry into the industry are both financial and regulatory. It can be difficult to finance a new boat if one has lost a previous boat. And many fisheries are now governed by permit systems designed to limit entry. In many fisheries new permits are simply not issued, meaning that if one has stopped fishing for a living, one may not be permitted to start again.

In short, then, decreases in demand may lead to increases in catches when the ability of fishers to continue in their trade is threatened. This process can be illustrated by the examples of demand management used above. In the case of salmon farming, the decline in prices caused by the increasing number of farmed salmon in the late 1980s to the mid-1990s resulted in increased efforts to catch them in the wild, as fishers tried to make up for the income lost through declining prices. This both increased the threat to stocks of salmon in the wild and undermined efforts by the United States and Canada to cooperate in the management of the threatened stocks. In the case of Atlantic swordfish, the success of the consumer boycott, to the extent that it decreased the demand curve for the catch, may well have put pressure on boats that rely on the species to increase their catches, to make up for lost revenue.

It is thus important to determine when we can expect the supply curves of particular fisheries to be backward-bending. The key financial characteristic examined here is the average level of debt outstanding on the fishery's vessels. The more highly indebted they are, the more likely fishers are to be in a situation in which they have to fear losing their vessels, and as a result the more likely the supply curve is to be s-shaped. As a general rule, we can expect fisheries that require larger (and therefore more expensive) vessels to involve higher levels of debt. The key technical characteristic is what might be called substitutability of supply, which is the extent to which a fishery can find alternate species to fish to support itself. Large ocean-going factory trawlers can move from one fishing ground to another relatively easily, and are thus likely to respond to decreases in demand for a species by fishing for different species rather than fishing for more of the same one. But many vessels, particularly smaller ones, are not suited to this behavior, because they lack either the range or the fishing gear to switch easily among species.\textsuperscript{11} And fishers for particularly high-value species may not be able to find other species that can support their vessels. Finally, the social characteristic that affects the supply curve is the availability and appeal of other employment opportunities in the communities in which the fishers find themselves.

\textsuperscript{10} For an empirical example of barriers to exit from the fishing industry, see Basch, Pena, and Dufey 1999.
\textsuperscript{11} On the subject of substitutability in the fishing industry, see Barkin and DeSombrero 2000.
The New England Fishery

We test the idea that fisheries can have backward-bending supply curves using a panel dataset of the New England fishery covering the years 1980–1998. New England provides a good case study for the argument made here both because it supports a broad variety of commercial fisheries, from inshore to deep sea, and because it has a long-established fishery tradition that has come under the sort of financial strain that is likely to cause the supply curve to bend backwards. The data come from the United States National Marine Fisheries Service (NMFS). The NMFS publishes data on catch quantities and prices at dock for most commercial fisheries on a monthly basis, and estimates of stocks of various fish by region on an annual basis.

The statistical test is based on data for 13 species, each representing a major commercial fishery, and collectively representing a wide range of types of commercial fishery. Annual catch and average figures for price-at-dock are used, for the years 1980–1998 in most cases. Both quantity and price figures are indexed, with the 1982–84 average equal to 100. The total panel dataset includes 237 observations. These price and quantity data allow an estimation of market equilibrium points. To get at the question of the shape of the supply curve, we need information on specific supply and demand characteristics as well. The supply of fish depends, first and foremost, on the health of the fish stock in question. The total biomass of the stock sets a maximum limit on the total catch, and provides a rough indicator of the maximum sustainable yield for the species. We use estimates of the health of the stock made annually by the NMFS.

Other factors that may affect the supply of fish might be the cost of input prices, such as boats, fuel, fishing gear, and industry productivity, which would

12. See, for example, Doeringer and Terkla 1995; and Dewar 1983.
13. The data are available by species and region at the NMFS website. Annual data can be found at http://www.st.nmfs.gov/commercial/landings/annual_landings.html.
14. The species are striped bass, bluefish, cod, winter flounder, yellowtail flounder, haddock, silver hake, mackerel, pollock, scallops, sea bass, shrimp, and plaice.
15. For some species, the period is somewhat shorter due to the unavailability of data for some years. In no case is the period less than 16 consecutive years. The series for striped bass, bluefish, and scallops start in 1982. The series for plaice ends in 1997, and that for mackerel in 1995.
16. The authors gratefully acknowledge information provided by the Northeast Fisheries Science Center. See NOAA/NMFS 1999, and NOAA/NMFS 1998. The NMFS’ stock estimates take three forms. Annual survey tows randomly sample the number of actual fish in small representative areas of ocean. Measures of the abundance perceived by the fishing fleet estimate the amount of fish caught per unit of effort on the part of fishers. And estimates of spawning stock biomass are calculated from virtual population analyses. See NOAA 1998. Not all forms of estimates are available for all species. We use those estimates that were available as consistent series throughout our sample period. When more than one set of estimates was available for a given species, we use the mean average of the usable series. The different measures of abundance generally yield similar results. For example, independent measures of abundance such as spawning stock biomass closely match the explicit measurement of catch per unit effort when both measures are available for the same species. Ibid., 16–17.
be boosted by technological innovation. The only two of these variables that we were able to assemble consistent time-series data on are fuel and interest rates. Diesel fuel is a major cost of operating fishing vessels, and interest rates have a significant impact on the cost of financing fishing vessels, so these two variables can reasonably act as proxies for the variability in the cost of fishing. However, when these variables were included in alternate specifications of our regressions, they proved to be statistically insignificant, and had no impact on the results.

In estimating an equation for the supply curve for fish, then, the quantity supplied should be a factor of the variables affecting the supply of fish, operationalized here as the stock of fish and input prices, and the price of fish. This equation is as follows:

$$Q_s = \alpha_0 + \alpha_1 S + \alpha_2 P + \varepsilon$$

Where $$Q_s$$ indicates the quantity supplied, $$\alpha_0$$ is a constant, $$S$$ is a vector of the variables affecting the supply of fish, $$P$$ indicates the price, and $$\varepsilon$$ represents random disturbances in the supply of fish. In the basic results, $$S$$ represents estimates of fish stocks, as discussed above, but variables representing the cost of catching fish are added to $$S$$ in later regressions.

The key characteristic that we use in estimating demand for a specific species of fish is relative price. This is based on the assumption that various species of fish can be used by consumers as substitutes for each other. For example, it assumes that if the price of cod goes up while the price of pollock remains stable, some consumers will switch to pollock. This will decrease the overall demand for cod. Other factors, such as changes in preferences (consumer tastes), also affect the demand for specific species. These changes are, however, very difficult to quantify, leaving us with relative price as the key input in determining demand.

But using relative price per se as an indicator of demand is problematic because we use demand in the regression analysis to estimate the shape of the supply curve (see below), and relative price may well correlate with $$\varepsilon$$, random disturbances in the supply of fish (a particularly stormy season would be an example of a random supply disturbance that affected fisheries for different species similarly). Therefore, we need a proxy for relative cost that does not correlate with $$\varepsilon$$. The proxy we use is relative stock. Other things being equal, a decline in stock should result in an increase in price, and therefore a measure of relative stocks should serve as a proxy for demand that does not run into the correlation problem to the same extent.

To operationalize this measure, we compare stocks of the species in question with those of the two largest fisheries by value in the region in the 1980–1998 period, Atlantic cod and yellowtail flounder (when estimating demand for one of these two species, we substitute for it the third largest, pollock). This measure of relative stock has a correlation with own-species price of −.37, but a
correlation with own-species stock of only \(-0.02\), suggesting that it successfully avoids the problem of correlation with \(e_s\).

All of this leads to an equation for the demand curve for fish that is similar to that for supply:

\[
Q_d = \beta_0 + \beta_1 D + \beta_2 P + e_d
\]

Equation (2)

Where \(Q_d\) indicates the quantity demanded, \(\beta_0\) is a constant, \(D\) is a vector of the variables affecting demand (operationalized here as relative stock), \(P\) indicates the price of fish, and \(e_d\) represents random disturbances in the demand for fish.

The difficulty that arises in testing equations (1) and (2) is that the price variable in both equations is a function of equilibrium quantity, and is therefore correlated with random disturbances, \(e_s\) and \(e_d\). To avoid this problem, we have to find proxies for price that are not correlated with random disturbances in supply and demand. In this case, we use the vectors \(D\) and \(S\) as these proxies in the supply and demand equations respectively. In the supply equation, price will clearly be related to levels of demand, but there is no reason to believe that \(D\) would be related to \(e_d\). Similarly, in the demand equation, price would logically be related to the supply of fish, but there is no reason to believe that \(S\) would be related to \(e_s\). Thus we can use the variable \(D\) to substitute for price in the supply equation (1), and the variable \(S\) to substitute for price in the demand equation (2).

The Empirical Test

The coefficients \(\alpha_2\) and \(\beta_2\) from equations (1) and (2) give us the slopes of the supply curve and demand curve respectively. With “normal” supply and demand curves, like those in figure 1, it is the case that \(\alpha_2 > 0\) and \(\beta_2 < 0\). If, however, the supply curve is backward-bending, as in figure 2, both coefficients will be less than 0. These equations are tested using the various measures discussed above in panel regressions allowing for fixed effects by species. Table 1 shows the results. Of the independent variables, \(\text{stock}\) is the supply-side indicator, while \(\text{relative stock}\) is the demand-side indicator as discussed above. Both \(\text{stock}\) and \(\text{relative stock}\) are also included in the regression lagged one year. The variable \(\text{price}\) is the fitted value for price, the proxy value estimated as suggested above, as estimates of the species stock for demand and as estimates of the stock of commercially competing species for supply.

The key results here are those for \(\text{price}\) in both equations. These figures represent the coefficients \(\alpha_2\) and \(\beta_2\), and hence the elasticities of demand and supply. The results for both coefficients are statistically significant well beyond the 99% level. The elasticity of demand is, as is the normal case for demand curves, negative. The results suggest an elasticity of demand of \(-2.6\), meaning that a 10% increase in the price of a particular type of fish should result, on average, in a 26% decrease in the quantity demanded of that fish.
The punchline is in the supply equation. This result suggests that the elasticity of supply is also negative, the opposite of what one would normally find in a supply curve. The coefficient here is very near to $-1$, meaning that on average, a decline in the price of a species will result in an increase of the same amount in the catch of that species. This particular elasticity strongly implies that fishers are trying to maintain a fixed income irrespective of the price of fish. In other words, the data strongly support the hypothesis that the structure of the fishing industry can cause its supply curves to be backward-bending, and thus to respond to decreases in demand by increasing the quantity supplied.

The results seem to be quite robust. Several variations of the regression were run, without fundamentally affecting the results. As suggested earlier, costs of fuel and interest rates were included in as supply variables, with no significant change in the results. Two-year lags of the stock and relative stock variables were added, again without any notable changes in the results. One version of the regression was run using a price-squared variable, to test for non-linearity in the supply curve. The result was similar elasticities of supply around the average price levels, suggesting that non-linearity does not affect the results strongly. The only alternate specification of the regression to make a significant difference was the inclusion of a lagged catch variable (a measure of the previous year's catch), which mutes any effects of serial correlation. This had the effect of decreasing the slope of the demand curve to $-1.10$ and that of the supply curve to $-0.37$, both still significant at the 99% level. It did not, however, affect the basic result, supporting the idea of a backward-bending supply curve.

**Conclusions**

The immediate conclusion to be drawn from the data is that large parts of the New England commercial fishery do in fact show the characteristics of a back-
ward-bending supply curve. This in turn suggests that fishers in the industry, when faced with decreasing demand for their product that threatens their ability to continue working in the industry, will often respond by increasing their efforts to catch fish rather than by leaving the fishery. These results, though, probably hold in many, if not most, regional fisheries worldwide. The characteristics that lead to a backward-bending supply curve in New England—capital-intensivity, indebtedness, regulatory structures that favor those already involved in the industry, and a cultural attachment to fishing—are to be found in many of the world’s major fisheries.

Determining whether a particular fishery will react to decreases in demand by increasing efforts to catch more fish is an empirical matter. New England was well suited to test the proposition because it has a variety of different specific fisheries, and because high-quality time-series data on catch quantities and prices, as well as stock estimates, are readily available. Fisheries involving fewer species, or fisheries for which less reliable data are available, will be more difficult to test for backward-bending supply curves. But in these fisheries one can still look for the characteristics that are likely to lead to this supply pattern. The more hesitant fishers are to leave the industry, whether for financial, regulatory, or cultural reasons, the more likely the pattern is to appear.

The policy implication of this research is that we should be careful about using forms of demand-side management in attempts to reduce overfishing. This includes government attempts to reduce consumption by increasing taxes, NGO attempts to reduce consumption by organizing consumer boycotts, and plans by either governmental or nongovernmental organizations to take the pressure off of fish stocks in the wild by promoting aquaculture. The corollary observation is that supply-side management, including such mechanisms as licensing and quotas, while likely to prove more politically challenging to implement, are much less likely to prove counterproductive.

References


