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PRODUCTIVITY AND INDUSTRIAL STRUCTURE UNDER MARKET INCENTIVES AND TRADITIONAL REGULATION

A CASE STUDY OF TRADABLE PROPERTY RIGHTS IN THE MIDDLE ATLANTIC SURF CLAM FISHERY

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Productivity and Industrial Structure under Market Incentives and Traditional Regulation

A Case Study of Tradable Property Rights in the Middle Atlantic Surf Clam Fishery

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Running Head: Tradable Property Rights in Fisheries

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Abstract

This paper contrasts the impact on productivity of two antithetical environmental regulatory policies: command-and-control regulation and the establishment of tradable property rights. A Tornqvist productivity index for the Middle Atlantic surf clam industry is estimated for periods in which each of the competing approaches was applied. The current and intense debate on the relative merits of command and control and tradable property rights makes empirical evidence of productivity under the competing regimes a timely contribution to public policy.

The index of total factor productivity exhibits three distinct regions, which reflect structural changes in the industry. From 1980 through 1984, when the fishery was managed by limits on the allowable number of fishing hours per week, total factor productivity averages 0.84. The index falls to an average of 0.70 between 1985 and 1990, a period of increasing restrictions on allowable fishing hours and ongoing negotiations regarding allocations of tradable property rights. Four of the five years preceding the implementation of tradable property rights exhibit a negative growth rate of total factor productivity, a result that is consistent with strategic behavior of industry participants. During 1991-1995, the initial years of individual transferable quotas, the index averages 0.85; the largest growth rates in productivity are in the initial two years after the policy transition. Much of the gain in productivity immediately following implementation of tradable property rights is a consequence of the incentives established during the policy negotiation period. Regression analysis shows that, after controlling for the effects of the surf clam population, effective fishing hours, the number of processing plants and the price of an alternative clam harvest, the mean index of productivity under individual transferable quotas is higher by 0.398 than under command-and-control. While this result gives positive evidence that individual transferable quotas improved productivity over command-and-control, the **productivity growth rates clearly demonstrate that the competitive behavior of participants** played an important role in shaping the outcome of the policy transition.

1. Introduction

Since the classic papers on externalities by Pigou [32] and Coase [8], 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 [40] 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 tradable permits for sulfur dioxide emissions during the Bush presidency[2]. In recent years transferable property rights have increased in popularity as a means to address environmental degradation both from

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[1] For reviews see Hahn and Noll [18] for application to pollution, Moloney and Pearse [26] for the first application to fisheries, and Varian [39] 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 [43] on cost uncertainty and Stavins [35] on benefit and cost uncertainty).

[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 [36].

pollution and from overexploitation of common property resources (such as marine fisheries). 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. Command-and-control regulation in fisheries consists of restrictions on gear and time and limitations on access to the resource. Transferable property rights, termed individual transferable quotas (ITQs), allocate shares of the total allowable catch to fishermen; ITQs were implemented in three major U.S. fisheries and drafted for two additional fisheries by 1996[3]. The introduction of individual transferable quotas created such heated debates that the re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act, passed in October 1996, placed a moratorium until October 2000 on the adoption of any new ITQ plans (Section 407(b) of the **Act). During this moratorium the National Research Council's Committee to Review Individual** Fishing Quotas is charged with reviewing individual transferable quotas programs in the United States and internationally and with making recommendations regarding their use. 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.

Economic theory predicts that command-and-control regulations distort cost minimization decisions by producers, resulting in inefficient use of resources. One consequence

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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.

of command-and control in fisheries has been tremendous capital stuffing in the industry[4]. Establishment of tradable property rights should internalize to the producer the true cost of environmental degradation, thus generating efficient production. The implication of tradable property rights for fisheries would be the release of excess capital from the fishery. In addition, the removal of production restrictions means that individual vessel owners would be able to choose inputs to efficiently produce a given harvest. Therefore one measure of comparison is the productivity under the competing policy approaches.

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 [21] simulate the production of 35 two-digit-level (Standard Industrial Classification) industries with and without environmental regulation. Papers by Conrad and Morrison [9], Conrad and Wastl [10], and Barbera and McConnell [2] use non-parametric index numbers to estimate total factor productivity indices for two-digit manufacturing industries. 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. By conflating different types of regulation and using aggregated industry level data, these papers

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[4] Gear restrictions, trip limits and limits on the number of allowed fishing hours are often met with increased capital in the fishery. Thus the cycle of increased capital necessitating increasingly stringent regulations begins. 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 [22].

[5] The work on the cost effectiveness of competing tools to regulate pollution is summarized by Tietenberg [38]. Of nine studies, eight find that the command and control policy costs at least 78 percent more than the least-cost approach. See also Whalley, J. and R. Wigle[45] and O'Ryan, R. E. [31].

fail to 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 [15] 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, the Gollop and Roberts results 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 [1].

Following this initial work, Fare, Grosskopf and Pasurka [14] estimate a measure of the relative efficiency of regulated and unregulated electric utilities by considering the indirect costs associated with restricted production possibilities imposed by regulation. 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 [6] use data envelope analysis to estimate efficiency for three categories of electric utility plants: plants that use scrubbers, plants that use compliance 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.

Calculation of the difference in productivity in a common property resource industry under alternative regulations is limited to a single piece. A working paper by Grafton, Squires and Fox [16] estimates a stochastic production frontier for the British Colombia halibut fishery under traditional regulation and under tradable permits. They find no statistically significant increase in cost efficiency under tradable permits. However, this is based on a small sample of firms and only three years of data (two years before tradable permits, the year of tradable permit implementation, and three years after implementation). In addition, there were years during the study in which no trades occurred, which may indicate structural problems in the quota market.

In the current paper, the question of the impact of policy on productivity is addressed through a case study of a single domestic fishery, the Middle Atlantic surf clam and ocean quahog fishery. This fishery was first managed with command-and-control regulation starting in 1976 and then managed with tradable property rights beginning in 1991, and it thus provides the best source of production data under these competing policy approaches. Estimating total factor productivity for the period 1979-1995 contrasts productivity growth under command-and-control management with that under a property rights regime. This case study therefore provides a unique opportunity both to test the economic arguments in favor of tradable property rights and to infer the probable implications of tradable property rights for other industries.

The index of total factor productivity exhibits three distinct regions corresponding to structural changes in the fishery and incentives created by policy negotiations. After controlling for the effects of the surf clam population, effective fishing hours, the number of processing plants and the price of an alternative clam harvest, the mean index of productivity under individual transferable quotas is higher by 0.398 than under command-and-control.

Methodology is addressed in Part 2, and the industry and data are detailed in Part 3. Part 4 reviews the calculations of productivity growth and the regression results.

II. Methodology

This paper proceeds in two steps. First an index of productivity and its growth rate is calculated. In the second step the index is regressed on variables that changed across the two regimes.

Productivity is calculated using an index number approach for two main reasons (see Grosskopf [17] on the relative merits of competing approaches)[6]. First, the nonparametric approach 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 the fishing industry is highly competitive and is made up of close-knit communities. Therefore, confidentiality of cost and production data is highly stressed. Given these data constraints, a nonparametric growth accounting approach provides a method which can actually be implemented by researchers and resource managers.

Calculation of Productivity

The index of total factor productivity in year t (TFP_t) is defined as the ratio of aggregate output (Y_t) to aggregate input (X_t):

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

One of the most defensible methods of aggregation is Divisia aggregation (see Diewert [11]). The Divisia index for inputs (outputs) is defined in terms of proportional rates of growth. Thus the Divisia index for aggregate input is:

$$(2)\ dX/dt = \Sigma_i\ ((W^i X^i)/C)\ (dX^i/dt)$$

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[6] 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 effect of regulation on the sum of technical change and efficiency change.

where W^i is the price of input i, X^i is the quantity of input i, and the total cost is $C=\Sigma_i W^i X^i$. The proportional rate of growth of input i is dX^i/dt. The Divisia index for aggregate output is:

$$(3)\ dY/dt = \Sigma_j\ ((P^j Y^j)/R)\ (dY^j/dt)$$

where P^j is the price of output j, Y^j is the quantity of output j, and the total revenue is $R=\Sigma_j P^j Y^j$. The proportional rate of growth of output j is dY^j/dt.

Given discrete data, the conventional approach to aggregating inputs and outputs is to use the Tornqvist discrete time approximation to the continuous time Divisia index[7]. Factor inputs are assumed to be bought in perfectly competitive markets such that inputs are paid their marginal products[8]. Outputs are also assumed to be sold in perfectly competitive markets. The Tornqvist aggregate input index in terms of proportional growth rates is then:

$$(4)\ \ln(X_t/X_{t-1}) = 0.5\ \Sigma_i\ (S_t^i + S_{t-1}^i)\ \ln(X_t^i / X_{t-1}^i)$$

where S_t^i is the cost share of input i in time t, $S_t^i = W_t^i X_t^i / C_t$. Likewise the aggregate output index in terms of proportional growth rates is:

$$(5)\ \ln(Y_t/Y_{t-1}) = 0.5\ \Sigma_j\ (R_t^j + R_{t-1}^j)\ \ln(Y_t^j / Y_{t-1}^j)$$

where R_t^j is the revenue share of output j in time t, $R_t^j = P_t^j Y_t^j / \Sigma_j P_t^j Y_t^j$. The Tornqvist index of total factor productivity growth is then [34][9]:

$$(6)\ \Delta TFP = 0.5\ \Sigma_j\ (R_t^j + R_{t-1}^j)\ \ln(Y_t^j / Y_{t-1}^j) - 0.5\ \Sigma_i\ (S_t^i + S_{t-1}^i)\ \ln(X_t^i / X_{t-1}^i)$$

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[7] 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 [11]. 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 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 [4].

[8] The fungibility of the factor inputs (vessel, labor and fuel) between competing uses makes the argument that this industry is small enough relative to the total US fishing industry that a competitive market for these inputs is a reasonable approximation.

[9] Diewert shows, "The 'Divisia' index may be approximated to the second order by taking a 'Divisia' index of 'Divisia' subindexes or in fact taking any superlative quantity index of superlative subindexes" [12].

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

Capacity Utilization

As shown by Berndt and Fuss [5], productivity measurements are biased when changes in capacity utilization of quasi-fixed factors are not disentangled from the productivity residual. There are two basic approaches to correcting for capacity utilization. The first is to develop weights for quantity of the quasi-fixed input; however, this approach requires econometric estimation and additional data. The second basic approach is to correct the service price weights. Within this approach there are several alternative corrections. In this analysis capital, which is the vessel, is quasi-fixed. As proposed by Hulten [20] and Berndt and Fuss [5] the quasi-rent to capital, Z_t^k, is calculated as the residual income not accruing to the variable inputs of labor and fuel per unit of capital stock. Equation (6) is thus rewritten as:

$$(7)\ \Delta\,\text{TFP} = 0.5\,\Sigma_j\,(R_t^j + R_{t-1}^j)\ln(Y_t^j / Y_{t-1}^j) - 0.5\,\Sigma_i\,(S_t^i + S_{t-1}^i)\ln(X_t^i / X_{t-1}^i)$$
$$-\,0.5\,(Z_t^k + Z_{t-1}^k)\ln(K_t/K_{t-1})$$

where R_t^j and Y_t^j are defined as before. 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.

III. The Industry

Middle Atlantic surf clams are harvested off the shores of Maryland, Virginia, New York, New Jersey, Rhode Island, Massachusetts, Maine and Delaware, with commercial stocks concentrated off the Northern New Jersey shore. The surf clam is an extremely slow growing and sessile species which is harvested using a hydrologic dredge. 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. The output of the surf clam fishery includes canned clam chowder, canned minced clams, canned sauces and juices and breaded products. The surf clam comprises the majority of the total U.S. production of these four products.

After the population of surf clams dramatically plummeted in 1976, legislation was enacted restricting allowable fishing time and limiting 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.

The first simplification of this analysis was to focus solely on the surf clam fishery and turn the problem into a single output framework.[10] There are three major choice variables in surf clam harvesting: capital (fishing vessel), labor and fuel. 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, it is a classic example of population taking [19]. Consequently the surf clam population is not a choice variable for the individual fisherman when he makes a production decision. 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.

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 abundance 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.)

IV. Results

TFP calculations

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[11]. 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.

Table 1: Total Factor Productivity, 1980-1995

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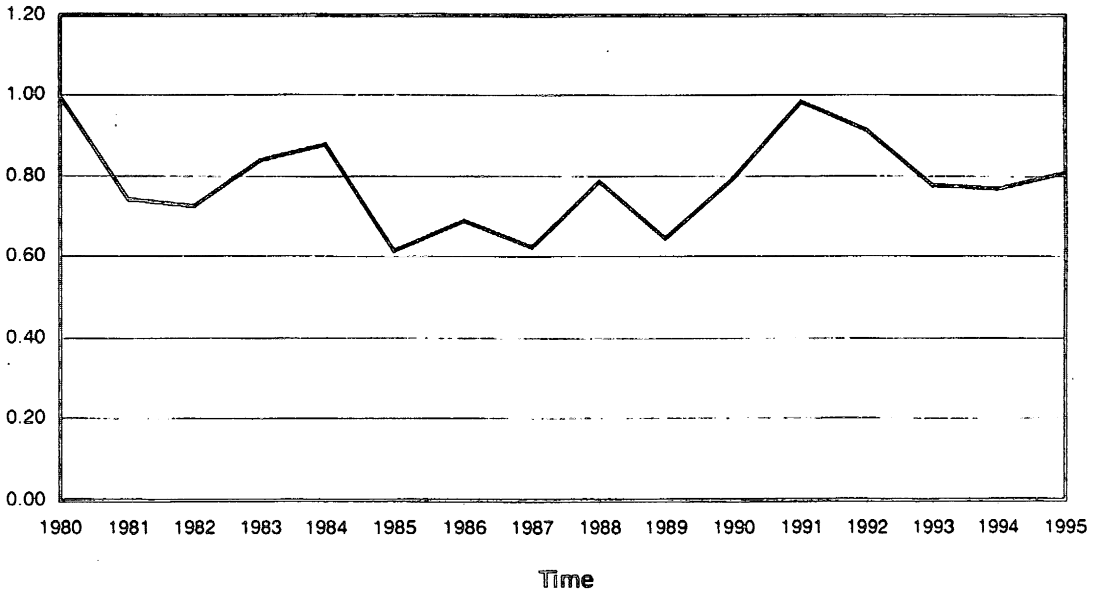
[10] After the implementation of the surf clam management plan, effort in excess of the surf clam quota was directed to the previously unharvested quahog species. The input and output data used in this paper are only for vessels with surf clam licenses.

[11] 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.

Year	Index of inputs	Index of outputs	TFP	Growth rate of TFP
1980*	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**
* Base year				

Figure 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[12]. 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 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

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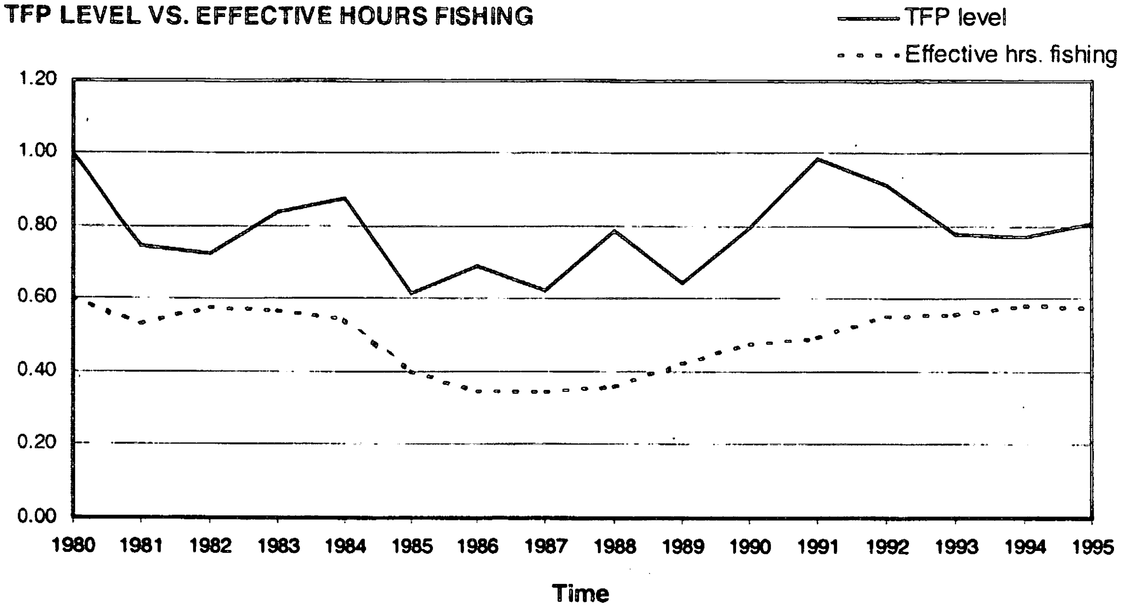
[12] The total annual quota was broken into quarterly quotas to smooth supply over the year.

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 2



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[13]. 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

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[13] 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.

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

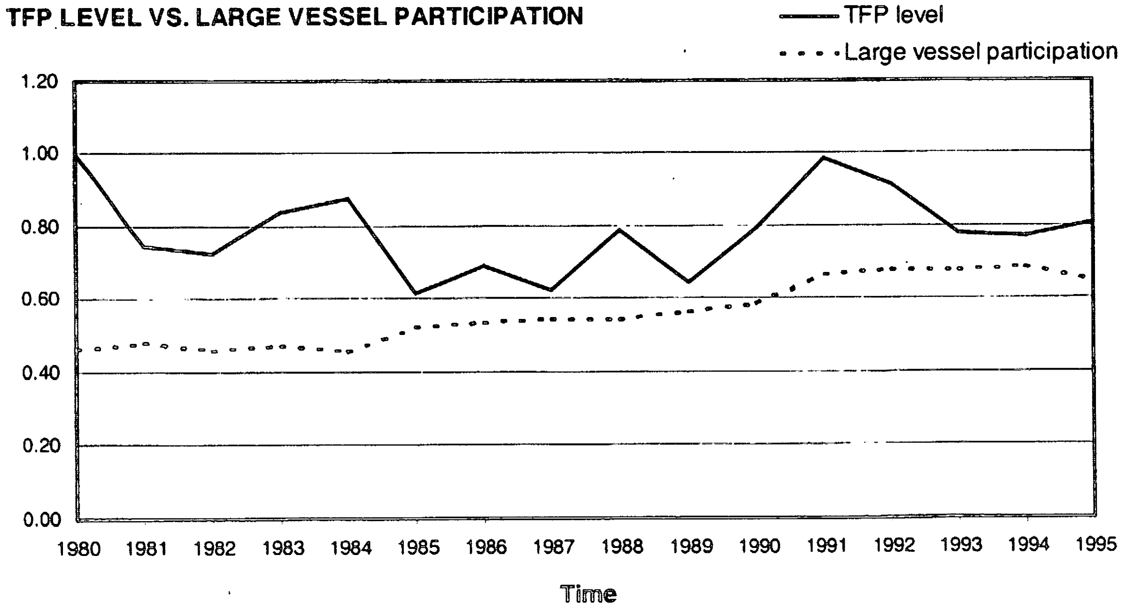
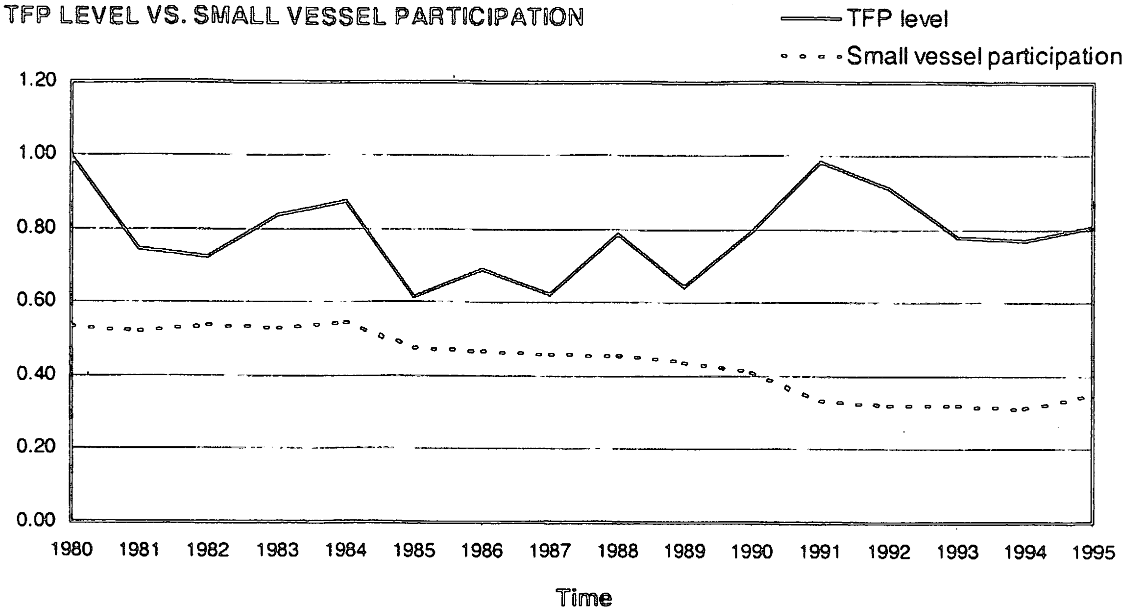


Figure 4



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.

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.

If all factors affecting productivity other than management regime remained the same across the two periods, then regressing the level of total factor productivity on a dummy variable for 1991-1995 would capture the effect of ITQs (see Equation 1 in Table 2)[14]. In theory, the industry-level productivity gain from ITQs results from the release of excess capital from the fishery and from allowing producers to choose the efficient level of inputs. Equation 1 indicates that the mean level of TFP was higher by 0.131 under ITQs than under command-and-control, but the coefficient is statistically significant only at the 16% level.

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 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. Effective fishing hours is controlled for in Equation 2. Although in this equation the ITQ dummy variable still has a positive coefficient (0.052), it is not statistically significant.

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.

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[14] 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 [3] maximum likelihood estimation method to obtain

Therefore, the number of processing plants may affect production by harvesters [29][15]. This variable is controlled for in Equation 3. When both effective hours fishing and number of processing plants are introduced, the mean TFP level under ITQs is 0.450 greater than under command-and-control. All three coefficients are statistically significant (see Equation 3 in Table 2).

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. The population of surf clams is introduced as a control in Equation 4 (population is the total biomass in thousands of metric tons off the coast of Northern New Jersey, the primary commercial harvesting area [30]). In this equation, the coefficient for ITQs remains positive at 0.437 and is statistically significant at the 1.6% level.

After the surf clam fishery came under heavy regulation, effort was redirected to the ocean quahog. Because both species are harvested using the same 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 meats (and excludes shell weight [28]). Equation 5 adds the price of ocean quahogs as a control. After controlling for effective hours fishing, processing plants, population

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efficient coefficient estimates and unbiased standard errors. After correcting Equations 1 through 5 for first order auto-correlation, the residuals from all 5 equations passed the runs test using the critical value of runs from [33].

[15] 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.

and price of quahog, the ITQ coefficient remains positive (0.398) but is significant only at the 9.6% level.

In all regressions the mean of TFP is greater under ITQs than under command-and-control. 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. Work by Weninger and Just indicates that adjustment under ITQs may be slower than predicted by theory because the rate of retirement of excess capital is determined by the opportunity cost of holding the individual quota [44]. Future analysis incorporating additional years of adjustment may show greater increases in productivity as additional capital exits the industry.

Table 2: Regression Results

	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5
Constant	1.091 (20.674) [.000]**	.636 (3.073) [.002]**	-.920 (-1.436) [.151]	-1.143 (-1.153) [.249]	-1.362 (-1.001) [.317]
ITQ	.131 (1.413) [.158]	.052 (.630) [.529]	.450 (2.694) [.007]**	.437 (2.418) [.016]*	.398 (1.662) [.096]
Effective Fishing Time		.963 (2.227) [.026]*	1.525 (3.760) [.000]**	1.753 (2.069) [.039]*	1.787 (1.977) [.048]*
Processing Plants			.035 (2.545) [.011]*	.036 (2.429) [.015]*	.037 (2.350) [.019]*
Clam Population				.001 (.003) [.763]	.001 (.272) [.786]
Price Quahog					.551 (.266) [.790]
R Squared	.321	.356	.564	.562	.583
Adjusted R Squared	.273	.256	.455	.402	.375
F-Statistic (Zero Slope)	5.056* [.041]	3.575 [.058]	4.550* [.024]	3.132 [.060]	2.392 [.113]

Note: T-statistics are in ( )
P-values are in [ ]
* 5% significance
** 1% significance

Conclusion

Much theoretical literature has been devoted to comparing the benefits of 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 industrial classifications 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 have the unintended consequence of biasing estimates of productivity growth. 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.

Appendix: Data

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 [25].

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 [28].

Inputs

In the surf clam industry, wages are paid as a direct percentage of the gross revenue. Pat Kurkel [24], 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 [25] 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 [13].

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 [30]. 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 [27]. 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.[16] A particularly strong year class was spawned in the late 1970s [41]; as a consequence,

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[16] 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.

estimating the abundance based on the subsequent population's growth parameters upwardly biases the abundance for the 1979-1981 period.

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