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Coase and the Clams: Constructing Markets for Property Rights in Fisheries

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Coase and the Clams: Constructing Markets for Property Rights in Fisheries

by

Sylvia Jean Brandt

B.A. (Oberlin College) 1992
M. A. (University of California, Berkeley) 1998

A dissertation submitted in partial satisfaction of the

requirements for the degree of

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in

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in the

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of the

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Committee in charge:

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Abstract

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Doctor of Philosophy in Agricultural and Resource Economics

University of California, Berkeley

Professor Michael Hanemann, Chair

This dissertation addresses the impact of environmental regulation on resource-based industries by analyzing firms' responses to current environmental policies and to predicted changes in the regulatory regime. This research presents a theoretical motivation for and empirical estimates of changes in productivity, industrial organization, and strategic behavior due to the transition from firm-level regulation of inputs and outputs ("command and control") to tradable property rights (or "individual transferable quotas") in the commercial fishing sector.

The first chapter reviews the empirical evaluations of markets for fishing rights. The following three chapters focus on the Mid-Atlantic surf clam and ocean quahog fishery, the first U.S. Federal marine fishery to create property rights. This industry implemented property rights in 1990 after fourteen years of command and control. The second chapter is an institutional analysis of the design and implementation of property rights in the clam industry. It discusses the role of pre-existing institutions in generating imperfections in the market for property rights.

The third chapter estimates the impact of tradable property rights on productivity. The period prior to implementation of property rights shows significant reduction in productivity as firms sought to maximize their share of the impending property rights. After the transition to property rights productivity rebounded to the level prior to strategic behavior. This chapter demonstrates the importance of firms' expectations on current industry outcomes and the short run losses associated with strategic behavior.

The fourth chapter develops an economic model of the individual firm's decision to participate in or exit the industry. First, the data demonstrate that while there was significant exit of fishing *vessels*, considerably fewer *firms* actually left the industry; and while those that did were primarily independent harvesters, this was equally true under both regulatory regimes. Second, empirical results show that long-term contracts with buyers (processors) and anticipation of future regulatory change had a preponderant impact on the exit decision.

This dissertation has two significant implications for resource management: first, the hypothesis that tradable property rights disproportionately harm small, independent harvesters must be rejected; and second, the manner in which policies are implemented is significant in determining their ultimate impact on industry structure.

Chair

DEDICATION

I dedicate my dissertation to James, my parents, and little Dauber.

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Chapter 1

Introduction to Property Rights for Fish

1.1 Tradable Property Rights As Environmental Regulation

Since the classic papers on externalities by Pigou (1920) and Coase (1960), economists have debated the appropriate tool to internalize the cost of externalities to producers and resource users. Tools advocated by economists include Pigovian taxes, tradable property rights and the compensation mechanism[1]. Historically, however, U.S. regulations have been dominated by a command-and-control approach. In the case of natural resources, traditional command-and-control approaches include proscriptions on technology and processes, strict input and output controls, and limiting access to the resource. The command-and-control approach to environmental regulation in the United States has been criticized for creating an adversarial relationship between regulators and industry. In his review of environmental regulation in Denmark, Netherlands, Germany, France, Japan, and the United States, Wallace (1995) concludes that arguments and counter-arguments about the excessive cost and burden of environmental regulation are strongest in the United States, and argues that inflexible, fragmented and legalistic regulations stifle innovation instead of encouraging creative solutions.

Although economists have for decades proposed tradable property rights, often in the form of tradable permits, as both a feasible and an efficient regulatory mechanism, tradable property rights were not utilized on a large scale until after the introduction of

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[1] For reviews see Hahn and Noll (1982) for application to pollution, Moloney and Pearse (1979) for the first application to fisheries, and Varian (1989) on the compensation mechanism. Theoretically, both Pigovian taxes and tradable permits generate the equivalent efficient equilibrium. In reality, asymmetric information destroys this equivalence (see Weitzman (1974) on cost uncertainty and Stavins (1996) on benefit and cost uncertainty).

tradable permits for sulfur dioxide emissions during the Bush presidency[2]. In recent years transferable property rights have emerged in the public policy discourse as a mechanism to address environmental degradation. For example, the December 1997 international meetings in Kyoto, Japan featured negotiations on the use of transferable carbon permits to mitigate global warming.

Perhaps the most dramatic stage for the controversy over command-and-control regulation versus a property rights approach is fishery regulation. Fisheries present one of the classic problems of market failure due to externalities. In the absence of property rights, each individual fisherman does not take into consideration the effect of his harvest on the total available stock. The result, which has been well documented in both theory and empirical investigation, is that rents are completely dissipated.

The Magnuson-Stevens Fishery Conservation and Management Act (Public Law 94-265) specifies the management and conservation goals for United States fisheries within 3-200 miles of the coast. There are eight regional management councils charged with designing and implementing the management plans: New England Council, Mid-Atlantic Council, South Atlantic Council, Caribbean Council, Gulf Council, Pacific Council, North Pacific Council, and Western Pacific Council. The main provisions of the Act are the National Standards for Conservation and Management. There are four major issues specified in the National Standards. Stocks of fish should be managed as a unit. Management should prevent overfishing while maintaining maximum biological

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[2] Prior to the sulfur dioxide tradable permits, other smaller scale trading programs had been tried by the EPA. In 1974, the EPA introduced a system of banking and offsets of emission allowances to improve local air quality, but their use has not been extensive. A more active market for permits existed in the lead trading system used for the reduction of lead in gasoline from 1982-1987. An allowance trading market along with a tax was used to meet the Montreal Protocol agreement on chlorofluorocarbons and halons. For a review see Stavins and Hahn (1993).

harvests. Management plans must not discriminate between residents or groups of fishermen. Economic efficiency can be used as a criteria to choose between management plans *only after* the allowable harvest is determined on biological conservation criteria. In order to limit overexploitation, United States federal fisheries have historically been regulated through command-and-control policies: limits on the number of hours that fishing is allowed, the type of gear allowed, or other inputs.

Despite the increasing adoption of systems based on property rights to regulate air and water pollution, the use of tradable property rights (also known as individual transferable quotas, or ITQs) in fisheries has reached a stalemate. ITQ-based systems have been implemented in four United States marine fisheries[3], but controversy over their re-distributive effects has led to numerous legal actions brought against the federal marine regulatory agency, the National Marine Fishery Service, and to the imposition in 1996 of strict limitations on the future implementation of ITQs in U.S. fisheries. The 1996 reauthorization of the Magnuson-Stevens Act, the main legislation governing fisheries regulation, imposed a moratorium on the use of tradable property rights in any additional U.S. marine fisheries until the year 2000 [Title III, Section 303, 104-297]. During the 106th Congress the moratorium was extended until October of 2001.

During this moratorium the National Research Council's Committee to Review Individual Fishing Quotas was charged with reviewing individual transferable quotas programs in the United States and internationally and with making recommendations regarding their use. The 1999 NRC review concluded that while property rights have the potential to reduce overcapitalization in fisheries, there are several remaining policy

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[3] ITQs were implemented in the Middle Atlantic surf clam and ocean quahog, the North Pacific halibut and sablefish and the South Atlantic wreckfish fisheries. ITQ plans were drafted for the Pacific sablefish and Gulf snapper fisheries.

concerns. The prominent concerns include the issue of equity of ITQs for current and future fishermen, impact on employment opportunities, and excessive market power (NRC, 1999). Little progress has been made in resolving the policy debate, and the moratorium is likely to continue. Two Senate bills were introduced in the 106th Congress to amend the Magnuson-Stevens Fishery Conservation and Management Act. Senate Bill 2832, introduced on June 29, 2000 by U.S. Senator Olympia Snow (R-ME), would extend the moratorium on the new implementation of tradable property rights in U.S. fisheries until October 1, 2003. The amended act introduced by Senators Kerry and Hollings (S.2973) replaces the term "individual tradable quota" with "exclusive rights based quota" (to incorporate cooperatives) and adds several welfare criteria.

The resolution to this volatile debate will guide the direction of future policies and will have wide-reaching ramifications for resource sustainability. Therefore, a comparison of ITQs and command-and-control regulation in fisheries is important both as a test of economic theory and as a timely contribution to the public policy debate.

The next section reviews the existing empirical studies of the creation of property rights for fisheries management. The subsequent chapters evaluate three aspects of the first property rights regime in the United States fishery: market imperfections, industry productivity, and equity.

1.2 Review of Empirical Evaluations of Property Rights in Fisheries

This section reviews the empirical evidence on ITQs using the following five criteria. First, do ITQs increase efficiency on the individual firm level? Second, are the industry level inefficiencies lower under ITQs than under command and control? Third, what are the implications for resource conservation and ecosystem health? Fourth, what are the impacts of ITQs on fishing communities? Finally, enforcement in ITQ fisheries is reviewed. The empirical studies reviewed in the previous section are primarily anecdotal in nature. The economic literature on tradable property rights in fisheries is discussed in the following chapters.

1.2.1 Firm Level Production

The cornerstone of fisheries regulation is the limit on the total amount of the species harvested each year (termed total allowable catch, TAC), which is determined by biological criteria. In the United States the annual harvest is set at the maximum level that can be taken without reducing the population beyond a minimum threshold. In the absence of property rights, individual harvesting firms then race against each other to maximize their share of the total harvest as possible. In contrast, in fisheries managed with ITQs, the fisherman has a guaranteed proportion of the total allowable catch [TAC] that can be harvested throughout the season.

Perhaps the most dramatic example of the race for fish is the infamous "Halibut Derby" during which twenty-four to forty-eight hour periods of frantic fishing led to accidents, loss of gear and extreme boom and busts in the supply of halibut. The increasing pressure of the race for fish led to 130 fishing related deaths in Alaska between 1990 and 1994 (Conway and Lincoln, 1995). ITQs were implemented in the North Pacific halibut fishery in 1995, and no fishing fatalities occurred in the halibut fishery in 1995 or 1996 (Conway, 1997). Under ITQ management the halibut fishery is now open from March until November (9 months). The longer season allowed fishermen to exploit the fresh halibut market, doubling the amount of fresh halibut sold from 15% to 33% (Knapp, 1997).

In 1990, the competition in the wreckfish fishery led to landing of the total allowable catch in the first two months of the season. The race for fish resulted in market saturation and dangerous fishing practices (SAFMC, 1991). The security of property rights under the ITQ system allowed fishermen to redirect fishing effort from the less productive months of the season (the post-spawning season) to more efficiently utilize the resource (Gauvin et. al., 1995). The longer fishing season has led to increased prices and decreased price variance (Gauvin et. al., 1995).

As in the North Pacific, individual vessel quotas in the British Columbia halibut fishery led to the development of a lucrative fresh halibut market, and interviews of fishermen after implementation indicate that in general fishermen feel better off and more secure about their retirement than under the derby system. The majority of fishermen reported reduced bycatch and gear loss as the pace of fishing slowed (Casey et al., 1995). Additionally, changes in fishing practices directly attributable to IVQs facilitated an increase in the halibut price by 55 percent from what it would have been under limited entry with no vessel output controls (Casey et al., 1995).

Likewise, captains in the Scotia-Fundy groundfish fishery report that the ITQ system allowed them to be more selective in their fishing and allowed small-boat captains to stay at port during bad weather or when fish were too far from port (McCay et al., forthcoming). In the Icelandic herring fishery herring catches tripled while fishing effort actually decreased 20 percent, resulting in technical efficiency that is 5 times higher than at the beginning of the individual vessel quota system 16 years ago (Arnason, 1993).

Instances where the race for fish continued can be attributed to lack of information about the new system. For example, racing in Lake Erie ITQ fisheries soon stopped when fishermen learned that they would not be penalized if they failed to harvest a portion of their quota (Berkes and Pocock, 1987). Likewise, racing in the British Columbia individual vessel quota program stopped when fishers learn that market gluts resulting from the race for fish depress prices substantially (Behnken, 1993). Ending the race for fish is one of the most robust results of ITQ management. The Lake Erie and British Columbia examples illustrate the importance of disseminating information on the property rights system.

Empirical review of ITQ programs provide testimony that participants remaining in the industry gain significant benefits from ITQ management. An OECD review documents increased profitability or increased cost-effectiveness in 23 individual quotas and individual transferable quotas systems (OECD, 1997).

Surveys of fishermen in ITQ fisheries provide valuable insight into their benefits for industry participants. For example 23 percent of those surveyed in a New Zealand fishers' group claimed that ITQs have increased product quality (Dewees, 1989). Eighty percent of surveyed British Columbia halibut fishers agreed or strongly agreed that they are better off with ITQs, and 59 percent of those interviewed said that individual crew shares increased on those vessels operating with less crew (Casey et al., 1995). Holders of ITQs in the fishery also stated that they believed that ITQs made them more competitive (McCay et al., forthcoming).

1.2.2 Industry Level Inefficiencies

The prevalence and persistence of overcapitalization in fisheries spawned research into the economic incentives under open access. The expansion of the wreckfish fishery from only two vessels in 1987 to ninety in 1991 provides an example of dramatic overcapitalization in response to traditional management. After only five years as an established fishery, it was commonly acknowledged by management that the fishery was already overcapitalized (Gauvin et. al., 1995). Analysis by the South Atlantic Fishery Management Council shows that the efficient number of vessels given the costs of fishing and projected future TACs to be only twenty vessels (SAFMC, 1990). After only one year of ITQs (started in 1992) the capitalization in the wreckfish fishery was moving close to the optimal level (Gauvin et. al., 1995).

Likewise, the dissipation of resource rent is a classic outcome of an open access fishery. A survey of the literature shows substantial gains in rent due to ITQs. The 1992 resource rent in the surf clam industry, the fishery with the longest history of ITQ management, was estimated at $11.4 million (Wang and Tang, 1994). Ex ante simulations of ITQs in the pot and longline sablefish fleet off the Pacific coast of the U.S. (specifically, the coasts of Washington, Oregon and California) estimated a potential gain in the mean rent per vessel at $73, 353 and total industry rent over $10 million (Squires et al., 1994). Simulations by Geen and Nayar estimate resource rent earned under ITQs in the Southern bluefin tuna fishery to be over $6 million. They estimate that alternative management regimes would earn less than 25 percent of the rent earned under ITQs (Geen and Nayar, 1988).

1.2.3 Resource Conservation

A major critique of ITQs is the possibility that they lead to increased highgrading, the discarding of lower valued fish for higher valued fish. Constructing ITQs in terms of poundage does not necessarily eliminate highgrading. For example, two small fish equal in weight to one large fish could still have a lower total market price. A large fish could provide a higher quality composition of meat and fat (the market for blue tuna in Tokyo is an excellent example). Indeed economic theory suggests that a profit maximizing fisherman may find it in his best interest to highgrade in some circumstances (see Anderson (1994, 1994b) Arnason (1994) and Turner (1997 and 1996)). Highgrading entails the cost of removing the unwanted catch and the additional cost of replacing it. The price difference between the high grade catch and low grade catch must be equal to or greater than these costs for highgrading to occur. These price differentials, however, may not hold in all fisheries. A review of ITQs in twelve fisheries states that highgrading is known or suspected in six (Muse and Schelle, 1989).

Some fisheries may inherently lack the necessary conditions for highgrading. For example, there is no evidence of highgrading in the surf clam fishery (Matthews, 1997). The properties of clam beds are well known and common knowledge in the fisheries. It is believed that ITQs can help reduce discard mortality through better targeting of populations (McCay, 1994). Highgrading in the wreckfish fishery appears to be a non-issue because there are no price premiums paid for certain sized fish, and there is little size variation (Gauvin, 1994).

While there has been a focus on the possibility that ITQs can exacerbate highgrading, the existence of highgrading is neither unique to nor inherent in property rights systems. Anderson (1994) has shown that highgrading can occur whenever there is a constraint on total landings for individual vessels. Many fishermen report that trip limits, for example, cause them to highgrade.

A second conservation goal is the reduction of bycatch. Bycatch remains an important problem under traditional management regimes, thus the questions are do ITQs exacerbate bycatch, and can they be structured to reduce bycatch? There is anecdotal evidence that reducing the time pressures inherent in traditional management enables fishermen to use more selective harvesting practices (Casey, et al. 1995; DFO, 1993). In some cases ITQs have almost ideal compliance with bycatch reduction regulations, such as the multi-species Lake Erie fishery (Crowley and Palsson, 1992). The Icelandic fisheries are a multi-species fishery as well, and there is little evidence of increased discarding under ITQs (Arnason, 1993).

In cases where bycatch is likely to be a problem one approach would be to use ITQs as an incentive to invest in and develop more selective gear. Levine and McCay (1987) show that investment in technology is related to perception about future profitability. Because ITQs reduce the uncertainty associated with the race for fish and frequent season closures, investment in selective gear could increase. Discounts in license fees and taxes for vessels with the most selective gear could stimulate investment in technology. Fishermen who demonstrate that they can fish selectively could be awarded greater initial quotas under ITQs, although this would likely create fierce allocation battles.

Unlike traditional management approaches ITQs address the economic incentives of fishermen; therefore, they can be structured in such a way to minimize highgrading and bycatch. The optimal structure, of course, depends on the characteristics of each fishery. For example, taxing high grade catch or subsidizing low grade catch to minimize the price differential reduces the incentive to highgrade (Anderson, 1994). An alternative is to have quotas for each grade of fish, a system that has been successfully used in the Lake Erie walleye fishery (Selby). Quotas can also be structured to reflect the multi-species nature of fisheries. Vessels could be required to hold quotas that reflect the mix of species and the fishery and be given the opportunity to buy or lease additional quota to cover bycatch from managers. This is one of several mechanisms used in New Zealand's program (Muse, 1991). A recent suggestion is to use a "value-based" approach where each fisherman is issued a quota allowing a total value of landings regardless of type (Turner, 1997). This approach minimizes the incentive to highgrade or discard bycatch, because by limiting the value of total catch rather than the quantity of each species it is still profitable to land all species caught (both directed catch and bycatch) until the maximum value is reached. Value-based ITQs may work best for fisheries with stable prices, otherwise price fluctuations could generate significant fluctuations in the proportions of species caught.

Additionally, ending the race for fish brings conservation benefits. After implementation of ITQs, the North Pacific Celtic season expanded from 1 to 2 days to a full nine months. The less frantic fishing season reduced lost and abandoned gear causing an estimated drop in fishing mortality of 23%, representing a substantial environmental benefit (Gilroy et al., 1996).

In conclusion, highgrading and bycatch are issues for any fishery management plan. The extent to which they are a problem depends on the characteristics of the specific fishery.

1.2.4 Impacts on Fishing Communities

The National Standards of the Magnuson-Stevens Fishery Conservation and Management Act states that, consistent with conservation requirements of the Act, management measures must minimizes adverse economic impact on fishery dependent communities. This section will discuss two types of impacts on fishing communities: employment and market concentration.

1.2.4a Fishing Employment

In Canada the traditional role of the Atlantic fisheries is the employer of last resort and in many areas is the employer of only resort (Crowley and Palsson, 1992). Canada began widespread use of rights based management in 1982, and previously had employed rights based management in a number of small fisheries. Therefore the record of employment under rights based fishing in Canada provides valuable guidance for U.S. policy. Incomes of crews have improved in all Canadian rights based fisheries (Crowley and Palsson, 1992). Studies of Nova Scotia fishery dependent communities show that although crew shares declined to cover the cost of ITQs, crew incomes did not decline (McCay et al., forthcoming).

After one year of tradable quota management there was a net increase in revenues of $3.3 million for license holders in the British Columbia sablefish industry (Crowley and Palsson, 1992). Furthermore, while the total employment of crew members declined, the average earnings per crew members increased (EB Economics, 1992a). The Lake Erie fishery also exhibited a dramatic decrease in employment and corresponding increase in income: total crew fell from 915 to 714 while average income increased from $25,000 to $40,000 within one year (Crowley and Palsson, 1992). In addition, ITQs may benefit workers in the processing sector because fish will be landed over longer period of time thus extending employment period in processing sector (Grafton et al., 1996).

In summary, there are often dislocations of crew members following consolidation of capital in the industry. The remaining payments to crew members, however, tend to increase following implementation of tradable property rights.

1.2.4b Exit and Market Concentration

Opponents often charge that ITQs unfairly burden small fishing firms, forcing them to exit the industry at a higher rate than large firms. This issue is raised with outstanding frequency at management council meetings to consider ITQs (as noted in Anderson, 1991). Current analyses of exit under individual transferable quotas, focus on exit of *vessels* rather than *firms*. For example, Wilen (1993) argues that the technology that is optimal under ITQs can be very different than that under limited access. Those vessels that were larger and faster may have been successful during the race for fish but may not compete successfully under a longer fishing season. Similarly, the OECD evaluation of ITQs found little evidence that small vessels were eliminated when ITQs were introduced (OECD, 1997). Because the evaluations have focused on vessels rather than firms, the debate over fairness of individual transferable quotas remained a standstill. This issue is the subject of Chapter Four: Equity Versus Efficiency.

A consequence of exit of small firms, opponents argue, is that tradable property rights will lead to market concentration. The surf clam fishery is often cited as evidence that ITQs lead to concentration of quota ownership in the harvesting sector; however, the history of concentration in surf clams is much more complicated than this simple diagnosis. Immediately after ITQs were implemented the number of holders of quota allocations decreased from the number initially allocated quotas until the top 10% of share owners held 39.2% of the surf clam allocations (Matthews, 1997). Since 1992 consolidation of allocation holdings has stabilized with 38.5% of the allocations held by the top 10% of owners (Matthews, 1997). However, McCay and Brandt (2001) show that concentration in the harvesting sector was present prior to implementation of ITQs.

In other fisheries, ITQs have lead to little increase in concentration or have actually reduced concentration. In the British Columbia halibut processing sector there was significant concentration before individual vessel quotas were implemented. After individual vessel quotas a substantial number of smaller firms entered the processing sector. One new dominant firm emerged after the policy change, but the other participants in the processing sector seem to be actually less concentrated (Casey et al., 1995).

Even in the absence of caps on holdings of quotas in the wreckfish fishery and heavy periods of quota trading, there was only a slight increase in the Herfindahl index of concentration (from 0.027 when shares were first allocated in January 1992, to 0.048 in August 1992, and to 0.064 in June of 1993). In fact, the index has remained significantly closer to perfect competition than to monopoly, and there is little potential for price setting behavior in the market at large (Gauvin et. al., 1995)[4].

1.2.5 Enforcement

For the individual transferable quotas to have value, the property rights must be exclusive and enforceable. Therefore, the success of ITQ management relies on effective tracking of individual harvests and quota holdings. The empirical evidence on ITQs suggests that detailed record-keeping is an important component to enforcing the individual firms quota constraints.

Examples of enforcement schemes are found in the British Columbia halibut, United States wreckfish, and United States clam fisheries. ITQs are enforced in the British Columbia halibut fishery with an elaborate system where every fish landed is tagged with the vessel's code, and the industry participants pay the costs of administration (Grafton et al., 1996). Participants in the industry conclude that since the halibut fishery transitioned from a derby style fishery to an ITQ, compliance with regulation has increased (EB Economics, 1992b).

Prior to implementation of ITQs in the surf clam and ocean quahog fishery, harvesters violated size limits and area closures (Matthews, 1997). Under ITQs a layered reporting and tracking system includes: vessels that harvest the clams, trucks that transport landings to processing plants, and processors. Since ITQ implementation and documentation of catch is described as "quite accurate" and discrepancies between vessel logbooks data, processor logbooks and weighout data are considered "most acceptable" to management and enforcement (Matthews, 1997). Also a high degree of voluntary

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[4] The wreckfish is sold as a substitute for grouper, and constitutes a small potion of the total market.

compliance is now exhibited in the fishery (Matthews, 1997). This compliance has been attributed to the unique gear used, geographical and availability limits of processors, the shore based nature of the market and the sedentary and long living nature of the clams. The expected increase in costs of management also seemed to have been exaggerated (NMFS, 1996).

Over the first one and one-half year period of ITQs for wreckfish there was only one suspected case of exceeding an individual quota (Gauvin et al., 1995). The high compliance in the wreckfish fishery can be partially attributed to the extensive tracking of catch with coupons, severe monetary penalties and incentives for fishermen to report violations (Gauvin, 1994 and Gauvin et al., 1995). The two key elements to successful enforcement seem to be a small number of landing sites and an extensive paper trail to track quotas.

One criticism of such extensive tracking systems is the administration costs. User-pay enforcement programs could further increase incentives for self-enforcement in fisheries. In many of the individual quota fisheries in Australia, Canada, Iceland and New Zealand industry pays for administration and enforcement with fees levied on quota owners (OECD, 1997). In the Canadian Pacific coast geoduck fishery, participants hired a private firm to monitor catches (Crowley and Palsson, 1992). Even in small fisheries, industry funding of enforcement can be successful. After one year of ITQs, dockside monitoring was funded by the Nova Scotia fishing industry (McCay et al., forthcoming).

Incentives for self regulation can be built into ITQ programs. In the U.S. wreckfish program, forfeited shares from violators are returned to a common pool for redistribution. A similar mechanism with a hotline for reporting violations seems to have contributed to higher compliance in the British Columbia halibut program (DFO, 1993).

1.3 Unresolved Debates

The fishing industry presents the classic case of externalities generated by a lack of clear property rights, and provides the perfect context to study the economics of regulatory change – in particular the definition and implementation of property rights to replace command-and-control regulation. Current debates over the relative merits of these two competing approaches are of critical importance to the future of fisheries management; the 1996 reauthorization of the Magnuson-Stevens act imposed a moratorium on the implementation of tradable property rights in any additional United States fisheries, pending resolution of the central economic questions of equity and efficiency raised by environmental regulation.

The following chapters present a theoretical motivation for and empirical estimates of changes in productivity, industrial organization, and strategic behavior due to the transition from command and control to individual transferable quotas in the Mid-Atlantic surf clam and ocean quahog industry, which saw a transition from traditional regulation to tradable property rights in 1990. The next chapter discusses the pre-existing institutions and their role in shaping the market for tradable property rights. The third chapter provides a methodology and empirical estimates to evaluate the economic criteria for fisheries regulation (Magnuson-Stevens Fishery Conservation and Management Act (1996), Sec. 301 [a][5]) by evaluating the impact of tradable property rights. The fourth chapter addresses the core socioeconomic issue in the policy debate over fisheries regulation: whether tradable property rights represent an unfair redistribution of the costs and benefits of regulation, favoring large harvesters over small harvesters.

Chapter 2

Regulatory History of the Surf Clam and Ocean Quahog Industry

2.1 Introduction

This chapter describes the surf clam and ocean quahog industry and the relevant institutional aspects of the industry. The next two sections describe the industry and its regulatory history. Section 2.4 provides descriptive statistics on fleet size, firm size and specialization. A simple two-period model of a forward-looking firm is presented to explain the escalation in effort prior to ITQs in section 2.5. This chapter concludes with a discussion of the contracting that dominates the industry and the implications for the market for property rights.

2.2 Basics of the Industry

With annual production valued at over $48 million, the Mid-Atlantic surf clam and ocean quahog fishery provides almost the entire supply for domestic processed clam products (NMFS, 1999). The output of the clam fishery includes canned clam chowder, canned minced clams, canned sauces and juices and breaded products. Surf clams and ocean quahogs are harvested off the shores of Maryland, Virginia, New York, New Jersey, Rhode Island, Massachusetts, Maine and Delaware, with the harvesting concentrated off the New Jersey shore. The quahog is found further from shore and at greater depth than the surf clam. Both clam species are sessile species that are harvested using a hydrologic dredge. The main difference between harvesting the two clam species is that the length of the hose to harvest the quahog is greater than that to harvest surf clams, and the length of a quahog trip is longer than a surf clam trip (typically 24 hours compared to 8 hours). The same vessels can be used for both species, the only necessary gear change is the change to a longer hose before a quahog trip. Location of the clam beds, as well as the varying properties of the beds (for example, average size of clam and quality of meat), is common knowledge in the industry.

2. 3 Regulatory History and Political Debate

This fishery has been an early adopter of innovative fishery management. It is also a fishery that portrays the dynamic play between the regulator and the regulated. The surf clam was harvested as early as 1870, but significant quantities were not harvested until the 1950s. The surf clam fishery expanded rapidly between the 1950s and early 1970s. During this expansion period the fishery was free and open to anyone able to purchase a vessel. As theory predicts, the open access surf clam fishery lead to decreased marginal returns and increased marginal costs. The decline in marginal returns was exacerbated by a shock to the clam population when anoxic waters off the coast of New Jersey killed off large portions of the surf clam stock. Although there was consensus in the industry that effort needed to be reduced, existing anti-trust legislation prohibited individual fishermen from acting collectively to reduce total harvests. Throughout this period the quahog remained an under utilized resource.

In 1977 the creation of the Mid-Atlantic Fishery Management Council, under the framework of the Magnuson-Stevens Fishery Conservation and Management Act (Public Law 94-265), provided the mechanism to regulate the effort in the fishery. In 1978 the Council established the first limited access policy in US marine fisheries. The limited access regulated granted licenses to vessels that had been harvesting surf clams but prohibited any new vessels from harvesting surf clams.

The council established limits on the total amount of clams to be harvested each year and divided the annual quota into quarterly limits in order to spread the harvest over the year. The existing harvesting capacity of licensed vessels was far greater than what was deemed a sustainable allowable quota. As fishermen raced to harvest their share of the total, the quarterly limits were met in progressively shorter times. In response, the fishery management council devised an allowable fishing time system. From 1979 through 1986, the council would determine the maximum number of hours allowed to harvest in a week and the number of weeks that limit would be in place.

As fishermen raced for a share of the total catch, the average allowable fishing hours fell from 36 hours a week in 1979 to 6 hours a week in 1984. The increasing stringency of surf clam regulations left the vessels idle for increasingly longer portions of the harvesting season. The cost of idle capital, as well as technological innovation in the processing sector, displaced fishing effort to the previously underutilized quahog (see Table 2.1). From 1980 to 1984 the total quahog harvest was 16,269,458 bushels. The total harvest of quahogs over 1985-89 was 22,879,392, an increase of 40.6% over the previous five-year total.

TABLE 2.1: SURF CLAM AND OCEAN QUAHOG HARVESTS (bu), 1979-1998

Year	Surf Clams	Ocean Quahogs
1979	1,674,209	3,034,696
1980	1,924,033	2,961,789
1981	1,976,438	2,888,287
1982	2,002,830	3,240,775
1983	2,411,940	3,215,640
1984	2,967,026	3,962,967
1985	2,909,330	4,569,509
1986	3,180,642	4,167,205
1987	2,819,819	4,743,025
1988	3,031,681	4,469,373
1989	2,838,408	4,930,280
1990	3,113,976	4,622,417
1991	2,673,413	4,839,824
1992	2,812,270	4,938,700
1993	2,834,717	4,811,941
1994	2,846,670	4,611,395
1995	2,545,305	4,628,323
1996	2,569,319	4,391,428
1997	2,413,575	4,279,059
1998	2,365,374	3,897,487

Source: "Overview of the Surf Clam and Ocean Quahog Quota Recommendations for 2000," Clayton Heaton and Thomas B. Hoff, Mid-Atlantic Fishery Management Council, Dover, Delaware.

Beginning in 1987 the council enacted a rudimentary allocation system. Rather than allocating a portion of the total allowable catch to vessels, the allocation was based on time limits on individual vessels. From 1987 until October 1990, each vessel was allocated 25 trips a year of duration of 6 hours a trip. The 25 trips were allocated across each quarter (6, 6, 6,7) such that the each vessel's total fishing time per quarter was approximately equal to the average fishing time allowed from 1984-1986. The change from limiting total time at sea to limiting per vessel trips reduced the cost of monitoring vessels.

By the mid-1980s, rapid growth in harvesting capacity and resulting inefficiencies prompted a debate over the establishment of a regulatory regime based on property rights. The formal discussion of ITQs began with a discussion paper written and circulated by the management council in 1986 (MAFMC, 1986). The proposal to implement some system of property rights dominated council meetings from the mid '80s through 1988 with the most contentious issue being the distribution of quotas amongst the industry participants. The policy negotiations throughout this entire period focused solely on the surf clam fishery.

Although the allocation formula was not approved until 1988, one thing was clear from all of the policy negotiations, the allocation would be based in some form on each vessel's history of quantity of harvests. The most common allocation scheme used in fisheries at that time was to grant individual allocations in proportion to the catch history of each vessel. Therefore, at the same time that harvesters were maximizing their current profit, they had the expectation that they could receive an allocation based on their catch history.

Amendment Eight, Fishery Management Plan for the Atlantic Surf Clam and Ocean Quahog Fishery, finalized the allocation formula[1]. The surf clam allocation included vessel catch (80%) and vessel capacity (20%), while the quahog allocation was based solely on vessel catch. For vessels harvesting surf clams the historical catch was equal to the vessel's total harvest over 1979-1988 (counting the years 1985-88 twice and

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[1] Amendment Eight: Fishery Management Plan for the Atlantic Surf Clam and Ocean Quahog Fishery was approved by the Mid-Atlantic Fishery Management Council in cooperation with the National Marine Fisheries Service and the New England Fishery Management Council in 1988 (MAFMC, 1988).

dropping the vessel's worst two years). Each vessel's catch ratio was the vessel's historical catch divided by the sum of all vessels historical catch. The vessel's cost factor was equal to the product of the vessel length, width and volume. The vessel's cost ratio was equal to the vessel's cost factor divided by the sum of the cost factors over all vessels. The vessel's initial surf clam allocation was then:

surf clam initial allocation percentage = 0.8 (catch ratio) + 0.2 (cost ratio)

For vessels harvesting quahogs the historical annual catch was equal to the vessel's average annual harvest over 1979-1988 (dropping the vessel's worst year). Each vessel's catch ratio was the vessel's historical annual catch divided by the sum of all vessels historical annual catch. The vessel's initial quahog allocation was equal to the vessel's catch ratio.

Firms had two ways to maximize their total catch history and thus initial allocation. They could increase the number of vessels that they owned, and they could increase the level of effort on each trip. Each of these effects are discussed in the next section.

2.4 Changes in the Fleet During Property Rights Negotiation

2.4.1 Fleet Size

While the number of *permitted vessels* did not change once limited access was implemented, there was an increase in the number of *active vessels* immediately prior to implementation of ITQs. After the moratorium on entry there remained some vessels that were permitted for the surf clam/quahog fishery, but had not been actively harvesting.

During the negotiations over ITQ allocations there was an incentive to use these vessels in harvesting in order to establish a catch history.

In 1980 there were 127 vessels actively participating in the surf clam fishery and 52 in the ocean quahog fishery. In 1989, the eve of the ITQ system (which began in October, 1990), there were 135 vessels harvesting surf clams and 69 harvesting ocean quahogs. The numbers of vessels actively harvesting each species (surf clams or quahogs) are given in Table 2.2. The changes between relevant policy periods are given below.

TABLE 2.2: FISHING VESSELS IN SURF CLAM AND OCEAN QUAHOG FISHERIES, 1980-1999

Year	Surf Clam	Quahog
1980	127	52
1981	123	47
1982	115	43
1983	117	36
1984	119	57
1985	130	64
1986	144	72
1987	142	71
1988	134	62
1989	135	69
1990	128	54
1991	75	49
1992	58	43
1993	50	36
1994	45	33
1995	36	35
1996	31	34
1997	33	28
1998	28	24
1999	28	21

TABLE 2.2 Percentage change		
1983-1986	23.10%	100.00%
1983-1999:	-76.10%	-41.70%
1989-1999	-79.30%	-69.60%
1991-1999	-62.70%	-57.10%

At the same time that firms had the incentive to activate previously latent effort (permitted vessels that were not actively harvesting), they also had the incentive to utilize substantially larger vessels. The steady increase in total and average capacity per vessel is shown in Table 2.3.

TABLE 2.3: CAPACITY OF FISHING VESSELS, 1983-1999 (GROSS REGISTERED TONNAGE, GRT)

Year	Total Vessels	Total GRT	Average GRT
1983	125	13992	112
1984	133	14691	110
1985	136	14846	109
1986	146	18006	123
1987	145	18145	125
1988	140	17786	127
1989	141	18150	129
1990	131	17103	131
1991	77	10550	137
1992	68	9464	139
1993	63	8800	140
1994	58	7962	137
1995	61	8420	138
1996	52	7391	142
1997	50	7057	141
1998	46	6507	141
1999	42	6067	144

Note: These figures (Table 2.2 and Table 2.3) are for vessels fishing in federal waters and do not include state fisheries, which take place in waters 0-3 nautical miles from coastal baselines; New Jersey, New York, and Massachusetts have their own fishery management systems for state waters. There is considerable overlap in participation between state and federal (3-200 nm) fisheries. Each of the state fisheries has limited entry, and New Jersey has weekly trip limits and has allowed the consolidation of vessels, but none uses individual transferable quotas.

2.4.2 Average Size of Firms

The numbers of total vessels in the industry show a change in the aggregate, but they obscure significant firm level changes. In addition to the incentives created by command-and-control, the anticipation of property rights allocated on a vessel basis exacerbated the incentive to overcapitalize. A particularly volatile question about implementing ITQs was whether or not to grant allocation to processing firms. Although processors claimed they had a stake in the resource, the precedent was to allocate only to harvesting firms. In order to maximize their expected allocation, processors had an incentive to own several vessels. In 1983 the average number of vessels and by processors was 6.9, but the average increased to 8.3 by 1989 (Table 2.4).

After implementation of ITQs, there were no longer time constraints on each vessel. The vertically-integrated processors and the non-integrated harvesting firms (firms that have more than three vessels and are not vertically integrated) drastically reduced their fleet sizes between 1983 and 1999 (Table 2.4). The average fleet size in 1999 was 4.0 for the independent fleet owners, a 34% reduction from the 1989 total (6.1), and for the processors it was 2.2, a 73% decline from the 1989 average size (8.3). The major decrease occurred, as expected, at the onset of ITQs.

TABLE 2.4: MEAN NUMBER OF VESSELS PER FIRM, 1983-1999

Year	Total	Non-integrated	Processors
1983	5.1	7	6.9
1984	5	7.1	6.6
1985	4.9	6.8	6.7
1986	4.6	5.6	7.1
1987	4.4	5.3	6.9
1988	4.5	5.2	7
1989	5.2	6.1	8.3
1990	5	6	7.8
1991	2.9	4	3.7
1992	2.8	4.2	3.2
1993	2.7	4.2	2.7
1994	3	5	2.8
1995	3	5.3	2.5
1996	2.8	5	2.3
1997	2.7	4.5	2.4
1998	2.6	4	2.4
1999	2.5	4	2.2
Change:			
'83-'99	51.00%	-42.90%	-67.90%
'89-'99	52.60%	-34.90%	-73.60%

2.4.3 Specialization

One of the striking structural consequences of ITQs appears to be greater specialization, in contrast to the pre-1990 pattern of either surf clamming or combining surf clamming with ocean quahogging. Prior to ITQs, most of the larger vessels fished for both surf clams and ocean quahogs because of the strong incentive to find uses for capital that would otherwise be idle due to limited surf clam fishing time. This effect is particularly noticeable during 1986-1989. The degree of the generalization substantially decreased after ITQs. In the 1991-1999, period particularly from 1995 on, there was significant specialization in either surf clams or ocean quahogs. More vessels fished only for ocean quahogs rather than combining that fishery with surf clamming over the course of the fishing year (Table 2.5).

TABLE 2.5: SPECIALIZED VERSUS GENERALIZED PRODUCTION, 1983-1999

Year	Only Surf Clam	Only Quahog	Both Fisheries	Total Vessels
1983	89	8	28	125
1984	76	14	43	133
1985	72	6	58	136
1986	74	2	70	146
1987	74	3	68	145
1988	78	6	56	140
1989	72	6	63	141
1990	77	3	51	131
1991	28	2	47	77
1992	25	10	33	68
1993	27	13	23	63
1994	25	13	20	58
1995	26	25	10	61
1996	18	21	13	52
1997	22	17	11	50
1998	22	18	6	46
1999	21	14	7	42

Percentage change:

1983-1986	-16.90%	-75.00%	150.00%	16.80%
1983-1999:	-76.40%	75.00%	-75.00%	-66.40%
1989-1999	-70.80%	133.30%	-88.90%	-70.20%
1991-1999	-25.00%	600.00%	-85.10%	-45.50%

2.5 Model of Firm Behavior During Negotiation

This section presents a simple two-period model where harvesters maximize profit and have the expectation of receiving allocations based on catch history. In this model the expectation of a policy change leads to a change in behavior today. The empirical evidence shows the escalation of effort to during the negotiations over ITQs allocations.

In this two-period problem assume profit is a function of the population of clams, A, and aggregate fishing effort, E, an aggregate index of inputs over all the firms vessels. The net profit from harvesting in period one is given by,

$$\pi_1 = P_1 \, Q(E_1, A_1) - C(E_1)$$

where

P = price of clams

Q = output given effort, E, and abundance, A

C = cost of effort E

subscript 1 indicates period 1

In the second period, the firm is allocated individual transferable quotas based on how much the firm harvested in period 1. The allocation rule is given by $H(Q(E_1,A_1))$. If in period 2 the firm harvests less than his individual quota, it can lease the allocation to another harvesting firm. The lease arrangement splits the market price for clams between the owner of the allocation and the harvesting firm (see 2.6 for description of lease arrangements). The price for clams is specified in long-run contracts. Therefore firms know in period 1 what their price for clams will be in period 2. Therefore in period 2:

$H(Q(E_1,A_1))$ = the quota owned by the firm

αP_2 = the portion of the market price of clams paid to the firm that owns the quota

$\alpha < 1$, and varies between 0.4-0.6

subscript 2 indicates period 2

$$\pi_2 = P_2\, Q(E_2,A_2) - C(E_2) + \alpha P_2\, [H(Q(E_1,A_1)) - Q(E_2,A_2)]$$

A forward looking firm maximizes its two-period profit, where second period profit is discounted a rate, r.

$$\mathcal{L}:\ P_1 Q(E_1,A_1) - C(E_1) + (1/(1+r))\{P_2\, Q(E_2,A_2) - C(E_2) + \alpha P_2\, [H(Q(E_1,A_1)) - Q(E_2,A_2)]\}$$

The first order conditions with respect to effort in each period, E_1 and E_2 are:

7) $P_1\, Q_{E1} + (1/(1+r))\, [\alpha P_2\, H_Q\, Q_{E1}] = C_{E1}$

8) $[P_2\, Q_{E2} - \alpha P_2\, Q_{E2}] = C_{E2}$

Factoring out the output, Q, in each first order condition gives:

7') $Q_{E1}\{P_1 + (1/(1+r))\, \alpha P_2\, H_Q\} = C_{E1}$

8') $P_2\, Q_{E2}\ (1 - \alpha) = C_{E2}$

Therefore the usual first order conditions differ from the usual equating of marginal profit of effort to the marginal cost of effort. In period two, the difference between the marginal profit of harvesting and the marginal profit of selling an allocation is equated to marginal cost. In the first period, effort is expanded until the marginal cost of effort equals the marginal profit of harvest plus the discounted marginal profit from the additional allocation tomorrow.

Given the political reality of the allocation process, the partial derivative of the harvesting rule is increasing in past harvests, $H_Q > 0$. Effort in period one is therefore an increasing function of P_1 and P_2.

The simple two-period model predicts that when firms anticipate that the initial allocation will be based on catch history, the firms will increase their effort in the first period. An increase in the rate of harvest (clam bushels per hour, Q_E) could be indicative of a shift from low to high effort. Comparing trends of the rate of harvest of surf clams to the rate of harvest of quahogs provides a simple test. Recall that the ITQ negotiations focused only on surf clams not quahogs. Harvesters testified in court that the industry did not predict that ITQ's would be implemented for the quahog[2]. The implementation of ITQ's for quahogs was effectively an unpredicted shock. As Table 2.6 shows, there was a distinct upward shift in the surf clam harvest rate in 1985, the year the discussions of ITQ's and surf clams began. Table 2.6 through Table 2.9 show the harvest rate in bushels of clams per hour fishing relative to the population of each species. Table 2.7 shows that the average harvest rate over the period of ITQ negotiation (12.7) was significantly higher than the average harvest rate prior to negotiation (4.5).

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[2] *Sea Watch International, et al. v. Secretary of Commerce*, 762 F. Supp. 370 (1991).

TABLE 2.6: ANNUAL HARVEST RATES OF SURF CLAMS, 1980-1999

Year	Mean	Standard Deviation	Minimum	Maximum
1980	3.91	4.17	0.07	63.71
1981	5.19	4.65	0.17	83.04
1982	3.23	2.35	0.06	49.56
1983	4.23	3.14	0.02	42.29
1984	6.47	4.51	0.28	54.97
1985	11.24	6.26	0.35	43.39
1986	13.98	7.06	0.01	44.05
1987	12.82	6.81	0.22	43.83
1988	12.85	7.33	0.21	65.95
1989	13.09	6.9	0.16	48.02
1990	13.78	7.4	0.21	122.46
1991	12.74	6.65	0.05	65.88
1992	12.43	7.36	0.45	76.91
1993	14.27	9.7	0.37	100.41
1994	14.17	10.44	2.11	87.66
1995	12.99	9.19	0.27	86.14
1996	11.37	7.53	1.76	76.46
1997	12.21	10.35	0.43	130.86
1998	14.18	14.99	0.5	128.52
1999	13.13	9.48	0.5	108.67

TABLE 2.7: AVERAGE SURF CLAM HARVEST RATES OVER POLICY PERIODS

Average	Mean	Standard Deviation
1980-99	10	8.5
1980-84	4.5	3.9
1985-88	12.7	6.9

In contrast to the shift in effort in the surf clam industry, the harvest rate of the quahog does not show a significant shift in effort (see Table 2.8 and Table 2.9).

TABLE 2.8: ANNUAL HARVEST RATES OF OCEAN QUAHOGS, 1980-1999

Year	Mean	Standard Deviation	Minimum	Maximum
1980	5.8	2.75	0.32	48.38
1981	6.12	2.44	0.4	32.8
1982	6.64	3.13	0.78	88.24
1983	7.16	3.18	0.24	87.54
1984	6.61	2.66	0.49	31.4
1985	6.95	2.74	0.32	32.96
1986	7.38	3.18	0.35	22.26
1987	7.69	3.57	0.5	76.24
1988	7.13	2.72	0	24.76
1989	6.72	2.73	0.34	20.51
1990	6.16	2.77	0.09	21.18
1991	3.63	3.5	0.01	20.15
1992	5.5	5.01	0.01	26.75
1993	5.1	3.39	0.03	19.24
1994	5.09	3.58	0.01	23.86
1995	5.12	4.25	0.02	134.12
1996	5.71	4.02	0.04	28.47
1997	4.47	4.11	0.02	21.57
1998	4.5	5.2	0	127.33
1999	4.16	4.95	0.03	141.99

The average harvest per hour in the quahog industry does not exhibit a large shift during ITQ negotiation.

TABLE 2.9: AVERAGE OCEAN QUAHOG HARVEST RATES OVER POLICY PERIODS

Average	Mean	Standard Deviation
1980-99	5.66	3.92
1980-84	6.468303	2.872811
1985-88	7.278396	3.083633

Note: Surf clam and ocean quahog population estimates are in biomass. Surf clam estimates (metric tons)are from The 30th Northeast Regional Stock Assessment Workshop (30th SAW), Northeast Fisheries Science Center Reference Document 00-03, April 2000, page 401. Quahog population estimates (1000 metric tons) are from The 31st Northeast Regional Stock Assessment Workshop (31st SAW), Northeast Fisheries Science Center Reference Document 00-15, Oct. 2000, page 238.

2.6 Discussion of Firm Exit

For this dissertation the firm is an entity that owns capital (i.e. vessels and/or ITQs) and makes decisions on investments, harvesting, contracting with processors, and whether or not to remain in the industry. Some firms have a single capital owner. Other firms are partnerships between two or more capital owners. Most partnerships in this industry are between individuals who are related by kinship or have personal friendships (types of firms and contracting are detailed in Section 2.7).

Under command-and-control regulation, vessel owners could participate in the industry only as harvesters. Therefore during command-and-control a firm was an entity that owned vessels and used them to harvest surf clams and/or quahogs. When ITQs were allocated the ITQ itself became a new form of capital distinct from the vessel. Since the implementation of property rights, therefore, firms can have one of three capital configurations. A firm can own only vessels and no ITQs. A firm could own both vessels and ITQs. Firms that own vessels as capital are termed *harvesting firms*, regardless of whether or not they own ITQs. The significant difference between command-and-control and ITQs is that under ITQs a firm could *sell its vessels* but *retain its ITQs*. A firm that owns ITQs but not vessels is still a significant capital owner in this fishery, and is termed an *allocation firm*. The sum of firms that are *harvesting firms* and *allocation firms* can therefore be greater than the number of vessels in the industry.

This dissertation is concerned with firm behavior. In particular the analysis looks at participation of *firms as capital owners*, not the activity of particular vessels. This distinction is important in the discussion of the firm's choice to be a harvesting firm, allocation firm or exit entirely.

For example, Firm A could be a single capital owner or a partnership of capital owners. Suppose Firm A owns two types of capital, two vessels and ITQs. In period one they use both types of capital to harvest clams. In period two the Firm could chose to sell its vessels but retain its ITQs. The firm can then lease the ITQs to harvesting firms, and in this scenario Firm A is an allocation firm (leasing arrangements are described more in Section 2.7). Firm A could either sell its vessels to another firm, Firm B, or scrapped the vessels entirely. If ownership of the vessels is transferred from Firm A to Firm B, the two firms are still distinct firms. Ceteris paribus, the number of vessels in the industry and the total number of firms in the industry are unchanged; however, the number of harvesting firms decreases by one and the number of allocation firms increases by one. Consequently, when economists look only at the number of boats in the industry, they are missing the transition of firm A into an allocation firm. The emergence of the allocation firm is a significant structural change in the industry caused directly by the introduction of ITQs.

If Firm A does not have a buyer for its vessels, it can scrap the vessels (they are either retro-fitted for another fishery or literally used for scrap). If Firm A's vessels are scrapped entirely but retains its ITQs, the total number of boats in the industry falls by two. Again the total number of firms is unchanged, but the number of harvesting firms decreases by one and the number of allocation firms increases by one.

Alternatively, Firm A could choose to sell both types of capital, its vessels and ITQs. In this scenario the firm no longer participates in the industry: the firm has exited the industry. The number of harvesting firms decreases by one, but the number of allocation firms is unchanged. Total number of firms falls by one. Again the number of vessels in the industry depends on whether or not Firm A finds a buyer in the industry for the vessels or the vessels are scrapped. If Firm A finds a buyer for the vessels the number of vessels is unchanged. If the vessels are scrapped, the total number of vessels falls. The reason it is important to distinguish *firm* from *vessels* and to distinguish between harvesting firms and allocation firms, is that looking only at number of vessels obscures the structural changes that occurred as a consequence of ITQs. Only by carefully characterizing the structural changes can economists contribute to the political disputes over ITQs.

2.7 Contracting in the Clam Industry

The literature on contracting in fisheries include: Stuster (1980), Wilson (1980), Johnson and Libecap (1982) and Matulich et al. (1995). As in the study on contracting by Johnson and Libecap, heterogeneity in the surf clam and ocean quahog fishery prevents the harvesters from negotiating collectively. Therefore, contracting between processors and harvesters is based on individual relationships in this clam industry. Contracting on an individual level is more pervasive in fishing (see Stuster (1980) and Wilson (1980) for additional examples) than the bilateral negotiations described in Matulich et al..

A critical concept in the discussion of contracts is the boundary of the firm. Most economic analyses of fisheries focus on the individual vessels, however one firm can own several vessels or allocations under different corporation names. Collaborative field interviews with Professor Bonnie McCay revealed that there exist three types of ownership: independents (1-2 vessels), fleet owners (3 or more vessels) and processors (owned by processing company). The type of firm determines the size of its market, bargaining power in contracting, and ability to bear risk. During our fieldwork we interviewed independents, fleet owners and vertically integrated harvesters. We interviewed an additional three processors that do not harvest.

Contracts between the harvesting firms and processors define the clam industry. All clams are sold to a processor based on a long-run contract (contracts are either written or a verbal "gentleman's agreement"). It is common to have an agreement or contract covering ten or more years (a five year contract is a minimum). There does not exist a spot market for either harvested clams (either surf clams or quahogs) or allocations. Clams, and hence allocations, are worthless unless you have a processor who agrees to be a buyer for the year.

The contracts specify harvesting schedules, price and will provide a harvester with enough quota to meet the contracted harvest. The processor meets the vessel at the dock at a specified time with a truck to transport the cages from the vessel to the processing plant. The contracts specify that processors will pay the prevailing market price for clams. Market price, however, is set by the processing oligopsony (there were 14 licensed processors in 1998, but only about five significant ones). Once the price is set for the year it does not change unless a fisherman continues to harvest in an area his processor has asked him to avoid[3]. Rather than using price to reward good harvest or

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[3] Some areas yield more rocks per tow, smaller clams and/or reduced meats per bushel than others. These imperfections increase the processor's costs by slowing the processing line. When the truckload of clams comes in, a processor employee marks each cage as full, 1/2 full, 1/4 full etc.. There is no representative for the vessel when the processor tallies the sum of cages. If a boat brings in a load with partially full cages,

punish bad harvests, processors use the threat of terminating the relationship. Punishment is also extracted by processors for disloyal behavior by harvesters. For example, harvesters that had supplied several processors were the first to be dropped from the contracts of a significant processor when it went through an inventory reduction. There is significant rhetoric about loyalty to your processor.

Loyalty to your processor is rewarded by renewal of contracts, financing, and provision of harvesting allocations. Harvesters often speak of their processors "taking care of them" by committing to providing a long-run market for their clams. Processors regularly provide financing to their supplier in exchange for commitment to supply clams. The financing is paid back at an agreed-upon rate per bushel harvested. Allocations needed to harvest more than the total allocations owned by the fishing firm are provided to the vessel by the processor.

In our interviews, processors referred to the boats that they own and the boats that they "manage" meaning, the boats with which they have long-run contracts. In fact, one significant processor even advertises itself as being vertically integrated with the harvesting sector. This processor in reality owns no vessels at all, but merely has effectively locked in its supply of all clams through long-run contracting. Although the surf clam and ocean quahog industry is particularly susceptible to processor control, in most fisheries there are points of entry into the marketplace that are controlled by either processors or dealers (see Matulich et al., 1995).

The model of Clark (1980) is the prototype for much of the research on property rights in fisheries. Given his assumptions, he shows that if the management authority

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the processor will ask the boat to move from that location. If the boat continues to bring in low grade cages, a processor can threaten to stop buying from him.

allocates individual catch quota, and new entrants must buy existing quota, two conditions follow. New entry of fishermen is reduced because fishermen must buy ITQs in order to harvest. The introduction of the cost of buying ITQs is essentially a new barrier to entry relative to open access. Second, because fishermen are no longer circumventing command-and-control regulation by expanding unregulated inputs, overcapitalization is reduced. Clark shows that if individual fishermen's quota allocations are transferable, then the market for quota transfers "throws up" a price for quota equal to the optimizing tax.

The market for clam property rights that emerged post-ITQ implementation differs markedly from the frictionless market described in much of the literature. The reality is that the market that appeared resembles one shaped by significant transaction costs. Stavins (1995) show that the existence of transaction costs can reduce the trading of property rights.

At this point it is helpful to define two concepts, the ITQ and the allocation. ITQ is the percentage of the total allowable catch held by the firm. Once the total allowable catch has been determined (in quantity of bushels) the firm's allocation is their ITQ (in percentage) multiplied by the total allowable harvest. The allocation is the quantity of bushels that the firm has a right to harvest. Rather than trade ITQ (percentage points), firms trade allocations - quantity of bushels.

Initially after the implementation of ITQs, some industry participants tried to create a niche for brokers of allocations. However, transfers have been dominated by personal relationships between independent harvesters, contracts or agreements between harvesters and their processors, and transfers between holding companies and processors.

When an allocation owner wants to buy or sell allocations, all information is transmitted through informal relationships. There is not now, nor has there ever been, a formal trading place for ITQs nor public posting of allocations available or demanded.

Rather than a market for property rights, transactions of individual transferable quotas are dictated by contracts. For transactions between two different firms (external transactions), contracts specify how the price per bushel of clams is split between the harvester and the allocation owner. The contracted share typically ranges from 60/40 to 50/50 between the harvester and the owner of allocation. For example, if an independent firm harvests using a processor owned allocation, the independent firm receives between $5 to $6 per cage of clams out of the $10 market price.

In addition to contracted external transactions, firms often transfer allocation between their own corporations[4]. The motivation for such internal transactions is to minimize labor costs. When a vessel harvests clams with a leased allocation, either internal or external, the lease price of the allocation can be deducted from the revenue before labor is paid (labor is paid a share of the total revenue of the trip, typically 30% of total revenue). By leasing allocations between corporations within the same firm, harvesting firms can minimize the total labor costs. As Table 2.10 shows, a significant amount of the recorded transactions are actually internal transactions.

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[4] Firms often divide their capital between separate corporations to minimize liability. Therefore, each firm's vessel may be registered to a different corporation. A true owner database that maps corporations into parent firms was used to distinguish between truly distinct firms. The true owner database is similar to the Who Owns Who, and was developed by McCay and Creed and updated by McCay and Brandt.

TABLE 2.10: TOTAL, INTERNAL, AND EXTERNAL TRANSACTIONS, 1991-1999

		Within Firm		Between firms	
Year	**Total**	**Frequency**	**% of total**	**Frequency**	**% of total**
1991	18	8	44.44%	10	55.56%
1992	79	20	25.32%	59	74.68%
1993	290	103	35.52%	187	64.48%
1994	169	45	26.63%	124	73.37%
1995	223	65	29.15%	158	70.85%
1996	480	139	28.96%	341	71.04%
1997	257	76	29.57%	181	70.43%
1998	443	72	16.25%	371	83.75%
1999	676	112	16.57%	564	83.43%
1991-99	2635	640	24.29%	1995	75.71%

Looking at the trades on the firm level shows that firms repeat transactions over multiple years. Table 2.11 shows the repeated external transactions between the two allocation owners that made the most annual transactions in 1996 and 1997. Because of confidentiality agreements, only the type of firm is revealed. Processor C accounted for 19.6% of all allocation transactions in 1996 and 20.4% of the transactions in 1997. But the allocation transactions show that this processor repeatedly transfers allocation to two independent harvesters and two harvesting fleets. These transactions from the processor to the harvesting firms are long-run agreements in which the processor agrees to provide a harvester with enough allocations to deliver the amount of clams specified in the harvesting contract.

The Surf Clam and Ocean Quahog Federal Management Plan disallows the use of ITQs as collateral. Some firms have circumvented this restriction by transferring all of their allocation to a holding company at beginning of the year and then transferring allocation back to the harvesting firm over the following year. These types of transfers account for a significant amount of the reported transactions. The allocation holding company (an accounting firm) accounted for 42.8% of the allocation transactions in 1996 and 48.6% of the allocation transactions in 1997.

TABLE 2.11: REPEATED EXTERNAL TRANSACTIONS, 1996 & 1997

	Allocation Seller			
	Processor C		**Holding Company**	
Allocation Buyer	**1996**	**1997**	**1996**	**1997**
Independent A	4	1		
Independent B	14	7		
Fleet A	29	13		
Fleet B	20	16		
Processor A			45	22
Processor B			47	31
Processor C			46	35
Bank			8	
Total	67	37	146	88

2.8 Implications for Analysis

This chapter describes the regulatory history of the surf clam and ocean quahog fishery. Data on fleet size, firm size and specialization illustrate structural changes both during ITQ negotiations and after ITQ implementation. The escalation in effort during ITQ negotiations is explained by a two-period model. In this model forward-looking firms increased effort prior to implementation in order to increase their share of the impending property rights. Rather than a spot market for quota allocations and harvested clams, this industry is dominated by long-run contracts and agreements.

The analysis in this chapter demonstrates the importance of strategic behavior and contracts in the evolution of property rights. The next two chapters evaluate productivity and the firm's exit decision. The regulatory history and institutions in this industry play a vital role in shaping the market for property rights.

Chapter 3

Productivity under Traditional Regulation and Property Rights

3.1 Introduction

A theme in environmental economics is the challenge of achieving both biological conservation and economic efficiency. The national fisheries legislation, the Magnuson-Stevens Act 1996, states that biological conservation is the primary goal and economic efficiency the secondary goal of fisheries management[1]. The economic question is, what regulatory tool maximizes economic efficiency given the biologically determined total allowable harvest?

Economic literature establishes that a given environmental standard can be met at a lower cost under tradable property rights than under command-and-control [2]. The empirical evidence demonstrates that a common consequence of command-and control in fisheries is tremendous overcapitalization[3]. In contrast, implementation of tradable property rights is predicted to both limit the number of fishermen and result in optimal harvesting capacity[4]. Therefore one measure of comparison is the productivity under the competing policy approaches.

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[1] National Standard One for fisheries management states, "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimal yield from each fishery for the United States fishing industry". National Standards Five and Seven state that management must consider efficiency and cost minimization (Title III Section 301).

[2] For reviews see Hahn and Noll (1982) for application to pollution, Moloney and Pearse (1979) for the first application to fisheries, and Varian (1989) on the compensation mechanism. Ellerman, et al. (2000) provide a review of the U.S. experience with property rights under the Acid Rain Program.

[3] Gear restrictions, trip limits and limits on the number of allowed fishing hours are often met with increased capital in the fishery. For example, by 1978 the capital in the surf clam fishery was large enough to harvest the entire year's quota in only 15 days (Keifer, 1992).

[4] Additionally, given a competitive market quota, the market price for quota should be equivalent to the Pigovian tax (Clark, 1980). In reality, asymmetric information destroys this equivalence (see Weitzman (1974) on cost uncertainty and Stavins (1996) on benefit and cost uncertainty).

This chapter provides a methodology and empirical estimates to evaluate the economic criteria for fisheries regulation by evaluating the impact of tradable property rights on productivity in the Mid-Atlantic surf clam and ocean quahog fishery. The results demonstrate the impact of firms' predictions about regulatory change on productivity in the industry. During property right negotiations firms race to maximize their allocations thus depressing productivity. Economic analyses must therefore compare productivity prior to negotiation to productivity post implementation to assess the increase in productivity due to the regulatory change. The next section discusses the economic literature on productivity and cost effectiveness under the two competing regulatory instruments. Methodology is addressed in Part 3, and the industry and data are detailed in Part 4. Part 5 reviews the calculations of productivity growth and the regression results.

3.2 Literature Review

While the literature on the cost effectiveness of regulation has reached a degree of consensus[5], empirical analysis of the relative effects of regulation on productivity is more ambiguous. The majority of the papers on policy and productivity analyze the effect of environmental regulation using aggregated industry data, and do not distinguish between different types of regulation. Jorgenson and Wilcoxen (1990) simulate the production of 35 two-digit-level (Standard Industrial Classification) industries with and without environmental regulation. Papers by Conrad and Morrison (1989), Conrad and Wastl (1995), and Barbera and McConnell (1990) use index numbers to estimate total factor productivity indices for two-digit manufacturing industries. The basic idea of the index number approach is to aggregate inputs into a single metric and aggregate output into a single metric. A change in productivity is then change in aggregate output not accounted for by change in aggregate input. The index number approach is a non-parametric approach and as such does not require the researcher to impose parametric restrictions on the underlying technology. However, the level of aggregation of these analyses required substantially restrictive assumptions. In addition, all of these papers neglect how different types of environmental regulation may have different effects on productivity growth and efficiency. Because they conflate different types of regulation and use aggregated industry level data, these papers do not give insight into the relative ranking of alternative approaches to environmental regulation.

A frequently cited paper on environmental regulation and productivity focuses on electric utilities. Gollop and Roberts (1983) estimate the effect of the stringency of environmental regulation on productivity growth in the electric power generation industry, and they find that regulation reduced the productivity growth rate of electric utilities after 1973 by about half a percentage point. In addition, Gollop and Roberts show technical regress during 1973-75, which they attribute to the sharp jump in fuel prices. Their results, however, are biased downward because they ignore the effect of decreasing capacity utilization during this period (Baily and Chakrabarti, 1988).

Following this initial work, Fare, Grosskopf and Pasurka (1986) estimate the relative efficiency of regulated and unregulated electric utilities by considering the indirect costs associated with restricted production possibilities imposed by regulation.

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[5] The work on the cost effectiveness of competing tools to regulate pollution is summarized by Tietenberg (1985). Of nine studies, eight find that the command-and-control policy costs at least 78 percent more than

While this work represents an interesting approach to modeling firm production under regulation, it uses only one year of data and does not consider how firms adapt their behavior and the effect this has on efficiency. Bernstein, Feldman, and Schinnar (1990) use data envelope analysis to estimate efficiency for three categories of electric utility plants: plants that use scrubbers, plants that use compliant fuel, and plants with no pollution controls. Again this work only provides estimates of efficiency for one year and compares only command-and-control regulation with no regulation. Given the social importance of environmental regulation, a more useful analysis would compare traditional command-and-control regulation with alternative regulatory approaches.

Estimates of the efficiency gains from implementing tradable property rights are available for two fisheries, the British Columbia halibut fishery and the surf clam/ ocean quahog fishery. Grafton, Squires and Fox (2000) estimate a stochastic production frontier for the British Columbia halibut fishery and calculate changes in technical efficiency, allocative efficiency and economic efficiency[6]. The production function is estimated as a Cobb-Douglas where the error term (e) has both a random component (V) and a half-normal inefficiency component (U), such that e = V-U. The study pools observations on firms from three years of data: two years before tradable permits (1988), the year of tradable permit implementation (1991), and three years after implementation (1994). The sample of 107 firms is neither a panel nor rotating panel. They specify technical inefficiency for each vessel as unforeseen or unexpected, therefore the technical

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the least-cost approach. See also Whalley, J. and R. Wigle (1991) and O'Ryan, R. E. (1996).

[6] A firm is defined as technically efficient if it produces a given output with the minimum quantity of inputs. Allocative efficiency requires the firm to equate the ratios of marginal products with the input price ratios to minimize cost given output and input prices. The condition for economic efficiency is the production of a given quantity of output at minimum cost (and is the product of technical efficiency and allocative efficiency)

inefficiency for each vessel is defined as the expected value of U conditional on the value of e, E[U|e]. They assume there is no technical change across the study period, because technology is embedded in the vessel or gear. All vessels in the sample were built prior to 1988, and harvesting gear was strictly regulated throughout the period. They estimate that short-run technical, allocative, and economic cost efficiency declined between 1988 and 1991. In contrast, all measures of short-run efficiency increased between 1991 and 1994. However, the only statistically significant changes at the five percent level are economic efficiency for large vessels and technical efficiency for small vessels. The authors argue that three factors prevented the gains from tradable property rights from being realized in 1991. First, they argue that there was a learning curve in knowing where to find halibut during times when the season was previously closed. Second, there was a prohibition on trading during 1991-1993. Vessels could not trade in order to reach the desired scale of operations[7]. Third, because there was uncertainty about property rights vessels retained redundant crew. The authors attribute the efficiency gains between 1991 and 1994 to the increase in temporary trading of individual quota[8].

The authors' explanation of their results however neglect the behavioral changes of firms in response to the regulatory change. The authors note that in 1988 a group of fishermen proposed the use of individual quotas to the regulatory agency, Canadian Department of Fisheries and Oceans. In 1990, 70 percent of the fishermen voted in favor of introducing individual quotas. The quotas were allocated *gratis*, and 70 percent was based on the best annual harvest over the past four years. The individual quotas were implemented in 1991 for a two-year trial, and only after the trial period could fishermen

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[7] Property rights were neither transferable nor divisible, 1991-1993.

temporarily transfer them. Permanent transfers were allowed after 1991, but only to newly entering vessels that were no more than 10 feet longer than the vessel transferring the quota. (Grafton, Squires and Fox, 2000). Because fishermen themselves were active participants in the regulatory process, they arguably were well aware of the rewards from delaying exit until they could realize the revenue from selling their quotas. Therefore vessels that were cost inefficient had an incentive to delay exit, thus depressing the average efficiency in the fleet.

A predicted result, and in fact goal, of tradable property rights is to reduce capital in the fishery, especially excluding those vessels that are the least cost efficient (Linder, et al., 1992 and Segerson and Squires, 1993). The authors note that vessels declined by 20 percent between 1991 and 1993 and an additional 11 percent between 1993 and 1994. A consequence is that the population of vessels remaining in 1994 is necessarily more efficient on average than the population from 1988 and 1991. Therefore the population's mean distance from the stochastic frontier decreases from 1988 to 1994. The authors use *different samples* of vessels from the population *for each year* they analyze. Their data are not a panel of the same vessels observed over time. The analysis cannot disaggregate any change in efficiency due to regulatory change from attrition bias. In fact, the authors note that throughout the period there were strict regulations on the length of the vessel and gear used in the fishery. Because regulation limited the two major inputs, capital and gear, it is even less likely that the result found in this study arises from a true increase in efficiency and more likely that it is due to natural attrition.

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[8] Temporary trades were not allowed in 1991 and 1992. In 1993 there were 178 trades and the number grew to 306 in 1994.

The second paper that estimates the efficiency gains from implementing tradable property rights is Weninger (1998). The author uses input and output data from surf clam and ocean quahog fishery during the last year before ITQs (1989) to estimate a translog variable cost function. He assumes that under ITQs, production will occur at minimum average total cost and that the total allowable harvest is distributed equally across each vessel in the industry (i.e. each vessel harvest = total allowable catch/number of vessels and industry). Because his estimated cost function does not exhibit cost complementarity[9], does have output specific increasing returns to scale, and is nonjoint-in-inputs[10]., his results indicate that the variable cost function should lead to specialized production. He projects that the minimum cost fleet will emerge under ITQs and will consist of a total of 21-25 specialized vessels that are homogeneous (eight vessels harvesting surf clam each of 200-GRT and thirteen vessels harvesting ocean quahogs each of 200-GRT). He calculates that the total industry cost to harvest the total quota in 1989 (the last year of command-and-control), based on 128 vessels in the fleet, was $28.4 million, and the projected cost to harvest the quota under the optimal ITQ fleet is $15.6 million. He concludes that there is a $12.8 million dollar cost saving annually.

However, Weninger's predicted ITQ fleet significantly differs from the industry that emerged post implementation. Ten years after implementing individual transferable quotas, the surf clam and ocean quahog industry has twice as many vessels still active then predicted by Weninger (in 1999, there were a total of 42 vessels active (McCay and Brandt, forthcoming)). In contrast to Weninger's prediction of a specialized fleet, there

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[9] Cost complementarity implies that the marginal cost of producing output a is reduced if output b is also produced. Cost complementarity is a sufficient condition for economies of scope.

[10] Nonjoint-in-inputs implies the existence of output specific cost functions.

remain generalized firms and vessels (21 vessels harvest surf clams only, 14 vessels harvest quahogs only and seven vessels are generalized). In addition, the fleet remains heterogeneous with no discernible increase in scale of operation (McCay and Brandt, forthcoming). The discrepancy between Weninger's predicted fleet and the realized fleet, suggest the importance of incorporating into our models both strategic behavior of firms and the institutional relationships in the industry. There are five aspects neglected in the Weninger study: the effect of behavior by forward looking firms prior to policy implementation, the change in the cost function, uncertainty, heterogeneity and institutions in the fishery.

1. Comparing the fleet in 1989 to the optimal ITQ fleet overstates the potential gains from individual transferable quota. Between 1980 and 1987 the number of large vessels (those greater than 100 gross registered tons) actually increased from 59 to 75 (MAFC, 1990). This increase in large vessels was a consequence of firms anticipating the regime change (see McCay and Brandt, forthcoming). This chapter details the shift in the industry composition during this period prior to implementation of property rights, and its effect on productivity. The conclusion of the following analysis is that the choice of the time frame for comparison can bias estimates of efficiency gains.
2. Weninger notes that he uses the identical cost function for both policy regimes, and he acknowledges that this could affect the results. The importance of the correct cost function on his results, however, is underemphasized. A critical benefit of property rights over command-and-

control is that property rights allow a firm to choose inputs to minimize cost. Under command-and-control the management regulations limited the time a vessel could be at sea; therefore, there was incentive to harvest under less than ideal conditions and as fast as possible (see McCay and Brandt, forthcoming). Therefore the cost equation under tradable property rights is likely to be substantially different than under command-and-control.

3. Weninger and Just (1997) argue that uncertainty about the value of ITQs can cause firms to delay exit from the industry. They use this model to explain the less than predicted amount of exit from the surf clam and ocean quahog fishery. While fisheries in general have an element of uncertainty, the surf clam and ocean quahog is an exception to this rule. Unlike many other examples of fisheries that implemented tradable property rights, this fishery had a history of consistent total allowable harvests (Heaton and Hoff, 2000). Output prices are remarkably stable over years, and the market for quota is dominated by long-run contracts. There is therefore very little value of waiting in this industry.

4. In this analysis Weninger assumes that each boat harvests an equal share of the annual total allowable harvest. This assumption completely neglects the structure of the ITQs allocation, which was based on each vessel's historical harvest. Because firms did not receive equal allocations, in order to harvest at the level Weninger imposes, firms would either have to buy or lease/sell their quota, a cost/ revenue that is not included in his cost function. There has

never nor never will be homogeneity in either the harvesting technology nor harvest levels.

5. All of the clams in this industry go into processed products. Therefore contracting with processors determines much of the industry's structure. The contract determines the harvesting schedule and whether the harvester harvests one clam species (surf clam or quahog) or both clam species. In this fishery, as in most fisheries, it is the processor that determines the conditions of the contract. A harvester that may be a high cost firm but can credibly commit to a contract will be favored over a low cost firm that cannot credibly commit. Therefore contractual relationships, not cost, drive much of the vessel exit.

The rest of this chapter describes the methodology and data use to estimate the change in productivity following implementation of property rights. By including data on production in the fishery prior to negotiations over property rights, the results show the effect of strategic behavior on industry productivity.

3.3 **Methodology**

Economists initially attempted to measure technical progress by comparing average productivity statistics for single inputs. Commonly the comparisons were simply between average labor products over time, and differences in average product of labor were attributed to technical progress (regress). An extension of this simple approach is to compare the *total factor productivity*, which is basically the average product of all inputs. Total factor productivity [TFP] is defined as the ratio of aggregate output to aggregate input. The calculation if TFP is a nonparametric approach because it does not require assumptions on the functional form of production. In order to compare the levels of TFP over years, it is natural to create an index of TFP, defined as TFP in year t relative to TFP in a base year. A second indicator of technical progress is the rate of change of TFP.

There are three basic approaches to calculating productivity: econometric, mathematical programming and index number (see Grosskopf (1993) on the relative merits of competing approaches). The econometric approach is stochastic, and it tries to disentangle effects of noise from change in productivity. Two disadvantages of the econometric approach is the need to assume a functional form for production and the significant data requirements. The mathematical programming approach is nonparametric and is basically a bounding technique. The mathematical programming approach requires a significant number of data points for each year in order to sketch out the empirical production frontier.

In this analysis productivity is calculated using an index number approach for two main reasons[11]. First, constructing an index is a nonparametric approach; therefore, it does not require restrictive assumptions about the functional form of production. Second, fishery research suffers from a severe paucity of data not only because of a lack of scientific data on stock abundance but also because information in the fishing industry is highly guarded. Researchers and managers are therefore unlikely to have access to cost and production data. The index number approach uses only observable data and can be used to estimate productivity change without estimation of cost, production or profit functions.

The next section describes the aggregation of the inputs and the calculation of both the index of TFP and its growth rate. Utilization of capital is described in 3.3.2. There are two steps in the analysis of productivity presented in this paper. First the level, index and growth rate of TFP are calculated. Second, the level of TFP is regressed against exogenous variables that changed across the two policy regimes. The results in Section 3.5 presents the index of TFP, the growth rate of TFP and regression results.

3.3.1 Calculation of Productivity

In this analysis there is the single output, quantity of surf clams. There are multiple inputs used to harvest clams. Total factor productivity, the average product of all inputs, in year t (TFP_t) is defined as the ratio of output (Y_t) to aggregate input (X_t):

$$(1)\ TFP_t = Y_t / X_t$$

The index of TFP is the ratio of TFP in year t to the level of TFP in year 0 (equation 2). The index of TFP can be interpreted as the ratio of the production function evaluated at two different periods in time holding the input bundle constant.

$$(2)\ \text{Index}\ (TFP_t) = TFP_t / TFP_0$$

Differentiating both sides of (1) with respect to time gives the rate of change of TFP:

$$(3)\ d(TFP)/dt = dY/dt - dX/dt$$

The first step to calculating total factor productivity [TFP] is to create a measure for aggregate input. Assume producers are cost minimizers, and the underlying production function can be approximated by a translog. Factor inputs are assumed to be bought in perfectly competitive markets such that inputs are paid their marginal products.

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[11] One criticism of the index number is that it does not allow for the decomposition of productivity change into its components of technical change and efficiency change. However, this analysis is concerned with

The fungibility of the variable factor inputs used in the clam industry (labor and fuel) between competing uses makes it reasonable to assume that the input market is competitive. Section 3.3.2 details the calculation of factor payments to capital, the vessel. Then the aggregate variable input can be written as a weighted sum of inputs where the weights are the cost shares of the inputs (See Diewert (1978) for a formal proof):

$$(4)\ X = \Sigma_i ((W^iX^i)/C)\ X^i$$

where W^i is the price of input i, X^i is the quantity of input i, and the total cost is $C=\Sigma_i W^iX^i$.

The index of total factor productivity in year t relative to base year 0, is then:

$$(5)\qquad \frac{\Sigma_i (S_t^{\,i} X_t^{\,i}) / Y_t}{\Sigma_i (S_0^{\,i} X_0^{\,i}) / Y_0}$$

Because production is observed at discrete points in time we need discrete approximations to the derivative of aggregate input and TFP with respect to time. The Tornqvist approximation of the rate of change in aggregate input is:[12]

$$(6)\ \ln(X_t/X_{t-1}) = 0.5\ \Sigma_i\ (S_t^{\,i} + S_{t-1}^{\,i})\ \ln(X_t^{\,i} / X_{t-1}^{\,i})$$

where $S_t^{\,i}$ is the cost share of input i in time t, $S_t^{\,i} = W_t^iX_t^i/C_t$.

The rate of change of TFP is then:

$$(7)\ \Delta TFP = \ln(Y_t / Y_{t-1}) - 0.5\ \Sigma_i\ (S_t^{\,i} + S_{t-1}^{\,i})\ \ln(X_t^{\,i} / X_{t-1}^{\,i})$$

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the effect of regulation on the sum of technical change and efficiency change.

[12] The economic theory of index numbers terms an index that is derived from a specific production function "exact" for that particular function. Diewert showed that if the technology can be represented as a homogenous translog function then the Tornqvist index is exact. The translog production function provides for great flexibility because it is a second-order approximation to any arbitrary twice continuously differentiable production function (Diewert, 1976). Although an individual vessel's fishing trip is likely to have a fixed proportions technology, there is significant variation across vessels (for example, in captain

The calculated total factor productivity growth reflects the sum of the changes in efficiency and technology under the competing policies.

3.3.2 Capacity Utilization

In the long-run firms can buy/sell their vessels; however, in the short-run the number of vessels owned by the firm is fixed. Therefore harvesting capital is quasi-fixed. The major gear (dredge, hose, hopper, etc.) is affixed to the vessel and is therefore included in the cost of the quasi-fixed capital. Unlike fuel and labor we cannot assume that capital is paid its marginal product.

The quasi-rent to capital approach developed by Hulten (1986) and Berndt and Fuss (1986) is for the quasi-fixed input (in this case, vessels and gear). Berndt and Fuss specify a production function partitioned into one subset of variable inputs and one subset of quasi-fixed inputs (capital). Quasi-fixed inputs are variable in the long-run but fixed in the short-run. In the short run, variable inputs are chosen to minimize cost given the existing stock of quasi-fixed inputs.

A firm chooses its level of the quasi-fixed factor for the next period given its expectations about future input and output prices. Whether or not a firm increases or decreases its quasi-fixed factor depends on the firm's expected value of the marginal value of that quasi-fixed factor. In the short run the marginal product value of the quasi-fixed input is not necessarily equal to its market price. In order to estimate TFP, the researcher needs an estimate of the shadow value of the quasi-fixed factor. Berndt and Fuss show that in the case of a single quasi-fixed factor, if the firm's expectations of the value of the marginal are realized then an appropriate estimate of the factor's shadow

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experience, age of vessel, etc.). These non-conformities may be used to justify the use of a smooth function to approximate an aggregate production function (Berck et. al., 1988).

price is an internal rate of return for that factor. Berndt and Fuss suggest using the "residual" approach. Hulten show that the internal rate of return to the quasi-fixed factor, the quasi-rent, is the residual income not accruing to the variable inputs of labor and fuel per unit of capital stock.

Therefore in this analysis the shadow value of the capital, Z_t^k, is approximated as, the difference between the revenue and total variable costs divided by the total number of vessels:

$$(8)\ Z_t^k = \frac{P_t Y_t - \Sigma_i W^i X^i}{K_t}$$

where P_t is price per bushel of clams, Y_t is the bushels of clams harvested, $\Sigma_i W^i X^i$ is total variable cost and K_t is the number of vessels.

Thus change in total factor productivity with both aggregate variable inputs (fuel and labor), X, and quasi-fixed input K (capital) is:

$$(9)\ \Delta\,\mathrm{TFP} = \ln(Y_t / Y_{t-1}) - 0.5\, \Sigma_i\, (S_t^i + S_{t-1}^i) \ln(X_t^i / X_{t-1}^i)$$
$$- 0.5\, (Z_t^k + Z_{t-1}^k) \ln(K_t/K_{t-1})$$

The cost share of variable input i is S_t^i, and the quantity of variable input i is X_t^i. The quasi-rent to capital is Z_t^k and the quantity of capital is K_t.

3.4 The Surf Clam and Ocean Quahog Industry

After the population of surf clams dramatically plummeted in 1976, legislation was enacted that restricted allowable fishing time and limited access for a period of fourteen years. This fishery thus provides a good source of information on the long run impact of command-and-control. By the mid-1980s escalation of harvesting capacity and associated inefficiencies prompted debate over the establishment of a regulatory regime based on property rights. In 1991, an individual transferable quota system based on catch histories of individual vessels and processing records of clam processing plants was enacted.

A simplification of this analysis was to focus solely on the surf clam fishery and turn the problem into a single output framework.[13] There are three major choice variables in surf clam harvesting: capital (fishing vessel), labor and fuel. The significant gear is fixed to the boat (hydrologic dredge, hopper, conveyer belt, hose, etc.). Therefore the cost of the major gear is reflected in the cost of capital (i.e. the vessel[14]). Based on preliminary data from a cost survey (conducted by McCay and Brandt for the Northeast Fishery Science Center), the costs of variable gear (such as wire) is minimal. The costs of variable gear are therefore not included in the current analysis. The surf clam population will affect the efficiency of a given set of inputs and is often written as an argument of the production function. Given that the surf clam industry is marked by significant competition among harvesters with little possibility for collusive behavior, the population of clams is taken as an exogenous variable (Heaton, 1996). Therefore only the choice variables of capital, labor and fuel are used as inputs in the construction of the index. I distinguished the quantity of inputs and outputs by two classes of vessels defined by hull weight: class one, vessels less than or equal to 100 gross registered tonnage [GRT]; and class two, vessels greater than 100 GRT.

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[13] After the implementation of the surf clam management plan, effort in excess of the surf clam quota was directed to the previously unharvested quahog species. The input and output data used in this paper are only for vessels with surf clam licenses.

[14] Quantity of gear vary with vessel size. The costs of the vessel are based on the size class of the vessels.

Due to the competitive nature of the industry, very little cost data exists; therefore, relevant time series were extrapolated from entries in National Marine Fishery Service (NMFS) logbooks and the Mid-Atlantic Fishery Management Council industry reports. All NMFS series except the abundance series cover the period 1979-1995. Published abundance series cover the years 1982-95, and abundance estimates for the years 1979-1981 are derived from the DeLurvy model. All data are in real 1992 dollars deflated by the GDP implicit price deflator. (See the appendix for further details on the data.)

3.5 Results

3.5.1 Total Factor Productivity

Table 1 presents the calculated index of inputs, index of outputs, total factor productivity [TFP] index and growth rate of total factor productivity. The average annual TFP before ITQs (1980-1990) was 0.76, and the average annual TFP during ITQs (1991-1995) was 0.85. Comparing only these two periods, however, overlooks many other important changes over the entire period. There are actually two break points in the total factor productivity index, 1985 and 1991 (see Figure 1). During the period 1980-1984 the index fluctuates around the value 0.84. In 1985, despite an increase in allowable quotas, the index drops to 0.62 and averages 0.69 from 1985 through 1990[15]. In 1991 the index reaches 0.98 and averages 0.85 from 1991 to 1995. The differences in the TFP index in the three periods reflect important changes in the industry.

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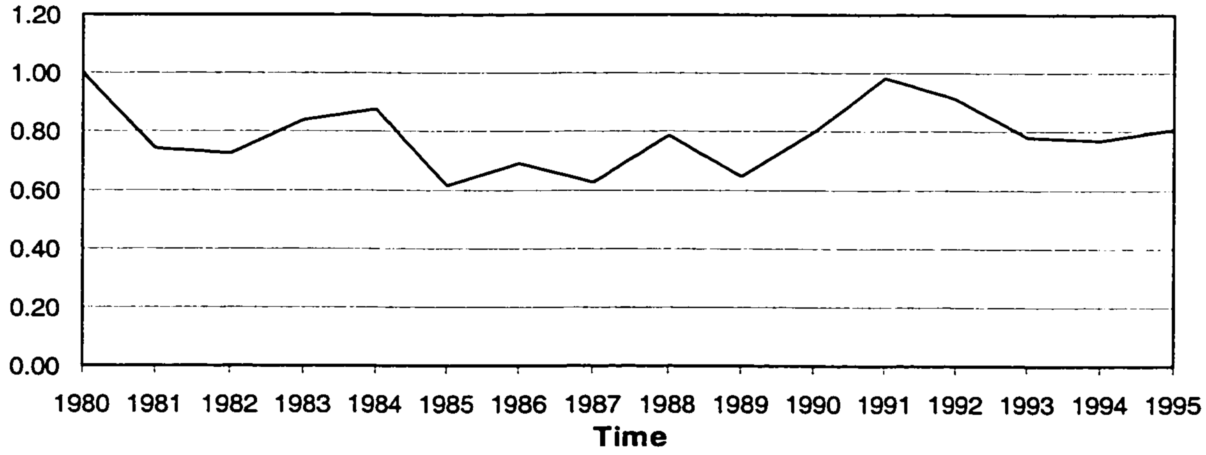
[15] The period between 1980 to 1984 saw an increase in the annual total allowable catch from 1,825 thousands of bushels for 1980 to 2,750 thousands of bushels for 1984. Then the annual total allowable catch maximized at 3,150 thousands of bushels in 1985. The quota remained above 3,000 thousand bushels through 1989.

Table 3.1: Total Factor Productivity, 1980-1995

Year	Index of inputs	Index of outputs	TFP Index	Growth rate of TFP
1980 (base year)	1.00	1.00	1.00	0.36
1981	1.20	0.89	0.74	0.06
1982	1.22	0.88	0.73	0.04
1983	1.25	1.05	0.84	0.19
1984	1.22	1.07	0.88	0.23
1985	1.38	0.85	0.62	-0.12
1986	1.38	0.95	0.69	-0.01
1987	1.23	0.77	0.63	-0.11
1988	1.19	0.94	0.79	0.12
1989	1.26	0.81	0.65	-0.08
1990	1.20	0.95	0.80	0.13
1991	0.76	0.75	0.98	0.34
1992	1.00	0.92	0.91	0.27
1993	1.13	0.88	0.78	0.11
1994	1.14	0.87	0.77	0.10
1995	0.96	0.78	0.81	0.15
1980-1990 average	1.23	0.92	0.76	0.07
1980-1984 average	1.18	0.98	0.84	0.18
1985-1990 average	1.27	0.88	0.69	-0.01
1991-1995 average	1.00	0.84	0.85	0.19

Figure 3.1: TFP Level 1980-1995



The period 1980-1984 differs from the period 1985-1990 in several ways. First, the number of allowable fishing hours was dramatically different between the two periods. During both periods the allowable number of fishing hours per week was set by the management council; as the total catch reached the quarterly quota the number of allowable fishing hours was reduced[16]. When total catch is regulated by restricting the number of hours that harvesting is permitted, the optimal strategy for the harvester is to invest in technology and to utilize harvesting methods that maximize the catch per hour of fishing. Because all vessels can harvest only when the fishery is open, there are boom-bust cycles in capital and labor utilization. The increased harvesting rate of the fleet necessitated increasingly stringent regulation. During the first period, the amount of time the fishery was open for harvesting fell from an average of 33.23 hours per week in 1980 to 24 hours per week in 1983 and 11.88 hours per week in 1984. Allowable fishing time then fell to 5.19 hours per week in 1985 and to 3.87 hours per week in 1986. Starting in 1987, fishing was controlled by trip limits: each vessel was allowed 25 trips per year with each trip limited to 6 hours (an average of 2.88 hours a week). Under this policy, granting vessels 25 fishing days, regardless of vessel size, served as a mechanism to allocate the annual total allowable catch among the vessels.

One measure of the effect of restricting allowable fishing time is effective hours of fishing, defined as the ratio of hours fishing to total hours at sea. The time of travel to the fishing ground represents a fixed cost of the trip. As allowable fishing time was decreased, the hours spent fishing decreased relative to the travel time. This ratio can be thought of as reflecting the cost efficiency of each trip. As seen in Figure 2, total factor

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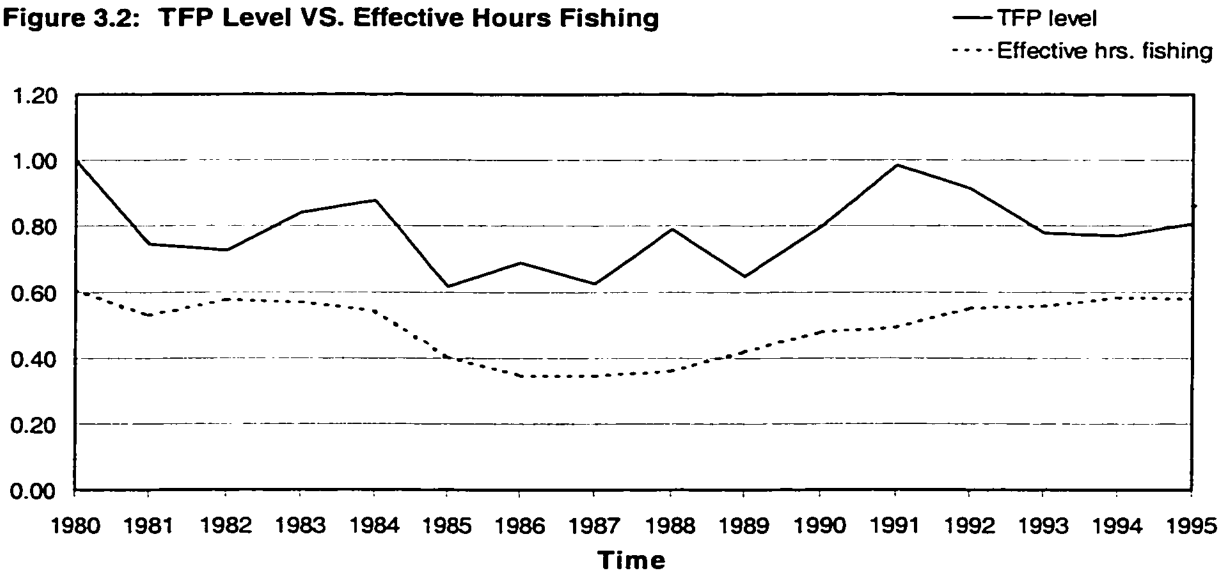
[16] The total annual quota was broken into quarterly quotas to smooth supply over the year.

productivity and effective hours fishing both sharply declined between 1984 and 1985, and effective hours fishing remained low through 1989, the same period during which total factor productivity had a trough. The total factor productivity index as calculated captures the effect of both changes in productivity and efficiency; in a sense, the effective hours fishing ratio captures the relative change in efficiency of inputs over these periods.

Figure 3.2: TFP Level VS. Effective Hours Fishing



Note: Effective hours fishing is defined as (hours fishing / total hours at sea).

Source: Mid Atlantic Fishery Council Report, August 16, 1996.

A second notable difference between the first and second periods is the mix of vessels that were active in the fishery. Throughout the period 1985 to 1990 there were more vessels active in the fishery than in the previous period (the number of active vessels peaked in 1986 at 144). As Figures 3 and 4 show, the ratio of large vessels to total vessels (small vessels to total vessels) increased (decreased) from 1984 to 1985[17].

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[17] Large vessels are defined as class three vessels, vessels with greater than 100 gross registered tonnage. Small vessels are less than or equal to 100 gross registered tonnage.

The increase in total vessels was primarily due to the entrance of large vessels. Although the moratorium in 1979 had prohibited new vessels from entering the fishery, some vessels that had surf clam permits were not active in the fishery; it was these vessels that became active in the 1985 to 1990 period. This movement of vessels back into the fishery reflected events in the politics of fishery management. During the negotiations for Amendment 3 to the surf clam fishery management plan (1981) two alternatives were discussed: a direct vessel allocation system and a permit limitation system. The management council submitted a plan to the National Oceanic and Atmospheric Administration that would grant surf clam permits only to those vessels that had valid permits under the moratorium and had harvested at least 2,500 bushels of surf clams. From this point until the ITQ plan was approved in 1989, there were numerous negotiations concerning vessel allocation systems based on vessels' harvesting histories. What was evident during these negotiations was that the only *politically viable* way to design a system of tradable property rights was to distribute the permits *gratis* to vessels. Therefore, given the potential windfall represented by being granted a share of the total allowable catch, those vessels which had surf clams permits had a vested interest in becoming and remaining active. As a result, the decision to distribute rights to active vessels encouraged previously inactive vessels to participate in the fishery, further increasing pressure on the resource. In addition, the policy was designed to base allocations on the historic catches of *vessels* rather than *firms*. This distinction can have significant impact on the industrial organization of the fishery, affecting concentration of quota ownership, characteristics of the fleet, labor and capital utilization and exit/entry decisions. The incentive to be active explains the increase in the number of vessels harvesting surf clams from 1985 to 1990.

From 1989 to 1990 TFP increased from 0.65 to 0.80 (ITQs were implemented in October 1990). During 1990 to 1995 TFP reached its maximum of 0.98 in 1991, the first full year of ITQs. During 1991-1995 TFP fluctuates around 0.85, almost the same as in the period 1980-1984. The effective hours fishing during ITQs reached approximately the same level as in the period 1980 through 1984 (see Figure 2).

The impressive growth rate of TFP between 1990 and 1991 in part reflects the dramatic decline in total vessels from 128 in 1990 to 75 in 1991. Exiting the industry was motivated by the change in economic incentives created by the management policy. Once ITQs were implemented, keeping a vessel active no longer served as a mechanism to claim a share of the harvest. Because there is no time constraint imposed by regulation, vessels can be selected based on their efficiency in production over the season rather than on maximizing catch per hour, and harvesters could select the most efficient vessels on which to consolidate production. As Figures 3 and 4 illustrate, the percentage of the fleet made up of large vessels remained at a higher level than in the pre-ITQs era.

Figure 3.3: TFP Level VS. Large Vessel Participation

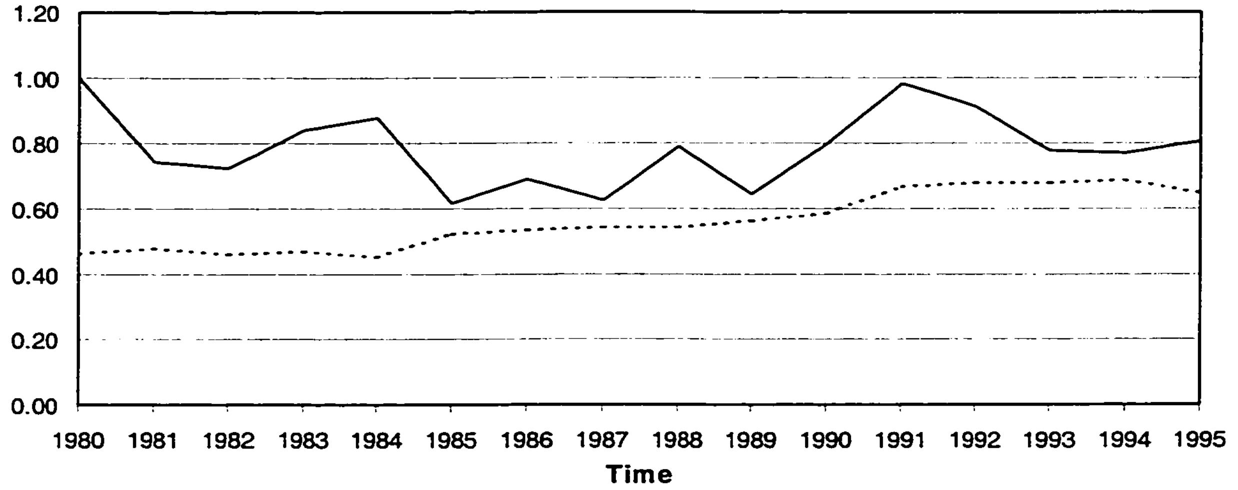
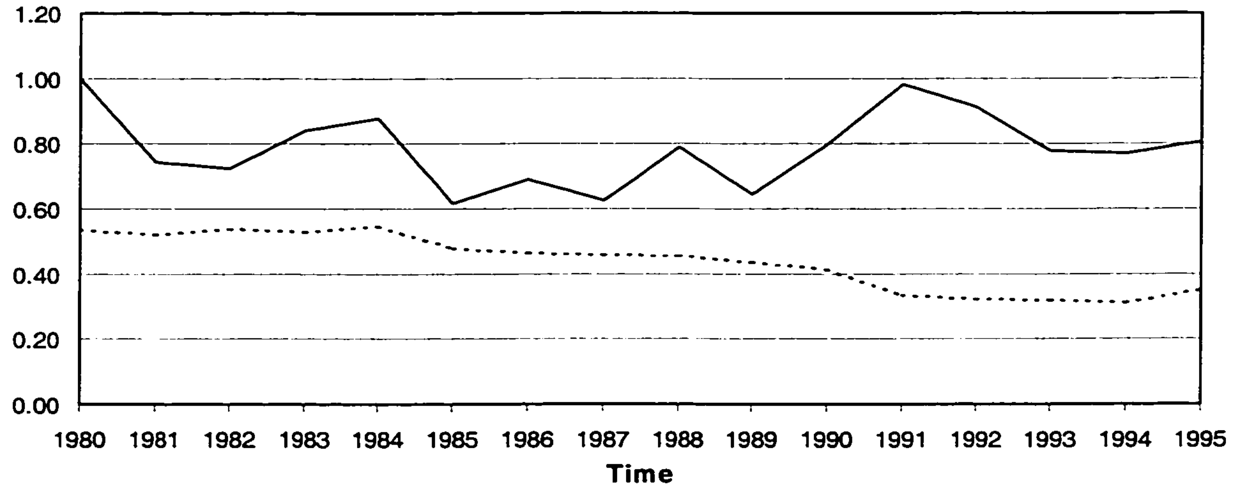


Figure 3.4: TFP Level VS. Small Vessel Participation



Note: Large vessel participation is defined as number of large vessels divided by total number of vessels. Small vessel participation is defined as number of small vessels divided by total number of vessels.

Source: Mid Atlantic Fishery Council Report, August 16, 1996.

The crucial lesson for future tradable property rights plans is that the socio-political environment can critically influence the negotiation of and consequences of regulation. Failure to incorporate the adaptive behavior of individual actors can lead to a misinterpretation of the effects of policy. These conclusions are critical when interpreting any estimates of productivity in fisheries subject to the 1996 Magnuson-Stevens Act's moratorium on new individual transferable quota programs.

3.5.2 Regression Results

The main relationship of interest is that between ITQ management and productivity. If all factors affecting the industry remained unchanged between the pre-ITQ and ITQ periods then the two periods would provide a natural experiment. However, given the many factors affecting the industry simultaneously, it is impossible to attribute the change in average TFP in the two periods solely to the introduction of ITQs. This section explains how regression analysis was used to control for these additional factors. The coefficient estimates, t-statistics, p-values, F-statistics and R-squared values for each equation are presented in Table 2[18].

If all factors affecting productivity other than management regime remained constant across the two periods, then regressing the level of total factor productivity on a dummy variable for 1991-1995 would captured the effects of ITQs. Obviously, more than the introduction of ITQs occurred during the two periods. One important difference, as described above, is in the effective hours of fishing. In addition to driving decisions

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[18] The Durbin-Watson statistic for ordinary least squares is in the indecisive zone for 16 observations. However, the lag in capital adjustment in the fishery would indicate that auto-correlation is likely to be present. The regression results presented in Table 2 used the Beach and McKinnon (1978) maximum likelihood estimation method to obtain efficient coefficient estimates and unbiased standard errors. After

for capital to enter or exit the industry, the management regime affects the efficiency of each trip. As discussed previously, one informative measure of the cost efficiency of fishing trips is the ratio of hours spent fishing to hours at sea, termed effective fishing hours. Other important variables to control for include: the number of processors, the surf clam population, and the price of the substitute species, the ocean quahog. As discussed in Part 3, the surf clam is sold by harvesters to processing plants to be made into clam strips, clam juice, etc. Therefore, the number of processing plants may affect production by harvesters (NMFS, 1980-1995)[19].

A production function for fisheries is often written with population of the species included as an argument. As discussed in Part 2, there is no obvious or best way to include a non-priced input, given that cost shares are used to weight inputs. An increase in population, keeping all other factors constant, would be expected to increase productivity. If, however, an increase in population results in an increased quota and attracts inefficient vessels to the fishery, then an increase in population may correspond to a decrease in productivity. An additional regressor is therefore surf clam population, measured as the total biomass in thousands of metric tons off the coast of Northern New Jersey, the primary commercial harvesting area (NEFSC, 1995).

After the surf clam fishery came under heavy regulation, fishing firms redirected effort to the ocean quahog. Because both species are harvested using the same

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correcting for first order auto-correlation, the residuals from all 5 equations passed the runs test using the critical value of runs from (Siegel, 1956).

[19] In addition to vessels, processing plants were also given allocations of surf clam quotas. Hence, just as in the case of harvesters, during the period before ITQs processing plants has an incentive to remain active in the industry. In fact the number of processing plants reached its peak of 40 in 1986 and remained high through 1990.

technology, the price of the ocean quahog represents an alternative for surf clam vessels. The price of the ocean quahog is in pounds of live meat (and excludes shell weight). After controlling for effective hours fishing, processing plants, population and price of quahog, the ITQ coefficient remains positive (0.398) but is significant only at the 9.6% level. A review of the other variables indicates that effective hours fishing and the number of processing plants are always significant at the 5% level while surf clam population and price of quahogs are never statistically significant.

Table 3.2: Regression Results

	Coefficient
Constant	-1.362 (-1.001) [.317]
ITQ	.398 (1.662) [.096]
Effective Fishing Time	1.787 (1.977) [.048]*
Processing Plants	.037 (2.350) [.019]*
Clam Population	.001 (.272) [.786]
Price Quahog	.551 (.266) [.790]
R Squared	.583
Adjusted R Squared	.375
F-Statistic (Zero Slope)	2.392 [.113]

Note: T-statistics are in ( )
P-values are in [ ]
* 5% significance

3.6 Conclusion

Much theoretical literature has been devoted to comparing tools to mitigate externalities. The impact of environmental regulation on productivity has important consequences for economic growth; therefore, one criterion for comparing policy tools is their relative effects on productivity. The majority of the empirical literature on productivity and environmental regulation focuses on broad industries and compares productivity under two scenarios: environmental regulation or no environmental regulation.

This paper seeks to bridge the gap between the theoretical benefits of a property rights approach to environmental regulation and the empirical evidence. There is strong evidence that fisheries under command-and-control regulation have an excess of capital. Under ITQs this surplus of capital is predicted to exit the industry, thereby reducing the inputs used to harvest a given quantity. ITQs are also thought to provide flexibility for producers, thus allowing them to choose the efficient level of inputs. One test of the economic theory of ITQs is then the difference in total factor productivity under the two regimes; this can be assessed through an analysis of the Middle Atlantic surf clam fishery from 1980 through 1995, during which each management policy was implemented.

Regression analysis shows that mean total factor productivity (as measured by a Tornqvist index of total factor productivity) is greater under ITQs than under command-and-control. After controlling for other changes over this period, the coefficient for a dummy variable representing ITQs is 0.398 and is significant at the 9.6% level. There is no evidence of a negative relationship between ITQs and productivity.

These results also indicate that strategic behavior by industry participants in response to policy changes can bias estimates of productivity growth. The race to maximize the firm's share of property rights will depress industry productivity prior to implementation. Economic analyses that compare years immediately prior to tradable property rights to years post implementation will capture both gains from property rights and from removing the race for allocation of property rights. This conclusion provides evidence that the benefits of market-based incentives can only be evaluated by taking into account the regulatory history of the industry.

3.7 Appendix

The National Marine Fishery Service requires all vessels to log their time at sea, number of trips, landings (quantity harvested) and gear type used. Entries are aggregated to protect confidentiality and are reported by the National Marine Fishery Service. The industry's regulatory body is the Mid-Atlantic Fishery Council, established in the late 1970s. To facilitate the debate over the transition to individual transferable quotas, in 1987 the Mid-Atlantic Fishery Council produced an extensive report on this industry, the Federal Management Plan (FMP). The FMP provided the basic statistics for this industry (MAFMC, 1988).

Output

Landings are measured as annual bushels of surf clams harvested by surf clam licensed vessels in the Economic Exclusion Zone (Mid-Atlantic Fishery Council bulletins). Prices per pound of clam meats were converted to prices per bushel at 1 bushel = 17 pounds.

Inputs

In the surf clam industry, wages are paid as a direct percentage of the gross revenue. Pat Kurkel (1996), NMFS Gloucester Lab, reports that the percentage is between 25% to 40% and averages 33%. Given the total revenue by class, labor costs are estimated as 33% of annual gross revenue. Quantity of labor utilized for each vessel class is calculated as the number of vessels in each class multiplied by the number of crew for that class.

The return to capital is calculated as the quasi-rent accruing to each unit of capital. The stock of the capital (annual number of vessels per class) is used as the measure of the flow of capital services.

Given the 1987 Federal Management Plan's estimates of total fuel use, total number of trips, and price per gallon, I estimate the average fuel use as 337.3 gallons per trip and 904.5 gallons per trip for class 1 and class 2 vessels, respectively. Then average annual fuel costs are estimated as: (number of trips in that class) * (average gallons used per trip) * (price per gallon). Price per gallon of number two diesel fuel is reported by the Energy Information Agency's Monthly Electronic Publication.

Abundance

Abundance is the estimated total biomass (in thousands of metric tons) off the coast of Northern New Jersey, which constitutes the primary commercial harvesting area. The abundance is estimated using a DeLurvy recruitment model with stocks sampled by weight of clams harvested per five-minute tow with a sixty-inch-wide dredge in both commercial and research tows (NEFSC, 1995). Because traditional age-based assessment techniques are inappropriate for invertebrate populations, only recently have stage-based models such as the DeLurvy model been applied to this industry (NEFSC, 1995). These modeling restrictions, as well as the limited number of sampling tows, restrict this published series to the period 1982-1995. Abundance for the period 1979-1981 was extrapolated using the DeLurvy model parameters and growth equation proposed by the NEFSC.[20] A particularly strong year class was spawned in the late 1970s (Weinberg, 1992) ; as a consequence, estimating the abundance based on the subsequent population's growth parameters upwardly biases the abundance for the 1979-1981 period.

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[20] The growth equation for surf clams is

$$B_{t+1} = [B_t + R_t - C_t]\exp[-M_t]$$

where the recruitment, R, is 7.56 mt for all t, the catch, C, is surf clam harvest in the Economic Exclusion Zone, the instantaneous natural mortality rate, M, is 0.05, and initial exploitable biomass is B. Parameter values are from NEFSC estimates.

Chapter 4

Efficiency versus Equity:
The Impact of Property Rights on Industry Structure

4.1 Introduction

Given the extensive economic literature on the advantages of tradable property rights over command-and-control systems, the persistence of traditional regulatory mechanisms in fishery policy appears incongruous. A major impediment to the adoption of tradable property rights in fisheries is a fundamental debate over how gains from increased efficiency and losses from restructuring will be distributed across participants in the industry. According to the theoretical economic literature, tradable property rights cause the number of vessels in a fishery to decline to the minimum necessary to harvest the annual quota, with the most inefficient vessels leaving the fishery (see Moloney and Pearse (1979), Clark (1980 and 1982), and Weninger and Just (1997)). Opponents of ITQs in fisheries interpret this to mean that "small producers" will be *forced* to exit, leading to domination of the industry by large fleet owners and firms that are vertically integrated through harvesting and processing (*Sea Watch International, et al., v. Robert Mosbacher*)[1]. Although relatively neglected in economic literature, equity is a major policy consideration in the fishing industry, and the legislation guiding fishery management reveals a preference for policies that are considered to be equitable (Karpoff (1987), McCay (1995), National Research Council (1999)); in fact, Title III, section 301

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[1] Two example of lawsuits over this issue are: *Sea Watch International, et al. v. Secretary of Commerce*, 762 F. Supp. 370 (1991) and *Alliance Against IFQs, et al. v. Secretary of Commerce* 84 F.3d 343 (9thCir. 1996). The plaintiffs in *Sea Watch International, et al., v. Robert Mosbacher* argue that the property right system violated the national equity and fairness standard, National Standard Four of the Magnuson-Stevens

of the Magnuson-Stevens Act explicitly stipulates that fairness and equity must be objectives of policy.

Current research in fishery economics is inadequate to address the impact of regulation on industry composition and equity. The theoretical literature does not distinguish between different types of harvesting firms, and empirical work typically models the behavior of individual *vessels*, not firms. As a result, existing research does not distinguish the effects of regulatory policies on different types of firms, and cannot evaluate the distribution of gains and losses across different types of firms. Because legislation guiding fisheries management is inherently political, opposing interpretations of the same observable phenomenon – reduction in the total number of vessels – have brought the development of market incentives to a standstill.

The policy debate over tradable property rights in fisheries, therefore, centers on the issues of whether and how tradable permits significantly alter the *composition* of the industry from the prevailing structure under traditional command-and-control regulation. A model of firm exit under these alternative regulatory regimes can address these policy issues by answering two key questions:

1. Does firm type (independent, fleet, or vertically integrated) affect the choice probability of the firm over: continuing to produce; converting to a model of allocation ownership; or exiting the fishing industry entirely ?
2. How does the firm's decision to harvest or exit differ under alternative regulatory policies?

In this analysis a firm is an entity that owns capital that is an input to the

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Act, because it is intended to drive a particular group of individuals, single vessel owners and small fleet harvesting of the clams, i.e. vessels and/or ITQs. As discussed in Section 2.6, this dissertation analyzes the behavior of the firms not vessels. A firm is said to exit the fishing industry when it divests itself of both types of capital, vessels and ITQs. A firm that owns only ITQs but not vessels is an allocation firm. A firm that owns vessels used to harvest clams, regardless of whether or not it owns ITQs, is a harvesting firm. This chapter discusses the firms' choice over the three states: allocation firm, harvesting firm, exit.

This chapter discusses the firms' choice over the three states: allocation firm, harvesting firm, and exit. Empirical evidence is presented from a fishery that has been regulated with two types of command-and-control regulation and a system of tradable property rights, the Mid-Atlantic surf clam and ocean quahog fishery. Section 4.5.3 presents a discrete choice model of the firm's decision to participate in the fishery (either as a harvesting firm or allocation firm) or to exit the fishery (sell both forms of capital, ITQs and vessels). The estimation is based on a unique data set that permits discrimination of firms based on size and on their relationships to the processing sector (i.e., whether they are vertically integrated).

The results show that the type of harvesting firm that exited did not differ under alternative regulatory policies. In fact, independent firms comprised nearly all exits throughout the entire period, and their exit decisions were determined primarily by the nature of their relationships with processors. What changed during the negotiation of ITQs and after their implementation was the timing of firm exit. In the years prior to implementation, firms chose to maximize their share of the property rights by delaying

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owners, out of fisheries.

their exit from the industry and actively amassing capital. The result was that inefficient firms did not exit until after the transition to property rights.

4.2 Case study

This theoretical model of firm behavior was tested through analysis of the Mid-Atlantic surf clam and ocean quahog fishery, which saw a transition from command-and-control regulation to ITQs in 1990. The central lesson to be drawn from this case study is that environmental policy is determined by an interactive process involving industry and regulators. Tradable property rights are implemented in industries that have an established structure reflecting this interaction. Therefore, the market for property rights and the corresponding industry structure are driven by the historically determined strategic positions of firms in the industry. The econometric model and empirical results will demonstrate how firm behavior prior to and during the implementation of tradable property rights influenced the restructuring of the industry.

4.2.1 The Industry

After the surf clam population dramatically plummeted in 1976, legislation was enacted restricting allowable fishing time and limiting access for a period of fourteen years[2]. By the mid-1980s, however, rapid growth in harvesting capacity and resulting inefficiencies prompted a debate over the establishment of a regulatory regime based on property rights. This led to the enactment in 1990 of a system of individual transferable

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[2] These clams grow slowly, live on the floor of the ocean, and do not move. They are clustered in groups known as beds, whose location and density are common knowledge in the fishery, and harvested using hydrologic dredges. They are located off the shores of Virginia, Maryland, Delaware, New Jersey, New

quotas (ITQs), with initial allocations based on individual vessels' catch history. The formula for distributing allocations was finalized in 1989 and implemented in 1990, but it was clear from negotiations beginning in the mid-1980s that allocations would be based in some form on historical harvest quantities[3]. Some boats that were permitted to participate in the surf clam/quahog fishery had not been used in harvesting, but now there was an incentive to put them into production in order to establish a catch history. As a result, while the number of *allowed* vessels could not change under limited access policies, the number of *active* vessels increased immediately prior to implementation of ITQs.

4.2.2 Data

The data used in this research were compiled from the confidential logbooks of every fishing trip made by every vessel in this fishery during the years 1980-1999 (provided by research agreement with the Northeast Fisheries Science Center of the National Marine Fisheries Service). Information contained in the logbooks for each trip includes: time spent fishing, time spent traveling, fishing location, port, quantity of each species caught, and purchasing processor. This information was matched with vessel license records that include vessel characteristics (year built, number and size of dredges, horsepower, and gross registered tonnage) and registered corporation of the vessel owner. Each registered vessel owner was assigned a unique firm identifier using a file of "true

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York, Rhode Island, Massachusetts, and Maine, with commercial stocks concentrated off the shore of northern New Jersey.

[3] The formal discussion of ITQs began with a discussion paper written and circulated by the management council in 1986 (MAFMC, 1986). Amendment Eight: Fishery Management Plan for the Atlantic Surf Clam and Ocean Quahog Fishery was approved by the Mid-Atlantic Fishery Management Council in

owners" (decision-making economic agents that could control multiple vessels through multiple corporations) created by McCay and Creed and most recently updated in the spring of 2000 by Brandt and McCay[4]. The total costs for each firm was calculated as functions of time fishing and time traveling given the vessels size. Total revenue are a function of the total quantity harvested by the firm and the price per bushel. See the appendix (*Definitions of Variables*) for details on how each variable was created.

The flow of profit earned by the firm (π_t) is defined as total harvesting revenue minus total harvesting cost. The amount of clams harvested by the firm depends on the size of its market. A harvesting firm's market is determined by the number of contracts the firm has[5], the firm's harvesting ability (clams caught per hour), and firm type (independent, fleet, or vertically integrated). The firm's characteristics are defined as:

Ability = firm's mean quantity harvested per hour fishing, relative to the industry mean

Contracts = number of processors the firm delivers to in a year, relative to the industry mean

Type = independent if firm owns one or two vessels and is not vertically integrated

= fleet if firm owns three or more vessels and is not vertically integrated

= vertically integrated if vessels are owned by a processor

The market value of capital is determined by the gross registered tonnage of the firm's vessels and the mean age of those vessels.

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cooperation with the National Marine Fisheries Service and the New England Fishery Management Council in 1988 (MAFMC, 1988).

[4] In the spring and summer of 2000, Brandt and McCay interviewed six of the twelve independent harvesters, three of the four fleet owners, two of the five harvesting processors, and an additional two processors that do not harvest.

[5] Because of endogeneity, a two-step estimation is used where a Poisson model is estimated and then the predicted number of contracts is used in the probit. See the appendix for details on the two-step estimation and Table A2 for Poisson model results.

The next section uses an econometric model to answer two empirical questions of significance to current policy debates. First, do the determinants of exit change from command-and-control regulation to ITQs? Second, does the exit decision following the implementation of ITQs affect firms differentially based on firm type, thereby demonstrating a redistribution of welfare due to regulatory change?

4.3 Theoretical Model: The Exit Decision

This section develops a theoretical model of the decision to exit the fishery or not under the two types of regulation, command-and-control and ITQs.

Under command-and-control regulation, the fishing firm has two choices: (1) remain in the industry and harvest clams or (2) exit the industry entirely. If the firm exits, it can sell its capital (vessels) and earn returns by investing the revenues, S. An exiting firm can sell its vessels to a harvesting firm. In this case the vessels remain in the industry although there is now one less firm (recall from Section 2.6 that the firm is the capital owner not the capital itself). If the exiting firm cannot find a buyer within the surf clam/ocean quahog fishery, it can sell the vessels for use in another fishery. Because the gear on these clam vessels is specialized to this fishery, the vessels must be retro-fitted for use in an alternative fishery. A vessel that has been retro-fitted has essentially been "scrapped" because it is no longer productive capital for this clam fishery. If the firm decides to remain in the industry as a harvester, then the value of this option is equal to the sum of expected profits, π, (yielded by the annual profit maximization problem) and the value of any future property rights allocation (allocations were based on historical harvests and were distributed free of charge).

Under tradable property rights, the firm has two types of capital -- boats and property rights -- and can earn returns from selling both. The vessels sold by the exiting firm can either be used by a remaining harvesting firm or "scrapped." By definition an exiting firm also sells its ITQs (if the firm retained its ITQs it would be an allocation firm). The exiting firm receives present value of returns from selling ITQs, M.

The firm compares the profitability of exiting now with the profitability of exiting at some future date (see Baden and Fuller (1989)). The firm exits when expected profit (π) plus any anticipated capital gain from deferring exit (S', $S'+M'$) is less than the interest that would be earned on capital from exiting now (S, $S+M$).

If we define:

π = anticipated profit in subsequent period

S = present value of returns from selling capital at beginning of period

S' = present value of anticipated gain in sell value from deferring closure

M = present value of returns from selling ITQs at beginning of period

M' = present value of anticipated gain in ITQ value from deferring closure

r = rate of return from investing revenue gained by selling capital

then under command and control, exit is profitable when:

$$\pi + S' < rS$$

and under property rights, a firm exits when

$$\pi + (S' + M') < r(S + M)$$

Therefore, the problem is how to estimate expected profit and the market value of capital.

4.3.1 Profit

The profit, π, is the present value of the stream of profits given optimal short- and intermediate-run decisions (the short-run and intermediate-run model of behavior is described in Brandt (2000))[6]. The critical firm characteristics that determine profitability are: the number of contracts the firm has with processors; the firm's ability to harvest efficiently (clams caught per hour); and firm type. Although omitted from most fisheries economic models, contract relationships determine the size of the available market (demand), the price at which product is sold, and access to financial capital and additional ITQs. An efficient harvester has a lower cost of production and higher value of an allocation than an inefficient harvester. We should expect then that an efficient harvester is more likely to remain in the industry. Firm type is critical for understanding the impact of regulatory change on industry structure. Firms that own one or two vessels and are not vertically integrated with the processing sector are defined as independents; firms with three or more boats that are not vertically integrated are defined as fleets; and firms that harvest clams and are vertically integrated are defined as processors[7].

If we define:

A_t = population abundance of clams in time t

P_t = price of clams in time t

F_t = firm characteristics, including number of contracts, harvesting ability, and type (independent, fleet, or processor)

B_t = total tonnage of vessels owned by firm in time t

$\rho = 1/(1+d)$, where d is the discount rate, $d>0$

Z_t = the vector of inputs (time spent fishing, time spent traveling) in time t, given the cost of inputs, At, Ft, Pt, Bt, and the current policy regime

f = production function

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[6] In the short run, the firm chooses the optimal time fishing, time traveling, and number of trips given input costs and fixed costs for the firm, and given the regulatory policy and the firm characteristics. In the intermediate run, the firm chooses its capacity given the regulatory policy.

[7] Conflicts between types of harvesters existed in almost every management discussion (McCay and Creed, 1990).

C = cost function

Then the firm chooses the vector of inputs Z_t (travel time, fishing time, number of trips) to maximize π, the present value of the stream of profit from harvesting

$$\text{Max} \quad \Sigma_{t=0,\ldots,\infty} \rho^t [P_t\ f(Z_t\,; B_t, F_t, A_t) - C(Z_t\,; B_t, F_t, A_t)] \text{ with respect to } Z_t.$$

Costs include the fixed costs of capital (vessel insurance, docking fees, etc.) and variable costs. The variable costs of fuel and gear are functions of the fishing time and travel time. Labor is paid on a share system at a rate of 0.3 of the total gross revenues of each trip. A firm's total cost is the sum of the cost for each vessel the firm owns. The revenue for the firm is the total bushels of clams harvested multiplied by the price per bushel. See the appendix 4.7.3 for additional details.

4.3.2 Market Value of Capital

Capital can take two forms: vessels and allocations (ITQs). The main determinants of vessel value include vessel size (measured in gross registered tonnage) and vessel age. The price of an allocation is equal to the present value of the revenue stream that the allocation could generate, which is dependent on the price received for clams.

TABLE 4.1: EXIT DECISION

Variables of interest depend on:		
π	**S**	**M**
Choice of inputs Time fishing Time traveling	*Vessel characteristics* Gross registered tons Age of vessels	*Market characteristics* Price of clams
Cost of inputs Cost of fuel per hour traveling Cost of fuel per hour fishing Cost of gear per hour fishing Cost of labor[8] Annual fixed costs[9]	*Market characteristics* Number of buyers	
Firm bargaining status Number of contracts *Type (Independent, Fleet, Processor)*		
Firm efficiency Ability (clams/hr)		

4.4 Econometric Model: Probit Model of Clam Industry

Recall that the firm exits if expected profit (π) plus any anticipated capital gain from deferring closure (S′, S′+M′) is less than the interest that would be earned on capital from exiting now (S, S+M). The rate of return from investing revenue gained by selling capital is r. These exit conditions are:

$\pi + S' < rS$ (under command and control) or

$\pi + (S' + M') < r(S + M)$ (under property rights).

While the economic value of each option (staying in the industry or exiting) cannot be observed, the choice of each firm is observed each year from 1982 until 1999. Therefore a discrete choice model where the unobserved (latent) variable is the difference in value between the two options is estimated. In this model the observed firm-specific variables distinguish firms that choose to exit from those that continue harvesting. At the end of each year, a harvesting firm chooses whether or not to renew its harvesting permit for the next year. Because the price and quantity of clams and quahogs are set by buyers (processors) through multi-year contracts, the best predictor of future profits, π_{t+1}, is this year's profit, π_t. Therefore, a reasonable framework for the firm decision is that, at the end of each year, the firm makes the discrete choice to stay or exit by evaluating future profit, π, value of capital, S and M, and anticipated capital gains, S′ and M′, given this year's profit and firm characteristics.

Let:

$Y_{it} = 0$ if, in year t, firm i exits industry

$Y_{it} = 1$ if, in year t, firm i continues to harvest

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[8] Labor is paid 0.3 of total revenue from each trip's clam harvest.

[9] The fixed costs include only direct costs. They do not include depreciation or opportunity cost.

Assuming the errors are normally distributed in the population, the probit model of the discrete choice between exiting and harvesting is estimated given the vector of firm variables in year t, X_{it}:

$$\Pr(Y_{it}=1|X_{it}) = \Phi(X_{it}\beta)$$

$$\Pr(Y_{it}=0|X_{it}) = 1 - \Phi(X_{it}\beta)$$

where, for each firm, the vector X_t is comprised of the profit this year (π_t) and the market value of both types of capital (S_t and M_t)[10]. To apply this model to the surf clam and ocean quahog fishery, the composition of the key variables π, S, and M must be specified for this industry. The profit earned by the firm (π_t) is defined by total harvesting revenue minus total harvesting cost. However, the harvester's market for clams is determined by the number of contracts the firm has[11], harvesting ability, and firm type. Without a guaranteed commitment from a processor to buy your clams, the harvest is worthless. There is no spot market for clams (see Section 2.7). The market value of capital is determined by the gross registered tonnage of the firm's vessels and the mean age of those vessels.

The likelihood function for the sample of N firms is then L, written:

$$L = \Pi_{i=1,\dots,N}\ [\Phi\,(X_{it}\beta)]^{Yit} \times [1 - \Phi\,(X_{it}\beta)]^{(1\text{-}Yit)}$$

The log-likelihood function for the sample is:

$$\ln L = \Sigma_{i=1,\dots,N}\ (Y_{it})\ \ln[\Phi\,(X_{it}\beta)] + (1 - Y_{it})\ \ln[1 - \Phi\,(X_{it}\beta)]$$

In order to allow the coefficients of exit to change across regulatory policy periods, the probit is estimated over three, three-year periods (1986-88, 1990-92 and 1993-95).

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[10] All variables are relative to all other active firms.

Within each three year panel, a firm can be observed up to three times. A reasonable assumption is that the firm's error terms are correlated over the three years (correlation is with observations of same firm *not* between firms) . If we fail to account for this correlation, the estimated standard errors of the coefficients will be too small. To account for the correlation of observations on the same firm the variance-covariance matrix of the estimators is estimated using a modified sandwich estimator of variance (Huber (1967), White (1980) and Rogers (1993)). The important distinction is that the score for each firm used in the estimate of variance is the sum of each the scores for that firm evaluated at each observation for that firm. See the appendix *(4.7.1 and 4.7.6)* for a full derivation of the probit model.

4.5 Empirical Results: Exit from Clam Industry

The empirical impact of regulatory change on the surf clam and ocean quahog fishery must be analyzed in three ways. First, changes in the overall composition of the fleet demonstrate the impact of ITQs on industry structure. However, in order to understand the dynamics of industrial organization, it is necessary to then consider the determinants of exit as they applied to different types of firms in different periods. Finally, a probit analysis reveals which firms within a give type exited or remained in the industry, showing the true importance of strategic behavior in responding to new regulatory policy.

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[11] Because of endogeneity of the number of contracts, a two-step estimation was used where a Poisson model is estimated and then the number of contracts predicted. See the appendix for details on the two-step estimation and Table A2 for Poisson model results.

4.5.1 Overall Participation in Industry

Overall participation by different types of firms can itself be measured using three sets of indicators: first, the absolute number of active vessels and firms in the industry; second, the distribution of active firms in the industry by type; and finally, the distribution of the actual harvest by type of firm.

The most striking change in the industry after the implementation of property rights was the significant reduction in the number of vessels in the industry. This reduction has been interpreted differently by economists and policymakers. Economists typically interpret this rationalization as a social gain on the assumption that less efficient producers left the industry. This reduction has also been interpreted as a "forcing out" of industry participants and therefore as a social loss.

However, because of the complex nature of vessel ownership, counting active vessels significantly overestimates both the number of firms that participated in the industry and the number that then exited from the industry. In fact, a significant portion of the reduction in active vessels is due to firms' decisions to consolidate harvesting on fewer vessels. As shown in Figure 4.1, there are two notable trends in the number of active vessels. The number of active boats increased prior to the implementation of property rights, only to drop immediately thereafter (from a peak of 146 in 1986 to only 42 in 1999). The initial increase in active vessels was a direct result of firms utilizing previously inactive vessels in order to establish a claim in the property rights system[12]. While many vessels exited the industry after property rights, the total number of firms in the industry has remained steady.

Under command-and-control regulation, vessel owners could only participate in the industry as harvesters. The implementation of property rights, however, created a new form of capital, the ITQ. After 1991 firms that sold their vessels but retained their ITQs became allocation firms. Therefore, the decrease in the number of harvesting firms was off-set by the emergence of the allocation firm. After ITQs the number of vessels in the clam industry declined; however, there was not a significant decline in the total number of firms (harvesting and allocation) in the industry. Figure 4.1 show this transition in the industry. The left scale is for number of firms, and the right scale is for number of boats. The lesson for economic evaluations of ITQs is that looking at number of vessels, misses the emergence of a new type of firm in the industry. The number of vessels in the industry is also a misleading indicator of the total participation in the industry.

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[12] See Brandt (2000) for a full model and empirical analysis. Brandt (1999) discusses the impact of this increase on industry level productivity.

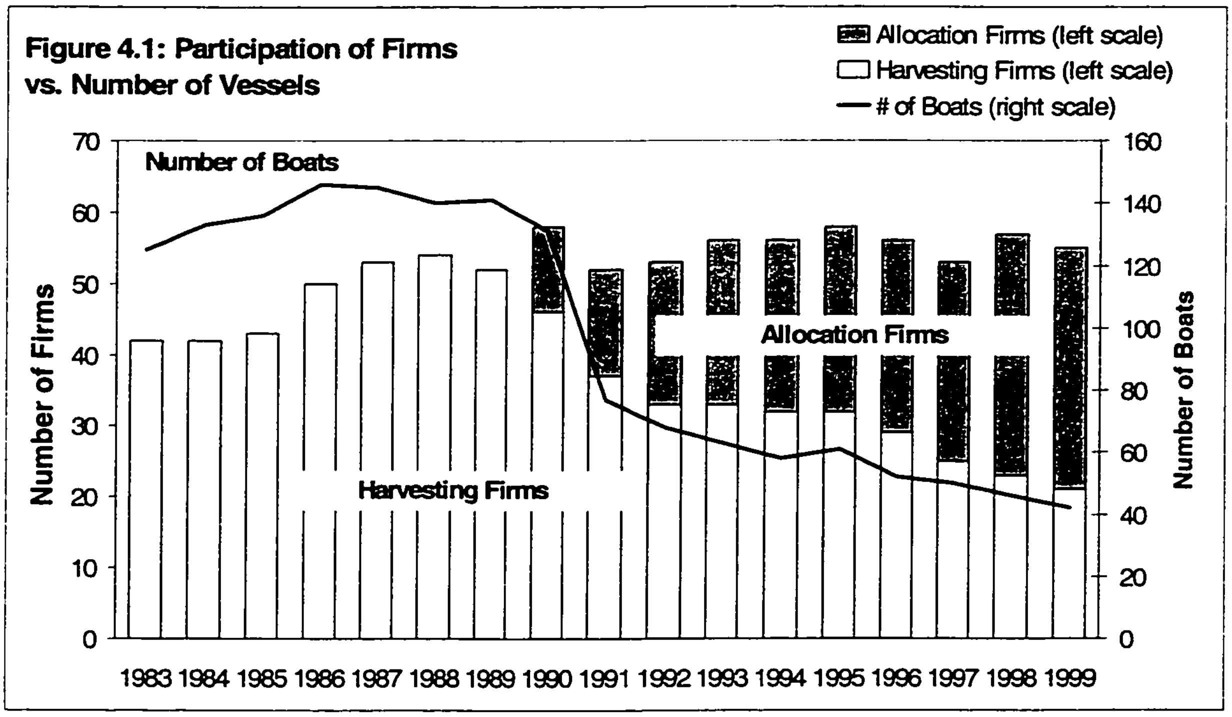
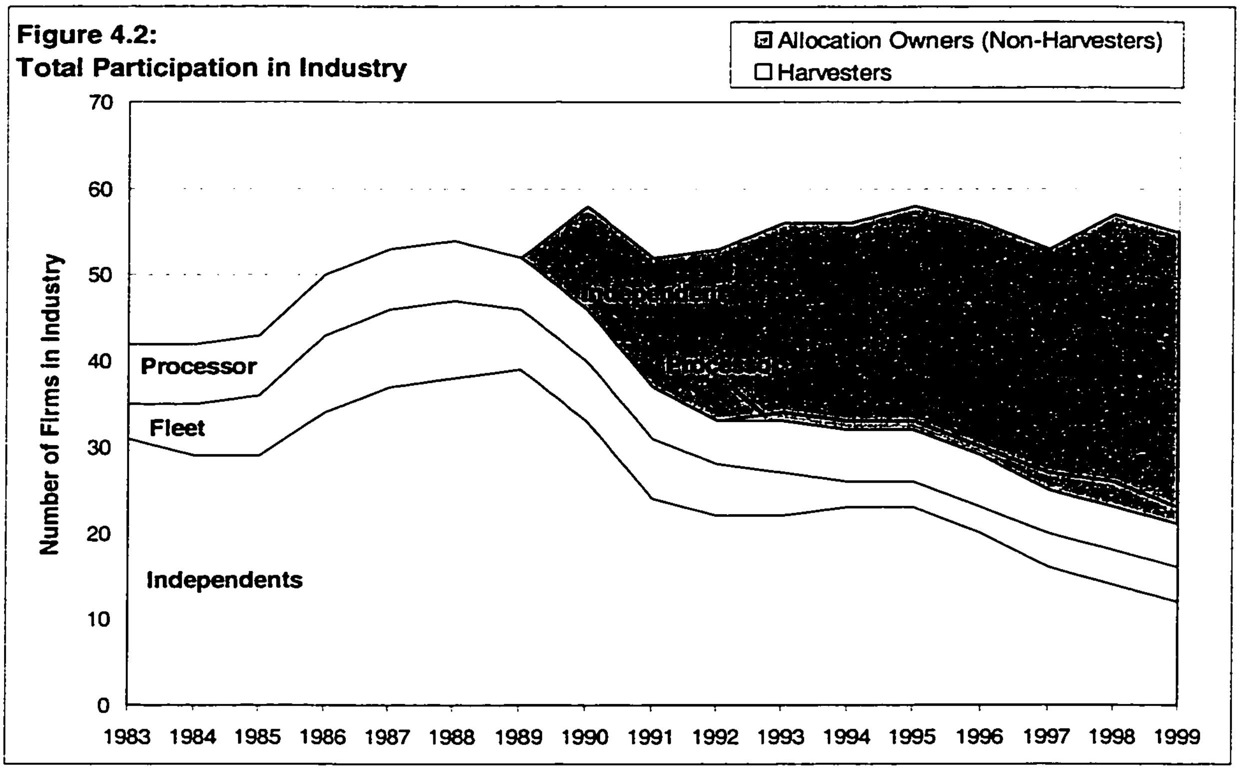


Figure 4.1: Participation of Firms vs. Number of Vessels

The second important policy issue, the impact of regulatory change on the type of firms in the industry, is addressed in Figure 4.2. In 1983, 74% of harvesting firms were independents, 10% were fleet owners, and 16% were vertically integrated firms. By 1999, this distribution of *harvesting firms* had shifted to 57% independents, 19% fleet owners, and 24% vertically integrated firms – giving the appearance that independent firms had been "forced out" of the industry by fleet owners and vertically integrated processors. However, looking at the composition of all firms in the industry (including both harvesters and former harvesters who now leased their allocations) yields a different picture. In 1999, the distribution of *all firms* in the industry was 80% independents, 7% fleet owners, and 13% vertically integrated firms (for annual counts, see appendix, Table A1: Participation in Industry). Under tradable property rights, firms participate in the industry both as harvesters and as allocation owners; looking only at the number of active vessels overstates the exit of firms from the industry and gives a distorted picture of the effect of regulatory change on industry structure.

Figure 4.2:
Total Participation in Industry



One of the arguments made against ITQs has been that catch and revenues will become concentrated in the hands of the largest harvesters. However, analyzing the surf clam and quahog fishery shows that this has not been the case. The distribution of the annual harvest across firm type shows that for both clam species, the share harvested by independents has actually grown under ITQs (see Figure Three: Surf Clams - Share of Catch by Firm Type, and Figure Four: Ocean quahogs- Share of Catch by Firm Type).

Figure 4.3: Surf Clams - Share of Catch by Firm Type

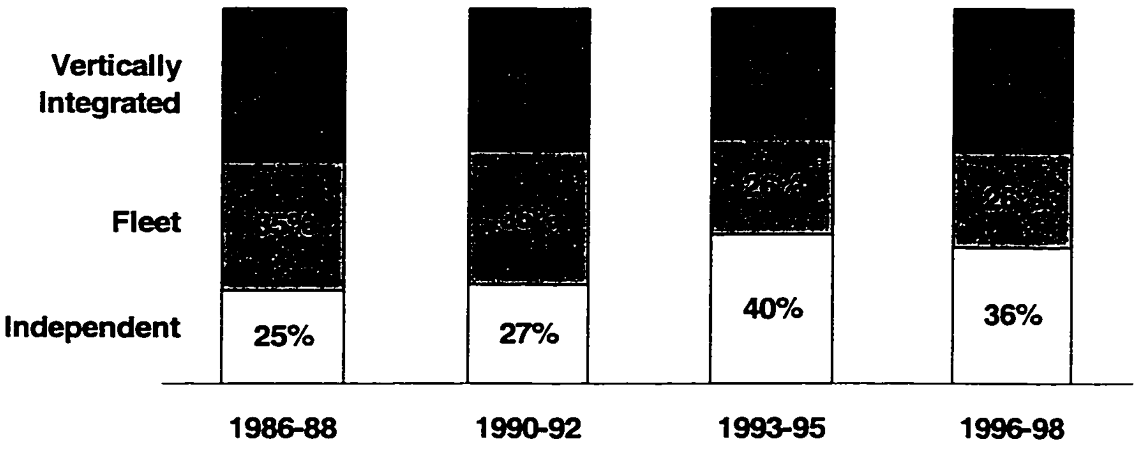
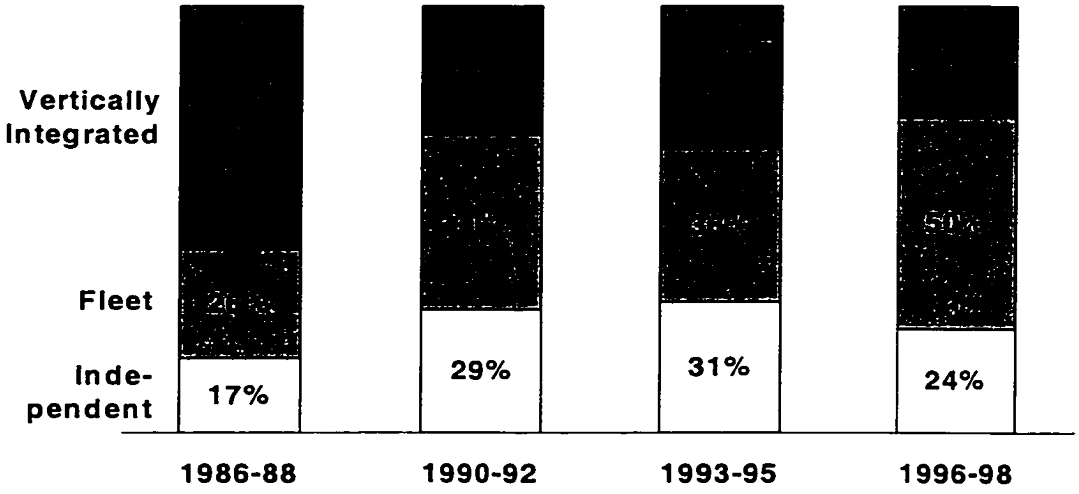


Figure 4.4: Ocean Quahogs - Share of Catch by Firm Type



4.5.2 Characteristics of Firm Choice over States

Beyond the overall distribution of vessels, firms, and catch in the fishery, it is important to consider the nature of the exit decision and the characteristics of exiting firms. After the implementation of tradable property rights, the transition out of harvesting could take two forms. First, firms could exit the industry entirely, selling both their boats and their allocations; this is the *exit state*. Second, they could cease harvesting while retaining their allocations, which is defined as the *allocation state*. (The allocation state is obviously only relevant for the period of regulation by ITQs.) Table 4.2: Firms Terminating Harvesting , shows the number of firms that transition out of harvesting are distributed between the exit state and the allocation state, and between independent firms and vertically integrated processors. As this table shows, those firms that exited the industry were overwhelmingly independents, both prior to and after the implementation of ITQs -- weakening the claim that ITQs have an especially negative impact on independents.

Table 4.2: Firms Terminating Harvesting

	Total		Independents		Processors	
Year	exit	allocation	exit	allocation	exit	allocation
1983	0		0			
1984	2		2			
1985	1		1			
1986	1		1			
1987	0		0			
1988	6		5		1	
1989	1	4	1	4		
1990	6	4	6	4		
1991	1	3	0	3	1	
1992	0	3	0	3		
1993	1	2	1	2		
1994	1	3	1	3		
1995	5	1	5	1		
1996	4	0	3	0	1	
1997	0	3	3	0		
1998	1	2	1	2		

Tables 4.3 through 4.5 compare the efficiency of firms that terminated harvesting (either by exiting or by becoming allocation firms) to those that remained as harvesters. Three periods are distinguished: the first period of command-and-control regulation, a period of initial restructuring after the implementation of ITQs, and subsequent years of tradable property rights.

Table 4.3: Relative Efficiency Under Command-and-Control, 1983-1988

	Firms that terminate harvesting	Firms that continue harvesting
Mean catch per hour	202.14	123.25
standard deviation	114.6	72.22

Table 4.4: Relative Efficiency During Restructuring, 1990-1991

	Firms that terminate harvesting	**Firms that continue harvesting**
Mean catch per hour	110.78	157.75
standard deviation	82.03	61.38

Table 4.5: Relative Efficiency Under ITQs, 1992-1999

	Firms that terminate harvesting	**Firms that continue harvesting**
Mean catch per hour	125.96	165.17
standard deviation	92.02	120.00

What is striking in Table 4.3 is that under command-and-control, it was not the least effective firms that stopped harvesting. In fact, we cannot reject the null hypothesis that firms terminating harvesting actually had a *higher* catch rate than those that remained (the p-statistic is 0.059). In contrast, after tradable property rights were implemented, it was -- as would be expected -- the more effective harvesters that continued harvesting (Tables 4.5 and 4.6). The null hypothesis that the efficiency of harvesting firms is greater than firms that terminated harvesting is not rejected (p-value is 0.04 for the restructuring period and 0.052 for 1992-1999). To understand this surprising result, it is necessary to differentiate, within each type of firm, firms that exited the industry from those that remained as harvesters.

4.5.3 Determinants of Transition out of Harvesting Sector

As shown in Table Two: Firms Exiting Harvesting Sector[13], exit over the entire

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[13] The change in the probability for an infinitesimal change in each independent, continuous variable, for the j^{th} element in the parameter vector, is given by $b_j^* = [\partial \Phi (X\beta) / \partial x_j] \big|_{x=\bar{x}} = \phi(\bar{x}\beta)b_j$ where x is the vector of sample mean values of the vector x. The discrete change in the probability for dummy variables

period was by independents and processors, with the only significant exit under command-and-control occurring in the period 1986-1988. The probit analysis distinguishes independents and processors that ceased harvesting from those that continued to harvest across four periods: the period immediately prior to implementation (1986-1988), the initial years of property rights (1990-1992), and the years following restructuring (1993-1995 and 1996-1998). Empirical estimates of the probability of continuing to harvest, given firm characteristics, are given in Table 4.6: Probit Coefficients.

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is $b_j^* = \Phi(\bar{x}_1 \beta) - \Phi(\bar{x}_0 \beta)$ where $x_1 = x_0 = x$, except that the j^{th} elements of x_1 and x_0 are set to 0 and 1, respectively.

Table 4.6: Probit Coefficients - Likelihood of Continuing to Harvest

		86-88	90-92	93-95	96-98
	P value for coefficient (1)				
	Marginal Change				
	Mean value				
π	Cost	-0.482	-0.524	0.575	1.940
		(0.747)	(0.699)	(0.757)	(0.272)
		(-0.008)	(-0.001)	(0.004)	(0.039)
		(2.535)	(1.746)	(1.837)	(1.621)
	Revenue	1.673	1.805	0.228	-0.860
		(0.522)	(0.330)	(0.888)	(0.665)
		(0.027)	(0.005)	(0.002)	(-0.017)
		(1.145)	(0.878)	(1.023)	(0.878)
	Ability	-1.346	-0.436	0.349	1.889*
		(0.148)	(0.228)	(0.545)	(0.056)
		(-0.021)	(-0.001)	(0.002)	(0.038)
		(0.993)	(1.000)	(1.012)	(1.005)
	Contracts	1.924	-1.525*	5.205*	1.354*
		(0.109)	(0.017)	(0.000)	(0.016)
		(0.031)	(-0.004)	(0.037)	(0.027)
		(1.006)	(1.002)	(0.998)	(0.996)
S	Tonnage	0.019	3.965*	1.185	0.128
		(0.993)	(0.025)	(0.664)	(0.949)
		(0.000)	(0.011)	(0.008)	(0.003)
		(1.083)	(0.966)	(0.959)	(0.831)
	Age of Capital	-0.123	0.287	-1.576	-0.695
		(0.398)	(0.325)	(0.127)	(0.679)
		(-0.002)	(0.001)	(-0.011)	(-0.014)
		(1.170)	(1.063)	(0.960)	(0.940)
	Constant	1.368	0.323	-3.614	-2.644
		(0.727)	(0.892)	(0.488)	(0.703)
	No of obs	89	82	62	45
	Wald Chi2	9.56	10.65	13.40	12.93
	P value (2)	0.1444	0.0996	0.0371	0.0442

* indicates significant at 10% level

(1) P value for chi-squared = -2(ln L(restricted) - ln L(full))
restriction is b=0 , for each coefficient separately

(2) P value for chi-squared = -2(ln L(initial) - ln L(final))

The determinants of exit differed significantly across the two regulatory regimes, as shown by the change in the predictive power of the model (the model of exit is significant only at the 0.144 level under command-and-control, and at the 0.010, 0.037, and 0.044 levels for the three later periods). After the implementation of ITQs, the economic model has statistically significant explanatory power in distinguishing firms that exited from those that remained in the industry, suggesting that the implementation of property rights did in fact produce a change in the way firms decided to exit or continue to harvest.

The results show that three factors were of significance in determining the decision to remain in or exit the fishery: firm efficiency, overall tonnage, and number of contracts with processors.

Conventional economic theory would predict that firms that are less efficient harvesters (as indicated by higher marginal costs or a lower production function) would exit first. However, the *opposite* actually occurred through 1992: under command-and-control and in the initial years of property rights, the ability to harvest efficiently (defined as the rate of clam harvest) has a negative effect on the likelihood to remain in the industry, and it is not until the 1996-1998 period that it has a significant and positive effect. Although it is not significant in the earlier periods, those firms that exited did have a higher catch rate than those that remained (see Tables 4.3-4.5). In addition, inspection of data on specific vessels shows that firms exiting in the final year of command–and-control sold their vessels to firms that remained in the industry (the majority of which are still in the industry).

These results are explained by strategic behavior on the part of firms in the industry. Despite constant debates over the specific allocation formula in the years prior to the implementation of ITQs, it was common knowledge to those involved in the policy process that allocations would be based on the historical harvest of each fishing boat. This system in effect created artificial demand for boats because of the property right value associated with each boat's historical harvest.[14] Firms that had vessels with higher catch rates were more valuable because they had a history of higher harvests. Buying out competing firms not only brought the associated record of historical harvests, but also decreased the number of competitors for property rights. In plaintiffs' testimony in *Sea Watch, et al. v. Secretary of Commerce*, the sale of a vessel in the surf clam fishery commanded a premium of $50,000 to $150,000 over the value of the vessel itself, reflecting the anticipated value of the future property rights associated with the vessels' historical catch.[15] This behavior provides empirical evidence that exit is the strategic game between competitors. As formalized by Ghemawat and Nalebuff (1985) players have an incentive to encourage rivals to exit because the remaining rivals may benefit from reduction in capacity and competition (rivals that have abandoned their investments are not able to re-enter easily).

In the restructuring period, firms sought to increase their allocation holdings by continuing to buy out firms that had acquired allocations based on their historical catches on each vessel. Additionally, some firms that had delayed exiting the industry until the allocation of property rights now sold their allocations and essentially used the revenue they received as a retirement fund.[16] The economic prediction that the least efficient harvesters exit is not borne out in the initial years of property rights. Instead, it is only

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[14] In interviews of current fishing firms, individuals revealed that they did in fact buy vessels solely for the property rights associated with them. In fact, after property rights were allocated some of these recently acquired vessels were sold at a minimum scrapped price of $1.00.

[15] *Sea Watch International, et al. v. Secretary of Commerce*, 762 F. Supp. 370 (1991).

after those firms that had delayed exit finally do leave the fishery that the least efficient firms exit.

Although tradable property rights do lead to exit by the least efficient firms, strategic behavior prompted by the implementation of those property rights introduces two inefficiencies. First, in the prelude to tradable property rights, strategic behavior leads to exit by the most efficient firms. Second, firms choose to delay their exit until property rights are implemented in order to gain additional revenue from selling their allocations[17]. As a result, comparing the years immediately before property rights to the long-run optimum overstates the gains from tradable rights, because strategic behavior immediately prior to implementation artificially lowers efficiency in the industry. In addition, that same strategic behavior extends the attrition process that eventually produces a more rationalized fleet.

During the 1990-92 period, firms that had large amounts of capacity (gross tonnage) were more likely to remain in the industry than those that did not. Because allocations were based on both gross registered tonnage and catch history, firms with significant capital enjoyed especially large allocations. While total capacity did not have a significant effect on the exit decision in most periods, in the 1990-92 period the larger allocations recently gained by firms with large amounts of capacity increased their incentive to remain in the fishery and capitalize on their allocations.

The third and final important factor is the number of processing contracts the firm has. This variable has a significantly positive impact on the likelihood of continuing to

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[16] Personal interviews.

[17] Firms did not reduce their number of boats even though it was estimated that in 1987, vessels less than 100 gross register tons on average were earning negative net revenue (see page 49 of Mid-Atlantic Fishery Management Council, 1988)

harvest in the last two periods, and has a significantly negative effect in the restructuring period. Outside the initial restructuring period, firms having more contracts are more likely to remain in the industry; given the importance of having a market, it is intuitive that having more contracts increases the firm's certainty of having processors to sell to and its bargaining power with those processors. The reversal of sign during the restructuring period is striking, but is explained by actual interviews with harvesters. In the 1990-1992 period, only a fraction of the total vessels in the industry were actually needed to harvest the entire quota (Keifer (1993) estimates that by 1978 the fleet was large enough to take the entire annual quota in 15 days). In this period, therefore, processors could ensure their clam supply by choosing to buy only from their most loyal harvesters; interviews revealed that those harvesters who attempted to bid processors against one another saw their contracts cancelled by processors after the implementation of ITQs. Some processors even induced harvesters to sign near-exclusive contracts, and fostered a rhetoric of "loyalty" to processors that was echoed in interviews with harvesters (Brandt, personal interviews).

Close inspection reveals that the factors determining exit did not have precisely the impact that would be predicted by traditional economic theory. In each case, it was strategic behavior on the part of individual firms that conditioned the effect of regulatory change. In anticipating and adapting to the implementation of ITQs, these firms played an important role in determining how the benefits of regulatory change would be shared across the industry as a whole.

4.6 Conclusion

Economic models of fisheries conclude that the fleet that emerges under ITQs is more efficient relative to that under command-and-control. The assertion in the volatile political debate over ITQs in the U.S. is that the efficient harvester is necessarily the large harvesting firm and vertically integrated harvester. Because provisions of both the Magnuson Act and the Small Business Administration make it illegal for regulation to disproportionately affect one size of firm, it is crucial to distinguish firm size from efficiency. A fundamental reason that the debate is at a standstill, is that the majority of empirical economic analyses use a vessel level analysis in which "large" is defined by the size of the vessel not the firm.

This objectives of this paper are to characterize the type of firms in the industry under both management regimes and to estimate the qualities of firms that determine the decision to continue harvesting. To explore this question, there is no better place to look than the surf clam and ocean quahog industry, which was the first U.S. marine fishery to undergo the transition from command-and-control regulation to individual transferable quotas. On balance, the claim that ITQs unfairly harm "small" fishermen, forcing them out of the fishery to the benefit of larger fleets and vertically integrated processors, is not borne out by the evidence.

Empirical analysis yields three significant results, all of which belie the supposed inequitable effects of tradable property rights. First, the pronounced decline in the number of active vessels in the fishery masks the fact that far fewer *firms* actually exited the industry; focusing on the actual economic actors involved shows considerably less socio-economic dislocation than is implied by vessel-level observations. Second, the share of firms that were independents, as well as the share of actual harvests taken by those independents, were not adversely affected by the change in regulatory policy, providing more evidence that small fishermen were able to maintain or even expand their economic importance in the fishery. Finally, analysis of firms that exited the fishery entirely shows that the *type* of firm choosing to exit did not change from the period of command-and-control regulation to the period of ITQs. Together, these results demonstrate that the introduction of tradable property rights did not lead to a redistribution of welfare across different types of participants in the industry.

In fact, looking closely at the firms that exited the industry demonstrates the prevalence of strategic behavior in response to and even in anticipation of regulatory change. This individually rational behavior led to two inefficient outcomes in the aggregate. First, there was an increase in the number of vessels in this already over-capitalized fishery. Second, under command-and-control and during the initial years of tradable property rights, those firms that exited were, contrary to conventional economic wisdom, more efficient producers than those that remained in the industry. The expected outcome, in which exiting firms tend to be the less efficient producers, did not take hold until the 1996-98 period. While the implementation of property rights did eventually lead to a rationalization of the industry, this was preceded by a significant adjustment period during which individual firm behavior produced the opposite result.

Individual firms were aware of the impending implementation of ITQs and acted accordingly. Recognizing the value of allocations, and that allocations would be distributed based on historical harvests by individual vessels, firms sought to buy vessels – particularly the most productive vessels – to acquire property rights and limit competition for future property rights. As a result, inefficient firms that might otherwise have exited remained in the fishery to amass capital and maximize their short-term harvests in anticipation of ITQs. Having maximized the property rights they would gain under the new regulatory system, many of these firms promptly exited the industry once that system was implemented; their owners chose to reap the rewards of their strategy by leasing their allocations to other harvesters. For these firms, the choice to exit had little to do with their actual productivity and more to do with their plans to obtain maximum benefit from regulatory change; as a result, the first years of ITQs saw as many efficient firms exit the industry as inefficient ones. It was only after this strategic behavior had worked its way out of the system that the expected efficiency benefits of property rights emerged.

While theoretically obvious, the gains for creating property right in fisheries are subject to tremendous debate. The strategic actions of well-informed economic actors play a major role in dictating whether, how, and for whom the benefits envisioned by economists, politicians, and regulators are achieved. The experience of the surf clam and ocean quahog fishery shows that tradable property rights can ultimately achieve their goals of efficiency without sacrificing equity, but how these goals are reached depends crucially on the way in which property rights are implemented, interpreted, and exploited by the various parties involved.

4.7 Appendix

4.7.1 Econometric Model

Recall that the firm exits if expected profit (π) plus any anticipated capital gain from deferring closure (S' , $S'+M'$) is less than the interest that would be earned on capital from exiting now (S, $S+M$). The rate of return from investing revenue gained by selling capital is r. These exit conditions are:

$\pi + S' < rS$ (under command and control) or

$\pi + (S' + M') < r(S + M)$ (under property rights)

While we observe neither the firms' valuation of its future profits, nor its valuation of its returns from liquidating assets, we do observe whether or not the firm exits the industry. Let Y be the indicator of firm choice; the error terms, ε_1 and ε_2, arise from the fact that while the firm knows the present value of staying or exiting we do not observe these values.

Under command and control we observe:

$Y=0$ if $\quad \pi + S' + \varepsilon_1 < rS + \varepsilon_2 \quad$ (exit)

$Y=1$ if $\quad \pi + S' + \varepsilon_1 > rS + \varepsilon_2 \quad$ (harvest)

Under property rights we observe:

$Y=0$ if $\quad \pi + S' + M' + \varepsilon_1 < r(S + M) + \varepsilon_2 \quad$ (exit)

$Y=1$ if $\quad \pi + S' + M' + \varepsilon_1 > r(S + M) + \varepsilon_2 \quad$ (harvest)

If we define:

$\eta \equiv \varepsilon_2 - \varepsilon_1$, and

F_η is the cumulative distribution function of η

then under command and control the probability of exit can be written as:

$$\Pr(Y=0) = \text{pr}\left((\pi+S') - rS \leq \eta\right) = 1 - F_n\left((\pi+S') - rS\right)$$

and the probability of harvesting can be written as:

$$\Pr(Y=1) = \text{pr}\left((\pi+S') - rS \geq \eta\right) = F_n\left((\pi+S') - rS\right)$$

Likewise, under property rights the probability of exit can be written as:

$$\Pr(Y=0) = \text{pr}\left((\pi+S'+M') - r(S+M) \leq \eta\right) = 1 - F_n\left((\pi+S'+M') - r(S+M)\right)$$

and the probability of harvesting can be written as:

$$\Pr(Y=1) = \text{pr}\left((\pi+S'+M') - r(S+M) \geq \eta\right) = F_n\left((\pi+S'+M') - r(S+M)\right)$$

If we assume η is distributed normally with σ variance, then the probability of exit under command and control is:

$$\Pr(Y=0) = 1 - \Phi\left[((\pi+S') - rS) / \sigma\right]$$

while the probability of harvesting is:

$$\Pr(Y=1) = \Phi\left[((\pi+S') - rS) / \sigma\right]$$

Again, the conditions are similar under property rights. The probability of exit is:

$$\Pr(Y=0) = 1 - \Phi\left[((\pi+S'+M') - r(S+M)) / \sigma\right]$$

and the probability of harvesting is:

$$\Pr(Y=1) = \Phi\left[((\pi+S'+M') - r(S+M)) / \sigma\right]$$

The likelihood function for the sample is then L. Let:

$Y_i = 0$ if firm i exits industry

$Y_i = 1$ if firm i continues to harvest

Then under command and control:

$$L = \Pi_{i=1,\ldots,N} \left\{\Phi\left[((\pi+S') - rS)/\sigma\right]\right\}^{Y_i} \times \left\{1 - \Phi\left[((\pi+S') - rS)/\sigma\right]\right\}^{(1-Y_i)}$$

and under property rights:

$$L = \Pi_{i=1,\ldots,N} \left\{\Phi\left[((\pi+S'+M') - r(S+M))/\sigma\right]\right\}^{Y_i} \times \left\{1 - \Phi\left[((\pi+S'+M') - r(S+M))/\sigma\right]\right\}^{(1-Y_i)}$$

4.7.2 Participation in Industry

Table 4.7 shows the number of firms that participate in the industry as either harvesters or as non-harvesters (firms that own allocations that they lease to harvesting firms). Harvesters can include independents, fleet owners, and processing firms; non-harvesters include processors (that do not also participate in harvesting) and non-processors (independent firms that sold their vessels but retained their allocations). The data show that, contrary to conventional characterizations, the implementation of ITQs did not lead to a significant reduction in the total number of firms participating in the industry.

Table 4.7: Participation in Industry

	Harvester			Non-Harvester		
	Independent	Fleet	Processor	Processor	Non-Processor	Total
1983	31	4	7			42
1984	29	6	7			42
1985	29	7	7			43
1986	34	9	7			50
1987	37	9	7			53
1988	38	9	7			54
1989	39	7	6			52
1990	33	7	6	0	12	58
1991	24	7	6	0	15	52
1992	22	6	5	0	20	53
1993	22	5	6	1	22	56
1994	23	3	6	1	23	56
1995	23	3	6	1	25	58
1996	20	3	6	1	26	56
1997	16	4	5	2	26	53
1998	14	4	5	3	31	57
1999	12	4	5	2	32	55

4.7.3 Costs and Revenue

Revenue for each trip is the market price for clams times the quantity of clams harvested. The meat price for each of the two species, surf clams and ocean quahogs, was provided by the National Marine Fisheries Service, Northeast Fishery Science Center and is the mean price paid per pound of meats reported in the processors' logbooks (one bushel of surf clams yields seventeen pounds of meats and one bushel of quahogs yields ten pounds of meats).

Costs data are provided in section 8.2 of Amendment Eight: Fishery Management Plan for the Atlantic Surf Clam and Ocean Quahog Fishery, Mid-Atlantic Fishery Management Council (1988). Variable costs include fuel, crew wages, and supplies.

> The quantity of fuel used per hour of travel = 0.04 x (horsepower of vessel engine)
>
> The quantity of fuel used per hour of fishing = 0.05 x (horsepower of vessel engine + horsepower of vessel pump)
>
> The quantity of fuel used at the dock per trip = 0.12 x (engine horsepower)
>
> The price per gallon of No. 2 diesel fuel is from the Energy Information Agency "Petroleum Marketing Monthly" (http://www.eia.doc.gov).
>
> The cost of gear, supplies, and repairs per hour of fishing = 0.15 x (horsepower of vessel engine + horsepower of vessel pump).
>
> Crew are paid on a share system and receive 30% of the per-bushel price. Therefore, 30% of the price per bushel is deducted as a labor cost.
>
> Annual fixed costs for each vessel class are: $54,360 for class 1 (<50 gross registered tons), $85,318 for class 2 (50-100 gross registered tons), and $147,582 for class 3 (>100 gross registered tons).

All dollar values are converted into 1999 dollars using the US-CPI.

4.7.4 Definitions of Variables

The variables used in the econometric model are created as weighted averages of each firm's values across all three classes of vessels. Then these variables are normalized for each firm relative to the industry mean.

Vessels in the fishing industry are categorized in three classes based on gross registered tonnage (class 1 includes boats of less than 50 gross registered tons class 2 includes boats between 50 and 100 gross registered tons; and class 3 includes boats greater than 100 gross registered tons). These classes of vessels differ in both their operating costs and their capacity. In order to reflect the asset composition of a firm (including operating economies of scale), each variable that is a composite of boat level data is weighted by the fraction of firm j's total capacity that is of class i (i=1,2,3).

If we define:

d_i is the relative harvesting power of a vessel of class i[18]

V_{ij} is the number of boats of class i owned by firm j

then the weighting factor W_{ij} is defined as

$$W_{ij} = [d_i \times V_{ij}] / [\Sigma_{i=1,2,3}\, d_i \times V_{ij}]$$

Because firms exit the fishery, the industry mean for each variable changes each year. In order to determine how firm characteristics relative to the existing fleet affect the probability of exiting, the estimation normalizes each firm value relative to the industry mean in each year.

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[18] According to Mid-Atlantic Fishery Management Council, these values are: class 1=1.0, class 2=1.8, and class 3=3.4 (1988).

The two variables that determine the firm's market value of capital are the gross registered tonnage of its boats and the mean age of its boats. The weighted total gross registered tonnage owned by firm j is the weighted sum of the gross registered tonnage of each of its boats, relative to the industry mean (Tonnage*). If we define $gtons_{ij}$ as the total tonnage of firm j's boats in class i, then firm j's relative tonnage is:

$$\text{Tonnage} = [\Sigma_{i=1,2,3} W_{ij} \times gtons_{ij}] / (\text{Tonnage}^*)$$

The weighted mean age of boats owned by firm j is the weighted mean of the age of its boats in each class ($meanage_{ij}$) relative to the industry mean (Age*):

$$\text{Age of capital} = [\Sigma_{i=1,2,3} W_{ij} \times meanage_{ij}] / (\text{Age}^*)$$

Profits are determined by the optimally chosen inputs (time fishing, time traveling, and number of trips) given input costs, annual fixed costs, and firm characteristics. The vessel logbooks record the time spent fishing, time spent traveling and, quantity harvested for each trip taken. For the typical vessel of each class, variable costs (cost per hour harvesting and per hour traveling) and annual fixed costs are taken from Mid-Atlantic Fishery Management Council, Amendment Eight (see appendix section *Costs and Revenue*).

For boats of class i owned by firm j, the annual cost ($Cost_{ij}$) is the sum of the variable costs over all N trips taken by all boats in class i, plus the sum of the annual fixed costs for all boats of class i (φ):

$$\text{Costij} = \varphi i + \Sigma n=1,\ldots,N \; [(\text{time fishing on trip n}) \times (\$/\text{hour fishing}) + (\text{time traveling on trip n}) \times (\$/\text{hour traveling})]$$

The firm's annual weighted cost (Cost) is the weighted sum of the firm's annual cost for each class of vessel, relative to the industry mean (Cost*).

$$\text{Cost} = [\Sigma_{i=1,2,3} W_{ij} \times Cost_{ij}] / (\text{Cost}^*)$$

For boats of class i owned by firm j, the annual revenue (Revenue_{ij}) is the product of the number of bushels harvested by boats of class i and the price per bushel, summed over all trips that year:

$$\text{Revenue}_{ij} = \Sigma_{n=1,\dots,N} [(\text{bushels harvested on trip n}) \times (\$/\text{bushel})]$$

The firm's annual revenue (Revenue) is the weighted sum of the annual revenue for each vessel, relative to the industry mean (Revenue*).

$$\text{Revenue} = [\Sigma_{i=1,2,3} W_{ij} \times \text{Revenue}_{ij}] / (\text{Revenue}^*)$$

The firm's characteristics are defined as:

Ability = firm's mean quantity harvested per hour fishing, relative to the industry mean

Contracts = number of processors the firm delivers to in a year, relative to the industry mean

Type = independent if the firm owns fewer than three vessels
= fleet if the firm owns three or more vessels
= vertically integrated if vessels are owned by a processor

4.7.5 Two-Stage Least Squares: Poisson Model of Contracts

There is no spot market either for harvested clams (surf clams or quahogs) or for allocations. Therefore, both clams and allocations are worthless in the absence of a processor who has contracted to be a buyer for the year. At a specified time, the processor meets the harvesting vessel at the dock with a truck to transport the cages (containing clams) from the vessel to the processing plant. All clams are sold to processors through long-term contracts (either written or verbal) specifying a price (called the "market price") that processors will pay for clams. The price is set for the year and does not change during the year unless a harvester's clams are of poor quality, and fluctuates little from year to year. As a result, one large processor describes itself as being vertically integrated with the harvesting sector despite owning no vessels at all; however, this processor has effectively guaranteed its future supply of clams through long-term contracting.

Processors are not only buyers of clams, but also provide financing to harvesters in two ways. First, processors provide harvesters with necessary allocations (beyond those owned by the fishing firm itself) and pay a reduced price for the corresponding harvests (typically 50-60% of the contracted price). Second, processors often provide financing to harvesters in exchange for a commitment to supply clams, which is paid back at an agreed-upon rate per bushel harvested.

For these reasons, contracts with processors are critical for a harvester to secure a market position. In order to optimally use their processing plant capacity, processors contract with harvesters that can reliably deliver the contracted supply. Some indicators that a harvesting firm can meet processors' requirements are harvesting ability, number of fishing trips taken by the firm, and capacity and horsepower (X_j) of the firm's vessels. As the total number of processors (P_t) declined over time, so did the expected total number of contracts. For each harvester, the number of contracts is discrete in nature and of small values. The number of contracts firm j has, $\mathcal{C}_j$, is drawn from a Poisson distribution with parameter λ_j, which is related to firm j's characteristics X_j.

The primary equation is:

$$\mathrm{Prob}(C_{jt} = \mathcal{C}_{jt}) = [\exp(-\lambda_{jt}) \times \lambda_{jt}^{\mathcal{C}_{jt}}] / \mathcal{C}_{jt}\,!$$

where the parameter is:

$$\ln \lambda_{jt} = \beta' X_{jt} + \alpha P_t$$

In the first stage, the model of contracts is estimated for the same subset of data used for the probit model. The results are in Table 4.6. The model as a whole is strongly significant. From the first-stage Poisson model, the fitted values of the number of contracts a firm has each year are determined. In the second stage, these values are used in the probit model.

Table 4.8: Poisson Model of Number of Processors

Variable Standard error (pr > z)	Coef
rate of harvest, t-1	-0.071 (0.063) (0.265)
number of trips, t-1	.103* (0.040) (0.010)
total tonnage, t-1	-.290* (0.174) (0.096)
total horsepower, t-1	.332* (0.155) (0.032)
number of processors in industry, t	.023* (0.007) (0.001)
constant	.383* (0.155) (0.013)
No of obs	383
LR Chi2	149.08
df	5
Prob> Chi2	0.000

4.7.6 Robust Variance Estimator

The robust variance estimates, which relax the assumption of independence across multiple observations of the same firm over the period, are produced using the estimator developed by Huber (1967), White (1980), and Rogers (1993). The observations on the N firms can be clustered into groups $G_1, G_2, \ldots, G_N$. The N groups are independent, but the multiple observations on each firm within the group are not independent. For the maximum-likelihood estimator, the estimate of variance is.

$$V^* = [N/(N-1)]\,\mathcal{V}\,(\textstyle\sum_{k=1,\ldots,N} U_k^{(G)\prime}\, U_k^{(G)})\,\mathcal{V}$$

where

$$\mathcal{V} = (-\partial^2 \ln L / \partial\beta^2)^{-1},$$

the second-order partial derivative of the log likelihood function (the conventional estimator of variance). $U_k^{(G)}$ is the contribution of the kth group to the scores, $\partial \ln L / \partial\beta$. Because the log likelihood function is additive in the observations denoted by j,

$$\ln L = \textstyle\sum_{j=1,\ldots,N} \ln L_j$$

Then

$$U_j = \partial \ln L_j / \partial\beta$$

and, therefore,

$$U_k^{(G)} = \textstyle\sum_{j\in G_k} (\partial \ln L_j / \partial\beta)$$

What differentiates this variance formula from the conventional estimator of variance, which does not allow for correlation across observations in a group, is that in the robust variance formula the scores used are the sums of individual scores within each group.

Chapter 5

Concluding Remarks

5.1 Adaptive Firm Behavior

The Coase theorem can generally be stated as follows (Myles, 1995): "In a competitive economy with complete information and zero transaction costs, the allocation of resources will be efficient and invariant with respect to the legal rules of entitlement." The focus of this dissertation is the implementation of property rights in the context of an industry with transaction costs and policy foresight. This dissertation provides examples of micro-behavior analogous to that described in the Lucas Critique. Previous evaluations of property rights in fisheries limited the comparisons to very narrow timeframes - primarily the last year of command-and-control to the year after property rights implementation (see discussion in 3.2). As discussed in section 1.2, the fishing industry plays an important role in developing regulation. In the case of surf clam and ocean quahog management, there was a five year negotiation period prior to implementation of ITQs (see 2.3). During this negotiation period firms were adapting their behavior to maximize their share of the impending property rights. The effects of firms' strategic behavior are evident in several dimensions of the industry: harvesting firm size, firm fishing effort, total capacity in the industry (see 2.4 and 2.5), total factor productivity (see 3.5), and firm exit (see 4.5). The next section summarizes the empirical evidence from the surf clam fishery and contrasts the interpretation of the results using two time frames: the year prior to implementation and the year after implementation, versus the year prior to negotiation to the year after implementation. As in the case of macroeconomic models, the adaptive behavior of agents critically affects how economists should interpret empirical results.

5.2 The Role of Time Frame on Policy Conclusions

Table 5.1 shows key descriptive statistics on the surf clam industry. These indicators include: the total number of vessels in the industry (measure of capacity), the mean number of vessels per vertically integrated firm (processing firm), the rate of harvest (clams per hour of fishing time) and the total factor productivity. Explanation of these indicators is detailed in Chapters 2 and 3. The first three columns are the absolute values of these indicators for the years 1984, 1989 and 1992. The fourth column contains the percent change from 1984 to 1992, and the final column is the percent change from 1989 to 1992. The negotiation over tradable property rights began in 1985; therefore, 1984 is the last year of command-and-control without property rights negotiation. The final full year of command-and-control was 1989. During 1991, the first full year of property rights, there was significant exit and restructuring; therefore, 1992 is the first full year of data on the ITQ fleet. The comparison of the 1992 indicators to those in 1984 reflects the difference between command-and-control and property rights in the absence of policy anticipation. The 1992-1984 comparison is therefore labeled "Lucas." By 1989, the industry had been significantly invested in ITQ negotiation for four years. Comparison of the indicators from 1992 to those in 1989 is a naive analysis in that it ignores the industry response to anticipated policy change.

Table 5.1: Key Industry Indicators: Two Perspectives

Indicator	1984	1989	1992	1984-1992 (Lucas)	1989-1992 (Naive)
Total # vessels	119	135	58	-51.26%	-57.04%
Mean # vessels/ VI firm	6.6	8.3	3.2	-51.52%	-61.45%
Harvest rate	6.47	13.09	12.43	92.12%	-5.04%
TFP	0.88	0.65	0.91	3.41%	40.00%

As Table 5.1 shows, the window of analysis can significantly affect the estimated gains from ITQs. The reductions in total capacity (total number of vessels) and average size of vertically integrated firms (mean number of vessels per firm) are overstated if the analysis ignores the strategic investment in capacity during negotiation.

The two perspectives reach *opposite* conclusions about the change in the rate of harvest. As chapter 2 discusses, firms increased their effort to maximize their historical record of harvests. When firms were no longer racing for the property right, the harvest rate declined from 1989-1992. However, under ITQs, firms were allowed to choose their harvest schedule rather than conform to the strictly imposed command-and-control schedule. As a consequence, the average harvest rate under ITQs is *higher* than command-and-control *without negotiation*, but it is *lower* than the harvest rate under command-and-control *with negotiation*.

The basic argument for ITQs is that they allow firms to minimize the cost of reaching regulatory goals. During ITQ negotiations in the surf clam industry, firms increased their harvest effort and expanded their capacity (see 3.5 for discussion). These strategic adjustments depressed total factor productivity during ITQ negotiation. The increase in total factor productivity is only 3.4% in the 1984 comparison, but the increase is 40% under the naive scenario. This significant difference between the two estimates of change in productivity implies that economists must take into account the adaptive behavior of the firm in empirical evaluations of ITQs. An analysis that uses the narrow timeframe misses the changes in the industry during the negotiation process.

5.3 Conclusion

This dissertation presents a theoretical motivation for and empirical estimates of changes in productivity, industrial organization, and strategic behavior due to the transition from firm-level regulation of inputs and outputs ("command and control") to tradable property rights (or "individual transferable quotas") in the Mid-Atlantic surf clam and ocean quahog fishery.

There are two significant implications for resource management of this research: first, the hypothesis that tradable property rights disproportionately harm small, independent harvesters must be rejected; and second, the manner in which policies are implemented is significant in determining their ultimate impact on industry structure. The results also demonstrate that economic analyses must incorporate adaptive behavior of firms to reach valid conclusions.

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